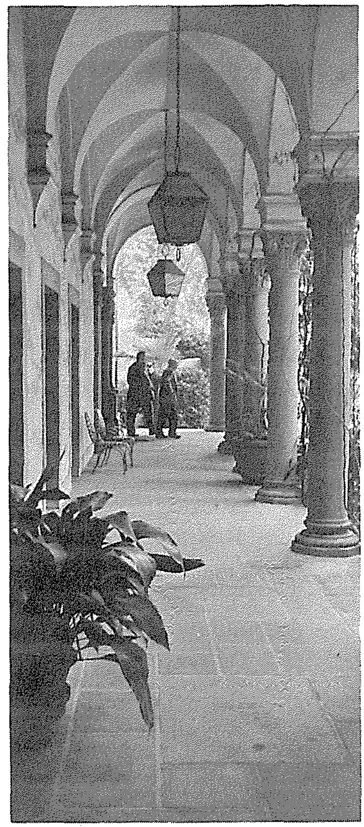
CATALOG

1960-1961

CALIFORNIA INSTITUTE OF TECHNOLOGY BULLETIN

VOLUME 69, NUMBER 3

CATALOG
1960-1961



CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA · CALIFORNIA

SEPTEMBER 1960

CONTENTS

ACADEMIC CALENDAR

1960-61

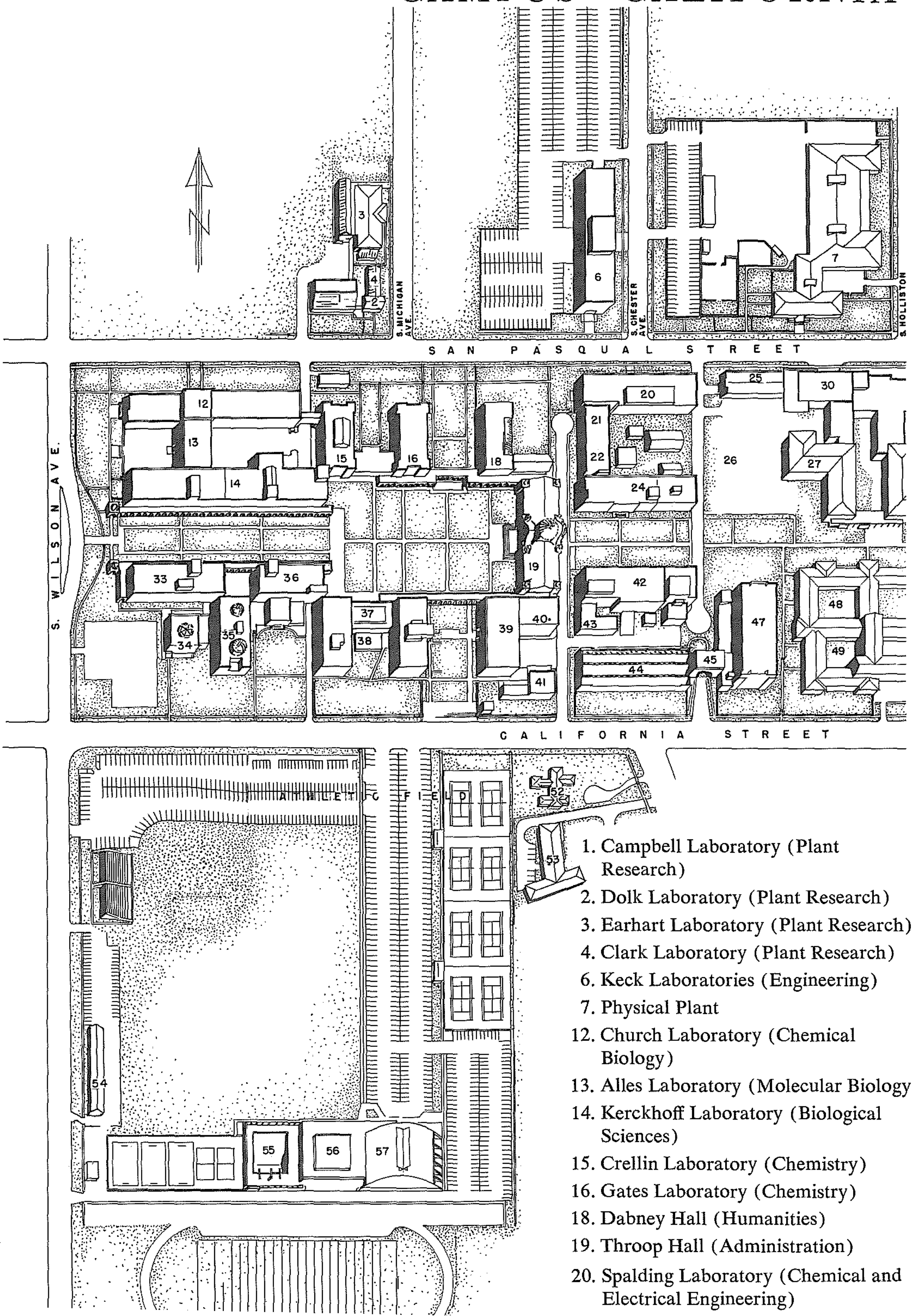
1960	FIRST TERM
September 22	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 22	Registration of students transferring from other colleges—8:00 a.m. to 12 noon.
September 22-24	Student Camp.
September 26	General Registration—8:30 a.m. to 3:30 p.m.
September 27	Beginning of instruction—8:00 a.m.
October 14	Last day for adding courses.
October 15	Examinations for the removal of conditions and incompletes.
October 22	Parents' Day.
Oct. 31-Nov. 5	Mid-Term Week.
November 5	MID-TERM.
November 7	Mid-Term deficiency notices due—9:00 a.m.
November 11	Last day for dropping courses.
November 11	French examination for admission to candidacy for degree of Doctor of Philosophy.
November 18	German examination for admission to candidacy for degree of Doctor of Philosophy.
November 21-25	Pre-registration for second term, 1960-61.
November 24-27	Thanksgiving recess.
November 24-25	Thanksgiving holidays for employees.
December 3	Students' Day.
December 3	College Entrance Board examinations for admission to the freshman class, September 1961.
December 12-16	Final examinations—first term, 1960-61.
December 17	End of first term, 1960-61, 12M.
Dec. 17-Jan. 3	Christmas vacation.
December 26	Christmas holiday for employees.
December 30	Registration Committee—9:00 a.m.

1961	SECOND TERM
January 2	New Year's holiday for employees.
January 3	General Registration—8:30 a.m. to 3:30 p.m.
January 4	Beginning of instruction—8:00 a.m.
January 14	College Entrance Board examinations for admission to the freshman class, September 1961. Scholastic Aptitude Test only.
January 20	Last day for adding courses.
January 21	Examinations for the removal of conditions and incompletes.
Jan. 30-Feb. 3	Mid-Term Week.
February 4	MID-TERM.
February 4	College Entrance Board examinations for admission to the freshman class, September 1961. Scholastic Aptitude Test only.
February 6	Mid-Term deficiency notices due—9:00 a.m.
February 10	Last day for dropping courses.
February 10	French examination for admission to candidacy for the degree of Doctor of Philosophy.
February 17	German examination for admission to candidacy for the degree of Doctor of Philosophy.
February 20-24	Pre-registration for third term, 1960-61.
March 18	College Entrance Board examinations for admission to the freshman class. September 1961.
March 13-17	Final examinations—second term, 1960-61.
March 18	End of second term, 1960-61, 12M.
March 24	Registration Committee—9:00 a.m.
March 18-26	Spring Recess.

1961	THIRD TERM
March 27	General Registration—8:30 a.m. to 3:30 p.m.
March 28	Beginning of instruction—8:00 a.m.
April 14	Last day for adding courses.
April 15	Examinations for the removal of conditions and incompletes.
April 24-29	Mid-Term Week.
April 29	Last day for obtaining admission to candidacy for Engineers' degrees.
April 29	MID-TERM.
May 1	Mid-term deficiency notices dues—9:00 a.m.
May 5	Last day for dropping courses.
May 5	French examination for admission to candidacy for the degree of Doctor of Philosophy.
May 12	German examination for admission to candidacy for the degree of Doctor of Philosophy.
May 15-19	Pre-registration for first term, 1961-62.
May 26	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy.
May 26	Last day for presenting theses for Engineers' degrees.
May 30	Memorial Day holiday.
May 30	Memorial Day holiday for employees.
May 29-31 & June 1-2	Final examinations for senior and graduate students, third term, 1960-61.
June 2-3	Examinations for admission to upper classes, September 1961.
June 5-9	Final examinations for undergraduate students, third term.
June 7	Meetings of committees on Courses in Science and Engineering—10:00 a.m.
June 7	Faculty meeting—2:00 p.m.
June 8	Class Day.
June 9	Commencement.
June 10	End of third term, 1960-61, 12M.
June 16	Registration Committee—9:00 a.m.
July 4	Independence Day holiday for employees.

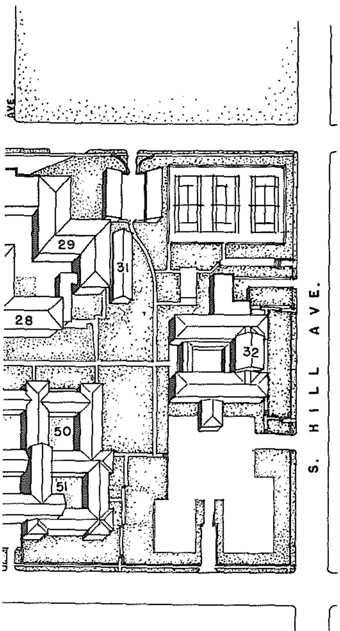
1961	FIRST TERM, 1961-62
September 4	Labor Day holiday for employees.
September 21	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 21	Registration of students transferring from other colleges, 8:00 a.m. to 12 noon.
September 21-23	Student Camp.
September 25	General Registration—8:30 a.m. to 3:30 p.m.
September 26	Beginning of instruction—8:00 a.m.

CAMPUS · CALIFORNIA



1. Campbell Laboratory (Plant Research)
2. Dolk Laboratory (Plant Research)
3. Earhart Laboratory (Plant Research)
4. Clark Laboratory (Plant Research)
6. Keck Laboratories (Engineering)
7. Physical Plant
12. Church Laboratory (Chemical Biology)
13. Alles Laboratory (Molecular Biology)
14. Kerckhoff Laboratory (Biological Sciences)
15. Crellin Laboratory (Chemistry)
16. Gates Laboratory (Chemistry)
18. Dabney Hall (Humanities)
19. Throop Hall (Administration)
20. Spalding Laboratory (Chemical and Electrical Engineering)

INSTITUTE OF TECHNOLOGY



THE CAMPUS of the California Institute is in a residential section of Pasadena, about a mile from the central business district. The area bounded by East California Street, South Hill Avenue, San Pasqual Street, and South Wilson Avenue is the central campus of about thirty acres, the first twenty-two acres of which were acquired in 1907, three years before the Institute moved from downtown Pasadena to its present location. In this area have been constructed, since 1909, nearly all of the principal facilities of the Institute—laboratories, lecture and class rooms, offices, undergraduate residence halls, and a clubhouse for the use of the graduate students, the staffs of the Institute, the Mount Wilson Observatory and the Huntington Library, and the California Institute Associates. The Institute has to date acquired approximately 18 acres of additional land north of San Pasqual Street.

Tournament Park, the area lying south of East California Street, was originally the property of the City of Pasadena. In March 1947 the citizens of the city voted to authorize the sale of Tournament Park to the Institute, and the formalities involved in the transfer of title were completed early in 1949. Tournament Park adds about twenty acres to the campus. Besides supplying parking space for students and staff, Tournament Park has the following facilities for athletics and recreation: eight tennis courts; three outdoor basketball and two volleyball courts; a football practice field; a quarter-mile track with a 220-yard straightaway; two baseball diamonds, one with a grandstand seating 5000; and a gymnasium and swimming pool.

22. Heating Plant
24. Engineering Building (Civil and Mechanical Engineering)
25. Sedimentation Laboratory
26. Site of future Student Center
27. Undergraduate Student House—Unit A
28. Undergraduate Student House—Unit B
29. Undergraduate Student House—Unit C
30. Chandler Dining Hall
31. Building T-4
32. Athenaeum
33. Mudd Laboratory (Geological Sciences)
34. Culbertson Hall (Industrial Relations, Auditorium)
35. Robinson Laboratory (Astrophysics)
36. Arms Laboratory (Geological Sciences)
37. Bridge Laboratory (Physics)
38. Cosmic Ray Laboratory
39. Sloan Laboratory (Mathematics, Physics)
40. Kellogg Radiation Laboratory (Physics)
41. Y.M.C.A., Receiving Room and Central Warehouse
42. Guggenheim Aeronautical Laboratory
43. Hydrodynamics Laboratory
44. Central Engineering Machine Shop
45. Merrill Wind Tunnel
47. Synchrotron Laboratory
48. Fleming Student House
49. Dabney Student House
50. Ricketts Student House
51. Blacker Student House
52. Arden House
53. Archibald Young Health Center
54. Building T-1 (Air Force ROTC)
55. Alumni Swimming Pool
56. Locker Room
57. Scott Brown Gymnasium

Section I

CALIFORNIA INSTITUTE OF TECHNOLOGY OFFICERS AND FACULTY

BOARD OF TRUSTEES

OFFICERS

MEMBERS OF THE BOARD
(Arranged in order of seniority of service with dates of first election)

TRUSTEE COMMITTEES

ELECTED COMMITTEES

EXECUTIVE COMMITTEE

Albert B. Ruddock, *Chairman*

Arnold O. Beckman
L. A. DuBridge
Herbert L. Hahn
William C. McDuffie
Robert L. Minckler
John O'Melveny
James R. Page
Edward R. Valentine
Harry J. Volk

H. H. G. Nash, *Secretary*

FINANCE COMMITTEE

James R. Page, *Chairman*

John E. Barber
Harry J. Bauer
L. A. DuBridge
Albert B. Ruddock
Edward R. Valentine
Harry J. Volk
P. G. Winnett

H. H. G. Nash, *Secretary*

APPOINTED COMMITTEES
(CHAIRMAN AND PRESIDENT ARE EX-OFFICIO MEMBERS)

BUDGET COMMITTEE

Harry J. Bauer, *Chairman*

Robert F. Bacher
F. Marion Banks
John E. Barber
Herbert L. Hahn

AUDITING COMMITTEE

John E. Barber, *Chairman*

Shannon Crandall, Jr.
J. S. Fluor
Robert L. Minckler
Harry J. Volk

JET PROPULSION LABORATORY COMMITTEE

Clark B. Millikan, *Chairman*

Robert F. Bacher
Arnold O. Beckman
John G. Braun
George W. Green
Charles S. Jones
Earle M. Jorgensen
Charles C. Lauritsen
Frederick C. Lindvall
Leonard S. Lyon
Robert L. Minckler
William H. Pickering
Howard P. Robertson
Keith Spalding
Howard G. Vesper

BUILDINGS AND GROUNDS COMMITTEE

Shannon Crandall, Jr., *Chairman*

F. Marion Banks
Arnold O. Beckman
Norman Chandler
J. Simon Fluor
George W. Green
Wesley Hertenstein
Frederick C. Lindvall
Lindley C. Morton
James R. Page
Edward R. Valentine

PALOMAR COMMITTEE

Richard R. Von Hagen, *Chairman*

Harry J. Bauer
John G. Braun
Leonard S. Lyon
Keith Spalding
Elbridge H. Stuart
Howard G. Vesper
Lawrence A. Williams
P. G. Winnett

COMMITTEE ON SPONSORED RESEARCH

C. D. Anderson, *Chairman*

William N. Lacey
Charles C. Lauritsen
Frederick C. Lindvall
Clark B. Millikan
Linus Pauling

COMMITTEE ON THE INDUSTRIAL RELATIONS SECTION

Harry J. Volk, *Chairman*

Norman Chandler
Charles S. Jones
Earle M. Jorgensen
Frederick C. Lindvall
William C. McDuffie
Lindley C. Morton
Hallett D. Smith
Elbridge H. Stuart

ATHENAEUM GOVERNING BOARD

Hallett D. Smith, *Chairman*

John E. Barber
George W. Beadle
Ira S. Bowen
Shannon Crandall, Jr.
George W. Green
Herbert L. Hahn
John E. Pomfret
Richard R. Von Hagen
Lawrence A. Williams

Robert B. King, *Secretary*

ADMINISTRATIVE OFFICERS OF THE INSTITUTE

Lee A. DuBridge, *President*

Chairmen of Divisions

Biology .... George W. Beadle
Chemistry and Chemical Engineering .... Ernest H. Swift
Civil, Electrical, and Mechanical Engineering and Aeronautics .. Frederick C. Lindvall
Geological Sciences .... Robert P. Sharp
Humanities .... Hallett D. Smith
Physics, Mathematics, and Astronomy .... Robert F. Bacher

Deans

Acting Dean of the Faculty .... George W. Beadle
Dean of Graduate Studies .... Frederic Bohnenblust
Dean of Admissions .... L. Winchester Jones
Dean of Students .... Paul C. Eaton
Dean of Freshmen .... Foster Strong

Business Officers

Vice-President for Business Affairs .... George W. Green
Comptroller .... R. B. Gilmore
Contract Administrator .... Ivan Betts
Director of Central Engineering Services .... Bruce H. Rule
Director of Personnel .... James Ewart
Director of Physical Plant .... Wesley Hertenstein
Manager of Graphic Arts .... Lowell E. Peterson
Patent Officer .... J. Paul Youtz
Purchasing Agent .... K. A. Jacobson
Safety Engineer .... Charles W. Easley

Other Administrative Officers

Secretary .... H. H. G. Nash
Registrar .... F. W. Maxstadt
Assistant Secretary .... R. B. Gilmore
Assistant to the President .... Charles Newton
Director of Athletics and Physical Education .... Harold Z. Musselman
Director of Health Services .... Richard F. Webb, M.D.
Director of Institute Libraries .... Roger F. Stanton
Director of Undergraduate Scholarships .... L. Winchester Jones
Assistant Director of Admissions .... Peter M. Miller
Director of Placements .... Donald S. Clark
Director of News Bureau .... James R. Miller
Editor of Engineering and Science .... Edward Hutchings, Jr.
Director of Industrial Associates .... Chester M. McCloskey
Master of Student Houses .... Robert A. Huttenback
Superintendent of the Guggenheim Aeronautical Laboratory .... Wm. H. Bowen

FACULTY OFFICERS AND COMMITTEES

1960-61

OFFICERS

Chairman: Henry Borsook

Vice Chairman: R. M. Badger

Secretary: G. W. Housner

STANDING COMMITTEES

FACULTY BOARD—*Beadle,* Bacher, Badger, Bohnenblust, Borsook, Brooks, D. S. Clark, J. K. Clark, Corcoran, Dix, Eaton, Greenstein, Hammond, Housner, Huttenback, Jones, Leighton, Lindvall, Maxstadt, McCann, Owen, Rannie, Sharp, Smith, Smythe, Stanton, Strong, Swift, Vreeland, Wood, Wu.

ACADEMIC FREEDOM AND TENURE—*Bacher,* Bohnenblust, Brown, Christy, Lindvall, Owen (Alt.), Pauling.

A.F.R.O.T.C.—*Eaton,* D. S. Clark, Green, Maj. MacKenzie, Maxstadt, Mayhew, Strong, Wayne.

CONVOCATIONS—*Eagleson,* D. S. Clark, J. Davies, Hertenstein, Nerrie, Newton, Paul, Capt. Stephenson.

COOPERATION WITH INDUSTRY—*Sage,* Bonner, Brown, Corey, Crede, T. Lauritsen, Manning, McCann, McCloskey, Sechler, Weir.

COURSE IN ENGINEERING—*Wood,* Acosta, H. Martel, Maxstadt, McKee, Oliver, Plesset, Sabersky, Sechler, Vreeland.

COURSE IN SCIENCE—*Smythe,* Albee, Apostol, Bowerman, Davis, Greenstein, Longwell, P. Miller, Robinson, Tyler.

EDUCATIONAL POLICIES—Corcoran, Dean, Elliot, Epstein, Hall, Marble, Owen, Sinsheimer, Wayland. (Chairman to be named)

FOREIGN STUDENTS—*Gilbert,* C. D. Anderson, Huttenback, Lurie, Vanoni, Wayland.

FRESHMAN ADMISSION—*Jones,* Allen, Dilworth, Eaton, Gould, Hammond, Huttenback, Leighton, Mayhew, P. Miller, Pings, Strong, Weir, Whaling, Wilts, Wood.

GRADUATE STUDY—*Bohnenblust,* Albee, Bacher, Beadle, Davis, Lees, Lindvall, Longwell, Lurie, McCann, Niemann, Oke, Sharp, H. D. Smith, Swift, Van Harreveld.

INSURANCE AND ANNUITIES—*Sechler,* Ewart, Felberg, Gray, Green, Larsen, Nash, Plesset, Van Harreveld, Wermel.

LIBRARY—*Stanton,* Apostol, DePrima, Deutsch, Elliot, Emerson, Gray, Helsey, King, Liepmann, Papas, Sage, Samples, Tyler, Waser, Zwicky.

MUSICAL ACTIVITIES—*Mead,* Dow, Duwez, Erdelyi, Frodsham, Gilbert, Hudson, Whaling.

NOMINATIONS—*Beadle,* Acosta, Badger, Bohnenblust, Borsook, Eaton, Housner, Jones, Sharp, Strong.

PATENTS—*Sechler,* Davidson, Langmuir, Leighton, Hudson, McCann, C. D. Anderson (ex-officio).

PHYSICAL EDUCATION—*Corcoran,* Emery, Huttenback, Jones, King, LaBrucherie, Maj. MacKenzie, Mathews, Mitchell, Musselman, Nerrie, Preisler, Smythe, Untereiner, Webb.

REGISTRATION—*Jones,* Anson, Dean, Eaton, Huttenback, Langmuir, Leighton, Lewis, Maxstadt, Owen, Press, Strong.

RELATIONS WITH SECONDARY SCHOOLS—*Sutton,* Cowan, Jones, J. Miller, Owen, Waser, Wayland.

SHOP FACILITIES—*Vreeland,* Green, Keighley, McKinney, Rule, Sechler, Smythe, Sturdivant.

STUDENT AID—*Stanton,* Eaton, Green, Jones, P. Miller, Nash, Strong.

STUDENTS' DAY—*Sutton,* Davidson, Hertenstein, Lewis, Maxstadt, Newton, Peterson, Sabersky, Scott, Williams.

STUDENT HEALTH—*Borsook,* Bohnenblust, Eaton, Green, Huttenback, Jones, Musselman, Strong, Van Harreveld, Webb, Weir.

STUDENT HOUSES—*D. S. Clark,* Eaton, Green, Huttenback, Richards, Sharp, Strong, Vreeland, Whaling.

STUDENT RELATIONS—*J. K. Clark,* Eaton, Fuller, Haagen-Smit, Helsley, Huttenback, Langmuir, Martel, Pings, Sabersky, D. Smith, Strong, Sutton, Wood.

UNDERGRADUATE SCHOLARSHIPS AND HONORS—*McCann,* Acosta, Bass, Bowerman, Eaton, Huttenback, Jones, King, Maxstadt, P. Miller, Sinsheimer, Stanton, Strong, Vreeland, Waser.

UPPER CLASS ADMISSION—*Jones,* Anson, Brooks, Eaton, Ellis, King, Langmuir, McCormick, McKinney, P. Miller, Strong, Vreeland.

USE OF THE ATHLETIC CENTER—*Dilworth,* D. S. Clark, Eaton, Green, Hertenstein, Lindvall, Musselman.

STAFF OF INSTRUCTION AND RESEARCH SUMMARY

DIVISION OF BIOLOGY

George W. Beadle, *Chairman*

PROFESSOR EMERITUS

George E. MacGinitie, M.A. . . . . *Biology*

PROFESSORS

Ernest G. Anderson, Ph.D. . . . . *Genetics*
George W. Beadle, Ph.D., D.Sc., Nobel Laureate . . . . *Biology*
James F. Bonner, Ph.D. . . . . *Biology*
Henry Borsook, Ph.D., M.D. . . . . *Biochemistry*
Max Delbrück, Ph.D. . . . . *Biology*
Renato Dulbecco, M.D. . . . . *Biology*
Sterling Emerson, Ph.D. . . . . *Genetics*
Arie Jan Haagen-Smit, Ph.D. . . . . *Bio-Organic Chemistry*
Alan J. Hodge, Ph.D. . . . . *Biology*
Norman H. Horowitz, Ph.D. . . . . *Biology*
Anton Lang, Ph.D. . . . . *Biology*
Edward B. Lewis, Ph.D. . . . . *Genetics*
Herschel K. Mitchell, Ph.D. . . . . *Biology*
Ray D. Owen, Ph.D. . . . . *Biology*
Robert L. Sinsheimer, Ph.D. . . . . *Biophysics*
Roger W. Sperry, Ph.D. . . . . *Hixon Professor of Psychobiology*
Alfred H. Sturtevant, Ph.D., D.Sc. . . . . *Thomas Hunt Morgan Professor of Genetics*
Albert Tyler, Ph.D. . . . . *Embryology*
Anthonie Van Harreveld, Ph.D., M.D. . . . . *Physiology*
Cornelis A. G. Wiersma, Ph.D. . . . . *Biology*

RESEARCH ASSOCIATES

Gordon A. Alles, Ph.D. . . . . *Biology*
Henry O. Eversole, M.D. . . . . *Plant Physiology*
William S. Stewart, Ph.D. . . . . *Biology*
Jean J. Weigle, Ph.D. . . . . *Biophysics*

SENIOR RESEARCH FELLOWS

Jacob W. Dubnoff, Ph.D. . . . . *Biology*
Henry Hellmers,[1] Ph.D. . . . . *Biology*
Geoffrey L. Keighley, Ph.D. . . . . *Biology*
Matthew S. Meselson, Ph.D. . . . . *Chemical Biology*
Marguerite Vogt, M.D. . . . . *Biology*

ASSISTANT PROFESSOR

Robert S. Edgar, Ph.D. . . . . *Biology*

VISITING ASSISTANT PROFESSOR

Charles J. Brokaw, Ph.D. . . . . *Biology*

INSTRUCTOR

Charles M. Steinberg, B.A. . . . . *Biology*

[1]U. S. Forest Service

RESEARCH FELLOWS

Harbans L. Arora, Ph.D.
Domenica G. Attardi, M.D.
Giuseppe Attardi, M.D.
Claudio Barigozzi, Sc.D.*
Max L. Birnstiel, D.Nat.Sci.
Hans J. Burkhardt, Ph.D.
Edward A. Carusi,[1] Ph.D.
Pen Ching Cheo, Ph.D.
Margaret I. H. Chipchase, Ph.D.
John H. Curme,[2] Ph.D.
Guy Echalier,[3] D.Sc.
Richard H. Epstein,[4] Ph.D.
Marguerite Fling, Ph.D.
Mitchell E. Glickstein, Ph.D.
Clyde R. Goodheart,[5] M.D.
Erich Heftmann,[4] Ph.D.*
George K. Helmkamp, Ph.D.
Harry R. Highkin, Ph.D.
George S. Hodgson,[3] M.D.
Homer Jacobson,[6] Ph.D.
John L. Jinks,[7] Ph.D.
Jiro Kato, Ph.D.
Hendrik J. Ketellapper, Ph.D.
Kurt Köhler,[8] D.Sc.
Hildegard Lamfrom, Ph.D.
James A. Lockhart, Ph.D.
John B. Loefer,[9] Ph.D.
Peter Lowy, Doctorandum
Wilbur M. Luce,[10] Ph.D.*
William D. McBride, D.D.S.
Alexander Miller, Ph.D.
Mary B. Mitchell, M.A.
K. W. Mundry,[3] Ph.D.
Moshe Negbi,[11] Ph.D.
Charles C. Nimmo,[12] Ph.D.
Arne W. Nordskog,[13] Ph.D.
David Norman,[14] Ph.D.
Daphne J. Osborne, Ph.D.
Lajos Piko,[15] D.V.M.
Clifford J. Pollard, Ph.D.
Richard L. Potter, Ph.D.
Ernst Reinhard,[16] D.Sc.
Joon Hee Rho,[3] Ph.D.
Gerhard Richter, Ph.D.
John Romberger,[17] Ph.D.
Clifford S. Sato, Ph.D.
Alberta J. Seaton, Sc.D.*
John D. Smith, Ph.D.
John Steiner, M.B.Ch.B.*
William H. Stone,[4] Ph.D.*
T. A. Sundararajan, Ph.D.
Shosuke Takemura, Ph.D.*
Paul O. P. Ts'o, Ph.D.
Dezsö Varju, Ph.D.
Theodore J. Voneida, Ph.D.
Joan M. Wallace, Ph.D.
Yasushi Watanabe,[18] Ph.D.
Roger Weil,[19] M.D.
Ulrich Winkler,[20] Ph.D.
J. A. D. Zeevaart,[21] Ph.D.

*In residence 1959-60
[1]Jane Coffin Childs Memorial Fund for Medical Research Fellow
[2]Campbell Soup Company
[3]National Academy of Sciences Fellow
[4]U. S. Public Health Service Fellow
[5]American Cancer Society Fellow
[6]John Simon Guggenheim Memorial Foundation Fellow
[7]Commonwealth Fund Fellow
[8]Max Planck Institute
[9]U. S. Dept. of the Navy, Office of Naval Research
[10]University of Illinois
[11]Rockefeller Foundation Fellow
[12]U. S. Department of Agriculture
[13]Iowa State College
[14]American Diabetes Society Fellow
[15]Lalor Foundation Fellow
[16]German National Research Council Fellow
[17]U.S. Forest Service
[18]International Cooperation Administration Fellow
[19]Damon Runyon Fund Fellow
[20]North Atlantic Treaty Organization Fellow
[21]Netherlands Organization for Pure Scientific Research Fellow

GRADUATE FELLOWS AND ASSISTANTS, 1959-60

Dennis Barrett, A.B.
Harris Bernstein, B.S.
Juan P. Bozzini, B.S.
Thomas A. Cole, B.A.
Paul H. Deal, A.B.
Michael Fried, B.A.
George D. Guthrie, A.B.
Charles R. Hamilton, B.S.
Boyd A. Hardesty, M.S.
Robert L. Heath, M.S.
Morton H. Kirsch, M.D.
Stanley G. Krane, M.S.
Dennis R. McCalla, M.S.
Martin Mendelson, A.B.
John R. Menninger, A.B.
Robert L. Millette, M.S.
D. James Morré, M.S.
Alan P. Roberts, B.A.
Ann Roller, M.S.
Donald C. Schreffler, M.S.
Richard F. Squires, B.S.
F. William Studier, B.S.
Millard Susman, A.B.
Colwyn B. Trevarthen, M.Sc.
Robert A. Weisberg, A.B.

Division of Chemistry and Chemical Engineering

Ernest H. Swift, *Chairman*

J. H. Sturdivant, *Executive Officer*

PROFESSORS EMERITI

Stuart J. Bates, Ph.D. . . . . *Physical Chemistry*
James E. Bell, Ph.D. . . . . *Chemistry*
Howard J. Lucas, D.Sc. . . . . *Organic Chemistry*
Laszlo Zechmeister, Dr.Ing. . . . . *Organic Chemistry*

PROFESSORS

Richard M. Badger,* Ph.D. . . . . *Chemistry*
Dan H. Campbell, Ph.D., Sc.D., ... *Immunochemistry*
William H. Corcoran, Ph.D. *Chemical Engineering*
Robert B. Corey, Ph.D. . . . . *Structural Chemistry*
Norman Davidson, Ph.D. . . . . *Chemistry*
George S. Hammond, Ph.D. . . . . *Organic Chemistry*
William N. Lacey, Ph.D. . . . . *Chemical Engineering*
Paul D. V. Manning, Ph.D. *Chemical Engineering*
Harden M. McConnell, Ph.D. . . . . *Physical Chemistry*
Carl G. Niemann, Ph.D. . . . . *Organic Chemistry*
Linus Pauling, Ph.D., Sc.D., L.H.D., U.J.D., D.H.C., D.F.A.,
LL.D., Nobel Laureate . . . . *Chemistry*
John D. Roberts, Ph.D. . . . . *Organic Chemistry*
Bruce H. Sage, Ph.D., Eng.D. . . . . *Chemical Engineering*
J. Holmes Sturdivant, Ph.D. . . . . *Chemistry*
Ernest H. Swift, Ph.D., LL.D. . . . . *Analytical Chemistry*
Jürg Waser, Ph.D. . . . . *Chemistry*
Don M. Yost, Ph.D. . . . . *Inorganic Chemistry*

RESEARCH ASSOCIATES

Edwin R. Buchman, D.Phil. . . . . *Organic Chemistry*
Edward W. Hughes, Ph.D. . . . . *Physical Chemistry*
Joseph B. Koepfli, D.Phil. . . . . *Chemistry*
Seeley G. Mudd, M.D. . . . . *Medical Chemistry*
Walter A. Schroeder, Ph.D. . . . . *Chemistry*
Jerome R. Vinograd, Ph.D. . . . . *Chemistry*
Oliver R. Wulf, Ph.D. . . . . *Physical Chemistry*

ASSOCIATE PROFESSORS

Paul A. Longwell, Ph.D. . . . . *Chemical Engineering*
Cornelius J. Pings, Ph.D. . . . . *Chemical Engineering*
G. Wilse Robinson, Ph.D. . . . . *Physical Chemistry*

SENIOR RESEARCH FELLOWS

Marjorie C. Caserio, Ph.D. . . . . *Chemistry*
Justine S. Garvey, Ph.D. . . . . *Chemistry*
Alvin F. Hildebrandt, Ph.D. . . . . *Chemistry*
Richard E. Marsh, Ph.D. . . . . *Chemistry*
Chester M. McCloskey, Ph.D. . . . . *Chemistry*
Matthew S. Meselon,[1] Ph.D. . . . . *Chemical Biology*
H. Hollis Reamer, M.S. . . . . *Chemical Engineering*
Kenneth N. F. Shaw, Ph.D. . . . . *Chemistry*
William G. Sly, Ph.D. . . . . *Chemistry*

*On leave of absence 1960-61.
[1]American Cancer Society Fellow.

VISITING ASSOCIATES

M. Gilbert Burford, Ph.D. .... *Chemistry*
Joseph A. Duke, S.J.,[1] Ph.D. .... *Chemistry*
Stewart E. Hazlet,[1] Ph.D. .... *Chemistry*
John Howe Scott, Ph.D. .... *Chemistry*
Heinz A. Staab, Ph.D. .... *Chemistry*
Peter E. Yankwich,[2] Ph.D. .... *Chemistry*

ASSISTANT PROFESSORS

Fred C. Anson, Ph.D. .... *Analytical Chemistry*
Robert M. Mazo, Ph.D. .... *Physical Chemistry*
John H. Richards, Ph.D. .... *Organic Chemistry*
George Neal Richter, Ph.D. .... *Chemical Engineering*
Robert G. Rinker, Ph.D. .... *Chemical Engineering*

INSTRUCTORS

Lowell B. Koppel, Ph.D. .... *Chemical Engineering*
William P. Schaefer, Ph.D. .... *Chemistry*

RESEARCH FELLOWS

Herman Ainis,* Ph.D.
Ephraim Ben-Zvi, Ph.D.
John Francis Catchpool, M.B., B.S.
Natalie Cremer,[4] Ph.D.
Henry H. Dearman, Ph.D.
Mostafa F. A. El Sayed, Ph.D.
Kenneth Emerson,[3] Ph.D.
Hans G. Essler, Ph.D.
Alfred Fischer, Ph.D.
Paul C. Haake,[3] Ph.D.
Donald W. Halford, Ph.D.
Melvin W. Hanna,[3] Ph.D.
Ernest M. Heimlich,* M.D.
George E. Hein, Ph.D.
Karst Hoogsteen, D.Sc.
Neil S. Isaacs, Ph.D.
William T. Jackson, Ph.D.
Fred Kaplan, Ph.D.
Lois M. Kay, M.S.
Richard T. Keys, Ph.D.
Theodore Kuwana, Ph.D.
Lee R. Mahoney, Ph.D.
Kuppuswamy Nagarajan, Ph.D.
Yasushi Nishiwaki,* M.D.
Dorothy Redlich, Ph.D.
Don Ridgeway, Ph.D.
Anil Kumar Saha, Ph.D.
Sten Samson, Fil. Lic.
Bernhard A. Seidel, Ph.D.
Brian L. Smith, Ph.D.
Eugene I. Snyder,[4] Ph.D.
Richard H. Stanford, Jr., Ph.D.
Dieter H. Sussdorf,[4] Ph.D.
Wilton E. Vannier,[5] M.D., Ph.D.
Gershon Vincow,[6] Ph.D.
Robert A. Wallace, Ph.D.
Chin-Hua Wu, Ph.D.
Tetsuo Yamane, Ph.D.
Emile Zuckerkandl, Ph.D.

[1]National Science Foundation Science Faculty Fellow
[2]National Science Foundation Senior Postdoctoral Fellow
[3]Arthur Amos Noyes Fellow
[4]United States Public Health Service Fellow
[5]Staff Member, National Institute of Allergy and Infectious Diseases
[6]National Science Foundation Postdoctoral Fellow
*In residence during 1959-60

GRADUATE FELLOWS AND ASSISTANTS, 1959-60

Henry I. Abrash, B.A.
Harold R. Almond, Jr., B.S.
Gerald J. Arenson, B.S.
John E. Baldwin, A.B.
William F. Beach, B.S.
Stuart B. Berger, B.A.
Frank B. Booth, M.S.
Robert E. Carter, A.B.
James S. Clovis, B.S.
Noundas Cocoltchos, B.S.
Robert F. Cuffel, B.S.
Henry H. Dearman, B.S.
Robert S. Deverill, B.S.
William F. Dove, Jr., A.B.
Joe A. Duardo, B.S.
Grover L. Farrar, B.S.
Louis D. Ferretti, B.A.
Bernard Foran, B.Sc.
Robert P. Foss, B.A.
James N. Foster, B.A.
Charles J. Fritchie, Jr., B.S.
Robert P. Frosch, B.S.
Donald C. Garwood, B.A.
Concetto R. Giuliano, B.S.
R. Clive Greenough, B.S.
David W. Hall, B.S.
John E. Hearst, B.E.
William P. Helman, B.S.
E. Alexander Hill, III, B.S.
William D. Hobey, B.S.
Merlin E. H. Howden, B.Sc.
Glen O. Hultgren, B.S.
William D. Hutchinson, M.S.
Albert Hybl, B.A.
James B. Ifft, B.S.
Noel D. Jones, B.S.
Richard T. Jones, M.D.
Glenn L. Keldsen, B.S.
Philip R. Kennicott, B.S.
James W. Kessel, B.S.
Leon F. Keyser, B.S.
Edgar F. Kiefer, B.S.
Donald M. King, B.S.
William Kozicki, M.A.Sc.
Alvin L. Kwiram, B.A.
Joel Kwok, B.S.
William G. Laidlaw, B.Sc.
Peter A. Leermakers, B.A.
Robert C. Leif, B.S.
Milton I. Levenberg, B.S.
Gerald R. Liebling, B.S.
Raymond P. Lutz, M.S.
William B. Mather, Jr., A.B.
Edward R. H. McDowell, B.S.
Arthur W. Merkl, B.S.
Hugh T. Millard, Jr., B.A.
Lawrence K. Montgomery, B.S.
Robert G. Mortimer, M.S.
Francis G. Moses, B.A.
Eugene B. Nebeker, B.S.
Robert C. Neuman, Jr., B.S.
J. Eric Nordlander, B.A.
Heiko H. Ohlenbusch, B.S.
Carole L. Olson, B.S.
Edwin S. Olson, B.A.
Manuel Panar, B.Sc.
James M. Peterson, B.S.
Max C. Richardson, B.S.
Ronald E. Rolfe, M.D.
Charles D. Russell, S.B.
Roy R. Sakaida, M.S.
Stephen G. Sawochka, B.S.
B. Alva Schoomer, Jr., B.S.
David I. Schuster, B.A.
Clayton S. Smith, M.S.
Irving G. Snyder, Jr., B.E.
Himan Sternlicht, B.S.
Robert F. Stewart, B.A.
Don D. Thompson, B.A.
Richard S. Tunder, B.S.
Harris E. Ulery, B.A.
Janis Vasilevskis, B.S.
Emilio C. Venezian, M.S.
Viani Rinantonio, B.S.
Martin Vogel, B.S.
William F. Wagner, Ch.E.
Harold P. Waits, B.S.
Frederic A. Wallace, A.B.
Yui-Loong Wang, M.S.
James H. Waters, S.B.
Ned C. Webb, B.A.
Thomas H. Wirth, A.B.
Daniel L. Wulff, B.S.
Tetsuo Yamane, B.S.

Division of Civil, Electrical, and Mechanical Engineering and Aeronautics

Frederick C. Lindvall, *Chairman*

Clark B. Millikan, Director, *Guggenheim Aeronautical Laboratory*

PROFESSORS EMERITI

Robert L. Daugherty, M.E. .... *Mechanical and Hydraulic Engineering*
Aladar Hollander, M.E. .... *Mechanical Engineering*
R. R. Martel, S.B. .... *Structural Engineering*
William W. Michael, B.S. .... *Civil Engineering*
Royal W. Sorensen, D.Sc. .... *Electrical Engineering*
Theodore von Kármán, Ph.D., Dr.Ing., Sc.D., LL.D., Eng.D. .... *Aeronautics*

PROFESSORS

Donald S. Clark, Ph.D. .... *Mechanical Engineering*
Julian D. Cole, Ph.D. .... *Aeronautics*
Frederick J. Converse,* B.S. .... *Soil Mechanics*
Charles E. Crede, M.S. .... *Mechanical Engineering*
Charles R. DePrima, Ph.D. .... *Applied Mechanics*
Pol E. Duwez, D.Sc. .... *Mechanical Engineering*
Lester M. Field, Ph.D. .... *Elecrical Engineering*
Yuan-Cheng Fung, Ph.D. .... *Aeronautics*
George W. Housner, Ph.D. .... *Civil Engineering and Applied Mechanics*
Donald E. Hudson, Ph.D. .... *Mechanical Engineering*
Arthur L. Klein, Ph.D. .... *Aeronautics*
Paco Lagerstrom,* Ph.D. .... *Aeronautics*
Robert V. Langmuir, Ph.D. .... *Electrical Engineering*
Lester Lees, M.S. .... *Aeronautics*
Hans W. Liepmann, Ph.D. .... *Aeronautics*
Frederick C. Lindvall, Ph.D. .... *Electrical and Mechanical Engineering*
Gilbert D. McCann, Jr., Ph.D. .... *Electrical Engineering*
Jack E. McKee, Sc.D. .... *Environmental Health Engineering*
Frank E. Marble, Ph. .... *Jet Propulsion and Mechanical Engineering*
Clark B. Millikan, Ph.D. .... *Aeronautics*
Charles H. Papas, Ph.D. .... *Electrical Engineering*
Stanford S. Penner, Ph.D. .... *Jet Propulsion*
William H. Pickering,* Ph.D. .... *Electrical Engineering*
Milton S. Plesset, Ph.D. .... *Applied Mechanics*
W. Duncan Rannie, Ph.D. .... *Robert H. Goddard Professor of Jet Propulsion*
August T. Rossano, Jr., D.Sc. (Visiting) .... *Environmental Health Engineering*
Ernest E. Sechler, Ph.D. .... *Aeronautics*
Homer J. Stewart,* Ph.D. .... *Aeronautics*
Vito A. Vanoni, Ph.D. .... *Hydraulics*
J. Harold Wayland, Ph.D. .... *Applied Mechanics*
Max L. Williams, Ph.D. .... *Aeronautics*
Charles L. Wilts, Ph.D. .... *Electrical Engineering*

RESEARCH ASSOCIATE

Simon Ramo, Ph.D. .... *Electrical Engineering*

ASSOCIATES

Henry Dreyfuss .... *Industrial Design*
Chuan C. Feng, Ph.D. (Visiting) .... *Engineering*

Leave of absence

ASSOCIATE PROFESSORS

Allan J. Acosta, Ph.D. .... *Mechanical Engineering*
R. John H. Bollard, Ph.D. (Visiting) .... *Aeronautics*
Norman H. Brooks, Ph.D. .... *Civil Engineering*
Francis S. Buffington, Sc.D. .... *Mechanical Engineering*
Thomas K. Caughey, Ph.D. .... *Applied Mechanics*
Donald E. Coles, Ph.D. .... *Aeronautics*
Albert T. Ellis, Ph.D. .... *Applied Mechanics*
Joel N. Franklin, Ph.D. .... *Applied Mechanics*
Nicholas George, Ph.D. .... *Electrical Engineering*
Roy W. Gould, Ph.D. .... *Electrical Engineering and Physics*
Harold Lurie, Ph.D. .... *Applied Mechanics*
Caleb W. McCormick, Jr., M.S. .... *Civil Engineering*
Hardy C. Martel, Ph.D. .... *Electrical Engineering*
Francis W. Maxstadt, Ph.D. .... *Electrical Engineering*
Robert D. Middlebrook, Ph.D. .... *Electrical Engineering*
Julius Miklowitz, Ph.D. .... *Applied Mechanics*
Dino A. Morelli, Ph.D. .... *Applied Mechanics*
Anatol Roshko, Ph.D. .... *Aeronautics*
Rolf H. Sabersky, Ph.D. .... *Mechanical Engineering*
Howell N. Tyson, B.S. .... *Mechanical Engineering and Engineering Graphics*
Thad Vreeland, Jr., Ph.D. .... *Mechanical Engineering*
David S. Wood, Ph.D. .... *Mechanical Engineering*
Theodore Y. Wu, Ph.D. .... *Applied Mechanics*
Edward E. Zukoski, Ph.D. .... *Jet Propulsion*

SENIOR RESEARCH FELLOWS

Paul J. Blatz, Ph.D. .... *Aeronautics*
Anthony Demetriades, Ph.D. .... *Aeronautics*
Theodore A. Jacobs, Ph.D. .... *Jet Propulsion*
Saul Kaplun, Ph.D. .... *Aeronautics*
Jack J. Kerrebrock, Ph.D. .... *Jet Propulsion*
Hans D. Krumhaar, Dr., D.Sc. .... *Aeronautics*
Sitaram Rao Valluri, Ph.D. .... *Aeronautics*

ASSISTANT PROFESSORS

Daniel G. Dow, Ph.D. .... *Electrical Engineering*
Robert Jahn, Ph.D. .... *Jet Propulsion*
James K. Knowles, Ph.D. .... *Applied Mechanics*
Toshi Kubota, Ph.D. .... *Aeronautics*
Carver A. Mead, Ph.D. .... *Electrical Engineering*
Francis J. Mullin, Ph.D. .... *Electrical Engineering*
Marc-Aurele Nicolet, Ph.D. .... *Electrical Engineering*
Winston W. Royce, Ph.D. .... *Aeronautics*
William R. Samples, Ph.D. .... *Civil Engineering*
Ronald F. Scott, Sc.D. .... *Civil Engineering*
David F. Welch, I.D. .... *Engineering Graphics*
Nathaniel W. Wilcox, A.B. .... *Engineering Graphics*

RESEARCH FELLOWS

Juan S. Carmona, C.E. .... *Civil Engineering*
I-dee Chang, Ph.D. .... *Aeronautics*
Din-Yu Hsieh, Ph.D. .... *Applied Mechanics*
Thomas G. Jones, Ph.D. .... *Aeronautics*
John F. Kennedy, Ph.D. .... *Civil Engineering*
Hans H. Kuehl, Ph.D. .... *Electrical Engineering*
Arthur F. Messiter, Jr., Ph.D. .... *Aeronautics*

G. J. Mohanrao, Sc.D., Ph.D. .... *Sanitary Engineering*
Barry L. Reeves, Ph.D. .... *Aeronautics*
Omar H. Sanchez, C.E. .... *Cvil Engineering*
Johnann Schaeffler, M.S. .... *Aeronautics*
Bradford Sturtevant, Ph.D. .... *Aeronautics*
William F. Warren, Ph.D. .... *Aeronautics*

INSTRUCTORS

Robert L. Harder, M.S. .... *Electrical Engineering*
Kenneth Lock, M.S. .... *Electrical Engineering*
Peter V. Mason, M.S. .... *Electrical Engineering*
Elliott Pinson, B.S.E. .... *Electrical Engineering*

GRADUATE FELLOWS AND ASSISTANTS

1959-60

Kenneth Hoyt Adams, B.S.
Harlow Garth Ahlstrom, M.S.
Daniel Kuo Yi Ai, M.S.
Pierre Alais
Frank Addison Albini, M.S.
David Ellsworth Anderson, M.S.
William Judson Anderson, M.S.
Robert James Arenz, M.S.
Richard Michael Aron, M.S.
John Fredrich Asmus, M.S.
Philip Robert Austin, B.A.E.
Charles Dwight Babcock, Jr., M.S.
Vladimir Vadim Baicher, B.S.
Eduardo Basso, C.E.
Richard Alan Baugh, B.S.
Jorge Behrmann-S., M.E.
Victor Sergeevich Beknyev, Cand.Sci.
Robert Harold Bond, M.S.
Charles Edward Brockway, B.S.C.E.
Sherwood Brofman, B.Ae.E.
Wilbur Parker Brown, M.S.E.
Robert Eugene Chandos, B.S.
William Stephen Childress, M.S.E.
Shin-kien Chow, B.S.A.
Walter Henry Christiansen, M.S.
René Clément Lucien Albert Collette, Ing.Civil A.I.M.
Daniel Joseph Collins, M.S.
Michael Anthony Cowan, M.S.
David Hastings Crimmins, B.E.E.
Jacques de Barbeyrac Saint-Maurice, Dipl. C.A.E.
Narsingh Deo, D.I.I.Sc.
Harold Ralph Dessau, M.S.
John Kalman Dienes, M.S.
Aldo Gene Di Loreto, M.S.
Harry Dym, B.E.E.
Everett Truman Eiselen, M.S.
David Arthur Evensen, B.S.
Viktor Evtuhov, M.S.
Henry Thomas Falvey, B.C.E.
Vittorio Fiorini, Ing.Ae.
Ronald Alvin Forbess, B.S.
Donald Charles Forster, M.S.
Michael Eugene Fourney, M.S.
Teruo Fujihara, M.Agric.
James Joseph Geiger, B.S.
Alain Nestor Genko, Ing.
Edward George Gibson, B.S.
Herbert Seymour Glick, M.Ae.E.
Stuart Goff, M.S.
Harris Gold, M.S.M.E.
Richard Morris Goldstein, M.S.
Robert Goldstein, B.S.
Jacek Piotr Gorecki, Dipl.Ing.
Egbert Graeve, Dipl. Ing.
Louise Ethel Gray, M.S.
L. Dale Green, B.S.
Andrew Guttman, M.S.
Kenneth Edwin Harwell, B.S.
Robert Henry Hertel, M.S.
Robert Hickling, M.Sc.
David Parks Hoult, M.S.
Din-Yu Hsieh, M.Sc.
Gordon Frierson Hughes, B.S.
Herbert Erwin Hunter, M.S.
William Norris Huse, Jr., B.S.
Izzat Muhammad Idriss, M.S.
Marcos Intaglietta, M.S.
Wilfred Dean Iwan, M.S.
Theodore Alan Jacobs, M.S.
Alexander Donald Jacobson, M.S.
Paul Christian Jennings, B.S.
Pierre Eugene Cyprien Joffres, Dipl.
Charles Richard Johnson, B.S.
Richard Alvin Johnson, B.S.
Walter Adrian Johnson, B.S.
Orval Elmer Jones, M.S.
Willard Otis Keightley, M.S.
John Fisher Kennedy, M.S.
Jirair Levon Kevorkian, M.A.E.
Vladimir Khvostchinsky, Dipl.Ing.
Kenneth Robert King, M.S.
William Klement, Jr. B.S.
William John Klenk, M.S.
Gerhard Joachim Klose, B.S.

Karl Kent Knapp, B.S.
Wolfgang Gustav Knauss, M.S.
William Wei-Lin Ko, M.S.
Murray Arnold Koerner, B.S.
Gordon Kramer, B.M.E.
Daniel Julius Krause, M.S.
Harvey N. Kreisberg, M.M.E.
Jean-Bernard Lagarde, Dipl.Ing.
Theodore Edmund Lang, M.S.
Marshall Lapp, B.Eng.Ph.
Raymond Walter Latham, M.S.
Kaye Don Lathrop, M.S.
Alfred George Lieberman, M.S.
Hans-Dieter Linhardt, Dipl.Ing.
Chung-Yen Liu, M.S.
James Reily Lloyd, M.S.
Malcolm Harvey Lock,
Dennis Vernon Long, M.S.
Richard Frederick Long, B.S.
Henry Lu-Meng, B.S.M.E.
Huey-Lin Luo, M.S.
Yen-Mow Lynn, M.S.
Dean MacGillivray, M.S.
Gordon Frank MacGinitie, M.S.
Donald MacMurray Malone, B.E.E.
Jean François Marin, M.S.
Gary Lynn Marlotte, M.S.
Gerald Albert Marxman, B.A.
Malcolm McColl, M.S.
William True McDonald, M.S.
Francis Clay McMichael, M.S.
Chiang-Chung Mei, M.S.
Karl Louis Meier, B.S.
Howard Carl Merchant, S.M.
Roger Edwin Messick, M.S.
Jean Maurice César Meuris, C.E.
Kenneth Martin Mitzner, M.S.
Maurice Mizrahi, Dipl.Ing.
Richard Stephen Muller, M.S.
Roddam Narasimha, D.I.I.Sc.(Ae)
Charl François Naude, M.S.
Michael Edmond James O'Kelly, B.E.
Daniel Burrhus Olfe, B.S.E.
Patrick Gerard O'Regan, M.S.
Robert Reid Parmerter, M.E.
William Thomas Peters, B.S.E.E.
Edward Richard Petersen, B.Sc.
James Sibley Petty, B.S.
Alfred Cyril Pinchak, M.S.E.
Elliot Neil Pinson, S.M.
Raymond Pittman, Jr., B.S.
Bernard Charles Reardon, M.S.
Roy Earl Reichenbach, M.S.
Eli Reshotko, M.M.E.
Ira Richer, B.E.E.
Robert Leopold Rosenfeld, S.B.
Nikhilesh Roy, M.S.
David Allison Russell, M.S.
Robert Vartan Samuelian, B.E.E.
Richard Allan Schapery, M.S.
William George Scheerer, B.E.E.
John Joseph Schuster, B.S.
Richard Anthony Scott, M.Sc.
Jason Gene Seubold, S.M.
William Lewis Shackleford, B.E.
Yun-Yuan Shi, M.Sc.
Fred Ichiro Shimabukuro, S.M.
Alex Shumka, M.S.
Peter Gerald Simpkins, Dipl.
William Dean Squire, B.S.
Roy Thorwald Stake, B.S.
Ronald Oran Stearman, M.S.
Jack Justin Stiffler, M.S.
Leonard Dewey Stimpson, Jr., M.S.
Edwin Jule Stofel, M.S.
Henry John Stumpf, M.S.
Bradford Sturtevant, M.S.
Salvatore Philip Sutera, M.S.
Ivan Edward Sutherland, B.Sc.
Byron Edwin Swartz, B.S.
Robert Hugh Taylor, M.S.
Terry Olin Teigen, B.S.
Robert Clem Titsworth, M.S.
Harry Warren Townes, B.S.
Wai Keung Tso, B.Sc.
Charles William Van Atta, M.S.E.
Paul Eugene Marie Vandenplas, Lic.Sc.Phys.
George Charpentier Vlases, M.S.
William Louis Waggoner, B.S.
Duen-pao Wang, M.S.
Neng-Ming Wang, M.S.
Ronald Watson, M.S.
Evan Otto Weiner, B.S.
Donald Martin Wiberg, B.S.
Ronald Howard Willens, M.S.
John Harold Willmorth, M.S.E.E.
Jack Wireman, B.S.M.E.
Jain-Ming Wu, M.S.
Ying-Chu Lin Wu, M.S.
Jonas Stasys Zmuidzinas, M.S.

Division of the Geological Sciences

Robert P. Sharp, *Chairman*

Frank Press, *Director of the Seismological Laboratory*

PROFESSORS

Hugo Benioff, Ph.D. . . . . *Seismology*
Harrison S. Brown, Ph.D. . . . . *Geochemistry*
Charles Hewitt Dix, Ph.D. . . . . *Geophysics*
**Albert E. J. Engel, Ph.D. . . . . *Geology*
Samuel Epstein, Ph.D. . . . . *Geochemistry*
Heinz A. Lowenstam, Ph.D. . . . . *Paleoecology*
Frank Press, Ph.D. . . . . *Geophysics*
Charles F. Richter, Ph.D. . . . . *Seismology*
Robert P. Sharp, Ph.D. . . . . *Geology*

RESEARCH ASSOCIATE

Ian Campbell, Ph.D. . . . . *Geology*

VISITING PROFESSORS

Edward Anders, Ph.D. . . . . *Geochemistry*

ASSOCIATE PROFESSORS

Arden Albee, Ph.D. . . . . *Geology*
Clarence R. Allen, Ph.D. . . . . *Geology*
**W. Barclay Kamb, Ph.D. . . . . *Geology*
Gennady W. Potapenko,[1] Ph.D. . . . . *Geophysics*
Gerald J. Wasserburg, Ph.D. . . . . *Geology*

SENIOR RESEARCH FELLOWS

Charles R. McKinney, B.S. . . . . *Geochemistry*
Claire C. Patterson, Ph.D. . . . . *Geochemistry*

ASSISTANT PROFESSORS

Manuel Bass, Ph.D. . . . . *Geology*
Egon T. Degens, Ph.D. . . . . *Geology*
Charles E. Helsley, Ph.D. . . . . *Geology*
Leon T. Silver, Ph.D. . . . . *Geology*
Hugh P. Taylor, Jr., Ph.D. . . . . *Geology*

RESEARCH FELLOWS

G. F. L. Dietzel, Ph.D. . . . . *Geophysics*
A. L. Hales, Ph.D. . . . . *Geophysics*
Bruce C. Murray, Ph.D. . . . . *Space Science*
Kihlo Park, Ph.D. . . . . *Geochemistry*
B. G. J. Upton, Ph.D. . . . . *Geology*

CURATOR OF MINERALOGY

William C. Oke . . . . . *Mineralogy*

***Leave of absence 1960-61*

GRADUATE FELLOWS AND ASSISTANTS, 1959-60

Shelton Alexander, M.S.
Don L. Anderson, M.S.
Charles B. Archambeau, M.S.
James L. Aronson, B.A.
Philip O. Banks, S.B.
Ari Ben-Menahem, M.S.
Shawn Biehler, M.S.E.
Robert R. Blandford, B.S.
Paul G. Bower, B.A.
William M. Chapple, M.S.
Armando Cisternas-S., Min.Eng.
James E. Conel, M.S.
James R. Dodd, A.M.
Bruce R. Doe, M.S.
Stèphane Dopp, Lic.Sci.
Michael B. Duke, B.S.
Norman B. Farha, B.S.
Fayet, Guy-Emile, Ing.
Clinton Frasier, B.S.
Bevan M. French, A.B.
John K. Frye, M.S.
George D. Garlick, B.Sc.
James A. Grant, M.A.
M. Grant Gross, M.S.
P. Edgar Hare, M.S.
David A. Harkrider, M.A.
James F. Hays, A.B.
John H. Healy, M.S.
Noel W. Hinners, B.S.
Andrew H. Jazwinski, B.S.
Dean M. Johnson, B.S.G.
Robert L. Kovach, M.A.
Marvin A. Lanphere, M.S.
Jimmy Larsen, B.S.
Nelson Liberman, M.A.
Richard L. Mauger, B.S.
Walter Mitronovas, B.S.
Robert A. Phinney, S.M.
Gerald D. Pollock, M.S.
David J. Roddy, M.S.
Maung Sann, B.Sc.
David L. Schleicher, B.S.
George A. Sellers, B.S.
Robert V. Sharp, B.S.
Dale R. Simpson, M.S.
Stewart W. Smith, M.S.
M. Nafi Toksöz, Gph.Eng.
John Watson, M.S.
Christian Weber, Doc.Ge.
John C. Wilson, M.S.
Robert E. Zartman, M.S.

Division of the Humanities

Hallett D. Smith, *Chairman*

PROFESSORS EMERITI

George R. MacMinn, A.B. .... *English*

PROFESSORS

J. Kent Clark, Ph.D. .... *English*
James C. Davies, Ph.D. .... *Political Science*
Harvey Eagleson, Ph.D. .... *English*
Horace N. Gilbert, M.B.A. .... *Business Economics*
Robert D. Gray, B.S. .... *Industrial Relations*
Hunter Mead, Ph.D. .... *Philosophy and Psychology*
Rodman W. Paul, Ph.D. .... *History*
Hallett D. Smith, Ph.D. .... *English*
Roger Stanton, Ph.D. .... *English*
Alfred Stern, Ph.D. .... *Languages and Philosophy*
Alan R. Sweezy, Ph.D. .... *Economics*
Ray E. Untereiner, Ph.D. .... *Economics*

RESEARCH ASSOCIATE

Michael T. Wermel,[1] Ph.D. .... *Industrial Relations*

ASSOCIATE PROFESSORS

Paul Bowerman, A.M. .... *Languages*
Melvin D. Brockie, Ph.D. .... *Economics*
Charles E. Bures, Ph.D. .... *Philosophy*
Paul C. Eaton, A.M. .... *English*
Heinz Ellersieck, Ph.D. .... *History*
David C. Elliot, Ph.D. .... *History*
Peter Fay, Ph.D. .... *History*
L. Winchester Jones, A.B. .... *English*
Beach Langston, Ph.D. .... *English*
George P. Mayhew, Ph.D. .... *English*
H. Dan Piper, Ph.D. .... *English*
Cushing Strout, Ph. D. .... *History*
John R. Weir, Ph.D. .... *Psychology*

LECTURERS

Edward Hutchings, Jr. .... *Journalism*
Alexander Kishkovsky, M.A. .... *Russian*
Alexander Kosloff, Ph.D. .... *Russian*
Peter Miller, Ph.D. .... *English*
Orpha Ochse, Ph.D. .... *Music*

VISITING LECTURERS

Edwin S. Munger, Ph.D. .... *International Affairs*
Lawrence Olson, Ph.D. .... *International Affairs*
Richard W. Patch, Ph.D. .... *International Affairs*
Albert Ravenholt .... *International Affairs*

[1]On leave of absence, 1960-61

ASSISTANT PROFESSORS

Robert Huttenback, Ph.D. .... *History*
Robert W. Oliver, Ph.D. .... *Economics*
David Smith, Ph.D. .... *English*

INSTRUCTORS

Paul R. Baker, Ph.D. .... *History*
Dwight Thomas, M.A. .... *English and Speech*
Robert D. Wayne, M.A. .... *German*

RESEARCH ASSISTANT

Doris Logan, B.A. .... *Public Affairs*

Division of Physics, Mathematics and Astronomy

Robert F. Bacher, *Chairman, Director of the Norman Bridge Laboratory*

PROFESSORS EMERITI

Eric T. Bell, Ph.D. .... *Mathematics*
Paul S. Epstein, Ph.D. .... *Theoretical Physics*

PROFESSORS

Carl D. Anderson, Ph.D., Sc.D., LL.D., Nobel Laureate .... *Physics*
Robert F. Bacher, Ph.D., Sc.D. .... *Physics*
H. F. Bohnenblust, Ph.D.[1] .... *Mathematics*
John G. Bolton, B.A. .... *Radio Astronomy*
R. F. Christy, Ph.D.[1] .... *Theoretical Physics*
Leverett Davis, Jr., Ph.D. .... *Theoretical Physics*
Robert P. Dilworth, Ph.D. .... *Mathematics*
Jesse W. M. DuMond, Ph.D. .... *Physics*
A. Erdelyi, D.Sc. .... *Mathematics*
Richard P. Feynman, Ph.D. .. *Richard Chace Tolman Professor of Theoretical Physics*
William A. Fowler, Ph.D. .... *Physics*
Murray Gell-Mann, Ph.D. .... *Theoretical Physics*
Jesse L. Greenstein, Ph.D. .... *Astrophysics*
Marshall Hall, Jr., Ph.D. .... *Mathematics*
Robert B. King, Ph.D. .... *Physics*
Charles C. Lauritsen, Ph.D. .... *Physics*
Thomas Lauritsen, Ph.D. .... *Physics*
Robert B. Leighton, Ph.D. .... *Physics*
Guido Munch, Ph.D. .... *Astronomy*
H. Victor Neher, Ph.D. .... *Physics*
John R. Pellam, Ph.D. .... *Physics*
H. P. Robertson, Ph.D. .... *Mathematical Physics*
Matthew Sands, Ph.D. .... *Physics*
William R. Smythe, Ph.D. .... *Physics*
Richard M. Sutton, Ph.D. .... *Physics*
John Todd, B.Sc. .... *Mathematics*
Robert L. Walker, Ph.D. .... *Physics*
Morgan Ward, Ph.D. .... *Mathematics*
Earnest C. Watson, Sc.D.[1] .... *Physics*
Fritz Zwicky, Ph.D. .... *Astrophysics*

[1]On leave of absence

VISITING PROFESSORS

Fred Hoyle, M. A. .... *Addison White Greenway Visiting Professor of Astronomy*
Helmut Wielandt, Ph.D. .... *Mathematics*
A. C. Zaanen, Dr. Math .... *Mathematics*

RESEARCH ASSOCIATES

Harry A. Kirkpatrick, Ph.D. .... *Physics*
Olga T. Todd, Ph.D. .... *Mathematics*
M. L. Wiedenbeck, Ph.D. .... *Physics*

ASSOCIATE PROFESSORS

T. M. Apostol, Ph.D. .... *Mathematics*
Charles A. Barnes, Ph.D. .... *Physics*
Felix Boehm, Ph.D. .... *Physics*
Eugene W. Cowan, Ph.D. .... *Physics*
Richard A. Dean, Ph.D. .... *Mathematics*
F. Brock Fuller, Ph.D. .... *Mathematics*
Alexander Goetz, Ph.D. .... *Physics*
Roy W. Gould, Ph.D. .... *Electrical Engineering & Physics*
W. A. J. Luxemburg, Ph.D. .... *Mathematics*
Maarten Schmidt, Ph.D. .... *Astronomy*
Alvin V. Tollestrup, Ph.D. .... *Physics*
Ward Whaling, Ph.D. .... *Physics*
Calvin H. Wilcox, Ph.D. .... *Mathematics*

SENIOR RESEARCH FELLOWS

Dieter Gaier, Ph.D. .... *Mathematics*
Ricardo Gomez, Ph.D. .... *Physics*
Thomas A. Matthews, Ph. D. .... *Radio Astronomy*
Joe H. Mullins, Ph.D. .... *Physics*
Gordon J. Stanley, Dipl.E.E. .... *Radio Astronomy*
John M. Teem, Ph.D. .... *Physics*

ASSISTANT PROFESSORS

Richard E. Block, Ph.D. .... *Mathematics*
Ralph W. Kavanagh, Ph.D. .... *Physics*
Jon Mathews, Ph.D. .... *Physics*
James E. Mercereau, Ph.D. .... *Physics*
J. B. Oke, Ph.D. .... *Astronomy*
Vincent Z. Peterson, Ph.D. .... *Physics*
T. Foster Strong, M.S. .... *Physics*
Fredrik Zachariasen, Ph.D. .... *Theoretical Physics*

VISITING ASSISTANT PROFESSOR

H. A. Weidenmuller, Ph.D. .... *Physics*

LECTURERS

Burton D. Fried, Ph.D. .... *Physics*
Robert W. Hellwarth, Ph.D. .... *Physics*

INSTRUCTORS

G. D. Chakerian, Ph.D. .... *Mathematics*
Charles R. Hobby, Ph.D. .... *Mathematics*
Charles R. B. Wright, Ph.D. .... *Mathematics*

RESEARCH FELLOWS

Alessandro Alberigi, Ph.D. .... *Physics*
Ludwig Bierman, Ph.D. .... *Physics*
E. C. Dade,[1] Ph.D. .... *Mathematics*
Sheldon L. Glashow, Ph.D. .... *Theoretical Physics*
Jean Humblet, D.Sc. .... *Physics*
Ulrich Hauser, Ph.D. .... *Physics*
Detlef Kamke, Ph.D. .... *Physics*
Marvin I. Knopp, Ph.D. .... *Mathematics*
Cevdet Kocak, Ph.D. .... *Mathematics*
Per Maltby, Ph.D. .... *Radio Astronomy*
Rudolf L. Moessbauer, Ph.D. .... *Physics*
David Morris, Ph.D. .... *Radio Astronomy*
T. Mayer-Kuckuk, Ph.D. .... *Physics*
Gerry Neugebauer, Ph.D. .... *Physics*
Jack C. Overley, Ph.D. .... *Physics*
Gerard J. Nijgh, Ph.D. .... *Physics*
Jogesh C. Pati,[2] Ph.D. .... *Theoretical Physics*
V. Radhakrishnan, B.Sc. .... *Radio Astronomy*
R. H. Spear, Ph.D. .... *Physics*
Edward J. Tully, Jr., Ph.D. .... *Mathematics*
Frank L. Vernon, Jr., Ph.D. .... *Physics*
A. Bruce Whitehead, Ph.D. .... *Physics*

GRADUATE FELLOWS AND ASSISTANTS, 1959-60

Jon G. Ables, A.B.
Norman W. Albright, B.S.
Ethan D. Alyea, Jr., A.B.
John P. Andelin, Jr., B.S.
Hugh R. Anderson, B.A.
R. Keith Bardin, B.S.
Thomas M. Bieniewski, B.S.
Harry H. Bingham, Jr., A.B.
James H. Boyden, M.S.
Richard E. Bradbury, B.A.
Richard T. Brockmeier, B.A.
Ronald E. Brown, B.S.
Berken Chang, B.S.
David B. Chang, B.S.
James T. Chang, B.S.
Hung Cheng, B.S.
Marvin Chester, B.S.
Donald D. Clayton, M.S.
Carl R. Clinesmith, B.S.
Richard L. Cohen, M.S.
Sidney R. Coleman, B.S.
Donald G. Coyne, B.S.
Melvin D. Daybell, B.S.
William E. Dibble, B.S.
Robert E. Diebold, B.S.
Frank S. Dietrich III, B.A.
Richard Dolen, B.E.Ph.
Norman D. Dombey, B.A.
John J. Domingo, B.S.
Ian M. Duck, M.Sc.
W. Farrell Edwards, M.S.
Christian A. Engelbrecht, M.Sc.
Victor A. Erma, M.A.
Thornton R. Fisher, B.A.
James L. C. Ford, Jr., M.S.
Lyman J. Fretwell, Jr., B.S.
Victor Gilinsky, B.E.Ph.
Howard B. Greenstein, Sc.B.
David E. Groce, B.S.
Donald E. Groom, A.B.
Gerhard E. Hahne, B.S.
G. Laurie Hatch, B.S.
Robert J. Hecht, S.B.
Thomas M. Helliwell, B.A.
Henry H. Hilton III, M.S.
John L. Honsaker, B.S.
James S. Howland, B.S.
Elisha R. Huggins, B.S.
Arthur J. Hundhausen, M.S.
Richard O. Hundley, M.S.
Thomas K. Hunt, B.A.
Carl K. Iddings, B.A.
Earl D. Jacobs, M.S.
Kenneth I. Kellermann, S.B.
Joseph R. Kilner, B.S.
Thomas R. Koehler, B.S.
Joel I. Krugler, B.E.E.
James D. Larson, M.S.
George M. Lawrence, B.S.
Andrew S. Lebor, B.S.
Arnold V. Lesikar, B.A.
Michael J. Levine, B.S.
Paul H. Levine, M.S.
John K. Link, B.S.
Robert L. Luttermoser, M.S.
Robert J. Macek, B.S.

[1]Harry Bateman Research Fellow
[2]Richard Chace Tolman Research Fellow

John O. Maloy, B.S.
J. Howard Marshall III, B.S.
James A. McCray, M.S.
James H. McNally, B.E.Ph.
John J. Merrill, M.S.
F. Curtis Michel, B.S.
James E. Midgley, B.S.E.
Ralph F. Miles, Jr., B.S.
Catalin C. Mitescu, B.E.Ph.
Alan T. Moffet, B.A.
Norton L. Moise, M.S.
Charles G. Montgomery, B.A.
Fernando B. Morinigo, B.S.
Arthur H. Muir, Jr., M.S.
Gerry Neugebauer, A.B.
John C. Nickel, B.A.
Peter D. Noerdlinger, A.B.
Thomas W. Noonan, B.S.
M. Emery Nordberg, Jr., M.S.
Harris A. Notarys, S.B.
Robert W. Noyes, B.A.
Jack C. Overley, S.B.
Peter D. M. Parker, B.A.
John D. Pearson, Sc.B.
Charles W. Peck, B.S.
Lewis S. Pilcher, S.B.
Philip M. Platzman, M.S.
Gerald L. Pollack, M.S.
R. Darden Powers, M.S.
Andrew P. Proudian, B.S.
Richard B. Read, B.S.
James H. Renken, M.Sc.
John D. Rogers, M.S.
Henry Ruderman, B.S.
Philip A. Seeger, B.A.
George A. Seielstad, A.B.
Edwin C. Seltzer, B.S.
Lionel S. Senhouse, Jr., M.S.
Edward J. Seppi, M.S.
Jon H. Shirley, A.B.
Warren L. Simmons, B.S.
George W. Simon, A.B.
Richard K. Sloan, M.S.
Frank T. Snively, B.S.
John R. Stevens, M.S.
William A. Steyert, M.S.
D. Gary Swanson, B.S.
Richard M. Talman, M.S.
Ivo Tammaru, B.S.
Terence C. Terman, M.S.
John R. Thomas, B.S.
Lorin L. Vant-Hull, M.S.
Joseph L. Vogl, M.S.
Mark H. Wagner, A.B.
William G. Wagner, B.S.
Robert W. Wilson, B.A.
Harold T. Yura, B.S.
George Zweig, B.S.

Mount Wilson and Palomar Observatories

Operated Jointly with the Carnegie Institution of Washington

Ira S. Bowen, *Director*
Horace W. Babcock, *Assistant Director*

OBSERVATORY COMMITTEE

Ira S. Bowen, *Chairman*
Horace W. Babcock
Robert F. Bacher
John G. Bolton
Jesse L. Greenstein
Allan R. Sandage

STAFF MEMBERS

Halton C. Arp, Ph.D.
Horace W. Babcock, Ph.D.
William A. Baum, Ph.D.
Ira S. Bowen, Ph.D., Sc.D.
Armin J. Deutsch, Ph.D.
Jesse L. Greenstein, Ph.D.
Fred Hoyle, M.A.
Robert P. Kraft, Ph.D.
Guido Munch, Ph.D.
J. Beverley Oke, Ph.D.
Allan R. Sandage, Ph.D.
Maarten Schmidt, Ph.D.
Olin C. Wilson, Ph.D.
Fritz Zwicky, Ph.D.

SENIOR RESEARCH FELLOWS IN ASTRONOMY

E. Margaret Burbidge, Ph.D.
Geoffrey R. Burbidge, Ph.D.
Alastair G. W. Cameron, Ph.D.
H. Lawrence Helfer, Ph.D.
Satoshi Matsushima, Ph.D.
Leonard Searle, Ph.D.

RESEARCH FELLOWS IN ASTRONOMY

Walter K. Bonsack, Ph.D.
John C. Brandt, Ph.D.
Giuseppa de Strobel Cayrel, D.Sc.
Roger Cayrel, Ph.D.
Alercio M. Gomes, Ph.D.
Roger F. Griffin, B.A.
John A. Hazlehurst, Ph.D.
Paul J. Hodge, Ph.D.
Leo Houziaux, Ph.D.
Jun Jugaku, Ph.D., D.Sc.
George W. Preston, Ph.D.
Alexander W. Rodgers, Ph.D.
Konrad Rudnicki, Ph.D.
Wallace L. W. Sargent, Ph.D.
George Wallerstein, Ph.D.
Ray Weymann, Ph.D.

ENGINEERS

Bruce H. Rule, B.S.
Byron Hill, B.S.

Air Science

PROFESSOR

Maj. Francis R. MacKenzie, U.S.A.F., B.S., M.B.A.

ASSISTANT PROFESSORS

Captain Andrew Henry, U.S.A.F., B.S.
Captain Cary D. Stephenson, U.S.A.F., B.S.

ASSISTANTS

T/Sgt. Willard J. Garner
S/Sgt. John E. Merchant
T/Sgt. Richard E. Stafford

Department of Physical Education

Harold Z. Musselman, A.B., *Director of Athletics and Physical Education*

COACHES

Bert LaBrucherie, B.E.
Warren G. Emery, M.S.
James H. Nerrie, B.S.
Edward T. Priesler, B.A.

PHYSICAL TRAINER

Dr. Floyd L. Hanes, D.O.

ASSISTANTS

Lee A. Andrews, B.A.
Shelby C. Calhoun, B.A.
Thomas K. Hunt, B.A.
John Lamb
Walter Mack, M.A.
Eugene Rock, B.S.

ATHLETIC COUNCIL

The intercollegiate athletic program is under the supervision of the Athletic Council, which consists of representatives of the Faculty, the Associated Students of the California Institute of Technology (ASCIT), and the Alumni of the Institute.

Industrial Relations Section

Robert D. Gray, B.S., *Director of Industrial Relations*
(Mrs.) Geraldine M. Beideman, M.A., *Associate Research Director, Benefits and Insurance Research Center*
(Mrs.) Helen L. Thompson, B.Ed., *Assistant to the Director*
Michael T. Wermel, Ph.D., *Research Director, Benefits and Insurance Research Center; Research Associate in Economics and Insurance; Associate Director, Management Development Center*
Arthur H. Young, *Lecturer Emeritus on Industrial Relations*

Student Health Services

Richard F. Webb, M.D., *Director of Health Services*

R. Stewart Harrison, M.D. .... *Assistant Director and Consultant in Radiology*
R. A. Crosse, M.D. .... *Institute Physician*
N. Y. Matossian, M.D.. *Institute Physician*
Daniel C. Siegel, M.D. .... *Consulting Physician*
Alice A. Shea, R.N. .... *Nursing Supervisor*

The Faculty Committee on Student Health acts in an advisory capacity to the Director of Health Services on all matters of policy pertaining to the Health Program and administers the Emergency Health Fund.

Student Musical Activities

Hunter Mead .... *Chairman, Faculty Committee on Musical Activities*
John C. Deichman .... *Director of Student Band*
Olaf Frodsham .... *Director of Student Glee Club*

FACULTY

Lee Alvin DuBridge, Ph.D., Sc.D., LL. D., *President*
A.B., Cornell College (Iowa), 1922; A.M., University of Wisconsin, 1924; Ph.D., 1926. California Institue, 1946-. (106 Throop) 415 South Hill Avenue.

Allan James Acosta, Ph.D., *Associate Professor of Mechanical Engineering*
B.S., California Institute, 1945; M.S., 1949; Ph.D., 1952. Assistant Professor, 1954-58; Associate Professor, 1958-. (207 Engr. Bldg.) 1779 East Mendocino, Altadena.

Arden Leroy Albee, Ph.D., *Associate Professor of Geology*
A.B., Harvard College, 1950; A.M., Harvard University, 1951; Ph.D., 1957. Visiting Assistant Professor, California Institute, 1959-60; Associate Professor, 1960-. (269 Arms) 1320 Hastings Ranch Drive.

Peter Albersheim, Ph.D., *Research Fellow in Biology*
B.S., Cornell University, 1956; Ph.D., California Institute, 1959. Research Fellow, 1959.

Allessandro Alberigi, Laur., *Research Fellow in Physics*
Laureate, University of Bologna, 1952. Staff Member, Laboratori Nazionali di Frascati, Rome. California Institute, 1960.

Clarence Roderic Allen, Ph.D., *Associate Professor of Geology*
B.A., Reed College, 1949; M.Sc., California Institute, 1951; Ph.D., 1954. Assistant Professor, 1955-59; Associate Professor, 1959-. (351 Arms) 1160 Cordova Street, Apt. 8.

Gordon Albert Alles, Ph.D., *Research Associate in Biology*
B.S., California Institute, 1922; M.S., 1924; Ph.D., 1926. Research Associate, 1939-. 770 South Arroyo Parkway.

Edward Anders, Ph.D., *Visiting Professor of Geochemistry*
A.M., Columbia University, 1951; Ph.D., 1954. Assistant Professor of Chemistry, University of Chicago, 1955-. California Institute, 1960.

Carl David Anderson, Ph.D., Sc.D., LL.D., Nobel Laureate, *Professor of Physics*
B.S., California Institute, 1927; Ph.D., 1930; Research Fellow, 1930-33; Assistant Professor, 1933-37; Associate Professor, 1937-39; Professor, 1939-. (22 Bridge) 2915 Lorain Road, San Marino.

Ernest Gustaf Anderson, Ph.D., *Professor of Genetics*
B.S., University of Nebraska, 1915; Ph.D., Cornell University, 1920. Associate Professor, California Institute, 1928-47; Professor, 1947-. (Biology Farm) 1227 South Temple City Boulevard, Arcadia.

Fred Colvig Anson, Ph.D., *Assistant Professor of Analytical Chemistry*
B.S., California Institute, 1954; Ph.D., Harvard University, 1957. Instructor, California Institute, 1957-58; Assistant Professor, 1958-. (11 Gates) 410 Churchill Road, Sierra Madre.

Tom M. Apostol, Ph.D., *Associate Professor of Mathematics*
B.S., University of Washington, 1944; M.S., 1946; Ph.D., University of California, 1948. Assistant Professor, California Institute, 1950-56; Associate Professor, 1956-. (356 Sloan) 3705 Alzada Road, Altadena.

Harbans Lall Arora, Ph.D., *Research Fellow in Biology*
B.S., Panjab University, India, 1944; M.S., 1945; Ph.D., Stanford University, 1949. California Institute, 1957-. (319 Kerckhoff) 720 Magnolia Street.

Halton Christian Arp, Ph.D., *Staff Member, Mount Wilson and Palomar Observatories*
A.B., Harvard College, 1949; Ph.D., California Institute, 1953. Mt. Wilson Observatory, 1957-. (Mt. Wilson Office) 2113 Minoru Drive, Altadena.

Domenica Gandini Attardi, M.D., *Research Fellow in Biology*
M.D., University of Padua, 1947. Assistant, Institute of Histology and General Embryology, University of Padua, 1957-. California Institute, 1959-60.

Horace Welcome Babcock, Ph.D., *Assistant Director, Mount Wilson and Palomar Observatories*
B.S., California Institute, 1934; Ph.D., University of California, 1938. Mt. Wilson Observatory, 1946-. (Mt. Wilson Office) 439 South Virginia Avenue.

Robert Fox Bacher, Ph.D., Sc.D., *Professor of Physics; Chairman, Division of Physics, Mathematics and Astronomy; Director, Norman Bridge Laboratory of Physics*
B.S., University of Michigan, 1926; Ph.D., 1930. California Institute, 1949. (111 E. Bridge) 345 South Michigan Avenue.

John P. Bader, Ph.D., *Research Fellow in Biology*
B.S., University of Rochester, 1955; Ph.D., 1960. California Institute, 1960-61.

Richard McLean Badger, Ph.D., *Professor of Chemistry*
B.S., California Institute, 1921; Ph.D., 1924. Research Fellow, 1924-28; International Research Fellow, 1928-29; Assistant Professor, 1929-38; Associate Professor, 1938-45; Professor, 1945-. (158 Crellin) 1963 New York Drive, Altadena.

Paul Raymond Baker, Ph.D., *Instructor in History*
A.B., Stanford University, 1949; M.A., Columbia University, 1951; Ph.D., Harvard University, 1960. California Institute, 1960-61.

Claudio Barigozzi, D.Sc., *Research Fellow in Biology*
D.Sc., University of Pavia, Italy, 1932. Professor of Genetics, University of Milan, 1948-. California Institute, 1960.

Charles Andrew Barnes, Ph.D., *Associate Professor of Physics*
B.A., McMaster University, 1943; M.A., University of Toronto, 1944; Ph.D., Cambridge University, 1950. Research Fellow, California Institute, 1953-54; Senior Research Fellow, 1954-55; 1956-58; Associate Professor, 1958-. (104 Kellogg) 1132 Constance Avenue.

Manuel Nathan Bass, Ph.D., *Assistant Professor of Geology*
B.S., California Institute, 1949; M.S., 1951; Ph.D., Princeton University, 1956. Fellow, Carnegie Institution, Washington, D.C., 1959-. Visiting Professor, California Institute, 1960-61.

Stuart Jeffrey Bates, Ph.D., *Professor of Physical Chemistry, Emeritus*
B.A., McMaster University, 1907; M.A., 1909; Ph.D., University of Illinois, 1912. California Institute, 1914-56. Professor Emeritus, 1956-. 2011 Rose Villa Street.

Robin Gilbert Charles Bathurst, M.Sc., *Visiting Assistant Professor of Geology*
B.Sc., Imperial College of Science and Technology, University of London; M.Sc., Cambridge University. Lecturer, University of Liverpool, 1951-. California Institute, 1960.

William Alvin Baum,* Ph.D., *Staff Member, Mount Wilson and Palomar Observatories*
B.A., University of Rochester, 1943; M.S., California Institute, 1945; Ph.D., 1950. Mt. Wilson and Palomar Observatories, 1950-. (Mt. Wilson Office) 566 North Marengo Avenue.

Klaus Bayreuther, Ph.D., *Research Fellow in Biology*
Ph.D., University of Wurzburg, 1955. Staff Member, Karolinska Institute, Stockholm, 1958-. California Institute, 1960-61.

George Wells Beadle, Ph.D., D.Sc., Nobel Laureate, *Professor of Biology; Chairman of the Division of Biology; Acting Dean of the Faculty*
B.S., University of Nebraska, 1926; M.S., 1927; Ph.D. Cornell University, 1931. Research Fellow, California Institute, 1931-36; Professor, Chairman of Division, 1946-; Acting Dean of the Faculty, 1960-. (161 Church) 1149 San Pasqual Street.

Robert Adolph Becker, Ph.D., *Research Associate in Physics*
B.S., College of Puget Sound, 1935; M.S., California Institute, 1937; Ph.D., 1941. Professor of Physics, University of Illinois, 1955-. Research Associate, California Institute, 1958; 1959; 1960.

Eric Temple Bell, Ph.D., *Professor of Mathematics, Emeritus*
A.B., Stanford University, 1904; A.M., University of Washington, 1908; Ph.D., Columbia University, 1912; California Institute, 1926-53; Professor Emeritus, 1953-.

James Edgar Bell, Ph.D., *Professor of Chemistry, Emeritus*
B.S., University of Chicago, 1905; Ph.D., University of Illinois, 1913. California Institute, 1916-45; Professor Emeritus, 1955-. 3438 Vosburg Street.

Victor Hugo Benioff, Ph.D., *Professor of Seismology*
A.B., Pomona College, 1921; Ph.D., California Institute, 1935. Assistant Professor, 1937; Associate Professor, 1937-50; Professor, 1950-. (Seismological Lab.) 5534 Rock Castle Drive, La Cañada.

Ephraim Ben-Zvi, Ph.D., *Research Fellow in Chemistry*
B.S., Israel Institute of Technology, 1952; Engr., 1953; Ph.D., University of California (Davis), 1960. California Institute, 1960-61. (6 Gates) 1314 Huntington Drive, South Pasadena.

Ed. Berg, Ph.D., *Research Fellow in Seismology*
Dipl. Phys., Saarbrucken University, 1953; Ph.D., 1955. Head, Department of Seismology, Institute for Scientific Research in Central Africa. California Institute, 1961.

Ludwig Biermann, Ph.D., *Research Associate in Physics*
Ph.D., Goettingen University, 1932. Professor of Physics, Max Planck Institut fur Physik, Munich. Visiting Professor of Astrophysics, California Institute, 1955; Research Associate, 1960.

Max Luciano Birnstiel, D.Sc., *Research Fellow in Biology*
Dipl. Sc., Federal Institute of Technology, Zurich, 1958; D.Sc., 1959. California Institute, 1960-61. (012 Kerckhoff) 249 South Catalina Avenue.

*Leave of absence, 1960-61

Paul J. Blatz, Ph.D., *Senior Research Fellow in Aeronautics*
B.S., Fordham University, 1944; Ph.D., Princeton University, 1947. Research Fellow, California Institute, 1958-59; Senior Research Fellow, 1959-. (Guggenheim) 156 West 7th Avenue, Claremont.

Richard Earl Block, Ph.D., *Assistant Professor of Mathematics*
A.B., University of Chicago, 1949; S.B., 1950; S.M., 1952; Ph.D., 1956. Bateman Research Fellow, California Institute, 1959-60; Assistant Professor, 1960-. (380 Sloan) 473 South El Molino Avenue.

Felix Hans Boehm, Ph.D., *Associate Professor of Physics*
Dipl.Phys., Federal Institute of Technology, Zurich, 1948; Ph.D., 1951. Research Fellow, California Institute, 1953-55; Senior Research Fellow, 1955-58; Assistant Professor, 1958-59; Associate Professor, 1959-. (157 West Bridge) 2578 Altadena Drive, Altadena.

Henri Frederic Bohnenblust,* Ph.D., *Professor of Mathematics; Dean of Graduate Studies*
A.B., Federal Institute of Technology, Zurich, 1928; Ph.D., Princeton University, 1931. Professor, California Institute, 1946-; Dean of Graduate Studies, 1956-. (114 Throop; 288 Sloan) 1798 North Pepper Drive.

R. John H. Bollard, Ph.D., *Visiting Associate Professor of Aeronautics*
B.E., University of New Zealand, 1948; M.E., 1949; Ph.D., Purdue University, 1954. Associate Professor of Aeronautical Engineering, Purdue University, 1956-. California Institute, 1960.

John Gatenby Bolton, B.A., *Professor of Radio Astronomy*
B.A., Cambridge University, 1941. Senior Research Fellow in Physics and Astronomy, California Institute, 1955-58; Professor, 1958-. (102 Robinson) 833 Oakwood Place.

James Frederic Bonner, Ph.D., *Professor of Biology*
A.B., University of Utah, 1931; Ph.D., California Institute, 1934. Research Assistant, 1935-36; Instructor, 1936-38; Assistant Professor, 1938-42; Associate Professor, 1942-46; Professor, 1946-. (128 Kerckhoff) 1740 Homet Road.

Henry Borsook, Ph.D., M.D., *Professor of Biochemistry*
Ph.D., University of Toronto, 1924; M.B., 1927; M.D., 1940. Assistant Professor, California Institute, 1929-35; Professor, 1935-. (226 Kerckhoff) 1121 Constance Street.

Ira Sprague Bowen, Ph.D., Sc.D., *Director, Mount Wilson and Palomar Observatories*
A.B., Oberlin College, 1919; Ph.D., California Institute, 1926. Instructor, California Institute, 1921-26; Assistant Professor, 1926-28; Associate Professor, 1928-31; Professor, 1931-45; Mt. Wilson Observatory, 1946-. (Mt. Wilson Office) 2388 North Altadena Drive, Altadena.

Paul Bowerman, A.M., *Associate Professor of Modern Languages*
A.B., Dartmouth College, 1920; A.M., University of Michigan, 1936. Instructor, California Institute, 1942-45; Assistant Professor, 1945-47; Associate Professor, 1947-. (9 Dabney) 707 Auburn Avenue, Sierra Madre.

John C. Brandt, Ph.D., *Research Fellow in Astronomy*
Ph.D., University of Chicago, 1960. California Institute, 1960-61. (Mt. Wilson Office).

Sidney Brenner, Ph.D., *Research Fellow in Biology*
M.Sc., University of Witwatersrand, South Africa, 1947; M.B.B., Oxford University, 1951; Ph.D., Cambridge University, 1958. Staff Member, Medical Research Council Unit for Molecular Biology, Cavendish Laboratory, Cambridge. California Institute, 1960.

Melvin David Brockie, Ph.D., *Associate Professor of Economics*
B.A., University of California (Los Angeles), 1942; M.A., 1944; Ph.D., 1948. Instructor, California Institute, 1947-49; Assistant Professor, 1949-53; Associate Professor, 1953-. (5 Dabney).

Charles Brokaw, Ph.D., *Visiting Assistant Professor of Biology*
B.S., California Institute, 1955; Ph.D., Cambridge University, 1958. Assistant Professor of Zoology, University of Minnesota, 1959-. California Institute, 1960.

Norman Herrick Brooks, Ph.D., *Associate Professor of Civil Engineering*
A.B., Harvard College, 1949; M.S., Harvard University, 1950; Ph.D., California Institute, 1954. Instructor, 1953-54; Assistant Professor, 1954-58; Associate Professor, 1958-. (101 Engineering Bldg.) 525 Stonehurst Drive, Altadena.

Harrison Scott Brown, Ph.D., *Professor of Geochemistry*
B.S., University of California, 1938; Ph.D., Johns Hopkins University, 1941. California Institute, 1951-. (016 Mudd) 5155 Stoneglenn Road, La Cañada.

Edwin Raphael Buchman, Dr.Phil.Nat., *Research Associate in Organic Chemistry*
Ch.E., Rensselaer Polytechnic Institute, 1922; S.M., Massachusetts Institute of Technology, 1925; Dr.Phil.Nat., University of Frankfurt, 1933. Research Fellow, California Institute, 1937-38; Research Associate, 1938-. (254 Crellin) 446 Devonwood Drive, Altadena.

Francis Stephan Buffington, Sc.D., *Associate Professor of Mechanical Engineering*
S.B., Massachusetts Institute of Technology, 1938; Sc.D., 1951. Assistant Professor, California Institute, 1951-56; Associate Professor, 1956-. (017 Engineering Bldg.) 1644 Kaweah Drive.

Geoffrey R. Burbidge, Ph.D., *Senior Research Fellow in Astronomy*
B.S., University of Bristol, 1946; Ph.D., University of London, 1951. Staff Member, Yerkes Observatory, 1958-. Research Fellow in Physics, California Institute, 1958; Senior Research Fellow, 1959; 1960.

*Leave of absence, 1960-61

Eleanor Margaret Burbidge, Ph.D., *Senior Research Fellow in Astronomy*
Ph.D., London University, 1943. Staff Member, Yerkes Observatory, 1958-. Research Fellow in Physics, California Institute, 1955-57; 1958; 1959; Senior Research Fellow, 1960.

Charles E. Bures, Ph.D., *Associate Professor of Philosophy*
B.A., Grinnell College, 1933; M.A., University of Iowa, 1936; Ph.D., 1938. Assistant Professor California Institute, 1949-53; Associate Professor, 1953-. (2 Dabney) 564 South Marengo Avenue.

Hans Joachim Burkhardt, Ph.D., *Research Fellow in Biology*
Ph.D., University of Tubingen, 1957. California Institute, 1959-. (222 Kerckhoff) 2804 High View, Altadena.

Brian M. H. Bush, Ph.D., *Research Fellow in Biology*
B.Sc., University of Natal, South Africa, 1954; M.Sc., Rhodes University, 1955; Ph.D., Cambridge University, 1960. California Institute, 1960-61.

Dan Hampton Campbell, Ph.D., *Professor of Immunochemistry*
A.B., Wabash College, 1930; M.S., Washington University, 1932; Ph.D., University of Chicago, 1936. Assistant Professor, California Institute, 1942-45; Associate Professor, 1945-50; Professor, 1950-. (131 Crellin) 1154 Mount Lowe Drive, Altadena.

Ian Campbell, Ph.D., *Research Associate in Geology*
A.B., University of Oregon, 1922; A.M., 1924; Ph.D., Harvard University, 1931. Assistant Professor, California Institute, 1931-35; Associate Professor, 1935-46; Professor, 1946-60; Research Associate, 1960-. 405 South Bonnie Avenue.

Juan Silvestre Carmona, C.E., *Research Fellow in Civil Engineering*
C.E., National University of Cuyo, Argentina, 1955. Assistant Professor of Civil Engineering, 1957-. California Institute, 1959-60.

Edward A. Carusi, Ph.D., *Research Fellow in Biology*
A.B., University of California (Los Angeles), 1950; M.A., 1953; Ph.D., 1958. California Institute, 1958-. (108 Kerckhoff) 4268 Adelaide Drive, La Canada.

Marjorie Constance Caserio, Ph.D., *Senior Research Fellow in Chemistry*
B.Sc., Chelsea Polytechnic, University of London, 1950; M.A., Bryn Mawr, 1951; Ph.D., 1956. Research Fellow, California Institute, 1956-59; Senior Research Fellow, 1959-. (358 Crellin) 370 Cherry Drive.

John Francis Catchpool, M.D., *Research Fellow in Chemistry*
B.S., London University; M.D., King's College Hospital Medical School, London University, 1954. California Institute, 1960-61. (102 Church) 615 East California Boulevard.

Thomas Kirk Caughey, Ph.D., *Associate Professor of Applied Mechanics*
B.Sc., Glasgow University, 1948; M.M.E., Cornell University, 1952; Ph.D., California Institute, 1954. Instructor, 1953-54; Assistant Professor, 1955-58; Associate Professor, 1958-. (319 Engineering Bldg.) 390 South Craig Avenue.

Gulbank Donald Chakerian, Ph.D., *Instructor in Mathematics*
Ph.D., University of California, 1960. California Institute, 1960-61. (280 Sloan).

I-dee Chang, Ph.D., *Research Fellow in Aeronautics*
B.S., National Central University, China, 1944; M.S., Kansas State College, 1955; Ph.D., California Institute, 1959, Research Fellow, 1959-. (215 Guggenheim) 209 South Oak Knoll.

Pen Ching Cheo, Ph.D., *Research Fellow in Biology*
B.S., University of Nanking, 1941; M.S., West Virginia University, 1949; Ph.D., University of Wisconsin, 1951. California Institute, 1957-. (112 Kerckhoff) 73 South Berkeley Avenue.

Margaret I. H. Chipchase, Ph.D., *Research Fellow in Biology*
Ph.D., University of Cambridge, 1959. California Institute, 1959. (012 Kerckhoff) 1288 Oak Grove Avenue, San Marino.

Roy Frank Chisnell, Ph.D., *Visiting Lecturer in Aeronautics*
B.Sc., M.Sc., London University, 1950; Ph.D., Manchester University, 1957. Lecturer in Mathematics and Engineering, Manchester University, 1955-. California Institute, 1960.

Robert Frederick Christy,* Ph.D., *Professor of Theoretical Physics*
B.A., University of British Columbia, 1935; Ph.D., University of California, 1941. Associate Professor, California Institute, 1946-50; Professor, 1950-. (203 Kellogg) 2810 Estado Street.

Donald Sherman Clark, Ph.D., *Professor of Mechanical Engineering; Director of Placements*
B.S., California Institute, 1929; M.S., 1930; Ph.D., 1934. Instructor, California Institute, 1934-37; Assistant Professor, 1937-45; Associate Professor, 1945-51; Professor, 1951-. (120 Throop) 665 Canterbury Road, San Marino.

J. Kent Clark, Ph.D., *Professor of English*
A.B., Brigham Young University, 1939; Ph.D., Stanford University, 1950; Instructor, California Institute, 1947-50; Assistant Professor, 1950-54; Associate Professor, 1954-60; Professor, 1960-. (301 Dabney) 473 Fillmore Street.

*Leave of absence, 1960-61.

Julian David Cole, Ph.D., *Professor of Aeronautics*
B.M.E., Cornell University, 1944; M.S. (AE) California Institute, 1946; Ph.D., 1949. Research Fellow, 1949-51; Assistant Professor, 1951-55; Associate Professor, 1955-59; Professor, 1959-. (221 Guggenheim) 3447 Glenrose Avenue, Altadena.

Donald Earl Coles, Ph.D., *Associate Professor of Aeronautics*
B.S., University of Minnesota, 1947; M.S., California Institute, 1948; Ph.D., 1953. Research Fellow, 1953-55; Senior Research Fellow, 1955-56; Assistant Professor, 1956-59; Associate Professor, 1959-. (304 Guggenheim) 1033 Alta Pine Drive, Altadena.

Robert I. Conhaim, Ph.D., *Instructor in History*
A.B., University of California (Los Angeles), 1950; M.A., 1951; Ph.D., 1960. California Institute, 1960-61. (Dabney) 623 Midvale Avenue, Los Angeles.

Frederick James Converse,* B.S., *Professor of Soil Mechanics*
B.S., University of Rochester, 1914. Instructor, California Institute, 1921-33; Assistant Professor, 1933-39; Associate Professor, 1939-47; Professor, 1947-. (107 Engineering Bldg.) 1416 Wembly Road, San Marino.

William Harrison Corcoran, Ph.D., *Professor of Chemical Engineering*
B.S., California Institute, 1941; M.S., 1942; Ph.D., 1948. Associate Professor, 1952-57; Professor, 1957-. (219 Spalding Bldg.) 6845 Ruthlee Avenue, San Gabriel.

Robert Brainard Corey, Ph.D., *Professor of Structural Chemistry*
B.Chem., University of Pittsburgh, 1919; Ph.D., Cornell University, 1924. Senior Research Fellow, California Institute, 1937-46; Research Associate, 1946-49; Professor, 1949-. (215 Church) 352 South Parkwood Avenue.

Eugene Woodville Cowan, Ph.D., *Associate Professor of Physics*
B.S., University of Missouri, 1941; M.S., Massachusetts Institute of Technology, 1943; Ph.D., California Institute, 1948. Research Fellow, 1948-50; Assistant Professor, 1950-54; Associate Professor, 1954-. (345 W. Bridge) 2215 Monte Vista Street.

Charles Edwin Crede, M.S., *Professor of Mechanical Engineering*
B.S., Carnegie Institute of Technology, 1935; M.S., Massachusetts Institute of Technology, 1936. Associate Professor, California Institute, 1958-60; Professor, 1960-. (221 Engineering) 2068 Midlothian Drive, Altadena.

John Cronly-Dillon, Ph.D., *Reserch Fellow in Biology*
B.A., Cambridge University, 1957; Ph.D., Princeton University, 1960. California Institute, 1960-61. (387 Alles).

John Henry Curme, Ph.D., *Research Fellow in Biology*
A.B., Harvard College, 1949; M.S., Kansas State College, 1951; Ph.D., Iowa State College, 1955. Pathologist and Geneticist, Campbell Soup Company, 1957-. California Institute, 1957-. (Earhart) 1749 Atchison.

Everett Clarence Dade, Ph.D., *Bateman Research Fellow in Mathematics*
Ph.D., Princeton University, 1960. California Institute, 1960-61. (274 Sloan).

Robert Long Daugherty, M.E., *Professor of Mechanical and Hydraulic Engineering, Emeritus*
A.B., Stanford University, 1909; M.E., 1914. California Institute, 1919-56; Professor Emeritus, 1956-. 373 South Euclid Avenue.

Norman Ralph Davidson, Ph.D., *Professor of Chemistry*
B.S., University of Chicago, 1937; B.Sc., Oxford University, 1938; Ph.D., University of Chicago, 1941. Instructor, California Institute, 1946-49; Assistant Professor, 1948-52; Associate Professor, 1952-57; Professor, 1957-. (5 Gates) 318 East Laurel Avenue, Sierra Madre.

James Chowning Davies, Ph.D., *Professor of Political Science*
B.A., Oberlin College, 1939; Ph.D., University of California, 1952. Assistant Professor, California Institute, 1953-56; Associate Professor, 1956-60; Professor, 1960-. (3 Dabney) 2444 Highland Avenue, Altadena.

James E. Davis, Ph.D., *Research Fellow in Biology*
S.B., Mississippi State College, 1956; Ph.D., Massachusetts Institute of Technology, 1960. California Institute, 1960-61.

*Leave of absence, first term, 1960-61

Leverett Davis, Jr., Ph.D., *Professor of Theoretical Physics*
B.S., Oregon State College, 1936; M.S., California Institute, 1938; Ph.D., 1941. Instructor, 1941-46; Assistant Professor, 1946-50; Associate Professor, 1950-56; Professor, 1956-. (207 East Bridge) 1772 North Grand Oaks Avenue, Altadena.

Richard Albert Dean, Ph.D., *Associate Professor of Mathematics*
B.S., California Institute, 1945; A.B., Denison University, 1947; M.S., Ohio State University, 1948; Ph.D., 1953. Bateman Research Fellow, California Institute, 1954-55; Assistant Professor, 1955-59; Associate Professor, 1959-. (358 Sloan) 1434 North Grand Oaks Avenue.

Henry Hursell Dearman, Ph.D., *Research Fellow in Chemistry*
B.S., University of North Carolina, 1956; Ph.D., California Institute, 1960. Research Fellow, 1960.

Egon Theodor Degens, Ph.D., *Assistant Professor of Geology*
Ph.D., Bonn University, 1955. Research Fellow, California Institute, 1958; Assistant Professor, 1960-. (218 Mudd) 306 South Chester Avenue.

Max Delbruck, Ph.D., *Professor of Biology*
Ph.D., University of Gottingen, 1931. California Institute, 1947-. (59 Church) 1510 Oakdale Street.

Anthony Demetriades, Ph.D., *Senior Research Fellow in Aeronautics*
B.A., Colgate University, 1951; Ph.D., California Institute, 1958. Research Fellow, 1958-60; Senior Research Fellow, 1960-. (108 Guggenheim) 2046 Oakwood Street, Altadena.

Charles Raymond DePrima, Ph.D., *Professor of Applied Mechanics*
B.A., New York University, 1940; Ph.D., 1954; Assistant Professor, California Institute, 1946-51; Associate Professor, 1951-56; Professor, 1956-. (321 Engineering Bldg.) 3791 Hampstead Road.

Armin Joseph Deutsch, Ph.D., *Staff Member, Mount Wilson and Palomar Observatories*
B.S., University of Arizona, 1940; Ph.D., University of Chicago, 1946. Mt. Wilson and Palomar Observatories, 1951-. (Mt. Wilson Office) 625 Coleman, Altadena.

Gerard Franciscus Ludovicus Dietzel, Ph.D., *Research Fellow in Geophysics*
Cand., State University of Utrecht, 1955; Ph.D., 1958. California Institute, 1960-61. (Seismological Lab.) 188 South Catalina

Robert Palmer Dilworth, Ph.D., *Professor of Mathematics*
B.S., California Institute, 1936; Ph.D., 1939. Assistant Professor, California Institute, 1943-45; Associate Professor, 1945-51; Professor, 1951-. (286 Sloan) 1748 North Grand Oaks Avenue, Altadena.

Charles Hewitt Dix, Ph.D., *Professor of Geophysics*
B.S., California Institute, 1927; A.M., Rice Institute, 1928; Ph.D., 1931. Associate Professor, California Institute, 1948-54; Professor, 1954-. (315 Mudd) 1506 Ramona Avenue, South Pasadena.

Daniel Gould Dow, Ph.D., *Assistant Professor of Electrical Engineering*
B.S.E., University of Michigan, 1952; M.S.E., 1953; Ph.D., Stanford University, 1958. California Institute, 1958-. (327 Spalding) 531 Athens, Altadena.

Henry Dreyfuss, *Associate in Industrial Design*
California Institute, 1947-. 500 Columbia Street, South Pasadena.

Jacob William Dubnoff, Ph.D., *Senior Research Fellow in Biology*
A.B., University of California (Los Angeles), 1931; M.A., 1933; Ph.D., California Institute, 1944. California Institute, 1936-. (225 Kerckhoff) 1930 North Normandie Avenue, Los Angeles.

Lee Alvin DuBridge, Ph.D., Sc.D., LL.D.
(See page 33.)

The Rev. Joseph A. Duke, S.J., Ph.D., *Visiting Associate in Chemistry*
A.B., Georgetown University, 1940; Ph.L., Woodstock College, 1941; S.T.L., 1946; M.S., Fordham University, 1942; Ph.D., 1952. Professor, Department Chairman; Director of Sciences, Wheeling College, 1955-. California Institute, 1959; 1960.

Renato Dulbecco, M.D., *Professor of Biology*
M.D., University of Torino, 1936; Senior Research Fellow, California Institute, 1949-52; Associate Professor, 1952-54; Professor, 1954-. (055 Church) 522 South Allen Avenue.

Jesse William Monroe DuMond, Ph.D., *Professor of Physics*
B.S., California Institute, 1916; M.E. (E.E.), Union College, 1918; Ph.D., California Institute, 1929. Research Associate, California Institute, 1931-38; Associate Professor, 1938-46; Professor, 1946-. (163 W. Bridge) 530 South Greenwood Avenue.

Pol Duwez, D.Sc., *Professor of Mechanical Engineering*
Metallurgical Engineer, School of Mines, Mons, Belgium, 1932; D.Sc., University of Brussels, 1933. Research Engineer, California Institute, 1942-47; Associate Professor, 1947-52; Professor, 1952-. (09 Engineering Bldg.) 1535 Oakdale Street.

Harvey Eagleson, Ph.D., *Professor of English*
B.A., Reed College, 1920; M.A., Stanford University, 1922; Ph.D., Princeton University, 1928. Assistant Professor, California Institute, 1928-38; Associate Professor, 1938-47; Professor, 1947-. (305 Dabney) 1706 Fair Oaks Avenue, South Pasadena.

Paul Conant Eaton, A.M., *Associate Professor of English; Dean of Students*
S.B., Massachusetts Institute of Technology, 1927; A.M., Harvard University, 1930. Visiting Lecturer in English, California Institute, 1946; Associate Professor, 1947-; Dean of Students, 1952-. (115 Throop). 700 Cornell Road.

Bruce Eberhart, Ph.D., *Research Fellow in Biology*
A.B., San Jose State College, 1950; Ph.D., Stanford University, 1956. Assistant Professor of Biology, Princeton University, 1958-. California Institute, 1961.

Guy Echalier, D.Sc., *Research Fellow in Biology*
Lic. Sc., Grenoble University, France, 1952; D.Sc., Sorbonne, 1957. Staff Member, Animal Biology Department, Sorbonne, 1959-. California Institute, 1959-60. (066 Church) 186 South Oak Knoll Avenue.

Robert Stuart Edgar, Ph.D., *Assistant Professor of Biology*
B.Sc., McGill University, 1953; Ph.D., University of Rochester, 1957. Research Fellow, California Institute, 1957; 1958-60; Assistant Professor 1960-. (60 Church) 356 South Michigan.

Heinz E. Ellersieck,** Ph.D., *Assistant Professor of History*
A.B., University of California (Los Angeles), 1942; M.A., 1948; Ph.D., 1955. Instructor, California Institute, 1950-55; Assistant Professor, 1955-. (13 Dabney) 3175 DelVina Street.

David Clephan Elliot, Ph.D., *Professor of History*
M.A., St. Andrew's University, 1939; A.M., Harvard University, 1948; Ph.D., 1951. Assistant Professor, California Institute, 1950-53; Associate Professor, 1953-60; Professor, 1960-. (4 Dabney) 1628 East Braeburn Road, Altadena.

Mostafa F. A. El-Sayed, Ph.D., *Research Fellow in Chemistry*
B.Sc., Ein Shams University, Cairo, 1953; Ph.D., Florida State University, 1959. California Institute, 1960-61.

Kenneth Emerson, Ph.D., *Arthur Amos Noyes Research Fellow in Chemistry*
B.A., Harvard College, 1953; M.A., University of Oregon, 1958; Ph.D., University of Minnesota, 1960. California Institute, 1960-61.

Albert Tromley Ellis, Ph.D., *Associate Professor of Applied Mechanics*
B.S., California Institute, 1943; M.S., 1947; Ph.D., 1953. Senior Research Fellow, 1954-57; Associate Professor, 1958-. (103 Engineering Bldg.) 1425 Lombardy Road.

Sterling Emerson, Ph.D., *Professor of Genetics*
B.Sc., Cornell University, 1922; M.A., University of Michigan, 1924; Ph.D., 1928. Assistant Professor of Genetics, California Institute, 1928-37; Associate Professor, 1937-46; Professor, 1946-. (200 Kerckhoff) 1207 Morada Place, Altadena.

Warren G. Emery, B.S., *Coach*
B.S., University of Nebraska, 1948. California Institute, 1955-. (Gymnasium) 426 North Oakland, Apt. 7.

Albert Edward John Engel,* Ph.D., *Professor of Geology*
A.B., University of Missouri, 1938; M.A., 1939; Ph.D., Princeton University, 1942. Assistant Professor, California Institute, 1948-49; Associate Professor, 1949-54; Professor, 1954-. (363 Arms).

Paul Sophus Epstein, Ph.D., *Professor of Theoretical Physics, Emeritus*
B.Sc., Moscow University, 1906; M.Sc., 1909; Ph.D., University of Munich, 1914. California Institute, 1921-53; Professor Emeritus, 1953-. (109 E. Bridge) 1484 Oakdale Street.

Richard Harris Epstein, Ph.D., *Research Fellow in Biology*
A.B., University of Rochester, 1950; Ph.D., 1957. California Institute, 1958-. (68 Church) 1124 East Del Mar Boulevard.

Samuel Epstein, Ph.D., *Professor of Geochemistry*
B.Sc., University of Manitoba, 1941; M.Sc., 1942; Ph.D., McGill University, 1944. Research Fellow, California Institute, 1952-53; Senior Research Fellow, 1953-54; Associate Professor, 1954-59; Professor, 1959-. (016 Mudd) 1175 Daveric Drive.

Arthur Erdelyi, D.Sc., *Professor of Mathematics*
Cand. Ing., Deutsche Technische Hochschule, Brno, Czechoslovakia, 1928; Dr. rer. nat. University of Prague, 1938; D.Sc., University of Edinburgh, 1940. California Institute, 1947-. (278 Sloan) 2121 Lambert Drive.

Hans G. Essler, Ph.D., *Research Fellow in Chemistry*
Dipl. Chem. Technische Hochschule of Munich, 1958; Dipl. Wirt. Ing., 1959; Ph.D., University of Munich, 1960. California Institute, 1960-61.

Henry Owen Eversole, M.D., *Research Associate in Plant Physiology*
M.D., University of California, 1908. California Institute, 1947-. (132 Kerckhoff) 209 Cima Linda Lane, Santa Barbara.

Peter Ward Fay, Ph.D., *Associate Professor of History*
B.A., Harvard University, 1947; B.A., Oxford University, 1949; Ph.D., Harvard University, 1954. Assistant Professor, California Institute, 1955-60; Associate Professor, 1960-. (11 Dabney) 400 Churchill Road, Sierra Madre.

*Leave of absence, 1960-61.
**Leave of absence, first term, 1960-61.

Chuan C. Feng, Ph.D., *Visiting Associate in Engineering*
B.S., The Chiao-Tung University, Shanghai, 1945; M.S., University of Missouri, 1955; Ph.D., 1959. Associate Professor of Civil Engineering, University of Mississippi, 1959-. California Institute, 1960.

Richard Phillips Feynman, Ph.D., *Richard Chace Tolman Professor of Theoretical Physics*
B.S., Massachusetts Institute of Technology, 1939; Ph.D., Princeton University, 1942. Visiting Professor, California Institute, 1950. Professor, 1950-59; Tolman Professor, 1959-. (209 Bridge) 844 Alameda Street, Altadena.

Lester Marshall Field,* Ph.D., *Professor of Electrical Engineering*
B.S., Purdue University, 1939; Ph.D., Stanford University, 1944. California Institute, 1953-. (Spalding) 2112 Canfield Avenue, Los Angeles.

Alfred Fischer, Ph.D., *Research Fellow in Chemistry*
B.Sc., University of Canterbury, New Zealand, 1953; M.Sc., 1955; Ph.D., 1960. California Institute, 1960-61.

Marguerite Fling, Ph.D., *Research Fellow in Biology*
A.B., Hunter College, 1941; Ph.D., Iowa State College, 1946. California Institute, 1946-. (220 Kerckhoff) 518 West Loma Alta Drive, Altadena.

William Alfred Fowler, Ph.D., *Professor of Physics*
Bach.Eng., Physics, Ohio State University, 1933; Ph.D., California Institute, 1936. Research Fellow, California Institute, 1936-39; Assistant Professor, 1939-42; Associate Professor, 1942-46; Professor, 1946-. (201 Kellogg) 1565 San Pasqual Street.

Joel N. Franklin, Ph.D., *Associate Professor of Applied Mechanics*
B.S., Stanford University, 1950; Ph.D., 1953. California Institute, 1957-. (121 Spalding) 2195 Las Lunas Street.

Burton David Fried, Ph.D., *Lecturer in Physics*
B.S., Illinois Institute of Technology, 1947; M.S., 1950; Ph.D., University of Chicago, 1952. Member, Senior Staff, Space Technology Laboratories. California Institute, 1960.

Francis Brock Fuller, Ph.D., *Associate Professor of Mathematics*
A.B., Princeton University, 1949; M.A., 1950; Ph.D., 1952. Research Fellow, California Institute, 1952-55; Assistant Professor, 1955-59; Associate Professor, 1959-. (256 Sloan) 418 North Marengo Avenue.

Yuan-Cheng Fung, Ph.D., *Professor of Aeronautics*
B.S., National Central University, 1941; M.S., 1943; Ph.D., California Institute, 1948. Research Fellow, 1948-51. Assistant Professor, 1951-55; Associate Professor, 1955-59; Professor, 1959-. (213 Guggenheim) 3558 Thorndale Road.

Dieter Gaier, Ph.D., *Senior Research Fellow in Mathematics*
Ph.D., University of Rochester, 1951. Professor of Mathematics, University of Giessen, Germany. California Institute, 1960-61. (272 Sloan).

Esra Galun, Ph.D., *Research Fellow in Biology*
M.Sc., The Hebrew University, 1954; Ph.D., 1959. Research Fellow, Weizmann Institute of Science, 1959-. California Institute 1961-62.

Justine Spring Garvey, Ph.D., *Senior Research Fellow in Chemistry*
B.S., Ohio State University, 1944; M.S., 1948; Ph.D., 1950. Research Fellow, California Institute, 1951-57; Senior Research Fellow, 1957-. (319 Church) 698 Arden Road.

Murray Gell-Mann, Ph.D., *Professor of Theoretical Physics*
B.S., Yale University, 1948; Ph.D., Massachusetts Institute of Technology, 1950. Associate Professor California Institute, 1955-56; Professor, 1956-. (209 East Bridge Lab.)

Nicholas George, Ph.D., *Associate Professor of Electrical Engineering*
B.S., University of California, 1949; M.S., University of Maryland, 1956; Ph.D., California Institute, 1959. Visiting Associate Professor, 1959-60; Associate Professor, 1960-. (333 Spalding) 1195 East Cordova Street.

Horace Nathaniel Gilbert, M.B.A., *Professor of Business Economics*
A.B., University of Washington, 1923; M.B.A., Harvard University, 1926. Assistant Professor of Business Economics, California Institute, 1929-30; Associate Professor, 1930-47; Professor, 1947-. (303 Dabney) 1815 Orlando Road, San Marino.

Avihu Ginzburg, B.Sc., *Research Fellow in Geophysics*
B.Sc., University of Western Australia, 1951. Technical Director, Geophysical Institute of Israel, 1957-. California Institute, 1959.

Sheldon Lee Glashow, Ph.D., *Research Fellow in Theoretical Physics*
A.B., Cornell University, 1954; A.M., Harvard University, 1955; Ph.D., 1959. California Institute, 1960-61.

Mitchell E. Glickstein, Ph.D., *Research Fellow in Biology*
B.A., University of Chicago, 1951; Ph.D., 1958. California Institute, 1958-. (313 Kerckhoff) 8810 East Arcadia, San Gabriel.

Leave of absence, 1960-61

Alexander Goetz, Ph.D., *Associate Professor of Physics*
Ph.D., University of Gottingen, 1921; Habilitation, 1928. California Institute, 1930-. (61 W. Bridge) 1317 Boston Street, Altadena.

Alercio Moreira Gomes, Ph.D., *Research Fellow in Astronomy*
B.Sc., C.E., University of Brazil; Ph.D., 1953. Professor of Astronomy, Naval Academy, 1954-; Professor of Astronomy, University of Brazil, 1957-. California Institute, 1959-61. (108 Robinson) 2034 Crary Street.

Ricardo Gomez, Ph.D., *Senior Research Fellow in Physics*
B.S., Massachusetts Institute of Technology, 1953; Ph.D., 1956. Research Fellow, California Institute, 1956-59; Senior Research Fellow, 1959-. (Synchrotron) 3191 Glenrose Avenue, Altadena.

Clyde R. Goodheart, M.D., *Research Fellow in Biology*
B.S., Northwestern University, 1953; M.S., 1957; M.D., Northwestern University Medical School, 1957. California Institute, 1958-. (066 Church) 2712 Doolittle Avenue, Arcadia.

Victor H. Goodman, Ph.D., *Research Fellow in Biology*
A.B., University of Missouri, 1947; Ph.D., Cornell University, 1951. Associate Professor of Botany, University of California (Riverside), 1959-. California Institute, 1959.

Roy Walter Gould, Ph.D., *Associate Professor of Electrical Engineering and Physics*
B.S., California Institute, 1949; M.S., Stanford University, 1950; Ph.D., California Institute, 1956. Assistant Professor, 1955-58; Associate Professor, 1958-. (325 Spalding) 1526 Vista Lane.

Robert Davis Gray, B.S., *Professor of Economics and Industrial Relations; Director of Industrial Relations Section*
B.S., Wharton School of Finance and Commerce, University of Pennsylvania, 1930. Associate Professor, California Institute, 1940-42; Professor, 1942-. (Culbertson Basement) 2486 Morslay Road, Altadena.

George W. Green, B.S., C.P.A., *Vice-President for Business Affairs*
B.S., University of California, 1937; C.P.A., State of California, 1941. California Institute, 1948; Vice-President, 1956-. (105 Throop) 2800 Shakespeare Drive, San Marino.

Jesse Leonard Greenstein, Ph.D., *Professor of Astrophysics; Staff Member, Mount Wilson and Palomar Observatories*
A.B., Harvard University, 1929; A.M., 1930; Ph.D., 1937. Associate Professor, California Institute, 1948-49; Professor, 1949-. (215 Robinson) 2057 San Pasqual Street.

Roger Francis Griffin, Ph.D., *Research Fellow in Astronomy*
B.A., Cambridge University, 1957; Ph.D., 1960. California Institute, 1960-61. (Mt. Wilson Office).

Arie Jan Haagen-Smit, Ph.D., *Professor of Bio-organic Chemistry*
A.B., University of Utrecht, 1922; A.M., 1926; Ph.D., 1929. Associate Professor, California Institute, 1937-40; Professor, 1940-. (118 Kerckhoff) 416 South Berkeley Avenue.

Paul Charles Haake, Ph.D., *Arthur Amos Noyes Research Fellow in Chemistry*
A.B., Harvard College, 1954; Ph.D., Harvard University, 1960. California Institute, 1960-61. (351-B Crellin) 427 Lola Avenue.

A. L. Hales, Ph.D., *Research Fellow in Geophysics*
B.Sc., M.Sc., University of Capetown, 1930; B.A., Cambridge University, 1933; M.A., 1952; Ph.D., University of Capetown, 1936. Director, Bernard Price Institute of Geophysical Research, 1954-. California Institute, 1960.

Marshall Hall, Jr., Ph.D., *Professor of Mathematics*
B.A., Yale University, 1932; Ph.D., 1936. California Institute, 1959-. (386 Sloan) 1695 East Loma Alta, Altadena.

George Simms Hammond, Ph.D., *Professor of Organic Chemistry*
B.S., Cates College, 1943; M.S., 1944; Ph.D., Harvard University, 1947. Research Associate, California Institute, 1956-57; Professor, 1958-. (251-A Crellin) 1521 East Mountain Street.

Philip C. Hanawalt, Ph.D., *Research Fellow in Biology*
B.A., Oberlin College, 1954; Ph.D., Yale University, 1959. California Institute, 1960-61.

Melvin Wesley Hanna, Ph.D., *Research Fellow in Chemistry*
B.S., University of California (Los Angeles), 1954; Ph.D., University of Minnesota, 1959. California Institute, 1959-. (51 Crellin) 94 South Bonnie Avenue.

Robert Leland Harder, M.S., *Instructor in Electrical Engineering*
B.S., Carnegie Institute of Technology, 1954; M.S., 1955. California Institute, 1958-. (134 Spalding) 551 South Hill Avenue.

Ulrich Hauser, Ph.D., *Research Fellow in Physics*
Ph.D., University of Heidelberg, 1957. Research Associate, University of Heidelberg. California Institute, 1960-61. (165 W. Bridge) 216 South Chester Avenue.

Anne M. Haywood, M.D., *Research Fellow in Biology*
S.B., Bryn Mawr College; M.D., Harvard Medical School, 1959. California Institute, 1960-61. (114 Kerckhoff) 929 East California Blvd.

John Hazlehurst, Ph.D., *Research Fellow in Astronomy*
B.S., Manchester University, England, 1956; M.S., 1957; Ph.D., 1959. Research Associate, University of Chicago. California Institute, 1960-61.

Stewart Emerson Hazlet, Ph.D., *Visiting Associate in Chemistry*
A.B., University of Dubuque, 1931; M.S., Iowa State University, 1933; Ph.D., 1935. Professor of Chemistry; Dean of the Graduate School, Washington State University, 1947-. California Institute, 1960-61.

Eric Heftmann, Ph.D., *Research Fellow in Biology*
B.A., New York University, 1942; Ph.D., University of Rochester, 1947. Biochemist, U.S. Public Health Service, Bethesda, Md., 1947-. California Institute, 1959.

Ernest M. Heimlich, M.D., *Research Fellow in Chemistry*
B.A., University of California (Los Angeles), 1947; M.D., Faculty of Medicine, University of Lausanne, Switzerland, 1952. Instructor in Pediatrics, University of California (Los Angeles) Medical School, 1956-. California Institute, 1959-60.

George E. Hein, Ph.D., *Research Fellow in Chemistry*
B.A., Cornell University, 1954; M.S., University of Michigan, 1957; Ph.D., 1959. California Institute, 1959. (262 Crellin) 1745 North Allen Avenue.

H. Lawrence Helfer, Ph.D., *Senior Research Fellow in Astronomy*
Ph.D., University of Chicago, 1954. Assistant Professor, University of Rochester, 1958-. Research Fellow, California Institute, 1957-58; Senior Research Fellow, 1959; 1960.

Henry Hellmers, Ph.D., *Senior Research Fellow in Biology*
B.S., University of Pennsylvania, 1937; M.S., 1939. Ph.D., University of California, 1950. Research Fellow, California Institute, 1951-55; Senior Research Fellow, 1955-. (130 Kerckhoff) 3700 Shadow Grove Road.

Robert W. Hellwarth, Ph.D., *Lecturer in Physics*
B.Sc., Princeton University, 1952; Ph.D., Oxford University, 1955. Research Fellow, California Institute, 1955-56; Lecturer, 1957-. (Kellogg) 522 Avondale, Santa Monica.

George M. Helmkamp, Ph.D., *Research Fellow in Biology*
B.A., Wartburg College, 1942; M.A., Claremont Graduate School, 1950; Ph.D., California Institute, 1953. Professor of Chemistry, University of California (Riverside). California Institute, 1959-60.

Charles E. Helsley, Ph.D., *Assistant Professor of Geology*
B.S., California Institute, 1956; M.S., 1957; Ph.D., Princeton University, 1960. Assistant Professor, 1960-61.

Captain Andrew Henry, B.S., *Assistant Professor of Air Science and Tactics*
B.S., University of Southern California, 1950; California Institute, 1958-. (Bldg. T) 700 South El Molino Avenue.

Alvin F. Hildebrandt,** Ph.D., *Senior Research Fellow in Chemistry*
B.S., University of Houston, 1949; Ph.D., Texas A and M College, 1956. Research Specialist, Jet Propulsion Laboratory, 1959-. California Institute, 1960-61. (62 Crellin) 2363 Mountain Avenue, La Crescenta.

Charles Ray Hobby, Ph.D., *Instructor in Mathematics*
B.A., University of California, 1951; M.S., University of Houston, 1957; Ph.D., California Institute, 1960. Instructor, 1960.

Alan J. Hodge, Ph.D., *Professor of Biology*
B.Sc., University of Western Australia, 1946; Ph.D., Massachusetts Institute of Technology, 1952. California Institute, 1960-. (090 Alles).

Paul W. Hodge, Ph.D., *Research Fellow in Astronomy*
B.S., Yale University, 1956; Ph.D., Harvard University, 1960. California Institute, 1960-61. (Mt. Wilson Office) 415 North El Molino Avenue.

George Stewart Hodgson, M.D., *Research Fellow in Biology*
M.D., University of Chile, 1948. Head, Biology Section, Nuclear Physics Laboratory, University of Chile, 1955-. California Institute, 1960-. (219 Kerckhoff) 2096 East Orange Grove Avenue.

Aladar Hollander, M.E., *Professor of Mechanical Engineering, Emeritus*
M.E., Joseph Royal University, Budapest, 1904. California Institute, 1944-51; Professor Emeritus, 1951-. 2385 Hill Drive, Los Angeles.

Karst Hoogsteen, Ph.D., *Research Fellow in Chemistry*
B.Sc., University of Groningen, 1947; Ph.D., 1951. California Institute, 1955-56; 1957-. (230 Church) 985 East San Pasqual Street.

Norman Harold Horowitz, Ph.D., *Professor of Biology*
B.S., University of Pittsburgh, 1936; Ph.D., California Institute, 1939. Research Fellow, California Institute, 1940-42; Senior Research Fellow, 1946; Associate Professor, 1947-53; Professor, 1953-. (218 Kerckhoff) 2495 Brigden Road.

George William Housner, Ph.D., *Professor of Civil Engineering and Applied Mechanics*
B.S., University of Michigan, 1933; M.S., California Institute, 1934; Ph.D., 1941. Assistant Professor, 1945-49; Associate Professor, 1949-53; Professor, 1953-. (233 Engineering Bldg.) 4084 Chevy Chase Drive.

**Part-time

Leo Houziaux, Ph.D., *Research Fellow in Astronomy*
Lic. Sc., University of Liege, 1955; Ph.D., 1960. California Institute, 1960-61. (Mt. Wilson Office).

Fred Hoyle, M.A., *Addison White Greenway Visiting Professor of Astronomy; Staff Member, Mount Wilson and Palomar Observatories*
M.A., Fellow, St. Johns College, Cambridge University. Plumian Professor of Astronomy and Experimental Philosophy, Cambridge University, 1958-. California Institute, 1953; 1954; 1956; 1957; 1959; 1960.

Din-Yu Hsieh, Ph.D., *Research Fellow in Applied Mechanics*
B.S., National Taiwan University, 1954; M.Sc., Brown University, 1957; Ph.D., California Institute, 1960. Research Fellow, 1960-61. (164 Hydro) 555 North El Molino Avenue.

Pien-Chien Huang, Ph.D., *Research Fellow in Biology*
B.S., National Taiwan University, Taiwan, 1953; M.S., Virginia Polytechnic Institute, 1956; Ph.D., The Ohio State University, 1959. California Institute, 1960-61. (202 Kerckhoff) 294 South Wilson Avenue.

Ru-Chih Chow Huang, Ph.D., *Research Fellow in Biology*
B.S., National Taiwan University, Taiwan, 1954; M.S., Virginia Polytechnic Institute, 1956; Ph.D., The Ohio State University, 1959. California Institute, 1960-61. (013 Kerckhoff) 294 South Wilson Avenue.

Donald Ellis Hudson, Ph.D., *Professor of Mechanical Engineering*
B.S., California Institute, 1938; M.S., 1939; Ph.D., 1942. Instructor, 1941-43; Assistant Professor, 1943-49; Associate Professor, 1949-55; Professor, 1955-. (323 Engineering Bldg.) 1988 Skyview Drive, Altadena.

Edward Wesley Hughes, Ph.D., *Research Associate in Chemistry*
B.Chem., Cornell University, 1924; Ph.D., 1935. Research Fellow, California Institute, 1938-43; Senior Research Fellow, 1945-46; Research Associate, 1946-. (154 Crellin) 1582 Rose Villa Street.

Jean Humblet, D.Sc., *Research Associate in Physics*
D.Sc., University of Liege, 1943. Staff Member, Astrophysical Institute, University of Liege. Research Fellow, California Institute, 1952-53; Research Associate, 1960-61. (Kellogg).

Edward Hutchings, Jr., B.A., *Lecturer in Journalism*
B.A., Dartmouth College, 1933. Editor of Engineering and Science Monthly, California Institute, 1948-. Lecturer, 1952-. (400 Throop) 2396 Highland Avenue, Altadena.

Robert A. Huttenback, Ph.D., *Assistant Professor of History; Master of Student Houses*
B.A., University of California (Los Angeles), 1951; Ph.D., 1959. Master of Student Houses; Lecturer in History, California Institute, 1958-60; Assistant Professor, 1960-. (107 Unit B, Student Houses) 1245 Arden Road.

Neil Stewart Isaacs, Ph.D., *Research Fellow in Chemistry*
B.Sc., University of Southampton, England, 1955; Ph.D., 1958. California Institute, 1960-61.

William Thomas Jackson, Ph.D., *Research Fellow in Chemistry*
B.S., University of Illinois, 1955; M.S., University of Wisconsin, 1957; Ph.D., 1960. California Institute, 1960-61. (262 Crellin) 438-B South Oakland Avenue.

François Jacob, M.D., D.Sc., *Research Fellow in Biology*
M.D., University of Paris, 1947; D.Sc., 1954. Chef de Service, Institut Pasteur, Paris. California Institute, 1960.

Theodore Alan Jacobs, Ph.D., *Senior Research Fellow in Jet Propulsion*
A.B., Emory University, 1950; M.S., University of Southern California, 1954; Ph.D., California Institute, 1960. Senior Research Fellow, 1960-61.

Homer Jacobson, Ph.D., *Research Fellow in Biology*
B.S., California Institute, 1941; M.S., Columbia University, 1942; Ph.D., 1948. Assistant Professor of Chemistry, Brooklyn College, 1950-. Gosney Fellow, California Institute, 1959-. (117 Kerckhoff) 118 South Chester Avenue.

Robert George Jahn, Ph.D., *Assistant Professor of Jet Propulsion*
B.S., Princeton University, 1951; Ph.D., 1955. California Institute, 1958-. (229 Engineering) 747 South Madison Avenue.

Harold E. Johns, Ph.D., *Research Fellow in Biology*
B.A., McMaster University, 1936; M.A., University of Toronto, 1937; Ph.D., 1939. Professor of Medical Biophysics, University of Toronto, 1956-. California Institute, 1960-61.

Louis Winchester Jones, A.B., *Associate Professor of English; Dean of Admissions; Director of Undergraduate Scholarships*
A.B., Princeton University, 1922. Instructor, California Institute, 1925-27; Assistant Professor, 1937-43; Associate Profesor, 1943-; Dean of Admissions, 1937-. (112 Throop) 361 California Terrace.

Richard Theodore Jones, M.D., *Research Fellow in Chemistry*
B.S., University of Oregon, 1953; M.S., 1956; M.D., 1956. Research Fellow, California Institute, 1959-. (102 Church) 992 East California Boulevard.

Thomas Griffith Jones, Ph.D., *Research Fellow in Aeronautics*
B.Sc., University College of Wales, 1956; Ph.D., 1959. California Institute, 1959-61. (203 Guggenheim) 83 South Berkeley Avenue.

Jun Jugaku, Ph.D., D.Sc., *Research Fellow in Astronomy*
A.M., University of Michigan, 1955; Ph.D., 1958; D.Sc., Kyoto University, 1958. Staff Member, Institute for Fundamental Physics, Kyoto University, 1958-. California Institute, 1959-. (204 Robinson) 419 South Catalina Avenue, Apt. 4.

Walter Barclay Kamb,* Ph.D., *Associate Professor of Geology*
B.S., California Institute, 1952; Ph.D., 1956. Assistant Professor, 1956-60; Associate Professor, 1960-. (310 Mudd) 430 North Mountain Trail, Sierra Madre.

Detlef Gustav Kamke, Ph.D., *Research Fellow in Physics*
Dipl.Phys., University of Goettingen, 1946; Ph.D., University of Marburg, 1951. Head Assistant, Nuclear Physics, University of Marburg, 1959-. California Institute, 1959-60.

Kiyoshi Kanai, Ph.D., *Research Associate in Civil Engineering*
Ph.D., University of Tokyo, 1941. Lecturer in Engineering, University of Tokyo, 1946-. California Institute, 1959.

Saul Kaplun, Ph.D., *Senior Research Fellow in Aeronautics*
B.S., California Institute, 1948; M.S., 1950; Ae.E., 1951; Ph.D., 1954. Research Fellow, 1954-57; Senior Research Fellow, 1957-. (215 Guggenheim) 200 South Catalina Avenue.

Theodore von Karman, Ph.D., Dr.Ing., Sc.D., LL.D., Sng.D., *Professor of Aeronautics, Emeritus*
M.E., Budapest, 1902; Ph.D., Gottingen, 1908. California Institute, 1928-49; Professor Emeritus, 1949-. 1501 South Marengo Avenue.

Jiro Kato, Ph.D., *Research Fellow in Biology*
Ph.D., Kyoto Imperial University, 1945. Assistant in Botany, Kyoto University, 1948. California Institute, 1959-60.

Ralph William Kavanagh, Jr., Ph.D., *Assistant Professor of Physics*
B.A., Reed College, 1950; M.A., University of Oregon, 1952; Ph.D., California Institute, 1956. Research Fellow, 1956-58; Senior Research Fellow, 1958-60; Assistant Professor, 1960-. (103 Kellogg) 338 South Arroyo Drive, San Gabriel.

Lois Marie Kay, M.S., *Research Fellow in Chemistry*
B.S., University of California (Los Angeles), 1949; M.S., 1952. Research Fellow, California Institute, 1955-58; 1959-. (208 Church) 4905 Lockhaven Street, Los Angeles.

Geoffrey Lorrimer Keighley, Ph.D., *Senior Research Fellow in Biology*
B.A., University of Toronto, 1926; M.S., California Institute, 1940; Ph.D., 1944. Instructor, 1943-46; Senior Research Fellow, 1946-. (227 Kerckhoff) 3112 Ewing Avenue, Altadena.

John Fisher Kennedy, Ph.D., *Research Fellow in Civil Engineering*
B.S., Notre Dame University, 1955; M.S., California Institute, 1956; Ph.D., 1960. Research Fellow, 1960-61. (166 Hydro) 2446 Mohawk Street.

Jack Leo Kerrebrock, Ph.D., *Senior Research Fellow in Jet Propulsion*
B.S., Oregon State College, 1950; M.S., Yale University, 1951; Ph.D., California Institute, 1956. Research Fellow, 1955-56; Senior Research Fellow, 1958-. (161 Hydro) 181 North Sunnyside, Sierra Madre.

Hendrik Jan Ketellapper, Ph.D., *Research Fellow in Biology*
B.Sc., State University of Utrecht, 1947; D.Sc., 1951; Ph.D., 1953. California Institute, 1957-. (126 Kerckhoff) 784 South Los Robles Avenue.

Robert Burnett King, Ph.D., *Professor of Physics*
B.A., Pomona College, 1930; Ph.D., Princeton University, 1933. Associate Professor, California Institute, 1948-52; Professor, 1952-. (57 Bridge) 1627 E. Mendocino, Altadena.

Harry Allister Kirkpatrick,** Ph.D., *Research Associate in Physics*
B.S., Occidental College, 1914; Ph.D., California Institute, 1931. Professor of Physics, Emeritus, Occidental College, 1957-. California Institute, 1958-. (058 West Bridge) 5340 Kincheloe Drive, Los Angeles.

Alexander Kishkovsky, A.M., *Lecturer in Russian*
M.A., University of Warsaw, 1939. Lecturer in Slavic Studies, University of Southern California, 1956-. California Institute, 1958-. (9 Dabney) 636 Micheltorena Street, Los Angeles.

Arthur Louis Klein,** Ph.D., *Professor of Aeronautics*
B.S., California Institute, 1921; M.S., 1924; Ph.D., 1925. Research Fellow in Physics and in Aeronautics, 1927-29; Assistant Professor, 1929-34; Associate Professor, 1934-54; Professor, 1954-. (224 Guggenheim) 437 via Almar, Palos Verdes Estates.

Marvin Isidore Knopp, Ph.D., *Research Fellow in Mathematics*
B.S., University of Illinois, 1954; A.M., 1955; Ph.D., 1958. California Institute, 1960. (384 Sloan)

Cevdet Kocak, Ph.D., *Research Fellow in Mathematics*
B.S., University of Istanbul, 1949; Ph.D., Technical University of Istanbul, 1954. Assistant Professor of Mathematics, Technical University of Istanbul, 1957-. California Institute, 1960.

*Leave of absence, 1960-61.

**Part-time.

James Kenyon Knowles, Ph.D., *Assistant Professor of Applied Mechanics*
B.S., Massachusetts Institute of Technology, 1952; Ph.D., 1957. California Institute, 1958-. (307 Engineering) 621 North Daisy Avenue.

Kurt Koehler, D.Sc., *Research Fellow in Biology*
D.Sc., University of Tubingen, 1956. Staff Member, Max-Planck-Institut, Tubingen, 1960-. California Institute, 1960.

Joseph Blake Koepfli, D.Phil., *Research Associate in Chemistry*
A.B., Stanford University, 1924; M.A., 1925; D.Phil., Oxford University, 1928. California Institute, 1932-. (105 Church) 955 Avondale Road, San Marino.

Lowell B. Koppel, Ph.D., *Instructor in Chemical Engineering*
B.S., Northwestern University, 1957; M.S., University of Michigan, 1958; Ph.D., Northwestern University, 1960. California Institute, 1960-. (313 Spalding) 1009 Fairview, Arcadia.

Alexander Kosloff, Ph.D., *Lecturer in Russian*
A.B., University of Moscow, 1937; A.M., University of California (Los Angeles), 1942; Ph.D., University of Southern California, 1954. Assistant Professor; Acting Head, Slavic Studies Department, University of Southern California, 1954-. California Institute, 1955-. (9 Dabney) 1115 West 31st Street, Los Angeles.

Robert Paul Kraft, Ph.D., *Staff Member, Mount Wilson and Palomar Observatories*
B.S., University of Washington, 1947; M.S., 1949; Ph.D., University of California, 1955. Mt. Wilson Observatory, 1960-. (Mount Wilson Office) 177 West Poppyfields Drive, Altadena.

Hans Krumhaar, Dr. Rer. Nat., *Senior Research Fellow in Aeronautics*
Dipl. Math., University of Goettingen, 1951; Dr. Rer. Nat., 1955. Scientific Assistant in Aeroelasticity, Institute of Aerodynamic Experimentation, Goettingen, 1955-. California Institute, 1959-. (223 Guggenheim) 1541 Rose Villa Street.

Toshi Kubota, Ph.D., *Assistant Professor of Aeronautics*
B.E., Tokyo University, 1947; M.S., California Institute, 1952; Ph.D., 1957. Research Fellow, 1957-59; Assistant Professor, 1959-. (109 Guggenheim) 300 South Michigan Avenue.

Hans H. Kuehl, Ph.D., *Research Fellow in Electrical Engineering*
B.S.E., Princeton University, 1955; M.S., California Institute, 1956; Ph.D., 1959. Research Fellow, 1959-60.

Theodore Kuwana, Ph.D., *Research Fellow in Chemistry*
B.S., Antioch College, 1954; M.S., Cornell University, 1956; Ph.D., University of Kansas, 1959. Research Fellow, California Institute, 1959-. (21 Gates) 1662 West Second, Los Angeles.

Bert La Brucherie, B.E., *Coach*
B.E., University of California at Los Angeles, 1929. California Institute, 1949-. (Gymnasium) 3850 Crestway Drive, Los Angeles.

William Noble Lacey, Ph.D., *Professor of Chemical Engineering*
A.B., Stanford University, 1911; Ch.E., 1912; M.S., University of California, 1913; Ph.D., 1915. Instructor, California Institute, 1916-17; Assistant Professor, 1917-19; Associate Professor, 1919-31; Professor, 1931-. Dean of Graduate Studies, 1946-56. (215 Spalding) 2024 Minoru Drive, Altadena.

Paco Axel Lagerstrom,* Ph.D., *Professor of Aeronautics*
Fil.Kand., University of Stockholm, 1935; Fil.Lic., 1939; Ph.D., Princeton University, 1942. Research Associate in Aeronautics, California Institute, 1946-47; Assistant Professor, 1947-49; Associate Professor, 1949-52; Professor, 1952-. (219 Guggenheim) 801 Montrose Avenue, South Pasadena.

Hildegard Lamfrom, Ph.D., *Research Fellow in Biology*
B.A., Reed College, 1943; M.A., Oregon State College, 1944; Ph.D., Western Reserve University, 1946. California Institute, 1958-. (225 Kerckhoff) 279 Pleasant Street.

Anton Lang, Ph.D., *Professor of Biology*
Ph.D., University of Berlin, 1939. Research Fellow, California Institute, 1950-52; Senior Research Fellow, 1952; Professor, 1959-. (125-A Kerckhoff) 149 West Woodbury Road, Altadena.

Robert Vose Langmuir, Ph.D., *Professor of Electrical Engineering*
A.B., Harvard University, 1935; Ph.D., California Institute, 1943; Senior Research Fellow, 1948-50; Assistant Professor, 1950-52; Associate Professor, 1952-57; (Synchrotron; 323 Spalding) 2310 Santa Anita Avenue, Altadena.

Beach Langston, Ph.D., *Associate Professor of English*
A.B., The Citadel, 1933; M.A., Claremont College, 1934; Ph.D., University of North Carolina, 1940. Assistant Professor, California Institute, 1947-53; Associate Professor, 1953-. (30 Dabney) 420 South Parkwood Avenue.

Charles Christian Lauritsen, Ph.D., *Professor of Physics*
Graduate, Odense Tekinshe Skole, 1911; Ph.D., California Institute, 1929. Assistant Professor, 1930-31; Associate Professor, 1931-35; Professor, 1935-. (202 Kellogg) 1444 Del Mar Boulevard.

Thomas Lauritsen, Ph.D., *Professor of Physics*
B.S., California Institute, 1936; Ph.D., 1939; Senior Research Fellow, California Institute, 1945; Assistant Professor, 1946-50; Associate Professor, 1950-55; Professor, 1955-. (205 Kellogg) 1559 Rose Villa Street.

*Leave of absence, 1960-61.

Lester Lees, M.S., *Professor of Aeronautics*
S.B., Massachusetts Institute of Technology, 1940; M.S., 1941. Associate Professor, California Institute, 1953-55; Professor, 1955-. (307 Guggenheim) 925 Alta Pine Avenue, Altadena.

Robert Benjamin Leighton, Ph.D., *Professor of Physics*
B.S., California Institute, 1941; M.S., 1944; Ph.D., 1947. Research Fellow, 1947-49; Assistant Professor, 1949-53; Associate Professor, 1953-59; Professor, 1959-. (18 Bridge) 3138 Ewing Avenue, Altadena.

Edward B. Lewis, Ph.D., *Professor of Biology*
B.A., University of Minnesota, 1939; Ph.D., California Institute, 1942. Instructor, 1946-48; Assistant Professor, 1948-49; Associate Professor, 1949-56; Professor, 1956-. (311 Kerckhoff) 805 Winthrop Road, San Marino.

Hans Wolfgang Liepmann, Ph.D., *Professor of Aeronautics*
Ph.D., University of Zurich, 1938. Assistant Professor, California Institute, 1939-46; Associate Professor, 1946-49; Professor, 1949-. (223 Guggenheim) 652 Antrim Place.

Frederick Charles Lindvall, Ph.D., *Professor of Electrical and Mechanical Engineering; Chairman of the Division of Civil, Electrical, and Mechanical Engineering and Aeronautics*
B.S., University of Illinois, 1924; Ph.D., California Institute, 1928. Instructor in Electrical Engineering, 1930-31; Assistant Professor, 1931-37; Associate Professor of Electrical and Mechanical Engineering, 1937-42; Professor, 1942-. Chairman of Division, 1945-. (201 Engr.) 1224 Arden Road.

Jerry B. Lingrel, Ph.D., *Research Fellow in Biology*
B.S., Otterbein College, 1957; Ph.D., The Ohio State University, 1960. California Institute, 1960-61.

Kenneth Lock, M.S., *Instructor in Electrical Engineering*
B.S., Battersea Polytechnic, London, 1955; M.S., Imperial College, London, 1957. Instructor, California Institute, 1959-. (223 Spalding) 211 South Oak Knoll Avenue.

James A. Lockhart, Ph.D., *Research Fellow in Biology*
B.A., University of Wisconsin, 1944; B.S., Michigan State College, 1946; M.S., 1949; Ph.D., University of California (Los Angeles), 1954; California Institute, 1955-. (017 Kerckhoff) 1635 South Tenth Avenue, Arcadia.

John B. Loefer, Ph.D., *Research Fellow in Biology*
A.B., Lawrence College, 1929; M.S., 1931; Ph.D., New York University, 1933. Coordinator for Biological Sciences, Office of Naval Research, 1953-. California Institute, 1954-. (03 Kerckhoff) 133 West Terrace Street, Altadena.

Paul Alan Longwell, Ph.D., *Associate Professor of Chemical Engineering*
B.S., California Institute, 1940; M.S., 1941; Ph.D., 1957. Instructor, 1955-56; Associate Professor, 1956-. (217 Spalding) 6834 Longmont, San Gabriel.

Heinz Adolph Lowenstam, Ph.D., *Professor of Paleoecology*
Ph.D., Chicago University, 1939. California Institute, 1952-. (361 Arms) 2252 Midwick Drive, Altadena.

Peter Herman Lowy, Doctorandum, *Research Fellow in Biology*
Doctorandum, University of Vienna, 1936. California Institute, 1946. Research Fellow, 1949-. (111 Kerckhoff) 188 South Meredith Avenue.

Howard Johnson Lucas, D.Sc., *Professor of Organic Chemistry, Emeritus*
B.A., The Ohio State University, 1907; M.A., 1908; D.Sc., 1953. California Institute, 1913-55; Professor Emeritus, 1955-. 561 South Wilson Avenue.

Harold Lurie, Ph.D., *Associate Professor of Applied Mechanics*
B.Sc., University of Natal, South Africa, 1940; M.Sc., 1946; Ph.D., California Institute, 1950. Lecturer in Aeronautics, 1948-50; Assistant Professor, 1953-56; Assistant Professor, 1956-. (325 Engineering Bldg.) 461 West Loma Alta Drive, Altadena.

Wilhelm A. J. Luxemburg, Ph.D., *Associate Professor of Mathematics*
Ph.D., University of Leiden, 1955. Assistant Professor, California Institute, 1958-60. Associate Professor, 1960-. (366 Sloan) 211 South El Molino, Apt. 5.

George Eber MacGinitie, M.A., *Professor of Biology, Emeritus*
A.B., Fresno State College, 1925; M.A., Stanford University, 1928. California Institute, 1932-57; Professor Emeritus, 1957-. 442 El Modena Avenue, Newport Beach.

Major Francis R. MacKenzie, M.B.A., *Professor of Air Science and Tactics*
B.S., University of Southern California, 1939; M.B.A., 1960. California Institute, 1957-. (Bldg. T-1) 443 South Sierra Madre Boulevard.

George Rupert MacMinn, A.B., *Professor of English, Emeritus*
A.B., Brown University, 1905. California Institute, 1918-54; Professor Emeritus, 1954-. (212 Dabney) 255 South Bonnie Avenue.

Satish C. Maheshwari, Ph.D., *Research Fellow in Biology*
B.Sc., Delhi University, 1952; M.Sc., 1954; Ph.D., 1958. Lecturer in Botany, University of Delhi. California Institute, 1960-61.

Per Maltby, Ph.D., *Research Fellow in Radio Astronomy*
B.A., University of Oslo, 1955; Ph.D., 1957, California Institute, 1960-61.

Paul DeVries Manning, Ph.D., *Professor of Chemical Engineering*
A.B., Stanford University, 1916; M.S., Throop College of Technology, 1917; Ph.D., Columbia University, 1927. California Institute, 1958-. (217 Spalding) 1700 San Pasqual Street.

Frank Earl Marble, Ph.D., *Professor of Jet Propulsion and Mechanical Engineering*
B.S., Case Institute of Technology, 1940; M.S., 1942; A.E., California Institute, 1947; Ph.D., 1948. Instructor, 1948-49; Assistant Professor, 1949-53; Associate Professor, 1953-57; Professor, 1957-. (225 Engineering Bldg.) 1665 East Mountain Street.

Maria Esther Marquinez, Ph.D., *Research Fellow in Biology*
Ph.D., Madrid University, 1955. Staff Member, National Institute of Agricultural Research, Madrid, 1955-. California Institute, 1960.

Richard Edward Marsh, Ph.D., *Senior Research Fellow in Chemistry*
B.S., California Institute, 1943; Ph.D., University of California at Los Angeles, 1950. Research Fellow, 1950-55; Senior Research Fellow, 1955-. (218 Church) 1947 Sherwood Road, San Marino.

Hardy Cross Martel, Ph.D., *Associate Professor of Electrical Engineering*
B.S., California Institute, 1949; M.B., Massachusetts Institute of Technology, 1950; Ph.D., California Institute, 1956. Instructor, 1953-55; Assistant Professor, 1955-58; Associate Professor, 1958-. (227 Spalding) 1545 Homewood Drive, Altadena.

Romeo Raoul Martel, S.B., *Professor of Structural Engineering, Emeritus*
S.B., Brown University, 1912; Instructor, California Institute, 1918-20; Assistant Professor, 1920-21; Associate Professor, 1921-30; Professor, 1930-60; Professor Emeritus, 1960-. (211 Engineering Bldg.) 809 Fairfield Circle.

Peter Vroman Mason, M.S., *Instructor in Electrical Engineering*
B.S., California Institute, 1951; M.S., 1952. Instructor, 1958-. (33 Spalding) 303 South Chester Avenue.

Jon Mathews, Ph.D., *Assistant Professor of Physics*
B.A., Pomona College, 1952; Ph.D., California Institute, 1957. Instructor, 1957-59; Assistant Professor, 1959-. (207 East Bridge) 459 West Loma Alta, Altadena.

Satoshi Matsushima, Ph.D., *Senior Research Fellow in Astronomy*
M.S., University of Kyoto, 1946; Ph.D., University of Utah, 1954. Associate Professor of Astronomy, Iowa State University, 1960-. California Institute, 1959; 1960.

Thomas Arnold Matthews, Ph.D., *Senior Research Fellow in Radio Astronomy*
B.A., University of Toronto, 1950; M.Sc., Case Institute of Technology, 1951; Ph.D., Harvard University, 1956. Research Fellow, California Institute, 1957-59; Senior Research Fellow, 1959-. (111 Robinson) 1905 Midlothian Drive, Altadena.

Francis William Maxstadt, Ph.D., *Associate Professor of Electrical Engineering; Registrar*
M.E., Cornell University, 1916; M.S., California Institute, 1925; Ph.D., 1931. Instructor, California Institute, 1919-33; Assistant Professor, 1933-47; Associate Professor, 1947-; Registrar, 1953-. (119 Throop) 600 West Ramona Avenue, Sierra Madre.

Theodor J. Mayer-Kuckuk, Ph.D., *Research Fellow in Physics*
Dipl., University of Heidelberg, 1951; Ph.D., 1953. Staff Member, Max-Planck-Institut fur Kernphysik, Heidelberg, 1960-. California Institute, 1960-61. (302 Kellogg) 1717 Mendocino Avenue, Altadena.

George P. Mayhew, Ph.D., *Associate Professor of English*
A.B., Harvard University, 1941; M.A., 1947; Ph.D., 1953. Assistant Professor, California Institute, 1954-60; Associate Professor, 1960-. (6 Dabney) 485 South Grand Avenue.

Robert Marc Mazo, Ph.D., *Assistant Professor of Physical Chemistry*
B.A., Harvard College, 1952; M.S., Yale University, 1953; Ph.D., 1955. California Institute, 1958-. (64 Crellin) 1043 Morado Place, Altadena.

Gilbert Donald McCann, Ph.D., *Professor of Electrical Engineering*
B.S., California Institute, 1934; M.S., 1935; Ph.D., 1939. Associate Professor, California Institute, 1946-47; Professor, 1947-. (125 Spalding) 2247 N. Villa Heights Road.

Chester Martin McCloskey, Ph.D., *Senior Research Fellow in Chemistry; Executive Director of Industrial Associates*
B.A., Whittier College, 1940; M.S., Iowa State University, 1942; Ph.D., 1944. Research Fellow, California Institute, 1953-57; Senior Research Fellow; Executive Director, 1957-. (110 Throop) 1981 Sinaloa Avenue, Altadena.

Harden Marsden McConnell, Ph.D., *Professor of Chemistry*
B.S., George Washington University, 1947; Ph.D., California Institute, 1951. Assistant Professor, 1956-58; Associate Professor, 1958-59; Professor, 1959-. (62 Crellin) 2062 New York Drive, Altadena.

Caleb W. McCormick, Jr., M.S., *Associate Professor of Civil Engineering*
B.S., University of California, 1945; M.S., 1948. Instructor, California Institute, 1949-51; Assistant Professor, 1951-57; Associate Professor, 1957-. (215 Engineering Bldg.) 1285 Leonard Avenue.

Jack Edward McKee, Sc.D., *Professor of Environmental Health Engineering*
B.S., Carnegie Institute of Technology, 1936; M.S., Harvard University, 1939; Sc.D., 1941. Associate Professor of Sanitary Engineering, California Institute, 1949-56; Professor, 1956-60; Professor of Environmental Health Engineering, 1960-. (113 Engr. Bldg.) 2026 Oakdale Street.

Charles Raymond McKinney, B.S., *Senior Research Fellow in Geochemistry*
B.S., E.E., Rose Polytechnic Inst., 1943; University of Minnesota, 1946. Research Fellow, California Institute, 1952-53; Senior Research Fellow, 1953-. (016 Mudd) 358 North Highland, Monrovia.

Carver Andress Mead, Ph.D., *Assistant Professor of Electrical Engineering*
B.S., California Institute, 1956; M.S., 1957; Ph.D., 1960. Instructor, 1958-59; Assistant Professor, 1959-. (27 Spalding) 749 North Catalina Avenue.

Hunter Mead, Ph.D., *Professor of Philosophy and Psychology*
B.A., Pomona College, 1930; M.A., Claremont College, 1933; Ph.D., University of Southern California, 1936. California Institute, 1947-. (209 Dabney) 626 North Chester Avenue.

James Edgar Mercereau, Ph.D., *Assistant Professor of Physics*
B.A., Pomona College, 1953; M.S., University of Illinois, 1954; Ph.D., California Institute, 1959. Assistant Professor, 1959-. (58 Bridge) 560 Punahou, Altadena.

Matthew Stanley Meselson, Ph. D., *Senior Research Fellow in Chemical Biology*
Ph.B., University of Chicago, 1951; Ph.D., California Institute, 1957. Research Fellow in Chemistry, 1957-58; Assistant Professor, 1958-60; Senior Research Fellow, 1960-. (313 Church) 255 South Wilson Avenue.

Arthur Frederic Messiter, Ph.D., *Research Fellow in Aeronautics*
B.E., Cornell University, 1952; M.Ae., 1953; Ph.D., California Institute, 1957. Research Fellow, 1959-. (203 Guggenheim) 400 North Madison Avenue.

William Whipple Michael, B.S., *Professor of Civil Engineering, Emeritus*
B.S., Tufts College, 1909. California Institute, 1918-1956. Professor Emeritus, 1956-. 388 South Oak Avenue.

Robert David Middlebrook, Ph.D., *Associate Professor of Electrical Engineering*
B.A., Cambridge University, 1952; M.S., Stanford University, 1953; Ph.D., 1955. Assistant Professor, California Institute, 1955-58; Associate Professor, 1958-. (233 Spalding) 1570 Wilson Avenue, San Marino.

Julius Miklowitz, Ph.D., *Associate Professor of Applied Mechanics*
B.S., University of Michigan, 1943; Ph.D., 1949. California Institute, 1956-. (317 Engineering Bldg.) 10112 Woodward Avenue, Sunland.

Alexander Miller, Ph.D., *Research Fellow in Biology*
B.S., University of Wisconsin, 1949; Ph.D., Columbia University, 1956. California Institute, 1957-. (204 Kerckhoff) 925 North Holliston Avenue.

Peter McNaughton Miller, Ph.D., *Lecturer in English; Assistant Director of Admissions and Undergraduate Scholarships*
A.B., Princeton University, 1934; Ph.D., 1939. California Institute, 1956-. Lecturer, 1957-. (112 Throop) 1590 Oakdale Street.

Clark Blanchard Millikan, Ph.D., *Professor of Aeronautics; Director of the Guggenheim Aeronautical Laboratory*
Ph.B., Yale University, 1924; Ph.D., California Institute, 1928. Assistant Professor, 1928-34; Associate Professor, 1934-40; Professor, 1940-; Director, 1945-. (205 Guggenheim) 690 Wendover Road.

Herschel Kenworthy Mitchell, Ph.D., *Professor of Biology*
B.S., Pomona College, 1936; M.S., Oregon State College, 1938; Ph.D., University of Texas, 1941. Senior Research Fellow, California Institute, 1946-49; Associate Professor, 1949-53; Professor, 1953-. (212 Kerckhoff) 1900 North Altadena Drive.

Mary B. Mitchell, M.A., *Research Fellow in Biology*
B.S., George Washington University, 1941; M.A., Stanford University, 1945. California Institute, 1946-. (210 Kerckhoff) 169 North Hudson Avenue.

Rudolf Ludwig Moessbauer, Dr. Rer. Nat., *Research Fellow in Physics*
B.S., Institute for Technical Physics, Munich, 1949; Dr. Rer. Nat., 1958. Staff Member, 1957-. California Institute, 1960-61. (160 West Bridge) 118 South Parkwood Avenue.

Govindaraju Jagan Mohanrao, Ph.D., *Research Fellow in Sanitary Engineering*
B.Sc., Andhra University, Waltair, India, 1950; M.Sc., 1951; Ph.D., University of Bombay, 1954; Sc.D., Massachusetts Institute of Technology, 1959. California Institute, 1959-. (113 Engineering).

Dino Antonio Morelli, Ph.D., *Associate Professor of Mechanical Engineering*
B.E., Queensland University, 1937; M.E., 1942; M.S., California Institute, 1945; Ph.D., 1946. Lecturer, 1948-49; 1958-59; Assistant Professor, 1949-56; Associate Professor, 1959-. (309 Engineering) 1375 Chamberlain Road.

David Morris, Ph.D., *Research Fellow in Radio Astronomy*
B.Sc., Manchester University, England, 1955; Ph.D., 1959. California Institute, 1959-60. (102 Robinson). Radio Observatory, Big Pine, California.

Seeley G. Mudd, M.D., *Research Associate in Medical Chemistry*
B.S., Columbia University, 1917; M.D., Harvard University, 1924; California Institute, 1931-. 1550 Oak Grove Avenue, San Marino.

Francis J. Mullin, Ph.D., *Assistant Professor of Electrical Engineering*
B.E.E., Villanova University, 1953; S.M.E.E., Massachusetts Institute of Technology, 1955; Ph.D., University of California, 1959. California Institute, 1958-. (233 Spalding) 1347 East Atchison.

Joe Hill Mullins, Ph.D., *Senior Research Fellow in Physics*
B.S., Agricultural and Mechanical College of Texas, 1950; M.S., California Institute, 1954; Ph.D., 1959. Research Fellow, 1959-60; Senior Research Fellow, 1960-. (Synchrotron) 471 West Grand View, Sierra Madre.

Guido Munch, Ph.D., *Professor of Astronomy; Staff Member, Mount Wilson and Palomar Observatories*
B.S., Universidad Nacional Autonoma de Mexico, 1938; M.S., 1944; Ph.D., University of Chicago, 1947. Assistant Professor, California Institute, 1951-54; Associate Professor, 1954-59; Professor, 1959-. (211 Robinson) 928 South El Molino Avenue.

Karl-Wolfgang Mundry, Ph.D., *Research Fellow in Biology*
Ph.D., University of Tubingen, 1954. Assistant, Max-Planck Institute for Biology, Tubingen, 1957-. California Institute, 1959-60.

Edwin S. Munger, Ph.D., *Professor of Geography*
M.S., University of Chicago, 1948; Ph.D., 1951. Visiting Lecturer, American Universities Field Staff, California Institute, 1954; 1957; 1960; Professor, 1961-.

Bruce Churchill Murray, Ph.D., *Research Fellow in Space Science*
S.B., Massachusetts Institute of Technology, 1953; S.M., 1954; Ph.D., 1955. Geophysicist, Air Force Research Center, Cambridge, Mass., 1958-. California Institute, 1960-61. (305 Mudd) 383 South Catalina Avenue.

Harold Z. Musselman, A.B., *Director of Athletics and Physical Education*
A.B., Cornell College, 1920. Instructor, California Institute, 1921-24; Manager of Athletics, 1924-35; Assistant Director of Physical Education and Manager of Athletics, 1935-42; Acting Director of Physical Education, 1942-43; Director of Physical Education and Manager of Athletics, 1943-47; Director of Athletics and Physical Education, 1947-. (Gymnasium) 1080 North Holliston Avenue.

Kuppuswamy Nagarajan, Ph.D., *Research Fellow in Chemistry*
B.Sc., Madras University, India, 1950; Ph.D., 1954. California Institute, 1959-60. (262 Crellin) 253 South Catalina Avenue.

Herbert H. G. Nash, *Secretary*
University of Manitoba, 1919. Chief Accountant, California Institute, 1922-35; Assistant Secretary, 1935-52; Secretary, 1952-. (108 Throop) 465 Allendale Road.

Moshe Negbi, Ph.D., *Research Fellow in Biology*
M.Sc., The Hebrew University, 1955; Ph.D., 1959. California Institute, 1959-. (132 Kerckhoff) 286 South Chester Avenue.

Henry Victor Neher, Ph.D., *Professor of Physics*
A.B., Pomona College, 1926; Ph.D., California Institute, 1931. Instructor and Assistant Professor of Physics, California Institute, 1933-40; Associate Professor of Physics, 1940-44; Professor of Physics, 1944-. (24 Bridge) 855 North Holliston Avenue.

James H. Nerrie, B.S., *Coach*
Diploma, Savage School for Physical Education, 1933; B.S., Rutgers University, 1941. California Institute, 1946-. (Gymnasium) 1561 Iroquois Avenue, Long Beach.

Gerry Neugebauer, Ph.D., *Research Fellow in Physics*
A.B., Cornell University, 1954; Ph.D., California Institute, 1959. Research Fellow, 1959.

Marc-Aurele Nicolet, Ph.D., *Assistant Professor of Electrical Engineering*
Ph.D., University of Basle, Switzerland, 1958. California Institute, 1959-. (25 Spalding) 248-A South Mentor Avenue.

Carl George Niemann, Ph.D., *Professor of Organic Chemistry*
B.S., University of Wisconsin, 1931; Ph.D., 1934. Assistant Professor, California Institute, 1937-43; Associate Professor, 1943-45; Professor, 1945-. (356 Crellin) 400 South Berkeley Avenue.

Gerard Johan Nijgh, Ph.D., *Research Fellow in Physics*
Ph.D., University of Amsterdam, 1955; Research Physicist, Institute for Nuclear Physics Research, Amsterdam, 1958-. California Institute, 1959-60.

Charles Colvin Nimmo, Ph.D., *Research Fellow in Biology*
Ph.D., Stanford University, 1942. Staff Member, Western Regional Research Laboratory, U.S. Department of Agriculture, Albany, California, 1942-. California Institute, 1959-60. (120 Kerckhoff) 4211 Los Nietos Drive, Los Angeles.

Yasushi Nishiwaki, M.D., *Research Fellow in Chemistry*
M.S., Osaka Imperial University, 1939; M.D., Kyoto University, 1954. Professor of Radiation Protection, Tokyo Institute of Technology, 1959-. California Institute, 1959.

Arend W. Noltes, Ph.D., *Research Fellow in Biology*
Ph.D., University of Utrecht, 1957. California Institute, 1960-61.

Arne William Nordskog, Ph.D., *Research Fellow in Biology*
B.S., University of Minnesota, 1937; M.S., 1940; Ph.D., 1943. Professor of Poultry Husbandry, Iowa State College, 1945-. California Institute, 1960.

David Norman, Ph.D., *Research Fellow in Biology*
M.S., Purdue University; Ph.D., 1958. California Institute, 1959-. (202 Kerckhoff) 112 West Ventura Street, Altadena.

John Beverley Oke, Ph.D., *Assistant Professor of Astronomy; Staff Member, Mount Wilson and Palomar Observatories*
B.A., University of Toronto, 1949; M.A., 1950; Ph.D., Princeton University, 1953. California Institute, 1958-. (220 Robinson) 1102 Beverly Way, Altadena.

Robert W. Oliver, Ph.D., *Assistant Professor of Economics*
A.B., University of Southern California, 1943; A.M., 1948; A.M., Princeton University, 1950; Ph.D,. 1957. California Institute, 1959-. (10 Dabney) 3952 East California Boulevard.

Lawrence Olson, Ph.D., *Visiting Lecturer in International Affairs*
Ph.D., Harvard University, 1954. American Universities Field Staff, 1955-. California Institute, 1957; 1960.

Daphne Osborne, Ph.D., *Research Fellow in Biology*
B.Sc., Kings College, University of London, 1945; M.Sc., 1946; Ph.D., 1950. Senior Scientific Officer, Agricultural Research Council, Department of Agriculture, Oxford University, 1952-. California Institute, 1950-51; 1960.

Jack Castle Overley, S.B., *Research Fellow in Physics*
S.B., Massachusetts Institute of Technology, 1954. Research Fellow, California Institute, 1960-61. (403 Kellogg) 670 Alta Vista Drive, Sierra Madre.

Ray David Owen, Ph.D., *Professor of Biology*
B.S., Carroll College, 1937; Ph.M., University of Wisconsin, 1938; Ph.D., 1941. Gosney Fellow, California Institute, 1946-47; Associate Professor, 1947-53; Professor, 1953-. (07 Kerckhoff) 1583 Rose Villa Street.

Charles Herach Papas, Ph.D., *Professor of Electrical Engineering*
B.S., Massachusetts Institute of Technology, 1941; M.S., Harvard University, 1946; Ph.D., 1948. Lecturer, 1952-54; California Institute, Associate Professor, 1954-59; Professor, 1959-. (331 Spalding) 534 Vallombrosa Drive.

Yair Parag, Ph.D., *Research Fellow in Biology*
M.Sc., Hebrew University, Jerusalem, 1956; Ph.D., Harvard University, 1960. California Institute, 1960-61.

Kilho Park, Ph.D., *Research Fellow in Geochemistry*
B.S., Texas A and M College, 1955; M.S., 1957; Ph.D., 1960. California Institute, 1960-61.

Richard W. Patch, Ph.D., *Visiting Lecturer in International Affairs*
B.A., Cornell University, 1951; Ph.D., 1956. American Universities Field Staff, 1957-. California Institute, 1960.

Jogesh C. Pati, Ph.D., *Richard Chace Tolman Research Fellow in Theoretical Physics*
B.Sc., Utkal University, India, 1955; M.Sc., Delhi University, 1957; Ph.D., University of Maryland, 1960. California Institute, 1960-61.

Claire Cameron Patterson, Ph.D., *Senior Research Fellow in Geochemistry*
A.B., Grinnell College, 1943; M.S., University of Iowa, 1944; Ph.D., University of Chicago, 1951. Research Fellow, California Institute, 1952-53; Senior Research Fellow, 1953-. (016 Mudd) 5300 Crown Avenue, La Cañada.

Arnold Milton Paul, Ph.D., *Instructor in History*
A.B., New York University, 1947; M.A., University of California (Los Angeles), 1952; Ph.D., 1958. California Institute, 1959-60.

Rodman Wilson Paul,* Ph.D., *Professor of History*
A.B., Harvard University, 1936; M.A., 1937; Ph.D., 1943. Associate Professor, 1947-51; Professor, 1951-. (8 Dabney) 586 La Loma Road.

*Leave of absence, second and third terms, 1960-61

Linus Pauling, Ph.D., Sc.D., L.H.D., U.J.D., D.H.C., D.F.A., LL.D., Nobel Laureate, *Professor of Chemistry*
B.S., (Che.E.), Oregon State College, 1922; Ph.D., California Institute, 1925. Research Associate, 1926-27; Assistant Professor, 1927-29; Associate Professor, 1929-31; Professor, 1931-; Chairman of the Division of Chemistry and Chemical Engineering, 1936-58. (205 Church) 3500 East Fairpoint Street.

John R. Pellam, Ph.D., *Professor of Physics*
B.S., Massachusetts Institute of Technology, 1940; Ph.D., 1947. California Institute, 1954-. (54 W. Bridge) 1340 East California Street.

Stanford S. Penner, Ph.D., *Professor of Jet Propulsion*
B.S., Union College, 1942; M.S., University of Wisconsin, 1943; Ph.D., 1945. Assistant Professor, California Institute, 1950-53; Associate Professor, 1953-57; Professor, 1957-. (209 Engineering Bldg.) 2008 Oakdale Street.

Vincent Z. Peterson, Ph.D., *Assistant Professor of Physics*
B.S., Pomona College, 1943; Ph.D., University of California, 1950. Research Fellow, California Institute, 1950-53; Senior Research Fellow, 1953-58; Assistant Professor, 1958-. (23 Bridge) 363 Mountain View Street, Altadena.

John Andrew Petruska, M.Sc., *Research Fellow in Biology*
B.Sc., Bishop's University, Quebec, 1953; M.Sc., McMaster University, Ontario, 1954. Research Fellow in Chemistry, California Institute, 1958-60; Research Fellow, Biology, 1960-. (Alles Laboratory) 361 South Oakland Avenue.

William Hayward Pickering, Ph.D., *Professor of Electrical Engineering; Director of Jet Propulsion Laboratory*
B.S., California Institute, 1932; M.S., 1933; Ph.D., 1936. Instructor, 1936-40; Assistant Professor, 1940-45; Associate Professor, 1945-47; Professor, 1947-; Director, Jet Propulsion Laboratory, 1954-. (Jet Propulsion Lab.) 2514 Highland Avenue, Altadena.

Lajos Piko, D.V.M., *Research Fellow in Biology*
Dipl., University of Agricultural Science, Budapest-Godollo, 1956; D.V.M., Veterinary School of Alfort, France, 1957. California Institute, 1959-. (302 Kerckhoff) 1541 Rose Villa Street.

Cornelius John Pings, Jr., Ph.D., *Associate Professor of Chemical Engineering*
B.S., California Institute, 1951; M.S., 1952; Ph.D., 1955. Associate Professor, 1959-. (217 Spalding) 423 Naomi Avenue, Arcadia.

Elliott Pinson, B.S.E., *Instructor in Electrical Engineering*
B.S.E., Princeton University, 1956. California Institute, 1960-61.

Henry Dan Piper, Ph.D., *Associate Professor of English*
A.B., Princeton University, 1939; Ph.D., University of Pennsylvania, 1950. Assistant Professor, California Institute, 1952-56; Associate Professor, 1956-. (313 Dabney) 3771 Alzada Road, Altadena.

Milton S. Plesset, Ph.D., *Professor of Applied Mechanics*
B.S., University of Pittsburgh, 1929; Ph.D., Yale University, 1932. Associate Professor, 1948-51; Professor, 1951-. (313 Engineering Bldg.) 625 Landor Lane.

Clifford Julius Pollard, Ph.D., *Research Fellow in Biology*
B.S., Prairie View A. and M. College, 1950; M.S., 1952; Ph.D., Georgetown University, 1960. California Institute, 1959-. (120 Kerckhoff) 293 South Chester Avenue.

Gennaday W. Potapenko,** Ph.D., *Associate Professor of Geophysics*
C.Sc., University of Moscow, 1917; M.A., Ph.D., (Habilitation), 1920. California Institute, 1930-. (104 Mudd) 1718 Oakdale Street.

Richard L. Potter, Ph.D., *Research Fellow in Biology*
B.A., Reed College, 1950; M.S., Washington State College, 1953; Ph.D., University of Rochester, 1956. California Institute, 1958-. (332 Kerckhoff) 271 South Wilson Avenue.

Edward T. Preisler, B.A., *Coach*
B.A., San Diego State College, 1941. California Institute, 1947-. (Gymnasium) 2776 Yorkshire Road.

Frank Press, Ph.D., *Professor of Geophysics; Director, Seismological Laboratory*
B.S., College of City of New York, 1944; M.A., Columbia University, 1946; Ph.D., 1949. California Institute, 1955; Director, 1957-. (314 Mudd; Seismological Lab.) 1972 Skyview Drive, Altadena.

Venkataraman Radhakrishnan, B.Sc., *Research Fellow in Radio Astronomy*
B.Sc., University of Mysore, 1950. California Institute, 1959-60. (101 Robinson) 122 North Oak Avenue, Apt. D.

**Part-time

Simon Ramo, Ph.D., *Research Associate in Electrical Engineering*
B.S., University of Utah, 1933; Ph.D., California Institute, 1936. California Institute, 1946-. 276 Tavistock Avenue, Los Angeles.

W. Duncan Rannie, Ph.D., *Robert H. Goddard Professor of Jet Propulsion*
B.A., University of Toronto, 1936; M.A., 1937; Ph.D., California Institute, 1951. Jet Propulsion Laboratory, 1946-; Assistant Professor of Mechanical Engineering, 1947-51; Associate Professor, 1951-55; Professor, 1955-. (208 Guggenheim) 272 E. Highland Avenue, Sierra Madre.

Silvio Ranzi, Ph.D., *Research Fellow in Biology*
Professor, Chairman, Department of Zoology, University of Milan. California Institute, 1960.

Albert Ravenholt, *Visiting Lecturer in International Affairs*
Staff Member, Institute of Current World Affairs, 1947-. American Universities Field Staff. California Institute, 1954; 1957; 1960.

H. Hollis Reamer, M.S., *Senior Research Fellow in Chemical Engineering*
A.B., University of Redlands, 1937; M.S., California Institute, 1938; Research Assistant, 1938-52; Research Fellow, 1952-58; Senior Research Fellow, 1958-. (357 Chem. Engr. Lab.) 1885 Woodlyn Road.

Dorothy von Redlich, Ph. D., *Research Fellow in Chemistry*
Ph.D., University of Bern, Switzerland, 1948. Research Assistant, Beth-El Hospital, New York City, 1957-. California Institute, 1958-60. (204 Church) 275 South Hudson Avenue.

Barry L. Reeves, D.Sc., *Research Fellow in Aeronautics*
D.Sc., Washington University, St. Louis, 1960. California Institute, 1960-61. (203 Guggenheim) 374 South Catalina Avenue.

Werner Reichardt, Ph.D., *Professor of Electrical Engineering and Biology*
Dipl. Technische Universitat, Berlin, 1950; Ph.D., 1952. Research Fellow in Biology, California Institute, 1955; Professor, 1960-.

Ernst Reinhard, D.Sc., *Research Fellow in Biology*
D.Sc., University of Wurzburg, 1953. California Institute, 1959-60. (123 Kerckhoff) 722 East California Blvd.

Joon Hee Rho, Ph.D., *Research Fellow in Biology*
B.S., Seoul National University, 1950; M.A., Duke University, 1956; Ph.D., 1958. Associate Professor, Sungkyunkwan University, Seoul, 1957-. California Institute, 1959-. 346 South Chester Avenue.

John Hall Richards, Ph.D., *Assistant Professor of Chemistry*
B.A., University of California, 1951; B.Sc., Oxford University, 1953; Ph.D., University of California, 1955. California Institute, 1957-. (361 Crellin) 1765 Oakwood Drive, Arcadia.

Charles Francis Richter, Ph.D., *Professor of Seismology*
A.B., Stanford University, 1920; Ph.D., California Institute, 1928. Assistant Professor, California Institute, 1937-47; Associate Professor, 1947-52; Professor, 1952-. (316 Mudd, Seismological Lab.) 1820 Kenneth Way.

George Neal Richter, Ph.D., *Assistant Professor of Chemical Engineering*
B.E., Yale University, 1951; M.S., California Institute, 1952; Ph.D., 1957. Research Fellow, 1956-58; Assistant Professor, 1958-. (365 Chem. Engr. Lab.) 364 Cliff Drive.

Gerhard Felix Richter, Ph.D., *Research Fellow in Biology*
Ph.D., University of Marburg, Germany, 1956. California Institute, 1959-60. (132 Kerckhoff) 155 North Wilson Avenue.

Don Ridgeway, Ph.D., *Research Fellow in Chemistry*
B.S., Yale University, 1952; Ph.D., University of Rochester, 1957. California Institute, 1957-. (011 Church) 536 East Elizabeth Street.

Robert Gene Rinker, Ph.D., *Assistant Professor of Chemical Engineering*
B.S., Rose Polytechnic Institute, 1951; M.S., California Institute, 1955; Ph.D., 1959. Research Fellow, 1959-60; Assistant Professor, 1960-. (313 Spalding) Student House C.

John D. Roberts, Ph.D., *Professor of Organic Chemistry*
B.A., University of California (Los Angeles), 1941; Ph.D., 1944. California Institute, 1953-. (360 Crellin) 2659 Tanoble Drive, Altadena.

Howard Percy Robertson, Ph.D., *Professor of Mathematical Physics*
B.S., University of Washington, 1922; M.S., 1923; Ph.D., California Institute, 1925. California Institute, 1947-. (101 East Bridge Lab.) 590 Auburn Avenue, Sierra Madre.

George Wilse Robinson, Ph.D., *Associate Professor of Physical Chemistry*
B.S., Georgia Institute of Technology, 1947; M.S., 1949; Ph.D., State University of Iowa, 1952. California Institute, 1959-. 45 Lowell Avenue, Sierra Madre.

John H. Robinson, Ph.D., *Research Fellow in Biology*
B.A., University of Buffalo, 1948; M.A., Cornell University, 1951; Ph.D., 1953. Assistant Professor, Princeton University, 1956-. California Institute, 1960-61.

John Romberger, Ph.D., *Research Fellow in Biology*
M.S., Pennsylvania State University, 1954; Ph.D., University of Michigan, 1957. California Institute, 1957-. (124 Kerckhoff) 196 South Greenwood Avenue.

Anatol Roshko, Ph.D., *Associate Professor of Aeronautics*
B.Sc., University of Alberta, 1945; M.S., California Institute, 1947; Ph.D., 1952. Research Fellow, 1952-54; Senior Research Fellow, 1954-55; Assistant Professor, 1955-58; Associate Professor, 1958-. (221 Guggenheim) 3130 Maiden Lane, Altadena.

August Thomas Rossano, Jr., D.Sc., *Visiting Professor of Environmental Health Engineering*
S.B., Massachusetts Institute of Technology, 1938; S.M., Harvard University, 1941; D.Sc., 1954. Sanitary Engineering Director, U.S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, 1959-. California Institute, 1959-. (119 Engineering Bldg.) 290 South Holliston Avenue.

Winston Walker Royce, Ph.D., *Assistant Professor of Aeronautics*
B.S., California Institute, 1951; M.S., 1952; Ph.D., 1959; Instructor, 1955-58; Assistant Professor, 1958-. (203 Guggenheim) 1719 South First Avenue, Arcadia.

Konrad Rudnicki, Ph.D., *Research Fellow in Astronomy*
Ph.D., Staff Member, Astronomical Observatory, Warsaw University. California Institute, 1961.

Rolf Sabersky, Ph.D., *Associate Professor of Mechanical Engineering*
B.S., California Institute, 1942; M.S., 1943; Ph.D., 1949. Assistant Professor, California Institute, 1949-55; Associate Professor, 1955-. (203 Engineering Bldg.) 2206 Loma Vista Street.

Bruce Hornbrook Sage, Ph.D., Eng.D., *Professor of Chemical Engineering*
B.S., New Mexico State College, 1929; M.S., California Institute, 1931; Ph.D., 1934; Eng.D., New Mexico State College, 1953. Research Fellow, 1934-35; Senior Fellow in Chemical Research, 1935-37; Assistant Professor, 1937-39; Associate Professor, 1939-44; Professor, 1944-. (213 Spalding) 3216 Mount Curve Avenue, Altadena.

Anil Kumar Saha, Ph.D., *Research Fellow in Chemistry*
B.Sc., Presidency College, Calcutta, 1949; M.Sc., University College of Science and Technology, Calcutta, 1952; Ph.D., 1959. Assistant Research Officer, Nutrition Research Unit, Indian Council of Medical Research, Calcutta University, 1958-. California Institute, 1960-61. (309 Church) 153 South Chester Avenue.

William R. Samples, Ph.D., *Assistant Professor of Civil Engineering*
B.S., West Virginia University, 1953; M.S., Harvard University, 1955; Ph.D., 1958. California Institute, 1959-. (119 Engr. Bldg.) 1057 East Morada, Altadena.

Sten Otto Samson, Fil.Lic., *Research Fellow in Chemistry*
Fil.Kand., University of Stockholm, 1953; Fil.Lic., 1956. California Institute, 1953-56; 1957-. (60 Crellin) 351 South Parkwood.

Omar Hugo Sanchez, C.E., *Research Fellow in Civil Engineering*
C.E., National University of Cuyo, Argentina, 1957. Assistant Professor of Civil Engineering, National University of Cuyo, 1957-. California Institute, 1959-60.

Allan Rex Sandage, Ph.D., *Staff Member, Mount Wilson and Palomar Observatories*
A.B., University of Illinois, 1948; Ph.D., California Institute, 1953. Mt. Wilson Observatory, 1948-. (Mt. Wilson Office) 619 East Washington Street, Apt. 14.

Matthew Linzee Sands, Ph.D., *Professor of Physics*
B.A., Clark University, 1940; M.A., Rice Institute, 1941; Ph.D., Massachusetts Institute of Technology, 1948; Senior Research Fellow, California Institute, 1950-52; Assistant Professor, 1952-53; Associate Professor, 1953-59; Professor, 1959-. (Synchrotron Lab.) 1546 Rose Villa Street.

Wallace Leslie William Sargent, Ph.D., *Research Fellow in Astronomy*
B.S., University of Manchester, England, 1956; Ph.D., 1959. California Institute, 1959-. (212 Robinson) 551 South Hill Avenue.

Clifford Sato, Ph.D., *Research Fellow in Biology*
B.S., University of Hawaii, 1951; Ph.D., Michigan State College, 1955 California Institute, 1955-. (015 Kerckhoff) 638 North Madison Avenue.

William Palzer Schaefer, Ph.D., *Instructor in Chemistry*
B.S., Stanford University, 1952; M.S., University of California (Los Angeles), 1953; Ph.D., 1960. Research Fellow, California Institute, 1960; Instructor, 1960-. (127 Crellin) 11018 East Maplefield Street, El Monte.

Johann Schaeffler, Dipl.Ing., *Research Fellow in Aeronautics*
Dipl.Ing., Technical Institute of Munich, 1958. Staff Member, Aerodynamics and Mechanics, Technical Institute of Munich, 1958-. California Institute, 1960-61. (223 Guggenheim) 1110 Steuben Street.

Maarten Schmidt, Ph.D., *Associate Professor of Astronomy; Staff Member, Mount Wilson and Palomar Observatories*
Ph.D., University of Leiden, 1956. Carnegie Fellow, Mount Wilson and Palomar Observatories, 1956-58. Associate Professor, California Institute, 1959-. (202 Robinson) 152 East Loma Alta Drive, Altadena.

Walter Adolph Schroeder, Ph.D., *Research Associate in Chemistry*
B.Sc., University of Nebraska, 1939; M.A., 1940; Ph.D., California Institute, 1943. Research Fellow, 1943-46; Senior Research Fellow, 1946-56; Research Associate, 1956-. (109 Church) 2110 East Washington Street.

Ronald Fraser Scott, Sc.D., *Assistant Professor of Civil Engineering*
B.Sc., Glasgow University, 1951; S.M., Massachusetts Institute of Technology, 1953; Sc.D., 1955. California Institute, 1956-. (121 Engineering) 2494 North Ganesha, Altadena.

Leonard Searle, Ph.D., *Senior Research Fellow in Astronomy*
Ph.D., Princeton University, 1956. Associate Professor, David Dunlap Observatory, Ontario, Canada. California Institute, 1960-61.

Alberta J. Seaton, Sc.D., *Research Fellow in Biology*
B.A., Howard University, 1946; M.S., 1947; Sc.D., University of Brussels, 1949. Associate Professor of Biology, Texas Southern University, 1954-. California Institute, 1959-60.

Ernest Edwin Sechler, Ph.D., *Professor of Aeronautics*
B.S., California Institute, 1928; M.S., 1929; Ph.D., 1933. Instructor, 1930-37; Assistant Professor, 1937-40; Associate Professor, 1940-46; Professor, 1946-. (224 Guggenheim) 2265 Montecito Drive, San Marino.

Bernhard August Seidel, Dr.Rer.Nat., *Research Fellow in Chemistry*
Dipl.Chem., University of Kiel, 1955; Dr.Rer.Nat., University of Heidelberg, 1957. California Institute, 1960-61.

Robert Phillip Sharp, Ph.D., *Professor of Geology; Chairman of the Division of Geological Sciences*
B.S., California Institute, 1934; M.S., 1935; A.M., Harvard University, 1936; Ph.D., 1938. Professor, California Institute, 1947-; Chairman of the Division, 1952-. (158 Arms) 1410 East Palm Street, Altadena.

Kenneth Noel Francis Shaw, Ph.D., *Senior Research Fellow in Chemistry*
B.A., University of British Columbia, 1940; M.A., 1942; Ph.D., Iowa State College, 1951. California Institute, 1958-. (202 Church) 2316 South California Avenue, Duarte.

Bruce L. Sheldon, Ph.D., *Research Fellow in Biology*
B.Sc., Sydney University, 1953; Ph.D., 1960. California Institute, 1960-61. (306 Kerckhoff) 2034 Crary Street.

Kung-Sing Shih, Ph.D., *Research Fellow in Mathematics*
M.S., Kyoto University, 1940; Ph.D., University of Illinois, 1953. Professor; Head, Department of Mathematics, National Taiwan University, 1950-. California Institute, 1960-61. (Sloan).

Jacques Signoret, D.Sc., *Research Fellow in Biology*
D.Sc., Unversity of Paris. Director of Embryological Research, University of Paris, 1957-. California Institute, 1960.

Leon Theodore Silver, Ph.D., *Assistant Professor of Geology*
B.S., University of Colorado, 1945; M.S., University of New Mexico, 1948; Ph.D., California Institute, 1955. Assistant Professor, 1955-. (015 Mudd) 3315 Crestford Drive, Altadena.

Robert Louis Sinsheimer, Ph.D., *Professor of Biophysics*
S.B., Massachusetts Institute of Technology, 1941; S.M., 1942; Ph.D., 1948. Senior Research Fellow, California Institute, 1953; Professor, 1957-. (188 Alles) 616 South Sierra Bonita Avenue.

William Glenn Sly, Ph.D., *Senior Research Fellow in Chemistry*
B.S., San Diego State College, 1951; Ph.D., California Institute, 1955. Assistant Professor of Chemistry, Harvard Mudd College, 1958-. Research Fellow, California Institute, 1956-57; Senior Research Fellow, 1959-. 416 West Third, Claremont.

Brian L. Smith, Ph.D., *Research Fellow in Chemical Engineering*
B.Sc., Queen Mary College, University of London, 1957; Ph.D., 1960. California Institute, 1960-61.

David Rodman Smith, Ph.D., *Assistant Professor of English*
B.A. Pomona College, 1944; M.A., Claremont Colleges, 1950; Ph.D., 1960. Instructor, California Institute, 1958-60; Assistant Professor, 1960-. (307 Dabney) 270 West Tenth Street, Claremont.

Hallett D. Smith, Ph. D., *Professor of English; Chairman of the Division of Humanities*
B.A., University of Colorado, 1928; Ph.D., Yale University, 1934. California Institute, 1949-. (204 Dabney) 1455 South Marengo Avenue.

John D. Smith, Ph.D., *Research Fellow in Biology*
Ph.D., Clare College, University of Cambridge, 1948. Senior Scientific Officer, Agricultural Research Council, Virus Research Unit, Cambridge, 1957-. California Institute, 1959-. (064 Church) 2173 San Pasqual Street.

William Ralph Smythe, Ph.D., *Professor of Physics*
A.B., Colorado College, 1916; A.M., Dartmouth College, 1919; Ph.D., University of Chicago, 1921. Research Fellow, California Institute, 1926-27; Assistant Professor, 1927-34; Associate Professor, 1934-40; Professor, 1940-. (107 E. Bridge) 674 Manzanita Avenue, Sierra Madre.

Eugene Irving Snyder, Ph.D., *Research Fellow in Chemistry*
B.S., Temple University, 1955; Ph.D., University of Chicago, 1959. California Institute, 1959-. (362 Crellin) 790 Sacramento Street, Altadena.

Royal Wasson Sorensen, D.Sc., *Professor of Electrical Engineering, Emeritus*
B.S., University of Colorado, 1905; E.E., 1928; D.Sc., 1938. California Institute, 1910-52; Professor Emeritus, 1952-. (225 Spalding) 384 South Holliston Avenue.

Raymond Harold Spear, Ph.D., *Research Fellow in Physics*
B.Sc., University of Melbourne, 1953; M.Sc., 1955; Ph.D., 1959. Senior Demonstrator in Physics, University of Melbourne, 1959-. California Institute, 1960-61.

Roger Wolcott Sperry, Ph.D., *Hixon Professor of Psychobiology*
A.B., Oberlin College, 1935; A.M., 1937; Ph.D., University of Chicago, 1941. California Institute, 1954-. (320 Kerckhoff) 1369 Boston Street, Altadena.

Heinz A. Staab, Dr.Habil., *Visiting Associate in Chemistry*
Dipl.Chem., University of Tubingen, 1951; Dr.Rer.Nat., University of Frankfurt, 1953; Dr. Habil., University of Heidelberg, 1957. Staff Member, Chemical Institute, University of Heidelberg, 1956-. California Institute, 1960.

Richard Henry Stanford, Jr., Ph.D., *Research Fellow in Chemistry*
B.A., The Rice Institute, 1954; Ph.D., 1958. California Institute, 1958-. (230 Church) Fleming House.

Gordon James Stanley, Dipl., *Senior Research Fellow in Radio Astronomy*
Dipl., New South Wales University of Technology, 1946. Research Engineer, California Institute, 1955-58; Senior Research Fellow, 1958-. (103 Robinson) 1654 East Loma Alta Drive, Altadena.

Roger Fellows Stanton, Ph.D., *Professor of English; Director of Institute Libraries*
B.S., Colgate University, 1920; M.A., Princeton University, 1924; Ph.D., 1931. Instructor, California Institute, 1925-31; Assistant Professor, 1931-47; Associate Professor, 1947-55; Professor, 1955-. (5 Dabney) 790 East Woodbury Road.

Charles Myron Steinberg, A.B., *Instructor in Biology*
A.B., Vanderbilt University, 1954. Instructor, California Institute, 1960. (60 Church) 406 South Mentor Avenue.

John Steiner, M.D., *Research Fellow in Biology*
B.S., University of Otago, New Zealand, 1956; M.D., 1958. Staff Member, Dunedin Hospital, 1959-. California Institute, 1960. (302 Kerckhoff) 800 San Rafael.

Captain Cary D. Stephenson, B.S., *Assistant Professor of Air Science and Tactics*
B.S., Oklahoma A. and M. College, 1952. California Institute, 1959-. (Bldg. T-1). 1449 Daveric Drive.

Alfred Stern, Ph.D., *Professor of Languages and Philosophy*
Ph.D., University of Vienna, 1923. Instructor, California Institute, 1947-48; Lecturer, 1948-50; Assistant Professor, 1950-53; Associate Professor, 1953-60; Professor, 1960-. (302 Dabney) 1049 West 35th Place, Los Angeles.

Homer Joseph Stewart, Ph.D., *Professor of Aeronautics*
B.Aero.E., University of Minnesota, 1936; Ph.D., California Institute, 1940. Instructor, 1939-42; Assistant Professor, 1942-46; Associate Professor, 1946-49; Professor, 1949-.

William Sheldon Stewart, *Research Associate in Biology*
B.A., University of California (Los Angeles), 1936; M.A., 1937; Ph.D., California Institute, 1939; Director, Los Angeles State and County Arboretum, 1955-. California Institute, 1955-. 1666 Oakwood Avenue, Arcadia.

William Harold Stone, Ph.D., *Research Fellow in Biology*
A.B., Brown University, 1948; M.S., University of Maine, 1949; Ph.D., University of Wisconsin, 1953. California Institute, 1960.

Thomas Foster Strong, M.S., *Assistant Professor of Physics; Dean of Freshmen*
B.S., University of Wisconsin, 1922; M.S., California Institute, 1937. Assistant Professor, 1944-; Dean of Freshmen, 1946-. (115 Throop) 1791 East Mendocino Street, Altadena.

Sewall Cushing Strout, Jr., Ph.D., *Associate Professor of History*
B.A., Williams College, 1947; M.A., Harvard University, 1949; Ph.D., 1952. California Institute, 1959-. (14 Dabney) 421 South Parkwood Avenue.

James Holmes Sturdivant, Ph.D., *Professor of Chemistry*
B.A., University of Texas, 1926; M.A., 1927; Ph.D., California Institute, 1930. Research Fellow, 1930-35; Senior Fellow in Research, 1935-38; Assistant Professor, 1938-45; Associate Professor, 1945-47; Professor, 1947-. (68 Crellin) 270 South Berkeley Avenue.

Peter A. Sturrock, Ph.D., *Senior Research Fellow in Electrical Engineering*
Ph.D., Cambridge University, 1951. Research Associate, Microwave Laboratory, Stanford University, 1953-. California Institute, 1960.

Alfred Henry Sturtevant, Ph.D., D.Sc., *Thomas Hunt Morgan Professor of Genetics*
A.B., Columbia University, 1912; Ph.D., 1914. California Institute, 1928-. (305 Kerckhoff) 1244 Arden Road.

Bradford Sturtevant, Ph.D., *Research Fellow in Aeronautics*
B.E., Yale University, 1955; M.S., California Institute, 1956; Ph.D., 1960. Research Fellow, 1960-61. (317 Guggenheim) 3516 North Marengo, Altadena.

Triplicane Asuri Sundararajan, Ph.D., *Research Fellow in Biology*
B.Sc., Presidency College, Madras, India, 1948; M.Sc., University of Madras, 1952; Ph.D., 1956. California Institute, 1959-60.

Dieter Hans Sussdorf, Ph.D., *Research Fellow in Chemistry*
B.A., University of Kansas City, 1952; Ph.D., University of Chicago, 1956. Research Associate, Argonne National Laboratory, 1958-. California Institute, 1959-. (320 Church) 15 West Naomi Avenue, Arcadia.

Richard Manliffe Sutton, Ph.D., *Professor of Physics; Director of Relations with Secondary Schools*
B.S., Haverford College, 1922; Ph.D., California Institute, 1929. Professor, 1958-. (207 E. Bridge) 2226 Crescent Drive.

Alan R. Sweezy, Ph.D., *Professor of Economics*
B.A., Harvard University, 1929; Ph.D., 1934. Visiting Professor, California Institute, 1949-50; Professor, 1950-. (311 Dabney) 433 South Greenwood Avenue.

Ernest Haywood Swift, Ph.D., *Professor of Analytical Chemistry; Chairman of the Division of Chemistry and Chemical Engineering*
B.S., University of Virginia, 1918; M.S., California Institute, 1920; Ph.D., 1924. Instructor, 1920-28; Assistant Professor, 1928-39; Associate Professor, 1939-43; Professor, 1943-; Chairman of Division, 1958-. (162 Crellin) 572 La Paz Drive, San Marino.

Shunro Tachibana, M.D., *Research Fellow in Biology*
M.D., Kurume Medical College, Japan, 1953; Dr.Med.Sc., Kyushu University, 1956. Chief Physician of Electro Physiology, Chikushi National Hospital, 1958. California Institute, 1960-61. (336 Kerckhoff) 169 North Hill Avenue.

Shosuke Takemura, D.Sc., *Research Fellow in Biology*
D.Sc., Nagoya University, 1959. Assistant, Faculty of Science, Nagoya University, 1953-. California Institute, 1959-60.

Mitsunobu Tatsumoto, D.Sc., *Research Fellow in Geochemistry*
D.Sc., Tokyo University, 1957. Lecturer, Tokyo University, 1957-. California Institute, 1959-60. (316 Mudd) 516 Mar Vista Avenue, Apt. 7.

Hugh Pettengill Taylor, Jr., Ph.D., *Assistant Professor of Geology*
B.S., California Institute, 1954; A.M., Harvard University, 1955; Ph.D., California Institute, 1959. Assistant Professor, 1959-. (218 Mudd) 2001 Hanscom Drive, South Pasadena.

Howard M. Temin, Ph.D., *Research Fellow in Biology*
B.A., Swarthmore College, 1955; Ph.D., California Institute, 1960. Research Fellow, 1959-60.

Dwight Thomas, M.A., *Instructor in English and Speech*
A.B., Monmouth College, 1931; M.A., University of Michigan, 1954. California Institute, 1955-. (309 Dabney) 275 South Marengo Avenue.

John Todd, B.Sc., *Professor of Mathematics*
B.Sc., Queen's University, Ireland, 1931. California Institute, 1957-. (262 Sloan). 1625 Sierra Bonita Lane.

Olga Taussky Todd, Ph.D., *Research Associate in Mathematics*
Ph.D., University of Vienna, 1930; M.A., University of Cambridge, 1937. California Institute, 1957-. (264 Sloan) 1625 Sierra Bonita Lane.

Seikichi Tokuda, Ph.D., *Research Fellow in Biology*
Ph.D., University of Washington, 1959. California Institute, 1960-61.

Alvin Virgil Tollestrup, Ph.D., *Associate Professor of Physics*
B.S., University of Utah, 1944; Ph.D., California Institute, 1950. Research Fellow, 1950-53; Assistant Professor, 1953-58; Associate Professor, 1958-. (Synchrotron) 268 Poppyfields Drive, Altadena.

Paul On Pong Ts'o, Ph.D., *Research Fellow in Biology*
B.S., Lingnan University, Canton, China, 1949; M.S., Michigan State University, 1951; Ph.D., California Institute, 1956. Research Fellow, 1955-. (017 Kerkchoff) 93 South Oak Avenue.

Edward J. Tully, Jr., Ph.D., *Research Fellow in Mathematics*
B.A., Fordham University, 1951; M.S., 1952; Ph.D., Tulane University, 1960. California Institute, 1960-61. (284 Sloan).

Albert Tyler, Ph.D., *Professor of Embryology*
A.B., Columbia University, 1927; M.A., 1928; Ph.D., California Institute, 1929. Instructor, 1929-37; Assistant Professor, 1938-45; Associate Professor, 1946-50; Professor, 1950-. (312 Kerckhoff) 530 Bonita Avenue, San Marino.

Howell Newbold Tyson, B.S., *Associate Professor of Mechanical Engineering and Engineering Graphics*
B.S., Massachusetts Institute of Technology, 1920. California Institute, 1936-. (216 Throop) 505 South Wilson Avenue.

Ray Edward Untereiner, Ph.D., *Professor of Economics*
A.B., University of Redlands, 1920; M.A., Harvard University, 1921; J.D., Mayo College of Law, 1925; Ph.D., Northwestern University, 1932. California Institute, 1925-. (10 Dabney) 1089 San Pasqual Street.

Brian Geoffrey Johnson Upton, Ph.D., *Research Fellow in Geology*
BA., Oxford University, 1955; M.A., 1958; Ph.D., 1959. Member, Danish Greenlandic Geological Survey, 1958-. California Institute, 1960.

P. S. Vaishwanar, M.Sc., *Research Fellow in Biology*
M.B.S., Agra University, 1947; M.Sc., Nagpur University, 1956. Lecturer in Physiology, Nagpur Medical College, 1956-. California Institute, 1960.

Sitaram Rao Valluri, Ph.D., *Senior Research Fellow in Aeronautics*
B.S., Indian Institute of Science, Bangalore, 1949; M.S., California Institute, 1950; Ph.D., 1954. Research Fellow, 1954-57; Senior Research Fellow, 1957-. (102 Guggenheim) 109 North Catalina Avenue.

Anthonie Van Harreveld, Ph.D., M.D., *Professor of Physiology*
B.A., Amsterdam University, 1925; M.A., 1928; Ph.D., 1929; M.D., 1931. Research Assistant, California Institute, 1934-35; Instructor, 1935-40; Assistant Professor, 1940-42; Associate Professor, 1942-47; Professor, 1947-. (332 Kerckhoff) 764 South Oakland Avenue.

Wilton Emile Vannier, M.D., Ph.D., *Research Fellow in Chemistry*
M.D., University of California, 1948; Ph.D., California Institute, 1958. Research Fellow, 1949-51; 1957-. (320 Church) 601 South Catalina Avenue.

Vito August Vanoni, Ph.D., *Professor of Hydraulics*
B.S., California Institute, 1926; M.S., 1932; Ph.D., 1940. Associate Professor, 1942-55; Professor, 1955-. (152 Hydro. Lab.) 3545 Lombardy Road.

Dezso Varju, Ph.D., *Research Fellow in Biology*
Ph.D., Georg August University, Goettingen, 1958. California Institute, 1959-. (61 Church) 1101 San Pasqual Street.

Frank Lee Vernon, Jr., Ph.D., *Research Fellow in Physics*
B.S., Southern Methodist University, 1949; M.S., University of California, 1952; Ph.D., California Institute, 1959. Staff Physicist, Microwave Laboratories, Hughes Research and Development, Culver City, 1959-. California Institute, 1959-60.

Gershon Vincow, Ph.D., *Research Fellow in Chemistry*
A.B., Columbia College, 1956; M.A., Columbia University, 1957, Ph.D., 1959. California Institute, 1960-61.

Jerome Vinograd, Ph.D., *Research Associate in Chemistry*
M.A., University of California (Los Angeles), 1957; Ph.D., Stanford University, 1939. Senior Research Fellow, California Institute, 1951-56; Research Associate, 1956-. (05 Church) 343 South Parkwood Avenue.

Marguerite M. P. Vogt, M.D., *Senior Research Fellow in Biology*
M.D., Medical Faculty in Berlin, 1937. Research Fellow, California Institute, 1950-54; Senior Research Fellow, 1954-. (057 Church) 1067 San Pasqual Street.

Theodore J. Voneida, Ph.D., *Research Fellow in Biology*
B.S., Ithaca College, 1953; M.Ed., Cornell University, 1954; Ph.D., 1959. California Institute, 1959-. (316 Kerckhoff) 442 Richard Circle, Los Angeles.

Thad Vreeland, Jr., Ph.D., *Associate Professor of Mechanical Engineering*
B.S., California Institute, 1949; M.S., 1950; Ph.D., 1952. Research Fellow, 1952-54; Assistant Professor, 1954-58; Associate Professor, 1958-. (117 Engineering Bldg.) 1209 Louise Avenue, Arcadia.

Paul A. Walker, Ph.D., *Research Fellow in Biology*
A.B., Bowdoin College, 1931; Ph.D., Harvard University, 1936. Professor; Chairman, Biology Department, Randolph-Macon College, 1945-. California Institute, 1960-61.

Robert Lee Walker, Ph.D., *Professor of Physics*
B.S., University of Chicago, 1941; Ph.D., Cornell University, 1948. Assistant Professor, California Institute, 1949-53; Associate Professor, 1953-59; Professor, 1959-. (263 W. Bridge; 103 Synchrotron) 993 Dale Street.

Joan Wallace, Ph.D., *Research Fellow in Biology*
B.S., Cornell University, 1951; M.S., Rutgers University, 1954; Ph.D., 1957. Research Assistant, California Institute, 1958-59; Research Fellow, 1959-. (021 Kerckhoff) 1288 Oak Grove Avenue, San Marino.

Robert A. Wallace, Ph.D., *Research Fellow in Chemistry*
B.S., Northern Illinois State Teachers College, 1953; Ph.D., University of Bonn, 1959. California Institute, 1960-61. (262 Crellin) 979 East Orange Grove Avenue.

George Wallerstein, Ph.D., *Research Fellow in Astronomy*
B.S., Brown University, 1951; M.S., California Institute, 1954; Ph.D., 1958, Instructor University of California, 1958-. Research Fellow, California Institute, 1958; 1959; 1960.

Morgan Ward, Ph.D., *Professor of Mathematics*
A.B., University of California, 1924; Ph.D., California Institute, 1928. Research Fellow, 1928-29; Assistant Professor, 1929-35; Associate Professor, 1935-40; Professor, 1940-. (388 Sloan) 1550 San Pasqual Street.

William F. Warren, Ph.D., *Research Fellow in Aeronautics*
B.M.E., Alabama Polytechnic Institute, 1948; M.Sc., Carnegie Institute of Technology, 1950; Ph.D., University of Maryland, 1960. California Institute, 1960-61.

Jurg Waser, Ph.D., *Professor of Chemistry*
B.S., University of Zurich, 1939; Ph.D., California Institute, 1944. Professor, 1958-. (119 Gates Laboratory) 1308 East California Street.

Gerald J. Wasserburg, Ph.D., *Associate Professor of Geology*
S.B., University of Chicago, 1951; S.M., 1952; Ph.D., 1954. Assistant Professor, California Institute, 1955-59; Associate Professor, 1959-. (357 Arms) 3100 Maiden Lane, Altadena.

Yasushi Watanabe, Ph.D., *Research Fellow in Biology*
Agr.B., Tohoku University, 1953; Agr.M., 1955; Ph.D., 1958. Research Fellow, Department of Agricultural Chemistry, Tohoku University, 1958-. California Institute, 1958-. (220 Kerckhoff) 419 South Catalina Avenue.

Earnest Charles Watson,** Sc.D., *Professor of Physics*
Ph.B., Lafayette College, 1914; Sc.D., 1958. Assistant Professor, California Institute, 1919-20; Associate Professor, 1920-30; Professor, 1930-; Dean of the Faculty, 1945-60.

J. Harold Wayland, Ph.D., *Professor of Applied Mechanics*
B.S., University of Idaho, 1931; M.S., California Institute, 1935; Ph.D., 1937. Research Fellow, 1939-41; Associate Professor, 1949-57; Professor, 1957-. (327 Engineering Bldg.) 361 South Greenwood Avenue.

Robert D. Wayne, M.A., *Instructor in German*
Ph.B., Dickinson College, 1935; M.A., Columbia University, 1940. California Institute, 1952-. (Dabney) 838 Lyndon Street, South Pasadena.

Richard Fouke Webb, M.D., *Director of Health Services*
A.B., Stanford University, 1932; M.D., University of Pennsylvania, 1936. California Institute, 1953-. (Health Center) 1025 Highland Street, South Pasadena.

Hans Arwed Weidenmuller, Ph.D., *Visiting Assistant Professor of Physics*
Ph.D., Institut fur Theoretical Physik, University of Heidelberg, 1957. Research Fellow, California Institute, 1959-60; Visiting Assistant Professor, 1960-61. (02 Kellogg) 762 Deodar Drive, Altadena.

Jean J. Weigle, Ph.D., *Research Associate in Biophysics*
Ph.D., University of Geneva, 1923. California Institute, 1949-. (207 Kerckhoff) 551 South Hill Avenue.

John R. Weir, Ph.D., *Associate Professor of Psychology*
B.A., University of California (Los Angeles), 1948; M.A., 1951; Ph.D., 1951. Associate, California Institute, 1951-53; Associate Professor, 1953-. (152 Throop) 2841 Highview Avenue, Altadena.

David F. Welch, I.D., *Assistant Professor of Engineering Graphics*
A.B., Stanford University, 1941; I.D., California Institute, 1943. Instructor, 1943-51; Assistant Professor, 1951-. (212 Throop) 2367 Lambert Drive.

Michael Theodore Wermel,* Ph.D., *Research Associate in Economics and Insurance*
B.S., New York University, 1931; M.S., Columbia University, 1932; Ph.D., 1939. California Institute, 1955-. (Culbertson Basement) 3145 La Suvida Drive, Los Angeles.

*Leave of absence 1960-61

**Leave of absence, 1960-62

Ray Weyman, Ph.D., *Research Fellow in Astronomy*
B.S., California Institute, 1956; Ph.D., Princeton University, 1959. California Institute, 1959-61. (212 Robinson) 1105 Dolores Drive, Altadena.

Ward Whaling, Ph.D., *Associate Professor of Physics*
B.A., Rice Institute, 1944; M.A., 1947; Ph.D., 1949. Research Fellow, California Institute, 1949-52; Assistant Professor, 1952-58; Associate Professor, 1958-. (102 Kellogg) 401 South Parkwood Avenue.

A. Bruce Whitehead, Ph.D., *Research Fellow in Physics*
B.Sc., University of New Brunswick, 1953; M.Sc., McGill University, 1955; Ph.D., 1957. Research Fellow, Atomic Energy Research Establishment, Harwell, England, 1957-. California Institute, 1961.

Marcellus Lee Wiedenbeck, Ph.D., *Research Associate in Physics*
B.S., Canisius College, 1941; M.S., Notre Dame University, 1942; Ph.D., 1945. Associate Professor of Physics, University of Michigan, 1949-. California Institute, 1960.

Helmut Wielandt, Ph.D., *Visiting Professor of Mathematics*
Ph.D., University of Berlin, 1935. Professor of Mathematics, University of Tubingen. California Institute, 1960-61. (362 Sloan).

Cornelis A. G. Wiersma, Ph.D., *Professor of Biology*
B.A., University of Leiden, 1926; M.A., University of Utrecht, 1929; Ph.D., 1933. Associate Professor, California Institute, 1933-47; Professor, 1947. (321 Kerckhoff) 350 South Greenwood Avenue.

Calvin H. Wilcox, Ph.D., *Associate Professor of Mathematics*
B.A., Harvard University, 1951; Ph.D., 1955. Instructor, California Institute, 1955-57; Assistant Professor, 1957-60; Associate Professor, 1960-. (266 Sloan).

Nathaniel White Wilcox, Ph.D., *Assistant Professor of Engineering Graphics*
A.B., Harvard University, 1917; A.B., School of Fine Arts (Boston), 1924. California Institute, 1932-. (216 Throop) 917 North Granada Avenue, Alhambra.

Max L. Williams, Jr., Ph.D., *Professor of Aeronautics*
B.S., Carnegie Institute of Technology, 1942; M.S., California Institute, 1947; A.E., 1948; Ph.D., 1950. Lecturer, 1948-50; Research Fellow, 1950-51; Assistant Professor, 1951-55; Associate Professor, 1955-60; Professor, 1960-. (226-A Guggenheim) 2036 San Pasqual Street.

Olin Chaddock Wilson, Ph.D., *Staff Member, Mount Wilson and Palomar Observatories*
A.B., University of California, 1929; Ph.D., California Institute, 1934. Mt. Wilson Observatory, 1931-. (Mt. Wilson Office) 1754 Locust Street.

Charles Harold Wilts, Ph.D., *Professor of Electrical Engineering*
B.S., California Institute, 1940; M.S., 1941; Ph.D., 1948. Assistant Professor, 1947-52; Associate Professor, 1952-57; Professor, 1957-. (123 Spalding) 1431 Brixton Road.

Ulrich Winkler, Ph.D., *Research Fellow in Biology*
Ph.D., Frankfurt University, 1957. Assistant, Institute of Microbiology, Frankfurt University, 1957-. California Institute, 1960-61. (60 Church) 145 South Wilson Avenue.

David Shotwell Wood, Ph.D., *Associate Professor of Mechanical Engineering*
B.S., California Institute, 1941; M.S., 1946; Ph.D., 1949. Lecturer, 1949-50; Assistant Professor, 1950-55; Associate Professor, 1955-. (309 Engineering Bldg.) 590 Elm Avenue, Sierra Madre.

Charles R. B. Wright, Ph.D., *Instructor in Mathematics*
B.A., University of Nebraska, 1956; M.A., 1957; Ph.D., University of Wisconsin, 1959. Research Fellow, California Institute, 1959-60; Instructor, 1960-. (370 Sloan) 532 East Mountain Street.

Chin Hua Wu, Ph.D., *Research Fellow in Chemistry*
B.S., Chiao-Tung University, China, 1949; Ph.D., University of California (Los Angeles), 1955. California Institute, 1955-57; 1958-. 3300 Las Lunas Street.

Theodore Yao-Tsu Wu, Ph.D., *Associate Professor of Applied Mechanics*
B.S., Chiao-Tung University, 1946; M.S., Iowa State College, 1948; Ph.D., California Institute, 1952. Research Fellow, 1952-55; Assistant Professor, 1955-57; Associate Professor, 1957-. (315 Engineering Bldg.) 3300 Las Lunas Street.

Oliver Reynolds Wulf, Ph.D., *Research Associate in Physical Chemistry*
B.S., Worcester Polytechnic Institute, 1920; M.S., American University, 1922; Ph.D., California Institute, 1926. California Institute, 1945-. (56 Crellin) 557 Berkeley Avenue, San Marino.

Tetsuo Yamane, Ph.D., *Research Fellow in Chemistry*
B.S., California Institute, 1956; Ph.D., 1960. Research Fellow, 1960-61. (6 Gates) 143 North Wilson Avenue.

Peter E. Yankwich, Ph.D., *Visiting Associate in Chemistry*
B.S., University of California, 1943; Ph.D., 1945. Professor of Chemistry, University of Illinois, 1957-. California Institute, 1960-61.

Don M. Yost, Ph.D., *Professor of Inorganic Chemistry*
B.S., University of California, 1923; Ph.D., California Institute, 1926. Instructor, California Institute, 1927-29; Assistant Professor, 1929-35; Associate Professor, 1935-41; Professor, 1941-. (107 Gates) 1025 San Pasqual Street.

Arthur Howland Young, *Lecturer in Industrial Relations, Emeritus*
California Institute, 1939-52. 3 Rosemary Lane, Santa Barbara.

A. C. Zaanen, Ph.D., *Visiting Professor of Mathematics*
Ph.D., University of Leiden, 1938. Professor of Mathematics, University of Leiden. California Institute, 1960-61. (364 Sloan).

Fredrik Zachariasen, Ph.D., *Assistant Professor of Theoretical Physics*
B.S., University of Chicago, 1951; Ph.D., California Institute, 1956. Assistant Professor, 1960-.

Laszlo Zechmeister, Dr.Ing., *Professor of Organic Chemistry, Emeritus*
Diploma of Chemist, 1911; Dr.Ing., 1913; Eidgenossische Technische Hochschule, Zurich, Switzerland. Professor, California Institute, 1940-1959; Professor Emeritus, 1959-. (254 Crellin) 1122 Constance Street.

J. A. D. Zeevaart, Ph.D., *Research Fellow in Biology*
M.S., Agricultural University, Wageningen, Holland, 1955; Ph.D., 1958. California Institute, 1960-. (121 Kerckhoff) 615 South El Molino Avenue, Apt. 6.

Emile Zuckerkandl, D.Sc., *Research Fellow in Chemistry*
M.S., University of Illinois, 1948; D.Sc., University of Paris, 1959. California Institute, 1959-60. (102 Church) 86 North Hill Avenue.

Edward Edom Zukoski, Ph.D., *Associate Professor of Jet Propulsion*
B.S., Harvard College, 1950; M.S., California Institute, 1951; Ph.D., 1954. Research Engineer, Jet Propulsion Laboratory, 1950-57; Lecturer, California Institute, 1956-57; Assistant Professor, 1957-60; Associate Professor, 1960-. (227 Engr.) 149 Reever Way, Altadena.

Fritz Zwicky, Ph.D., *Professor of Astrophysics; Staff Member, Mount Wilson and Palomar Observatories*
B.S., Federal Institute of Technology, Zurich, Switzerland, 1920; Ph.D., 1922. Research Fellow International Education Board, California Institute, 1925-27; Assistant Professor of Theoretical Physics, 1927-29; Associate Professor, 1929-41; Professor of Astrophysics, 1942-. (201 Robinson) 2065 Oakdale Street.

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRADUATE FELLOWS, SCHOLARS AND ASSISTANTS, 1959-60

Jon Gordon Ables, *National Science Foundation Fellow, Physics*
A.B., Knox College, 1959

Henry Ivan Abrash, *U.S. Public Health Service Fellow, Chemistry*
B.A., Harvard College, 1956

Kenneth Hoyt Adams, *Kaiser Aluminum and Chemical Corporation Fellow, Mechanical Engineering*
B.S., California Institute, 1959

Harlow Garth Ahlstrom, *Institute Scholar, Aeronautics*
B.S., University of Washington, 1959; M.S., 1959

Daniel Kuo Yi Ai, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., Swarthmore College, 1953; M.S., University of Wisconsin, 1954

Pierre Alais, *French Foreign Ministry Fellow, Engineering Science*
Agrigé de Sciences Physiques, Ecole Normale Supérieure (Paris)

Frank Addison Albini, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1958; M.S., 1959

Norman Webster Albright, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1956

Shelton Setzer Alexander, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.S., University of North Carolina, 1956; M.S., California Institute, 1959

Harold Russell Almond, Jr., *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., California Institute, 1956

Ethan Davidson Alyea, Jr., *Graduate Research Assistant, Institute Scholar, Physics*
A.B., Princeton University, 1953

John Philip Andelin, Jr., *Howard Hughes Fellow, Physics*
B.S., California Institute, 1955; M.S., Stanford University, 1956

David Ellsworth Anderson, *Institute Scholar, Aeronautics*
B.S.A.E., West Virginia University, 1954; M.S., California Institute, 1958

Don Lynn Anderson, *National Science Foundation Fellow, Geology*
B.S., Rensselaer Polytechnic Institute, 1955; M.S., California Institute, 1959

Hugh Riddell Anderson, *Graduate Research Assistant, Institute Scholar, Physics*
B.A., State University of Iowa, 1954

William Judson Anderson, *Institute Scholar, Aeronautics*
B.S., Iowa State College, 1957; M.S., 1958

Charles Bruce Archambeau, *Graduate Teaching Assistant, Murray Scholar, Geology*
B.S., University of Minnesota, 1955; M.S., 1959

Gerald Jack Arenson, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*
B.S., California Institute, 1959

Robert James Arenz (S.J.), *Institute Scholar, Aeronautics*
B.S., Oregon State College, 1945; M.S., Lic. in Phil., St. Louis University, 1957

Richard Michael Aron, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.S.E., Princeton University, 1956; M.S., California Institute, 1957

James Louis Aronson, *Woodrow Wilson Foundation Fellow, Geology*
B.A., The Rice Institute, 1959

John Fredrich Asmus, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1958; M.S., 1959

Philip Robert Austin, *Tau Beta Pi Fellow, Dobbins Scholar, Aeronautics*
B.A.E., University of Detroit, 1959

Charles Dwight Babcock, Jr., *National Aeronautics and Space Administration Fellow, Aeronautics*
B.S., Purdue University, 1957; M.S., California Institute, 1958

Vladimir Vadim Baicher, *National Science Foundation Co-operative Fellow, Aeronautics*
B.S., California Institute, 1959

John Edwin Baldwin, *Charles L. Parsons Fellow, Murray Scholar, Chemistry*
A.B., Dartmouth College, 1959

Richard Balsam, *Graduate Teaching Assistant, Institute for Defense Analysis Scholar, Mathematics*
B.S., University of Illinois, 1959

Philip Oren Banks, *Graduate Teaching Assistant, Institute Scholar, Geology*
S.B., Massachusetts Institute of Technology, 1958

R. Keith Bardin, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1953

J. Frederick Bartlett, *Graduate Research Assistant, Drake Scholar, Astronomy*
B.S., Yale University, 1958

Eduardo Basso, *Internatioal Co-operation Administration Fellow, Civil Engineering*
C.E., University of Chile, 1953

Richard Alan Baugh, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1959

William Frederick Beach, *U.S. Public Health Service Fellow, Chemistry*
B.S., Rutgers University, 1957

Jorge Behrmann-S., *The Henry L. and Grace Doherty Charitable Foundation, Inc., Fellow, Mechanical Engineering*
M.E., Universidad Tecnica Federico Santa María (Valparaiso, Chile), 1958

Victor Sergeevich Beknyev, *Inter-University Travel Grant for Soviet Students, Institute Scholar, Mechanical Engineering*
Cand.Sci., Moscow University, 1955

Ari Ben-Menahem, *H. E. Linden Fellow, Graduate Research Assistant, Bennett Scholar, Geology*
M.Sc., The Hebrew University (Jerusalem, Israel), 1954

Ronald David Bercov, *Woodrow Wilson Foundation Fellow, Mathematics*
B.Sc., (Hons.), University of Alberta, 1959

Stuart Brooke Berger, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Alfred University, 1956

Harris Bernstein, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.S., Purdue University, 1956

Shawn Biehler, *Graduate Teaching Assistant, Blacker Scholar, Geology*
B.S.E., Princeton University, 1958; M.S.E., 1959

Thomas Mark Bieniewski, *Graduate Teaching Assistant, ARCS Scholar, Physics*
B.S., University of Detroit, 1958

Harry Hobart Bingham, Jr., *Graduate Research Assistant, Institute Scholar, Physics*
A.B., Princeton University, 1952

Robert Roy Blandford, *Graduate Research Assistant, Institute Scholar, Geology*
B.S., California Institute, 1959

Thomas Kelman Boehme, *Graduate Teaching Assistant, ARCS Scholar, Mathematics*
B.S., University of Oklahoma, 1952; M.S., Oklahoma Agricultural and Mechanical College, 1957

Robert Harold Bond, *International Business Machines Corporation Fellow, Electrical Engineering*
B.S., Colorado State University, 1958; M.S., California Institute, 1959

Frank Bliss Booth, *United States Rubber Postgraduate Fellow, Chemistry*
B.S., University of California at Los Angeles, 1953; M.S., 1954

Paul George Bower, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.A., The Rice Institute, 1955

James Harrison Boyden, *Rand Corporation Fellow, Physics*
B.S., Carnegie Institute of Technology, 1954; M.S., 1955

Juan Pablo Bozzini, *University of Buenos Aires Fellow, Biology*
Lic. en Bi., University of Buenos Aires, 1957

Richard Edwin Bradbury, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.A., The Johns Hopkins University, 1957

Richard Taber Brockmeier, *Woodrow Wilson Foundation Fellow, Physics*
B.A., Hope College, 1959

Charles Edward Brockway, *Graduate Research Assistant, Dobbin Scholar, Civil Engineering*
B.S.C.E., University of Idaho, 1959

Sherwood Brofman, *Institute Scholar, Aeronautics*
B.Ae.E., Brooklyn Polytechnic Institute, 1957

Ronald Edmund Brown, *National Science Foundation Fellow, Physics*
B.S., University of Washington, 1956

Wilbur Parker Brown, *Howard Hughes Fellow, Electrical Engineering*
B.S.E., University of Michigan, 1957; M.S.E., 1958

Robert Everett Carter, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
A.B., Columbia College, 1958

Robert Eugene Chandos, *Westinghouse Educational Foundation Fellow, Electrical Engineering*
B.S., California Institute, 1959

Subhash Chandra, *Graduate Research Assistant, Institute Scholar, Astronomy*
B.S., University of Lucknow, 1954; M.S., 1958

Berken Chang, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., California Institute, 1958

David Bing Jue Chang, *National Science Foundation Fellow, Physics*
B.S., University of Washington, 1956

James Tseng-hsu Chang, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Columbia University, 1955

William Massee Chapple, *National Science Foundation Co-operative Fellow, Geology*
B.S., California Institute, 1956; M.S., California Institute, 1957

Hung Cheng, *Graduate Teaching Assistant, Laws Scholar, Physics*
B.S., California Institute, 1959

Marvin Chester, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., The City College of New York, 1952

William Stephen Childress, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S.E., Princeton University, 1956; M.S.E., 1958

Shin-kien Chow, *C. T. Loo Foundation Fellow, Institute Scholar, Civil Engineering*
B.S.A., National Taiwan University, 1957

Walter Henry Christiansen, *Boeing Fellow, Aeronautics*
B.S., Carnegie Institute of Technology, 1956; M.S., California Institute, 1957

Armando Cisternas-S., *International Co-operation Administration Fellow, Geology*
Min.Eng., University of Chile, 1957

Barry Gillespie Clark, *National Science Foundation Fellow, Astronomy*
B.S., California Institute, 1959

Donald Delbert Clayton, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Southern Methodist University, 1956; M.S., California Institute, 1959

Carl Rudolph Clinesmith, *Woodrow Wilson Foundation Fellow, Physics*
B.S., University of Washington, 1959

James Stanley Clovis, *Graduate Teaching Assistant, Laws Scholar, Chemistry*
B.S., Waynesburg College, 1959

Noundas Cocoltchos, *Stauffer Chemical Company Fellow, Chemical Engineering*
B.S.Ch.E., Worcester Polytechnic Institute, 1959

Richard Lewis Cohen, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Haverford College, 1957; M.S., California Institute, 1959

Thomas Alan Cole, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.A., Wabash College, 1958

Sidney Richard Coleman, *National Science Foundation Fellow, Physics*
B.S., Illinois Institute of Technology, 1957

René Clément Lucien Albert Collette, *Belgian-American Foundation Fellow, Institute Scholar, Electrical Engineering*
Ing. Civil A.I.M., University of Liège, 1958

Daniel Joseph Collins, *Ford Foundation Fellow, Graduate Research Assistant, Institute Scholar, Engineering Science*
B.A., Lehigh University, 1954; M.S., California Institute, 1955

James Ekstedt Conel, *Pan-American Petroleum Foundation Fellow, Geology*
B.A., Occidental College, 1955; M.S., California Institute, 1957

Michael Anthony Cowan, *Radio Corporation of America Fellow, Electrical Engineering*
B.S., Purdue University, 1957; M.S., California Institute, 1958

Donald Gerald Coyne, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., University of Kansas, 1958

Peter Linton Crawley, *National Science Foundation Co-operative Fellow, Graduate Teaching Assistant, Mathematics*
B.S., California Institute, 1957; M.S., 1958

David Hastings Crimmins, Jr., *Atomic Energy Commission Fellow, Mechanical Engineering*
B.E.E., University of Detroit, 1957

Robert Fredrick Cuffel, *John Stauffer Scholar, Chemical Engineering*
B.S., Iowa State College, 1959

Melvin Drew Daybell, *National Science Foundation Fellow, Physics*
B.S., New Mexico College of Agricultural and Mechanical Arts, 1956

Paul Hugh Deal, *Graduate Teaching Assistant, Institute Scholar, Biology*
A.B., Sacramento State College, 1958

Henry Hursell Dearman, *Dow Chemical Fellow, Chemistry*
B.S., University of North Carolina, 1956

Jacques de Barbeyrac Saint-Maurice, *French Foreign Ministry Fellow, Electrical Engineering*
Dipl. C.A.E., Ecole Nationale Supérieure de l'Aeronautique (Paris), 1959

Narsingh Deo, *Graduate Teaching Assistant, Drake Scholar, Electrical Engineering*
B.Sc. (Hons.), Patna University, 1956; D.I.I.Sc., Indian Institute of Science, 1959

Harold Ralph Dessau, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1957; M.S., 1958

Robert Stanford Deverill, *National Science Foundation Co-operative Fellow, Graduate Teaching Assistant, Chemistry*
B.S., California Institute, 1958

William Edwin Dibble, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1954

Robert Ernest Diebold, *National Science Foundation Fellow, Physics*
B.S., University of New Mexico, 1958

John Kalman Dienes, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.A., Pomona College, 1957; M.S., California Institute, 1958

Frank Sigel Dietrich III, *National Science Foundation Fellow, Physics*
B.A., Haverford College, 1959

Aldo Gene Di Loreto, *Institute Scholar, Electrical Engineering*
B.S., California Institute, 1956; M.S., 1957

James Robert Dodd, *National Science Foundation Fellow, Geology*
A.B., Indiana University, 1956; A.M., 1957

Bruce Roger Doe, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.S., University of Minnesota, 1954; B.Geol.E., 1954; M.S., Missouri School of Mines, 1956

Richard Dolen, *Gerard Swope Fellow, Physics*
B.Eng.Phy., Cornell University, 1957

Norman David Dombey, *Graduate Teaching Assistant, E. N. Brown Scholar, Physics*
B.A., Magdalen College, Oxford, 1959

John Jacob Domingo, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1955

Stéphane Dopp, *Belgian-American Educational Foundation Fellow, Geology*
Lic. Sci., University of Louvain, 1958

William Franklin Dove, Jr., *National Science Foundation Fellow, Chemistry*
A.B., Amherst College, 1958

Joe Aguirre Duardo, *Graduate Teaching Assistant, Laws Scholar, Chemistry*
B.S., University of California at Los Angeles, 1959

Ian Morley Duck, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.Sc., Queen's University, 1955; M.Sc., University of British Columbia, 1956

Michael B. Duke, *John Stauffer Fellow, Geology*
B.S., California Institute, 1957; M.S., Pennsylvania State University, 1958

Harry Dym, *Graduate Research Assistant, Dobbins Scholar, Electrical Engineering*
B.E.E., The Cooper Union, 1959

Everett Truman Eiselen, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1956; M.S., 1957

Christian Albertus Engelbrecht, *Standard-Vacuum Oil Company (South Africa) Fellow, Graduate Teaching Assistant, Physics*
B.Sc., University of Pretoria, 1955

Victor Ado Erma, *National Science Foundation Co-operative Fellow, Graduate Teaching Assistant, Physics*
B.S., University of Texas, 1953; M.A., 1955

David Arthur Evensen, *Murray Scholar, Aeronautics*
B.S., Worcester Polytechnic Institute, 1959

Viktor Evtuhov, *Howard Hughes Fellow, Electrical Engineering*
B.S., University of California at Los Angeles, 1956; M.S., California Institute, 1957

Henry Thomas Falvey, *Graduate Teaching Assistant, Dobbins Scholar, Civil Engineering*
B.C.E., Georgia Institute of Technology, 1958

Norman Sam Farha, *Graduate Research Assistant, Institute Scholar, Geology*
B.S., University of Kansas, 1958

Grover Louis Farrar, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Randolph-Macon College, 1956

Guy-Emile Fayet, *French Ministry of Foreign Affairs Fellow, Geology*
Ing., Institut Français du Pétrole (Rueil-Malmaison), 1959

Louis Domenic Ferretti, *Institute Scholar, Chemistry*
B.A., University of Pennsylvania, 1957

Vittorio Fiorini, *Institute Scholar, Aeronautics*
Ing.Ind., University of Bologna, 1954; Ing.Ae., Polytechnic Institute of Turin, 1955

Thornton Roberts Fisher, *National Science Foundation Fellow, Physics*
B.A., Wesleyan University, 1958

Bernard Foran, *Graduate Research Assistant, Institute Scholar, Chemistry*
B.Sc. General, London University, 1951; B.Sc. Special, 1952

Ronald Alvin Forbess, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1959

James Lawrence Collier Ford, Jr., *Graduate Research Assistant, Institute Scholar, Physics*
B.A., Montana State University, 1955; M.S., California Institute, 1959

Donald Charles Forster, *Howard Hughes Fellow, Electrical Engineering*
B.S., University of Southern California, 1955; M.S., California Institute, 1957

Robert Paul Foss, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Northwestern University, 1958

James Norman Foster, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Occidental College, 1959

Michael Eugene Fourney, *Institute Scholar, Aeronautics*
B.S.A.E., West Virginia University, 1958; M.S., California Institute, 1959

Bevan Meredith French, *National Science Foundation Fellow, Geology*
A.B., Dartmouth College, 1958

Lyman Jefferson Fretwell, Jr., *National Science Foundation Fellow, Physics*
B.S., California Institute, 1956

Michael Fried, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.A., Hunter College, 1959

Charles Julius Fritchie, Jr., *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Tulane University, 1958

Robert Peter Frosch, *Woodrow Wilson Foundation Fellow, Chemistry*
B.S., Union College, 1959

John Keith Frye, *Graduate Research Assistant, Institute Scholar, Geology*
A.B., Oberlin College, 1957; M.S., University of Minnesota, 1959

Teruo Fujihara, *Rockefeller Foundation Fellow, Civil Engineering*
Master of Agriculture, Kyushu University, 1953

George Donald Garlick, *Graduate Teaching Assistant, Drake Scholar, Geology*
B.Sc., University of Witwatersrand, 1956

Donald Charles Garwood, *National Science Foundation Fellow, Chemistry*
B.A., Kalamazoo College, 1957

James Joseph Geiger, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., Purdue University, 1959

Alain Nestor Genko, *French Foreign Ministry Fellow, Electrical Engineering*
Ing., Ecole Supérieure d'Electricité (Paris), 1959

Edward George Gibson, *National Science Foundation Fellow, Mechanical Engineering*
B.S., University of Rochester, 1959

Victor Gilinsky, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.E.Ph., Cornell University, 1956

Concetto Richard Giuliano, *National Science Foundation Fellow, Chemistry*
B.S., University of Southern California, 1957

Herbert Seymour Glick, *Institute Scholar, Aeronautics*
B.E.Ph., Cornell University, 1951; M.Ae.E., 1953

Stuart Goff, *Graduate Teaching Assistant, Electrical Engineering*
B.S., California Institute, 1958; M.S., 1959

Harris Gold, *Del Mar Science Foundation Fellow, Institute Scholar, Aeronautics*
B.M.E., Polytechnic Institute of Brooklyn, 1958; M.S.M.E., Columbia University, 1959

Richard Morris Goldstein, *Francis J. Cole Fellow, Electrical Engineering*
B.S., Purdue University, 1947; M.S., California Institute, 1959

Robert Goldstein, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Mechanical Engineering*
B.S., Columbia University, 1959

Jacek Piotr Gorecki, *National Research Council of Brazil Fellow, Aeronautics*
Dipl. Ing., Ecole Centrale des Arts et Manufactures (Paris), 1940

Egbert Graeve, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
Dip.Ing., Technische Hochschule Aachen, 1955

James Alexander Grant, *Graduate Teaching Assistant, Bennett Scholar, Geology*
B.Sc. (Hons.), Aberdeen University, 1957; M.A., Queen's University (Ontario), 1959

Louise Ethel Gray, *Amelia Earhart Fellow, Engineering Science*
B.S., University of California at Los Angeles, 1957; M.S., 1959

L. Dale Green, *Graduate Teaching Assistant, Roeser Scholar, Electrical Engineering*
B.S., California Institute, 1959

R. Clive Greenough, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
S.B., Massachusetts Institute of Technology, 1953

Howard Burt Greenstein, *Institute Scholar, Physics*
Sc.B., Brown University, 1956

David Eiben Groce, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute of Technology, 1958

Donald Eugene Groom, *National Science Foundation Fellow, Physics*
A.B., Princeton University, 1956

Meredith Grant Gross, Jr., *National Science Foundation Fellow, Geology*
A.B., Princeton University, 1954; M.S., California Institute, 1959

George Drake Guthrie, *U.S. Public Health Service Fellow, Biology*
A.B., Wabash College, 1954

Andrew Guttman, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., College of the City of New York, 1957; M.S., California Institute, 1958

Gerhard Ernest Hahne, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., California Institute, 1956

David Warren Hall, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of Arizona, 1957

Charles Robert Hamilton, *U.S. Public Health Service Fellow, Biology*
B.S., University of the South, 1957

Boyd Archer Hardesty, *U.S. Public Health Service Fellow, Biology*
B.S., State College of Washington; 1953; M.S., 1956

Peter Edgar Hare, *Graduate Research Assistant, Institute Scholar, Geology*
B.S., Pacific Union College, 1954; M.S., University of California, 1955

David Garrison Harkrider, *Sidney Schafer Fellow, Institute Scholar, Geology*
B.S., The Rice Institute, 1953; M.A., 1957

Daniel Everett Harris, *Graduate Research Assistant, Institute Scholar, Astronomy*
B.A., Haverford College, 1956; M.S., California Institute, 1957

Kenneth Edwin Harwell, *Tau Beta Pi Fellow, Dobbins Scholar, Aeronautics*
B.S., University of Alabama, 1958

G. Laurie Hatch, *General Electric Company Fellow, Physics*
B.S., Tufts University, 1959

James Fred Hays, *National Science Foundation Fellow, Geology*
A.B., Columbia College, 1954

John Helding Healy, *Graduate Research Assistant, Institute Scholar, Geology*
S.B., Massachusetts Institute of Technology, 1951; M.S., California Institute, 1957

John Eugene Hearst, *National Science Foundation Fellow, Chemistry*
B.E., Yale University, 1957

Robert Lambdin Heath, *Graduate Teaching Assistant, Institute Scholar, Biology*
S.B., Massachusetts Institute of Technology, 1956; S.M., 1958

Robert Joseph Hecht, *Graduate Research Assistant, Laws Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1958

Richard Lee Held, *National Defense Education Act Fellow, Mathematics*
B.S., University of Wisconsin, 1959

Thomas McCalfree Helliwell, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.A., Pomona College, 1958

William Phillip Helman, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., California Institute, 1958

Robert Henry Hertel, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
S.B., Massachusetts Institute of Technology, 1958; M.S., California Institute, 1959

Robert Hickling, *Graduate Teaching Assistant, Institute Scholar, Engineering Science*
M.A., University of St. Andrews, 1954; M.Sc., University of London, 1957

E. Alexander Hill, III, *National Science Foundation Fellow, Chemistry*
B.S., Allegheny College, 1957

Henry Hoyt Hilton, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Yale University, 1952; M.S., 1952

Noel William Hinners, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.Sc., Rutgers University, 1958

Charles Ray Hobby, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.S., University of California, 1951; M.S., University of Houston, 1957

William David Hobey, *Du Pont Postgraduate Teaching Assistant, Chemistry*
B.S., Tufts University, 1957

John Leonard Honsaker, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1955

David Parks Hoult, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
S.B., Massachusetts Institute of Technology, 1957; M.S., California Institute, 1958

Merlin Evelyn Harry Howden, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.Sc. (Hons.), University of Sydney, 1958

James Secord Howland, *Woodrow Wilson Foundation Fellow, Physics*
B.S., University of Florida, 1959

Din-Yu Hsieh, *International Nickel Company, Inc. Fellow, Engineering Science*
B.Sc., National Taiwan University, 1954; M.Sc., Brown University, 1957

Elisha Rhodes Huggins, *Graduate Teaching Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1955

Gordon Frierson Hughes, *Douglas Research Fellow, Graduate Research Assistant, Electrical Engineering*
B.S., California Institute, 1959

Glen Owen Hultgren, *National Science Foundation Fellow, Chemistry*
B.S., University of California, 1958

Arthur James Hundhausen, *National Science Foundation Fellow, Physics*
B.S., University of Wisconsin, 1958

Richard O'Neil Hundley, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1957; M.S., 1959

Thomas Kintzing Hunt, *National Science Foundation Fellow, Physics*
B.A., Pomona College, 1959

Herbert Erwin Hunter, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., University of Maryland, 1956; M.S., California Institute, 1957

William Norris Huse, Jr., *Institute Scholar, Electrical Engineering*
B.S., California Institute, 1959

William Day Hutchinson, *Paul E. Lloyd Fellow, Chemistry*
B.S., Morehouse College, 1955; M.S., California Institute, 1957

Albert Hybl, *Shell Companies Foundation Fellow, Chemistry*
B.A., Coe College, 1954

Carl Kenneth Iddings, *Graduate Research Assistant, Institute Scholar, Physics*
B.A., Harvard College, 1955

Izzat Muhammad Idriss, *Clarence Hicks Memorial Fellow, Civil Engineering*
B.C.E., Rensselaer Polytechnic Institute, 1958; M.S., California Institute, 1959

James Brown Ifft, *U.S. Public Health Service Fellow, Chemistry*
B.S., Pennsylvania State University, 1957

Marcos Intaglietta, *Graduate Research Assistant, Institute Scholar, Mechanical Engineering*
B.S., University of California, 1957; M.S., California Institute, 1958

Wilfred Dean Iwan, *Bendix Aviation Corporation Fellow, Mechanical Engineering*
B.S., California Institute, 1957; M.S., 1958

Earl Donald Jacobs, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1953; M.S., 1954

Theodore Alan Jacobs, *Institute Scholar, Engineering Science*
A.B., Emory University, 1950; M.S., University of Southern California, 1954

Alexander Donald Jacobson, *Howard Hughes Staff Doctoral Fellow, Electrical Engineering*
B.S., University of California at Los Angeles, 1955; M.S., 1958

Leslie Sari Jacobson, *Institute Scholar, Biology*
B.S., Brooklyn College, 1954; M.A., 1955

Andrew Honoré Jazwinski, *Graduate Teaching Assistant, Murray Scholar, Geology*
B.S., The Pennsylvania State University, 1959

Paul Christian Jennings, *John Stauffer Fellow, Civil Engineering*
B.S., Colorado State University, 1959

Pierre Eugène Cyprien Joffres, *French Ministry of Foreign Affairs Fellow, Graduate Teaching Assistant, Mechanical Engineering*
Dipl., Ecole Centrale des Arts et Manufactures (Paris), 1958; Dipl., Ecole Nationale Supérieure du Pétrole et des Moteurs (Rueil), 1959

Charles Richard Johnson, *Graduate Teaching Assistant, T. S. Brown Scholar, Mechanical Engineering*
B.S., California Institute, 1959

Dean Martin Johnson, *National Science Foundation Fellow, Geology*
B.S.G., College of Puget Sound, 1959

Richard Alvin Johnson, *Graduate Teaching Assistant, Institute Scholar, Civil Engineering*
B.S., California Institute, 1956

Walter Adrian Johnson, *National Science Foundation Fellow, Aeronautics*
B.S., California Institute, 1959

Noel Duane Jones, *National Science Foundation Fellow, Chemistry*
B.S., Rensselaer Polytechnic Institute, 1959

Orval Elmer Jones, *National Science Foundation Fellow, Mechanical Engineering*
B.S., Colorado State University, 1956; M.S., California Institute, 1957

Willard Otis Keightley, *National Science Foundation Faculty Fellow, Civil Engineering*
B.S., Wayne State University, 1951; M.S., 1956

Glenn Lloyd Keldsen, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Antioch College, 1958

Kenneth Irwin Kellermann, *Graduate Research Assistant, E. N. Brown Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1959

John Fisher Kennedy, *Corning Glass Works Foundation Fellow, Civil Engineering*
B.S., University of Notre Dame, 1955; M.S., California Institute, 1956

Philip Ray Kennicott, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of Utah, 1953

James Wesley Kessel, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of Michigan, 1958

Jirair Levon Kevorkian, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.A.E., Georgia Institute of Technology, 1955; M.A.E., 1956

Leon Frank Keyser, *National Science Foundation Fellow, Chemistry*
B.S., University of Notre Dame, 1959

Vladimir Khvostchinsky, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*
Dipl. Ing., University of Lausanne, 1954

Edgar Francis Kiefer, *National Science Foundation Fellow, Chemistry*
B.S., Stanford University, 1957

Joseph Roland Kilner, *National Science Foundation Co-operative Fellow, Graduate Teaching Assistant, Physics*
B.S., Case Institute of Technology, 1957

Donald Menford King, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B..S., State College of Washington, 1957

Kenneth Robert King, *Shell Companies Foundation Fellow, Mechanical Engineering*
B.S., California Institute, 1953; M.S., 1954

Morton Hilliard Kirsh, *National Institute of Infantile Paralysis Fellow, Biology*
A.B., Washington University, 1954; M.D., 1958

William Klement, Jr., *Graduate Research Assistant, Blacker Scholar, Engineering Science*
B.S., California Institute, 1958

William John Klenk, *Firestone Tire and Rubber Company Fellow, Electrical Engineering*
B.S.S., University of Dayton, 1957; M.S., California Institute, 1958

Gerhard Joachim Klose, *Graduate Teaching Assistant, Dobbins Scholar, Mechanical Engineering*
B.S., California Institute, 1959

Karl Kent Knapp, *Graduate Teaching Assistant, Mechanical Engineering*
B.S., California Institute, 1959

Wolfgang Gustav Knauss, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., California Institute, 1958; M.S., 1959

William Wei-Lin Ko, *Institute Scholar, Aeronautics*
B.S., National Taiwan University, 1950; M.S., California Institute, 1959

Thomas Richard Koehler, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Seattle University, 1954

Murray Arnold Koerner, *Graduate Teaching Assistant, Electrical Engineering*
B.S., California Institute, 1959

Joseph Kohler, *Graduate Teaching Assistant, Laws Scholar, Mathematics*
B.Sc., Ohio State University, 1957

Robert Louis Kovach, *Graduate Research Assistant, Dobbins Scholar, Geology*
Gp. Engr., Colorado School of Mines, 1955; M.A., Columbia University, 1959

William Kozicki, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*
B.A.Sc., University of Toronto, 1953; M.A.Sc., 1957

Gordon Kramer, *Howard Hughes Fellow, Engineering Science*
B.M.E., The Cooper Union, 1959

Stanley Garson Krane, *Graduate Teaching Assistant, Institute Scholar, Biochemistry*
B.S., City College of New York, 1957; M.S., Michigan State University, 1958

Daniel Julius Krause, *National Science Foundation Co-operative Fellow, Mechanical Engineering*
B.Met.E., The Ohio State University, 1958; M.S., California Institute, 1959

Harvey N. Kreisberg, *Graduate Teaching Assistant, Drake Scholar, Mechanical Engineering*
B.M.E., Rensselaer Polytechnic Institute, 1958; M.M.E., 1959

Joel Ivan Krugler, *Cooper Union Fellow, Laws Scholar, Physics*
B.E.E., The Cooper Union, 1959

Alvin Lloyd Kwiram, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Walla Walla College, 1958

Joel Kwok, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of California, 1959

Jean-Bernard Lagarde, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*
Dipl. Ing., Ecole Nationale d'Ingénieurs Arts et Métiers (Paris), 1959

William George Laidlaw, *Woodrow Wilson Foundation Fellow, Chemistry*
B.S., University of Western Ontario, 1959

Theodore Edmund Lang, *Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1957; M.S., 1958

Marvin Alder Lanphere, *National Science Foundation Fellow, Geology*
B.S., Montana School of Mines, 1955; M.S., California Institute, 1956

Marshall Lapp, *Institute Scholar, Engineering Science*
B.Eng.Ph., Cornell University, 1955

Jimmy Carl Larsen, *National Science Foundation Fellow, Geology*
B.S., University of California at Riverside, 1958

James Daniel Larson, *Graduate Research Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1957; M.S., California Institute, 1959

Raymond Walter Latham, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B. Eng., McGill University, 1958; M.S., California Institute, 1959

Kaye Don Lathrop, *Atomic Energy Commission Fellow, Mechanical Engineering*
B.S., United States Military Academy, 1955; M.S., California Institute, 1959

George Melvin Lawrence, *National Science Foundation Fellow, Physics*
B.S., University of Utah, 1959

Andrew Scott Lebor, *National Science Foundation Fellow, Physics*
B.S., University of Cincinnati, 1956

Peter Anthony Leermakers, *National Science Foundation Fellow, Chemistry*
B.A., Wesleyan University, 1958

Robert Cary Leif, *National Science Foundation Fellow, Chemistry*
B.S., University of Chicago, 1959

Arnold Vincent Lesikar, *National Science Foundation Fellow, Physics*
B.A., The Rice Institute, 1958

Milton Irwin Levenberg, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Illinois Institute of Technology, 1958

Michael Jerry Levine, *National Science Foundation Fellow, Physics*
B.S., University of Illinois, 1958

Paul Hersh Levine, *Graduate Teaching Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1956; M.S., California Institute, 1957

Nelson Liberman, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.A., University of Buffalo, 1954; M.A., 1957

Alfred George Lieberman, *Consolidated Electrodynamics Fellow, Electrical Engineering*
B.S., Polytechnic Institute of Brooklyn, 1958; M.S., California Institute, 1959

Gerald Richard Liebling, *National Science Foundation Fellow, Chemistry*
B.S., Polytechnic Institute of Brooklyn, 1959

Hans-Dieter Linhardt, *Institute Scholar, Mechanical Engineering*
Dipl. Ing., Technische-Hochschule (Munich), 1955

John Kailin Link, *National Science Foundation Fellow, Physics*
B.S., Antioch College, 1959

Chung-Yen Liu, *Institute Scholar, Aeronautics*
B.S., Taiwan College of Engineering, 1955; M.S., Brown University, 1958

James Reily Lloyd, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1956; M.S., 1957

Malcolm Harvey Lock, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
Higher Natl. Cert., Hatfield Technical College (England), 1954

Dennis Vernon Long, *Ford Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Civil Engineering*
B.S., California Institute, 1949; M.S., 1955

Richard Frederick Long, *Clarence Hicks Memorial Fellow, Mechanical Engineering*
B.S., California Institute, 1959

Henry Lu-Meng, *Graduate Teaching Assistant, Dobbins Scholar, Mechanical Engineering*
B.S.M.E., Purdue University, 1958

Huey Lin Luo, *C. T. Loo Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Engineering Science*
B.S., National Taiwan University, 1956; M.S., Iowa State College, 1959

Robert Lee Luttermoser, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Michigan, 1948; M.S., 1950

Raymond Paul Lutz, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of Florida, 1953; M.S., 1955

Yen-Mow Lynn, *Institute Scholar, Aeronautics*
B.S., National Taiwan University, 1956; M.S., California Institute, 1957

Robert James Macek, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., South Dakota State College, 1958

Dean MacGillivray, *Institute Scholar, Aeronautics*
B.A.Sc., University of British Columbia, 1955; M.A.Sc., 1956; M.S., California Institute, 1957

Gordon Frank MacGinitie, *General Electric Foundation Fellow, Electrical Engineering*
B.S., Stanford University, 1957; M.S., 1959

Donald MacMurray Malone, *Graduate Teaching Assistant, Drake Scholar, Electrical Engineering*
B.E.E., Cornell University, 1959

John Owen Maloy, *International Business Machines Fellow, Physics*
B.S., University of Arizona, 1954

Murli Hukumal Manghnani, *Institute Scholar, Geology*
B.Sc., Bihar University, 1957; M.Sc., 1958; M.S., Montana State University, 1959

Jean François Marin, *Graduate Research Assistant, Institute Scholar, Mechanical Engineering*
Ing. Civ., Ecole Nationale Supérieur des Mines (Paris), 1957; M.S., California Institute, 1958

Gary Lynn Marlotte, *Douglas Aircraft Fellow, Aeronautics*
B.S.A.E., Purdue University, 1958; M.S., California Institute, 1959

J. Howard Marshall, III, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1957

Gerald Albert Marxman, *Space Technology Laboratories Fellow, Mechanical Engineering*
B.A., Case Institute of Technology, 1956

William Brewster Mather, Jr., *National Science Foundation Fellow, Chemistry*
A.B., Princeton University, 1957

Richard LeRoy Mauger, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.S., Franklin and Marshall College, 1958

Sann Maung, *Burmese Government Scholar, Geology*
B.Sc., University of Rangoon, 1958

Dennis Robert McCalla, *National Research Council of Canada Fellow, Institute Scholar, Biology*
B.Sc., University of Alberta, 1957; M.Sc., University of Saskatchewan, 1958

Malcolm McColl, *Firestone Tire and Rubber Company Fellow, Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.S., Wayne State University, 1957; M.S., California Institute, 1958

James Arthur McCray, *Graduate Research Assistant, Institute Scholar, Physics*
A.B., Millikin University, 1954; M.S., Agricultural and Mechanical College of Texas, 1955

William True McDonald, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1957; M.S., 1958

Edward Rae Held McDowell, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*
B.Chem.E., Cornell University, 1955

Francis Clay McMichael, *Graduate Research Assistant, Institute Scholar, Civil Engineering*
B.S., Lehigh University, 1958; M.S., California Institute, 1959

James Henry McNally, *Woodrow Wilson Foundation Fellow, Physics*
B.Eng.Phys., Cornell University, 1959

Chiang-Chung Mei, *Institute Scholar, Aeronautics*
B.S.C.E., National Taiwan University, 1955; M.S., Stanford University, 1958

Karl Louis Meier, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Mechanical Engineering*
B.S., Washington University, 1959

Martin Mendelson, *U.S. Public Health Service Fellow, Biology*
A.B., Cornell University, 1958

John Robert Menninger, *National Science Foundation Fellow, Biology*
A.B., Harvard College, 1957

Howard Carl Merchant, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., University of Washington, 1956; S.M., Massachusetts Institute of Technology, 1957

Arthur William Merkl, *National Science Foundation Fellow, Chemistry*
B.S., University of Cincinnati, 1958

John Jay Merrill, *Howard Hughes Fellow, Physics*
B.S., California Institute, 1955; M.S., 1956

Roger Edwin Messick, *Graduate Teaching Assistant, Institute Scholar, Engineering Science*
B.S., University of Illinois, 1951; M.S., 1952

Jean Maurice César Meuris, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
C.E., University of Brussels, 1957

F. Curtis Michel, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., California Institute, 1955

James Eardley Midgley, *National Science Foundation Fellow, Physics*
B.S.E., University of Michigan, 1956

Dimitri Manuel Mihalas, *National Science Foundation Fellow, Astronomy*
A.B., University of California at Los Angeles, 1959

Ralph Fraley Miles, Jr., *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1955

Hugh Thompson Millard, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Coe College, 1957

Robert Loomis Millette, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.S., Oregon State College, 1954; M.S., 1959

Catalin Dan Mitescu, *Standard Oil Fellow, Physics*
B. Eng., McGill University, 1958

Walter Mitronovas, *National Science Foundation Fellow, Geology*
B.S., Pennsylvania State University, 1959

Kenneth Martin Mitzner, *Howard Hughes Fellow, Electrical Engineering*
S.B., Massachusetts Institute of Technology, 1958; M.S., California Institute, 1959

Maurice Mizrahi, *Graduate Teaching Assistant, Aeronautics*
Dipl. Ing., Ecole Nationale Supérieure de l'Aeronautique (Paris), 1959

Alan Theodore Moffet, *National Science Foundation Fellow, Physics*
B.A., Wesleyan University, 1957

Norton Leonard Moise, *United States Steel Foundation Fellow, Physics*
B.S., University of Illinois, 1948; M.A., University of California at Los Angeles, 1954; M.S., California Institute, 1959

Charles Gray Montgomery, *National Science Foundation Fellow, Physics*
B.A., Yale University, 1959

Lawrence Kernan Montgomery, *General Electric Educational and Charitable Fund Fellow, Chemistry*
B.S., Colorado State University, 1957

Fernando Bernardo Morinigo, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., University of Southern California, 1957

Durward James Frederick Morré, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.S., University of Missouri, 1957; M.S., Purdue University, 1958

Robert George Mortimer, *National Science Foundation Fellow, Chemistry*
B.S., Utah State University, 1958; M.S., 1959

Francis Guy Moses, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., University of Delaware, 1958

Arthur H. Muir, Jr., *Graduate Research Assistant, Institute Scholar, Physics*
A.B., Williams College, 1953; M.S., California Institute, 1955

Richard Stephen Muller, *National Science Foundation Fellow, Electrical Engineering*
M.E., Stevens Institute of Technology, 1955; M.S., California Institute, 1957

Roddam Narasimha, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.E., University of Mysore, 1953; D.I.I.Sc.(Ae), Indian Institute of Science, 1955

Charl François Naudé, *South African Council for Scientific and Industrial Research Fellow, Francis J. Cole Fellow, Mechanical Engineering*
B.S., University of Stellerbosch, 1955; M.S., California Institute, 1957

Eugene Byrd Nebeker, *Graduate Teaching Assistant, Murray Scholar, Chemical Engineering*
B.S., Stanford University, 1959

Gerry Neugebauer, *Institute Scholar, Physics*
B.A., Cornell University, 1954

Robert Canute Neuman, Jr., *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of California at Los Angeles, 1959

John Carl Nickel, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.A., University of California at Riverside, 1958

Peter David Noerdlinger, *Howard Hughes Fellow, Physics*
A.B., Harvard College, 1956

Thomas Wyatt Noonan, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., California Institute, 1955

Martin Emery Nordberg, Jr., *General Electric Educational and Charitable Fund Fellow, Physics*
B.S., University of Rochester, 1957; M.S., California Institute, 1959

John Eric Nordlander, *National Science Foundation Fellow, Chemistry*
B.A., Cornell University, 1956

Robert Henry Norton, Jr., *Institute Scholar, Astronomy*
B.S., California Institute, 1957; M.S., 1958

Harris Anthony Notarys, *Graduate Research Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1954

Robert Wilson Noyes, *Graduate Research Assistant, Institute Scholar, Physics*
B.A., Haverford College, 1957

Heiko Herbert Ohlenbusch, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Columbia University, 1959

Michael Edmond James O'Kelly, *Graduate Research Assistant, Institute Scholar, Mechanical Engineering*
B.E., National University of Ireland (Cork), 1958

Daniel Burrhus Olfe, *National Science Foundation Co-operative Fellow, Engineering Science*
B.S.E., Princeton University, 1957

Carole Lois Olson, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Colorado State University, 1958

Edwin Soland Olson, *National Science Foundation Fellow, Chemistry*
B.A., St. Olaf College, 1959

Patrick Gerard O'Regan, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.E., University College (Cork), 1957; M.S., California Institute, 1959

Jack Castle Overley, *Graduate Research Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1954

Manuel Panar, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.Sc. (Hons.), University of Alberta, 1957

Peter Donald MacDougall Parker, *Graduate Teaching Assistant, Danforth Scholar, Physics*
B.A., Amherst College, 1958

Robert Allan Ridley Parker, *Graduate Teaching Assistant, Danforth Scholar, Astronomy*
B.A., Amherst College, 1958

Robert Reid Parmerter, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., California Institute, 1958; M.S., 1959

John Davie Pearson, *Graduate Research Assistant, Institute Scholar, Physics*
B.Sc., Brown University, 1956

Charles William Peck, *National Science Foundation Fellow, Physics*
B.S., New Mexico Agricultural and Mechanical College, 1956

William Thomas Peters, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.S.E.E., Duke University, 1959

Edward Richard Petersen, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.Sc., University of Alberta, 1959

James Macon Peterson, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Wake Forest College, 1958

James Sibley Petty, *Institute Scholar, Aeronautics*
B.S., California Institute, 1959

Robert Alden Phinney, *National Science Foundation Fellow, Geology*
S.B., Massachusetts Institute of Technology, 1959; S.M., 1959

Lewis Stephen Pilcher, *Howard Hughes Fellow, Physics*
B.A., Middlebury College, 1955; S.B., Massachusetts Institute of Technology, 1955

Alfred Cyril Pinchak, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S.E.E., Case Institute of Technology, 1957; M.S.E., Purdue University, 1959

Elliot Neil Pinson, *Space Technology Laboratories Fellow, Electrical Engineering*
B.S.E., Princeton University, 1956; S.M., Massachusetts Institute of Technology, 1957

Raymond Pittman, Jr., *Graduate Teaching Assistant, Institute Scholar, Civil Engineering*
B.S., University of Illinois, 1959

Philip Moss Platzman, *Howard Hughes Fellow, Physics*
S.B., Massachusetts Institute of Technology, 1956; M.S., California Institute, 1957

Gerald Leslie Pollack, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Brooklyn College, 1954; M.S., California Institute, 1957

Gerald Douglas Pollock, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.Sc., University of Manitoba, 1955; M.Sc., 1958

R. Darden Powers, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Oklahoma, 1955; M.S., California Institute, 1957

Andrew Peter Proudian, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., Fresno State College, 1958

Bimalendu Raychaudhuri, *West Bengal Government Fellow, Geology*
B.Sc., Presidency College (Calcutta), 1948; M.Sc., 1951; M.S., California Institute, 1955

Richard Bradley Read, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1957

Bernard Charles Reardon, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.E., University College (Cork), 1957; M.S., California Institute, 1959

David Francis Rearick, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.S., University of Florida, 1950; M.S., Adelphi College, 1956

Roy Earl Reichenbach, *Institute Scholar, Mechanical Engineering*
B.M.E., The Ohio State University, 1956; M.S., 1956

James Howard Renken, *Howard Hughes Fellow, Physics*
B.S., The Ohio State University, 1957; M.S., 1958

Eli Reshotko, *Institute Scholar, Aeronautics*
B.M.E., The Cooper Union, 1950; M.M.E., Cornell University, 1951

Max Cotner Richardson, *Socony Mobil Fellow, Chemical Engineering*
B.S., University of Missouri, 1956

Ira Richer, *Charles Le Geyt Fortescue Fellow, Institute Scholar, Electrical Engineering*
B.E.E., Rensselaer Polytechnic Institute, 1959

David John Roddy, *Graduate Teaching Assistant, Institute Scholar, Geology*
A.B., Miami University, 1955; M.S., 1957

John David Rogers, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1956; M.S., 1958

Ronald Efrom Rolfe, *U.S. Public Health Service Fellow, Chemistry*
M.D., Stanford University School of Medicine, 1956

Ann Roller, *U.S. Public Health Service Fellow, Biology*
B.A., Sarah Lawrence College, 1952; M.S., Georgetown University, 1957

Robert Leopold Rosenfeld, *Garrett Corporation Fellow, Mechanical Engineering*
S.B., Massachusetts Institute of Technology, 1959

Nikhilesh Roy, *International Co-operation Administration Fellow, Civil Engineering*
B.E., Calcutta University, 1949; M.S., California Institute, 1952

Henry Ruderman, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Rensselaer Polytechnic Institute, 1956

Howard Calvin Rumsey, Jr., *National Science Foundation Co-operative Fellow, Mathematics*
B.S., California Institute, 1957; M.S., 1958

Charles Dyer Russell, *National Science Foundation Fellow, Chemistry*
S.B., Massachusetts Institute of Technology, 1957

David Allison Russell, *Institute Scholar, Aeronautics*
B.Eng., University of Southern California, 1956; M.S., California Institute, 1957

Robert Dean Ryan, *National Science Foundation Co-operative Fellow, Graduate Teaching Assistant, Mathematics*
B.S., California Institute, 1954

Roy Ryosuke Sakaida, *Union Carbide Corporation Fellow, Chemical Engineering*
B.S., University of California at Los Angeles, 1953; M.S., California Institute, 1957

Robert Vartan Samuelian, *Howard Hughes Fellow, Electrical Engineering*
B.E.E., Pratt Institute, 1959

Stephen George Sawochka, *John Stauffer Fellow, Chemical Engineering*
B.S., Purdue University, 1959

Richard Allan Schapery, *Rand Coporation Fellow, Aeronautical Engineering*
B.S., Wayne State University, 1957; M.S., California Institute, 1958

William George Scheerer, *Graduate Teaching Assistant, Drake Scholar, Electrical Engineering*
B.E.E., Syracuse University, 1959

David Lawrence Schleicher, *Graduate Teaching Assistant, Dobbins Scholar, Geology*
B.S., The Pennsylvania State University, 1959

Bertrand Alva Schoomer, Jr., *Graduate Research Assistant, Institute Scholar, Chemistry*
B.S., Louisiana Polytechnic Institute, 1955

David Israel Schuster, *National Science Foundation Fellow, Chemistry*
B.A., Columbia College, 1956

John Joseph Schuster, *Graduate Research Assistant, Murray Scholar Electrical Engineering*
B.S., California Institute, 1959

Henry Philip Schwarcz, *Institute Scholar, Geology*
B.A., University of Chicago, 1952; M.S., California Institute, 1955

Richard Anthony Scott, *Graduate Teaching Assistant, Institute Scholar, Engineering Science*
B.Sc., University College (Cork), 1957; M.Sc., 1959

Philip Arthur Seeger, *Graduate Research Assistant, Institute Scholar, Physics*
B.A., The Rice Institute, 1958

George Andrew Seielstad, *National Science Foundation Fellow, Physics*
A.B., Dartmouth College, 1959

George August Sellers, *Woodrow Wilson Foundation Fellow, Geology*
B.S., The Pennsylvania State University, 1959

Edwin Charles Seltzer, *National Science Foundation Co-operative Fellow, Physics*
B.S., California Institute, 1959

Lionel Sydney Senhouse, Jr., *Howard Hughes Staff Doctoral Fellow, Physics*
B.M.E., College of the City of New York, 1955; M.S., University of California at Los Angeles, 1957

Edward Joseph Seppi, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Brigham Young University, 1952; M.S., University of Idaho, 1956

Jason Gene Seubold, *Daniel and Florence Guggenheim Fellow, Aeronautics*
S.M., Massachusetts Institute of Technology, 1959

William Lewis Shackleford, *National Science Foundation Fellow, Mechanical Engineering*
B.E., Yale University, 1959

Robert Victor Sharp, *Graduate Research Assistant, Institute Scholar, Geology*
B.S., California Institute, 1956

Yun-Yuan Shi, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., National Taiwan University, 1955; M.Sc., Brown University, 1958

Fred Ichiro Shimabukuro, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
S.B., Massachusetts Institute of Technology, 1956; S.M., 1956

Jon Hardy Shirley, *Francis J. Cole Fellow, Physics*
A.B., Middlebury College, 1957

Donald Cecil Shreffler, *National Science Foundation Fellow, Biology*
B.S., University of Illinois, 1954; M.S., 1958

Alex Shumka, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.A.Sc., University of Toronto, 1957; M.S., California Institute, 1958

Warren Lee Simmons, *Link Foundation Fellow, Dobbins Scholar, Physics*
B.S., Syracuse University, 1959

George Warren Simon, *Howard Hughes Fellow, Physics*
A.B., Grinnell College, 1955

Peter Gerald Simpkins, *NATO Research Fellow, Aeronautics*
Dipl., Northampton College of Advanced Technology (England), 1957; Dipl., Training Centre for Experimental Aeronautics (Brussels), 1959

Dale Rodekohr Simpson, *Graduate Teaching Assistant, Institute Scholar, Geology*
B.S., Pennsylvania State University, 1956; M.S., California Institute, 1958

Richard Kanne Sloan, *Institute Scholar, Physics*
B.S., Pennsylvania State University, 1954; M.S., California Institute, 1956

Clayton Sutherland Smith, *Allied Chemical and Dye Corporation Fellow, Chemical Engineering*
B.S., Purdue University, 1958; M.S., California Institute, 1959

Stewart Wilson Smith, *Standard Oil Company of California Fellow, Geology*
S.B., Massachusettes Institute of Technology, 1954; M.S., California Institute, 1958

Frank Thomas Snively, *National Science Foundation Fellow, Physics*
B.S., Antioch College, 1959

Irving George Snyder, Jr., *National Science Foundation Fellow, Chemical Engineering*
B.E., Yale University, 1959

William Dean Squire, *Institute Scholar, Electrical Engineering*
B.S., California Institute, 1950

Richard Felt Squires, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.S., Michigan State University, 1958

Roy Thorwald Stake, *Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1957

Ronald Oran Stearman, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., Oklahoma Agricultural and Mechanical College, 1955; M.S., California Institute, 1956

Himan Sternlicht, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Columbia University, 1958

John Richard Stevens, *Graduate Research Assistant, Institute Scholar, Physics*
B.A., Pomona College, 1956; M.S., California Institute, 1959

Robert Farrell Stewart, *Graduate Research Assistant, Institute Scholar, Chemistry*
B.A., Carleton College, 1958

Jack Justin Stiffler, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.A., Harvard College, 1956; M.S., California Institute, 1957

Leonard Dewey Stimpson, Jr., *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
A.B., Whittier College, 1949; M.A., University of California, 1951; M.S., California Institute, 1957

Edwin Jule Stofel, *Gillette-Paper Mate Fellow, Mechanical Engineering*
B.S., California Institute, 1953; M.S., 1954

William Albert Steyert, Jr., *Graduate Research Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute, 1956

F. William Studier, *National Science Foundation Fellow, Biology*
B.S., Yale University, 1958

Henry John Stumpf, *Curtiss-Wright Fellow, Mechanical Engineering*
B.S., Newark College of Engineering, 1951; M.S., California Institute, 1957

Bradford Sturtevant, *Institute Scholar, Aeronautics*
B.E., Yale University, 1955; M.S., California Institute, 1956

Millard Susman, *U.S. Public Health Service Fellow, Biology*
A.B., Washington University, 1956

Salvatore Philip Sutera, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.M.E., The Johns Hopkins University, 1954; M.S., California Institute, 1955

Ivan Edward Sutherland, *National Science Foundation Fellow, Electrical Engineering*
B.Sc., Carnegie Institute of Technology, 1959

Donald Gary Swanson, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.Th., Northwest Christian College, 1958; B.S., University of Oregon, 1958

Byron Edwin Swartz, *Graduate Teaching Assistant, Murray Scholar, Electrical Engineering*
B.S., California Institute, 1959

Richard Michael Talman, *National Research Council of Canada Fellow, Institute Scholar, Physics*
B.A., University of Western Ontario, 1956; M.S., 1957

Ivo Tammaru, *Woodrow Wilson Foundation Fellow, Physics*
B.S., California Institute, 1959

Robert Hugh Taylor, *Institute Scholar, Civil Engineering*
B.A., Swarthmore College, 1949; B.S., University of Colorado, 1957; M.S., California Institute, 1958

Terry Olin Teigen, *Graduate Teaching Assistant, Dobbins Scholar, Electrical Engineering*
B.S., California Institute, 1959.

Terence Christopher Terman, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Stanford University, 1952; M.S., California Institute, 1955.

John Rhodes Thomas, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., California Institute, 1957

Don Dean Thompson, *Graduate Research Assistant, Institute Scholar, Chemistry*
B.A., University of California at Riverside, 1956

Robert Charles Thompson, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.A., University of British Columbia, 1954; M.A., 1956

Robert Clem Titsworth, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., New Mexico College of Agriculture and Mechanic Arts, 1957; M.S., California Institute, 1958

M. Nafi Toksoz, *Turkish Mineral Research and Development Institute Fellow, Graduate Teaching Assistant, Institute Scholar, Geology*
Geoph. Eng., Colorado School of Mines, 1958

Harry Warren Townes, *National Science Foundation Fellow, Mechanical Engineering*
B.S., Brown University, 1959

Colwyn Boyd Trevarthen, *Graduate Teaching Assistant, Institute Scholar, Biology*
B.Sc., University of New Zealand, 1952; M.Sc., 1954

Wai Keung Tso, *Graduate Teaching Assistant, Institute Scholar, Civil Engineering*
B.Sc.(Eng.), University of London, 1959

Richard Tunder, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Case Institute of Technology, 1957

Ben Robert Turner, *Institute Scholar, Physics*
B.S., State College of Washington, 1955

Harris Ellsworth Ulery, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*
B.A., Grinnell College, 1959

Charles William Van Atta, *Convair Fellow, Aeronautics*
B.S.E., University of Michigan, 1957; M.S.E., 1958

Paul Eugène Marie Vandenplas, *Institut Interuniversitaire des Sciences Nucléares Research Fellow, Engineering Science*
I.C.A., Ecole Royale Militare (Brussels), 1954; Lic.Sc.Phys., Université Libre (Brussels), 1958

Lorin Lee Vant-Hull, *Institute Scholar, Physics*
B.S., University of Minnesota, 1954; M.S., University of California at Los Angeles, 1956

Janis Vasilevskis, *Graduate Research Assistant, Institute Scholar, Chemistry*
B.S., University of California, 1958

Emilio Cesare Venezian, *Peter E. Fluor Memorial Fellow, Chemical Engineering*
B.Eng., McGill University, 1958; M.S., California Institute, 1959

Rinantonio Viani, *Graduate Research Assistant, Drake Scholar, Chemistry*
Dott.Chem., University of Pisa, 1958

George Charpentier Vlases, *National Science Foundation Fellow, Aeronautics*
B.S., The Johns Hopkins University, 1958; M.S., California Institute, 1959

Martin Vogel, *National Science Foundation Fellow, Chemistry*
B.S., California Institute, 1955

Joseph Louis Vogl, Jr., *Space Technology Laboratories Fellow, Physics*
A.B., Columbia College, 1957; M.S., California Institute, 1959

William Louis Waggoner, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*
B.S., California Institute, 1959

Mark Hoy Wagner, *Graduate Research Assistant, Institute Scholar, Physics*
A.B., Miami University, 1958

William Frederick Wagner, *National Science Foundation Fellow, Chemical Engineering*
Ch.E., University of Cincinnati, 1959

William Gerard Wagner, *National Science Foundation Co-operative Fellow, Graduate Teaching Assistant, Physics*
B.S., California Institue, 1958

Harold Paul Waits, *Graduate Teaching Assistant, Blacker Scholar, Chemistry*
B.S., University of Illinois, 1959

Frederick Andrew Wallace, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
A.B., Harvard College, 1958

Duen-pao Wang, *Graduate Teaching Assistant, Institute Scholar, Engineering Science*
B.S., National Taiwan University, 1956; M.S., Virginia Polytechnic Institute, 1958

Neng-Ming Wang, *Graduate Teaching Assistant, Institute Scholar, Engineering Science*
B.S., National Taiwan University, 1955; M.S., University of Texas, 1958

Yui-Loong Wang, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*
B.S., Taiwan College of Engineering, 1956; M.S., California Institute, 1958

James Harvey Waters, *Graduate Research Assistant, Institute Scholar, Chemistry*
S.B., Massachusetts Institute of Technology, 1953

John Watson, *National Science Foundation Fellow, Geology*
B.S., University of Oklahoma, 1954; M.S., 1959

Kenneth Watson, *Institute Scholar, Geology*
B.A., University of Toronto, 1957; M.S., California Institute, 1959

Ronald Watson, *National Science Foundation Faculty Fellow, Mechanical Engineering*
B.S.(M.E.), Illinois Institute of Technology, 1952; M.S., California Institute, 1953

Ned Conder Webb, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Vanderbilt University, 1959

Christian Claude Weber, *French Foreign Ministry Fellow, Drake Scholar, Geology*
Lic. ès Sciences, University of Paris, 1957; Doc.Ge., 1959

Paul Morris Weichsel, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.S., The City College of New York, 1953; M.S., New York University, 1954

Evan Otto Weiner, *Institute Scholar, Aeronautics*
B.S., California Institute, 1959

Robert Avrum Weisberg, *National Science Foundation Co-operative Fellow, Biology*
A.B., Harvard College, 1958

Donald Martin Wiberg, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1959

Robert Le Roy Wildey, *Graduate Research Assistant, Institute Scholar, Astronomy*
B.S., California Institute, 1957; M.S., 1958

Ronald Howard Willens, *Institute Scholar, Engineering Science*
B.S., California Institute, 1953; M.S., 1954

Douglas Warren Willett, *National Defense Education Act Fellow, Mathematics*
B.S., South Dakota School of Mines and Technology, 1959

John Harold Willmorth, *Howard Hughes Fellow, Electrical Engineering*
B.S.E., Princeton University, 1957; M.S.E.E., University of Washington, 1958

John Coe Wilson, *Kennecott Fellow, Géology*
B.S., California Institute, 1953; M.A., University of Kansas, 1955

Kenneth Geddes Wilson, *Institute Scholar, Physics*
A.B., Harvard College, 1956

Robert Woodrow Wilson, *National Science Foundation Fellow, Physics*
B.A., The Rice Institute, 1957

Jack Wireman, *Murray Scholar, Mechanical Engineering*
B.S.M.E., University of Kentucky, 1958

Thomas Henry Wirth, *Woodrow Wilson Foundation Fellow, Chemistry*
A.B., Cornell University, 1959

William Munger Woodruff, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.S., University of Michigan, 1958; M.S., 1958

Jain-Ming Wu, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., National Taiwan University, 1955; M.S., California Institute, 1959

Ying-Chu Lin Wu, *Amelia Earhart Fellow, Institute Scholar, Aeronautics*
B.E., National Taiwan University, 1955; M.S., Ohio State University, 1959

Daniel Lewis Wulff, *National Science Foundation Fellow, Chemistry*
B.S., California Institute, 1958

Tetsuo Yamane, *CAPES Fellow, Chemistry*
B.S., California Institute, 1956

Harold Thomas Yura, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1959

Robert Eugene Zartman, *National Science Foundation Fellow, Geology*
B.S., Pennsylvania State University, 1957; M.S., California Institute, 1959

Jonas Stasys Zmuidzinas, *Schlumberger Foundation Fellow, Electrical Engineering*
B.S., Indiana Technical College, 1958; M.S., California Institute, 1959

George Zweig, *Woodrow Wilson Foundation Fellow, Physics*
B.S., University of Michigan, 1959

CALIFORNIA INSTITUTE ASSOCIATES

The California Institute Associates are a group of public-spirited citizens, interested in the advancement of learning, who were incorporated in 1926 as a non-profit organization for the purpose of promoting the interests of the California Institute of Technology. Information concerning the terms and privileges of membership can be secured from the Secretary of the California Institute, Room 108 Throop Hall.

Officers

William Clayton
PRESIDENT

Seeley G. Mudd
VICE-PRESIDENT

W. Herbert Allen
VICE-PRESIDENT

Alexander King
SECRETARY

Ernest A. Bryant
TREASURER

Herbert H. G. Nash
ASSISTANT SECRETARY—ASSISTANT TREASURER

Directors

W. Herbert Allen
Gordon A. Alles
Lloyd L. Austin
Thomas Beyrle
Ernest A. Bryant
Frank R. Capra
William Clayton
Leon W. Delbridge
Jerome K. Doolan
E. T. Foley
John S. Griffith
Herbert B. Holt
Preston Hotchkis
Willard W. Keith
Dan A. Kimball
Alexander King
John R. Mage
Seeley G. Mudd
Stuart O'Melveny
Simon Ramo
Billings K. Ruddock

Advisory Committee

James R. Page, Chairman

John E. Barber
Lee A. DuBridge
A. B. Ruddock

Membership Committee

Stuart O'Melveny, Chairman
Leon W. Delbridge
John S. Griffith
John R. Mage

Fred S. Albertson
George W. H. Allen
W. Herbert Allen
Gordon A. Alles
Mrs. Gordon A. Alles
Lloyd L. Austin
John B. F. Bacon
William J. Bailey
Franklin Baldwin
Mrs. Franklin Baldwin
Mrs. Russell H. Ballard
F. M. Banks
Allyn H. Barber
John E. Barber
Harry J. Bauer
S. D. Bechtel
Garner A. Beckett
Arnold O. Beckman
Mrs. Arnold O. Beckman
Elmer Belt
Mrs. Russell Bennett
Mrs. William C. Beschorman
Thomas Beyrle
Miss Eleanor M. Bissell
Mrs. Fred H. Bixby
Mrs. E. J. Blacker
Mrs. Edward W. Bodman
Otis Booth
Victor von Borosini
Mrs. Rebecca F. Boughton
Mrs. Carl F. Braun
John G. Braun
James R. Brehm
Mrs. Lawrence B. Brooks
Ernest A. Bryant
William Norris Bucklin, Jr.
William H. Burgess
Carleton F. Burke
Richard J. Burke
T. S. Burnett
Mrs. R. R. Bush
Mrs. Robert W. Campbell
Frank R. Capra
Norman Chandler
Edward R. Chilcott
Mrs. Alfred B. Clark
Miss Lucy Mason Clark
William Clayton
Mrs. William Clayton
Arthur M. Clifford
Henry H. Clifford
Mrs. George I. Cochran
Fred H. Cole
John C. Cosgrove
Mrs. Hamilton H. Cotton
Mrs. Margaret R. Craig-McKerrow
Shannon Crandall
Shannon Crandall, Jr.
Lady William Charles Crocker
Homer D. Crotty
Richard Y. Dakin
Justin Dart
W. Thomas Davis
Mrs. Addison B. Day
Mrs. Mark Justin Dees
Leon W. Delbridge
Mrs. E. B. de Surville
Mrs. Donald R. Dickey
Jerome K. Doolan
Thornton G. Douglas
George W. Downs
Henry Dreyfuss
L. A. DuBridge
Mrs. Harry L. Dunn
E. E. Duque
Mrs. John H. Eagle
Lloyd R. Earl
Hubert Eaton
Mrs. Edith A. English
C. Pardee Erdman
Henry O. Eversole
Leonard K. Firestone
Mrs. John H. Fisher
Mrs. Herbert Fleishhacker
Mrs. Thomas Fleming
J. S. Fluor
Philip S. Fogg
E. T. Foley
Albert E. Foote
George E. Frazer
W. H. Freeman
Mrs. Robert N. Frick
John J. Garland
Gabriel M. Giannini
Robert L. Gifford
Harold S. Gladwin
Mrs. Harold S. Gladwin
Samuel Goldwyn

Mrs. Claude M. Griffeth
John S. Griffith
Gardner K. Grout, II
Herbert L. Hahn
Mrs. George E. Hale
Miss Evelyn Hamburger
Pierpont M. Hamilton
John W. Hancock
Arnold D. Haskell
Mrs. Arthur Hill
Cortlandt T. Hill
Mrs. Frank P. Hixon
Mrs. George Grant Hoag
Collis H. Holladay
Mrs. Webster B. Holmes
Herbert B. Holt
William S. Hook
Vaino A. Hoover
Preston Hotchkis
Mrs. Willard C. Jackson
Mrs. John E. Jardine
J. Stanley Johnson
Charles S. Jones
George F. Jones
W. Alton Jones
Earle M. Jorgensen
Willard W. Keith
William S. Kellogg
Mrs. James Kennedy
Clarence F. Kiech
Dan A. Kimball
Alexander King
Frank L. King
Th. R. Knudsen
Joseph B. Koepfli
Mrs. William Lacy
Oscar Lawler
Fred B. Lewis
Mrs. Howard B. Lewis
T. Allen Lombard
Alfred Lee Loomis
Mrs. James B. Luckie
Charles Luckman
Leonard S. Lyon
Mrs. Douglas A. Macmillan
Mrs. James E. MacMurray
H. Kirke Macomber
John R. Mage
Fred S. Markham
Murray S. Marvin
Tom May
Mrs. Manfred Meyberg
Mrs. Ben R. Meyer
Louis Meyer, Jr.
Bruce H. Mills
Robert L. Minckler
George A. Mitchell
Louis T. Monson
Mrs. Cox Morrill
Lindley C. Morton
R. H. Moulton
Seeley G. Mudd
Seeley W. Mudd, II
William C. Mullendore
Mrs. William B. Munro
John S. Murray
Elvon Musick
Mrs. Arthur McCallum
John A. McCone
William C. McDuffie
Milbank McFie
J. Wallace McKenzie
John R. McMillan
Mrs. Malcolm McNaghten
Mrs. John McWilliams
William F. Nash, Jr.
Robert V. New
Mrs. James G. Newcomb
Harlan J. Nissen
K. T. Norris
Mrs. Henry W. O'Melveny
John O'Melveny
Stuart O'Melveny
Mrs. Benjamin E. Page
James R. Page
Mrs. James R. Page
Mrs. I. Graham Pattinson
Ralph E. Phillips
Mrs. June Braun Pike
Mrs. Clarence B. Piper
Mrs. William M. Prindle
Mrs. Charles H. Prisk
W. F. Prisk
Simon Ramo
Burton C. Rawlins
Richard S. Rheem
Mrs. Alden G. Roach
Harold Roach
Mrs. Harry W. Robinson
Mrs. Frederick Roeser
Albert B. Ruddock
Mrs. Albert B. Ruddock

Billings K. Ruddock
Merritt K. Ruddock
Robert O. Schad
Mrs. Howard J. Schoder
Mrs. Richard J. Schweppe
Homer T. Seale
Frank R. Seaver
Peter V. H. Serrell
Leroy B. Sherry
Herman V. Shirley
Dana C. Smith
Ralph L. Smith
Howard G. Smits
Keith Spalding
Mrs. Keith Spalding
Mrs. Silsby M. Spalding
E. G. Starr
David H. Steinmetz, III
Mrs. Charles F. Stern
Mrs. Dillon Stevens
Ron Stever
Mrs. Charles H. Strub
Elbridge H. Stuart
Reese H. Taylor
Mrs. John Treanor
Edward E. Tuttle
Edward R. Valentine
Mrs. W. L. Valentine
William W. Valentine
J. Benton Van Nuys
Howard G. Vesper
Harry J. Volk
Richard R. Von Hagen
Charles B. Voorhis
Mrs. Thomas W. Warner
Mrs. Gurdon W. Wattles
Robert Welles
George S. Wheaton
J. Robert White
R. J. Wig
James W. Wilkie
Leighton A. Wilkie
Robert J. Wilkie
Lawrence A. Williams
P. G. Winnett
Mrs. Archibald B. Young
Gerald C. Young

INDUSTRIAL ASSOCIATES

The Industrial Associates, established in 1949, consists of companies which have chosen to participate in an organized plan of cooperation with the Institute. An annual fee together with a strong research interest qualifies a company for membership; the income is unrestricted and is employed for the general support of the Institute. The purpose of the plan is to encourage better communication and intellectual interchange between the Institute staff and the Industrial Associates. This is achieved through exchange of visits by personnel of the companies and faculty members, by special conferences, and by distribution of research reports. The plan in no way affects the cordial relationships which exist generally between industrial personnel and the Faculty of the Institute.

Additional information is available at the Office for Industrial Associates, Throop Hall.

The members of the Industrial Associates as of September 1, 1960, are listed below.

Aerojet—General Corporation

Beckman Instruments, Inc.

Bell Telephone Laboratories, Inc.

Bendix Aviation Corporation

Boeing Airplane Company

Burroughs Corporation

California Research Corporation

Campbell Soup Company

Carnation Company

Continental Oil Company

Convair—A Division of General Dynamics Corporation

Douglas Aircraft Company, Inc.

E. I. du Pont de Nemours and Company, Inc.

Eastman Kodak Company

Ford Motor Company

General Electric Company

General Motors Corporation

Giannini Controls Corporation

Gulf Research and Development Company

Hercules Powder Company

Hughes Aircraft Company

International Business Machines Corporation

International Minerals and Chemical Corporation

Lockheed Aircraft Corporation

North American Aviation, Inc.

The Ohio Oil Company

Packard Bell Electronics Corporation

Pan American Petroleum Corporation

Phelps Dodge Corporation

Phillips Petroleum Company

Richfield Oil Corporation

Shell Oil Company

Socony Mobil Oil Company, Inc.

Standard Oil Company of California

The Superior Oil Company

Texaco Inc.

Thompson Ramo Wooldridge Inc.

Union Carbide Corporation

Union Oil Company of California

United States Steel Corporation (Columbia-Geneva Steel Division and Consolidated Western Steel Division)

Westinghouse Electric Corporation

Section II

CALIFORNIA INSTITUTE OF TECHNOLOGY

THE primary purpose of the undergraduate school of the California Institute of Technology, as stated by the Trustees, is "to provide a collegiate education which will best train the creative type of scientist or engineer so urgently needed in our educational, governmental, and industrial development." It is believed that this end will be more readily attained at the Institute because of the contacts of its relatively small group of undergraduate students with the members of its relatively large research staff. Advancement in understanding is best acquired by intimate association with creative workers who are, through research and reflection, extending the boundaries of knowledge.

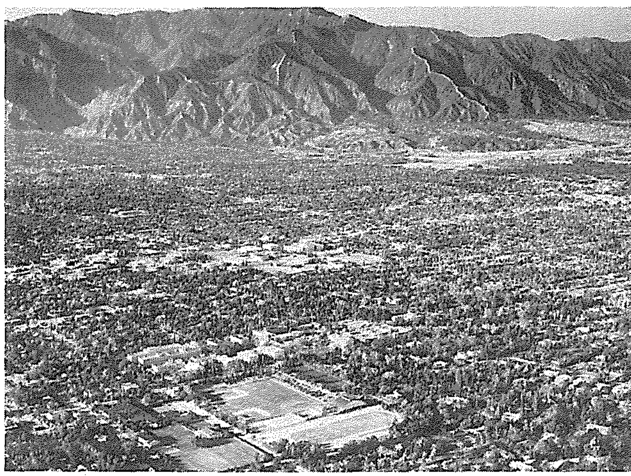
The Institute offers two four-year undergraduate courses, one in Engineering and the other in Science, both leading to the degree of Bachelor of Science and both planned so that interchange between them is not unduly difficult. For the first year, the work of all undergraduates is identical. Differentiation between these two courses begins with the second year. The Engineering course is of a general, fundamental character, with a minimum of specialization in the separate branches of engineering. It includes an unusually thorough training in the basic sciences of physics, chemistry, and mathematics, as well as the professional subjects common to all branches of engineering. With minor exceptions, the student does not concentrate in his chosen field until the fourth year. The Engineering course also includes a large proportion of cultural studies, time for which is secured by eliminating the more narrowly particularized subjects. Such a curriculum, it is hoped, will provide a combination of the fundamental scientific training with a broad human outlook. This is, in fact, the type of collegiate education endorsed by leading engineers —a training which avoids technical narrowness on the one hand and broad superficiality on the other.

The course in Science affords, even more fully, an intensive training in physics, chemistry, and mathematics. In the third and fourth years optional studies are included which permit some measure of specialization in a chosen field of science. Instruction is also provided in French and German and Russian, with the object of giving the student a sufficient reading knowledge to follow the scientific and technical literature in those languages. The Science course includes the same proportion of cultural studies as the Engineering course, and for the same reason—to enlarge the student's mental horizon beyond the limits of his immediate professional interest and thus better qualify him to realize his opportunities and fulfill his responsibilities as a citizen and a member of his community.

The inclusion in the curriculum of a large proportion of non-scientific and non-technical subjects is one of the fundamental elements in the Institute's educational policy. The purpose which these studies is meant to achieve has already been indicated. Under the general designation of the Humanities, they include literature and composition, history and government, economics, philosophy, and psychology. To them the student devotes about one-fourth of his time during his undergraduate years (and if he proceeds for the degree of Master of Science he continues with elective subjects in the Humanities throughout his fifth year). Formal instruction in the Humanities is supplemented by lectures by, and opportunities for contact with, distinguished scholars who are attracted to Pasadena by the opportunities for research at the Huntington Library and Art Gallery. In addition to these academic and semi-academic pursuits, the Institute encourages a reasonable participation in student activities of a social, literary, or artistic nature, such as student publications, debating, dramatics, and music; and all undergraduates are required to take regular exercise, preferably in the form of intercollegiate or intramural sports. In short, every effort is made in the undergraduate section of the Institute to carry on a well-rounded, well-integrated program which will not only give the student sound training in his professional field but will also develop character, breadth of view, general culture, and physical well-being.

In the graduate section the Institute offers courses leading to the degree of Master of Science, which normally involves one year of graduate work; the engineer's degree in any of the branches of engineering and in geology, with a minimum of two years; and the degree of Doctor of Philosophy. In all the graduate work, research is strongly emphasized, not only because of its importance in contributing to the advancement of science and thus to the intellectual and material welfare of mankind, but also because research activities add vitality to the educational work of the Institute. Graduate students constitute a comparatively large portion (about forty percent) of the total student body. Engaged themselves on research problems of varying degrees of complexity, and taught by faculty members who are also actively engaged in research, they contribute materially to the general atmosphere of intellectual curiosity and creative activity which is engendered on the Institute campus.

In order to utilize Institute resources most effectively, two general lines of procedure are followed. First, the Institute restricts the number of fields in engineering and science in which it offers undergraduate and graduate study, believing that it is better to provide thoroughly for a limited number than to risk diffusion of personnel, facilities, and funds in attempting to cover a wide variety of fields. Second, and in line with this policy of conservation of resources, the student body is strictly limited to that number which can be satisfactorily provided for. The size of the undergraduate group is limited by the admission of 180 Freshmen each September. Admission is granted, not on the basis of priority of application, but on a careful study of the merits of each applicant, including the results of competitive entrance examinations, high school records, and interviews by members of the Institute Staff. Applicants for admission with advanced standing from other institutions and for admission to graduate study are given the same careful scrutiny. These procedures result, it is believed, in a body of students of exceptionally high ability. A high standard of scholarship is also maintained, as is appropriate for students of such high competence.



Pasadena, at the foot of the San Gabriel Mountains.
In the foreground, the Caltech campus.

HISTORICAL SKETCH

The California Institute of Technology, as it has been called since 1920, developed from a local school of arts and crafts, founded in Pasadena in 1891 by the Honorable Amos G. Throop and named, after him, Throop Polytechnic Institute. It had at first been called Throop University, but the title was soon considered too pretentious. The Institute included, during its first two decades, a college, a normal school, an academy, and, for a time, an elementary school and a commercial school. It enjoyed the loyal support of the citizens of Pasadena, and by 1908 the Board of Trustees had as members Dr. Norman Bridge, Arthur H. Fleming, Henry M. Robinson, J. A. Culbertson, C. W. Gates, and Dr. George Ellery Hale. It was the dedication, by these men, of their time, their brains, and their fortunes that transformed a modest vocational school into a university capable of attracting to its faculty some of the most eminent of the world's scholars and scientists. A statement in The Throop Institute Bulletin of December 1908 shows the situation at this time and the optimism of the friends of the Institute:

"Although Throop Institute requires from $80,000 to $90,000 a year to pay its operating expenses and meet its current obligations, the financial condition of the school was never sounder than at present. Its revenues are not sufficient to pay its expenses, but good friends are each year found willing and able to contribute to its deficiency fund. It is in the certainty of a continuance of this confidence in its work and mission that its officers and trustees are pressing forward toward a realization of larger plans for the Institute."

These larger plans were the vision of George Ellery Hale, astronomer and first director of the Mount Wilson Observatory, who foresaw the development in Pasadena of a distinguished institution of engineering and scientific research. Hale well knew that a prime necessity was modern, well-equipped laboratories, but he stressed to his fellow-trustees that the aim was not machines, but men. "We must not forget," he wrote in 1907, "that the greatest engineer is not the man who is trained merely to understand machines and apply formulas, but is the man who, while knowing these things, has not failed to develop his breadth of view and the highest qualities of his imagination. No creative work, whether in engineering or in art, in literature or in science, has been the work of a man devoid of the imaginative faculty."

The realization of these aims meant specializing, so the Trustees decided in 1908 to separate the elementary department, the normal school and the academy, leaving only a college of technology which conferred Bachelor of Science degrees in electrical, mechanical, and civil engineering.

In 1910 Throop Polytechnic Institute moved from its crowded quarters in the center of Pasadena to a new campus of twenty-two acres on the southeastern edge of town, the gift of Arthur H. Fleming and his daughter Marjorie. The president, Dr. James A. B. Scherer, and his faculty of 16 members, opened their doors to 31 students that September. When, on March 21, 1911, Theodore Roosevelt delivered an address at Throop Institute, he declared, "I want to see institutions like Throop turn out perhaps ninety-nine of every hundred students as men who are to do given pieces of industrial work better than any one else can do them; I want to see those men do the kind of work that is now being done on the Panama Canal and on the great irrigation projects in the interior of this country—and the one hundredth man I want to see with cultural scientific training."

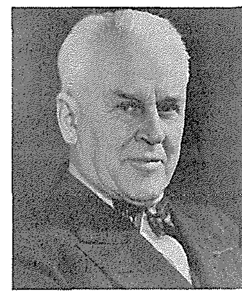
It would have surprised Roosevelt to know that within a decade the little Institute, known after 1914 as Throop College of Technology, would have again raised its sights, leaving to others the training of mere efficient technicians and concentrating its own efforts on Roosevelt's "hundredth men." On November 29, 1921, the Trustees declared it to be the express policy of the Institute to pursue scientific researches of the greatest importance and at the same time, "to continue to conduct thorough courses in engineering and pure science, basing the work of these courses on exceptionally strong instruction in the fundamental sciences of mathematics, physics, and chemistry; broadening and enriching the curriculum by a liberal amount of instruction in such subjects as English, history, and economics; and vitalizing all the work of the Institute by the infusion in generous measure of the spirit of research."

Perhaps some causes of this change are the rapid growth of southern California between 1911 and 1921, the springing up everywhere of high schools and vocational schools which relieved Throop of some of its responsibilities, and the increasing public interest in scientific research as the implications of modern physics became better known. But the immediate causes of the change in the Institute at Pasadena were men. George Ellery Hale still held to his dream. Arthur Amos Noyes, Professor of

Physical Chemistry and former Acting President of the Massachusetts Institute of Technology, served part of each year as Professor of General Chemistry and Research Associate from 1913 to 1919, when he resigned from M.I.T. to devote full time to Throop as Director of Chemical Research. In a similar way Robert Andrews Millikan began, before the war, to spend a few months a year at Throop as Director of Physical Research. In 1921, when Dr. Norman Bridge agreed to provide a research laboratory in physics, Dr. Millikan resigned from the University of Chicago and became administrative head of the Institute as well as director of the Norman Bridge Laboratory. The name of the Institute was then changed to its present one.

HALE

NOYES



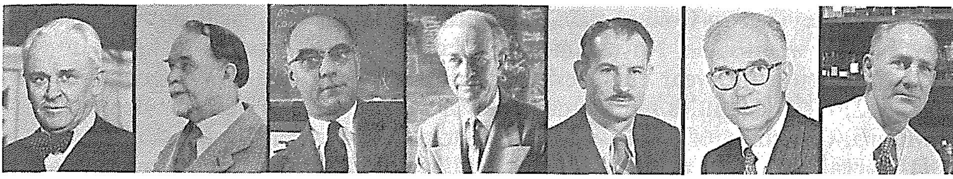
MILLIKAN

The great period of the Institute's life began, then, under the guidance of three men of vision—Hale, Noyes, and Millikan. They were all distinguished research scientists, and they soon attracted graduate students. In 1920 the enrollment was 9 graduate students and 359 undergraduates under a faculty of 60; a decade later there were 138 graduate students, 510 undergraduates, and a faculty of 180. At the present time there are about 700 undergraduates, 550 graduate students, and a faculty of about 450.

The Institute also attracted financial support, from individuals, corporations and foundations. In January 1920 the endowment had reached half a million dollars. In February of that year it was announced that $200,000 had been secured for research in chemistry and a like amount for research in physics. Other gifts followed, from Trustees and friends, southern Californians who could now feel pride in the Institute as well as hope. The Southern California Edison Company provided a high-voltage laboratory, with the million-volt Sorensen transformer. Philanthropic foundations bearing the names of Carnegie, Rockefeller, and Guggenheim came forth with needed help when new departments or projects were organized.

In 1923 Millikan received the Nobel Prize in Physics. (Within two years, if anyone had known where to look, he could have found four future Nobel Laureates on the campus). He had attracted to the Institute such men as Charles Galton Darwin, Paul Epstein, and Richard C. Tolman. In 1924 the Ph.D. degree was awarded to nine candidates.

It was inevitable that the Institute would enlarge its field; it could not continue to be merely a research and instructional center in physics, chemistry, and engineering. But the Trustees pursued a cautious and conservative policy, not undertaking to add new departments except when the work done in them would be at the same high level as that in physics and



CALTECH'S NOBEL LAUREATES

Robert A. Millikan, Thomas Hunt Morgan, Carl D. Anderson, Linus Pauling, Edwin M. McMillan, William B. Shockley, and George W. Beadle

chemistry. In 1925 a gift of $25,000 from the Carnegie Corporation of New York made possible the opening of a department of instruction and research in geology. A seismological laboratory was constructed, and Professors John P. Buwalda and Chester Stock came from the University of California to lead the work in the new division. Later gifts, especially from Mr. and Mrs. Allan C. Balch, and the gift of the Arms and Mudd laboratories, contributed further to the establishment of the geological sciences at Caltech.

In 1928 the California Institute began its program of research and instruction in biology. There had been a chair of biology, named for Charles Frederick Holder, in the old Throop Institute, but it was not until the efforts of the C.I.T. trustees, the General Education Board, the Carnegie Institution of Washington, and William G. Kerckhoff were combined that a program of research and teaching at the highest level was inaugurated. Thomas Hunt Morgan became the first chairman of the new Division of Biology and a member of the Executive Council of the Institute. Under Morgan's direction the work in biology developed rapidly, especially in genetics and biochemistry. Morgan received the Nobel Prize in 1933.

The Guggenheim Graduate School of Aeronautics was founded at the Institute in the summer of 1926, and the laboratory finished in 1929, but courses in theoretical aerodynamics had been given at the Institute for many years by Professors Harry Bateman and P. S. Epstein. As early as 1917 the Throop Institute had a wind tunnel in which, the catalogue proudly boasts, constant velocities of 4 to 40 miles an hour could be maintained, "the controls being very sensitive." The new program, under the leadership of Theodore von Kármán, included graduate study and research at the level of the other scientific work at the Institute, and GALCIT was soon a world-famous research center in aeronautics.

In 1928 George Ellery Hale and his associates at the Mt. Wilson Observatory developed a proposal for a 200-inch telescope and attracted the interest of the General Education Board in providing $6,000,000 for its construction. The Board proposed that the gift be made to the California Institute and the Institute agreed to be responsible for the construction and operation. The huge instrument was erected on Palomar Mountain, and the Mount Wilson and Palomar Observatories are now operated jointly through an agreement between the Institute and the Carnegie Institution of Washington. Teaching and research in astronomy and astrophysics thus became a part of the Institute program.

Although the emphasis upon the humanities or liberal arts as an important part of the education of every scientist and engineer was traditional even in the Throop College days, a reiterated insistence upon this principle was made when Hale, Noyes, and Millikan created the modern Caltech. In 1942, when a five-year engineering course leading to the M.S. degree was offered, the humanities requirement was included. In 1925 William Bennett Munro, Chairman of the Division of History, Government, and Economics at Harvard, joined the Institute Staff, and he soon became a member of the Executive Council. In 1928 Mr. and Mrs. Joseph B. Dabney gave the Dabney Hall of Humanities, and friends of the Institute provided an endowment of $400,000 for the support of instruction in humanistic subjects. Later Mr. Edward S. Harkness added a gift of $750,000 for the same purpose.

Largely on the initiative of Henry M. Robinson the California Institute Associates were organized in 1925. These men and women, now numbering 240, are the successors of those early dedicated pioneers who saw in Throop College the potentiality of becoming a great and famous institution. The Institute Associates, by their continued support, have played a vital part in the Institute's progress. In 1949 the Industrial Associates Program was organized as a mechanism for providing corporations with the opportunity of supporting fundamental research at the Institute and of keeping in touch with new developments in science and engineering.

For the five years beginning with the summer of 1940, the Institute devoted an increasingly large part of its personnel and facilities to the furthering of national defense and the war effort. The Institute's work during this period fell for the most part into two main categories: special instructional programs, and research on the development of the instrumentalities of war. The first included participation in the Engineering, Science, and Management War Training Program, in which a total of over 24,000 students were enrolled in Institute-supervised courses; advanced meteorology for Army Air Force cadets; advanced work in aeronautics and ordnance for Army and Navy officer personnel; and the provision of instruction (as well as housing and subsistence) for a unit of the Navy V-12 Engineering Specialists. The research and development work was carried on for the most part under nonprofit contracts with the Office of Scientific Research and Development. These contracts had a total value of more than $80,000,000 and at their peak involved the employment of more than 4000 persons. Rockets, jet propulsion, and anti-submarine warfare were the chief fields of endeavor. The Jet Propulsion Laboratory in the upper Arroyo Seco continues under Institute management a large-scale program of research in this field. It was operated under contract with the Department of the Army until 1958 when it was transferred to the newly established National Aeronautics and Space Administration.

In 1945 R. A. Millikan retired as chairman of the executive committee; he served as vice chairman of the Board of Trustees until his death in 1953. Dr. Lee A. DuBridge became President of the California Institute on September 1, 1946.

Today the California Institute has over 8,200 alumni scattered all over the world, many eminent in their fields of engineering and science. Four of them have received Nobel prizes: Carl D. Anderson (B.S. '27, Ph.D. '30), Edwin M. McMillan (B.S. '27, M.S. '29), Linus Pauling (Ph.D. '25), and William Shockley (B.S. '32).

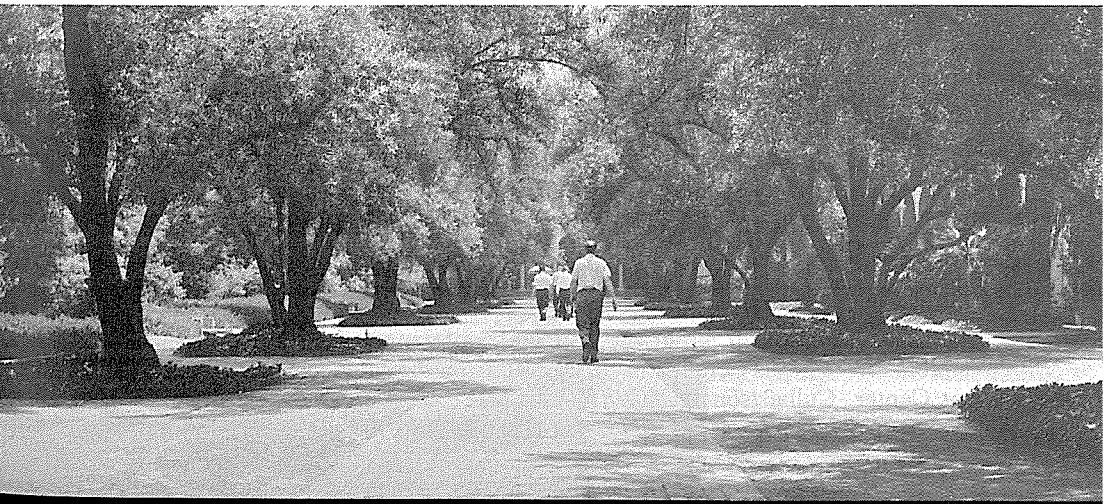
As the Institute has developed in effectiveness and in prestige it has attracted a steady flow of gifts for buildings, for endowment, and for current operations. The gifts invested in plant now total over $26,000,000 and those invested in endowment over $45,000,000.

In recent years new developments have taken place in all of the divisions. In 1948 the Palomar Observatory and the 200-inch Hale telescope were dedicated. In 1949 the Earhart Plant Research Laboratory was completed and in 1950 a new engineering building. In 1951 a cosmic ray laboratory was built and in the next year a synchrotron was constructed for the study of atomic nuclei. In 1954 the generosity of the alumni and of the late Scott Brown, a member of the Associates, provided a gymnasium and swimming pool. In 1955 the completion of the Norman W. Church Laboratory for Chemical Biology pointed to new activities in an important field of science. 1957 saw the completion of the Eudora Hull Spalding Laboratory of Engineering, an important addition to the facilities available for instruction and research in chemical and electrical engineering, and a new student health center, the gift of Mrs. Archibald Young in memory of her late husband who was long an Institute Associate. A new radio astronomy observatory—one of the finest in the world—was completed in the Owens Valley in 1959.

In February 1958 the Trustees announced the launching of a drive to secure $16,100,000 to finance 18 needed buildings and an enlarged faculty salary fund. The goal was later raised to $19,500,000. By April 1960 the pledges to this campaign totaled over $18,000,000. The first unit, a physical plant building, was completed in May 1959; and construction was completed by June 1960 of a new mathematics and physics building, the gift of the Alfred P. Sloan Foundation; of a new laboratory of molecular biology, the gift of Dr. Gordon A. Alles (B.S. '22, Ph.D. '26) and the U. S. Public Health Service; and of a plant research laboratory, the gift of the Campbell Soup Company and the U. S. Public Health Service.

Completion is scheduled for the fall of 1960 for the W. M. Keck Engineering Laboratories, three undergraduate student houses, and the Harry Chandler Dining Hall. Construction will begin in 1960-61 on four graduate houses, the Firestone Laboratory of Aeronautics, the Karman Laboratory of Fluid Mechanics and Jet Propulsion (gift of the Aerojet-General Corporation), the Robert A. Millikan Library (gift of Dr. Seeley G. Mudd), the Arnold O. Beckman Auditorium, and the P. G. Winnett Student Center.

Olive Walk, which bisects the campus



THE INDUSTRIAL RELATIONS SECTION

The Industrial Relations Section was established in 1939 through special gifts from a substantial number of individuals, companies, and labor unions. The work and program of the Section are guided by the Committee of the Industrial Relations Section, consisting of Trustees appointed by the Board and Faculty members appointed by the President.

The Section has developed a five-fold program of activities and service for companies, unions, associations, and individuals: (1) a reference library of books, pamphlets, magazines, and other materials related to industrial relations; (2) specialized courses or series of meetings without academic credit for representatives of companies and unions; (3) periodic conferences of business executives and of union and government officials for the discussion of current labor problems; (4) surveys and research studies on problems of industrial relations; and (5) a series of bulletins and circulars which are the product of these activities.

Detailed information about the specific services of the Section and the fees involved can be secured from the Director of the Industrial Relations Section, Culbertson Hall.

The Benefits and Insurance Research Center

In recognition of the growing importance of employee benefit and insurance programs in industrial relations, the Benefits and Insurance Research Center was established in 1955 as a part of the Industrial Relations Section. The Center is financed through special gifts from a large number of companies interested in supporting a program of objective research and instruction in this field. In its special area the work of the Center parallels closely the program of activities and services developed by the Industrial Relations Section.

Detailed information about the specific activities and services of the Center can be secured from the Director of the Industrial Relations Section or the Research Director of the Benefits and Insurance Research Center, Culbertson Hall.

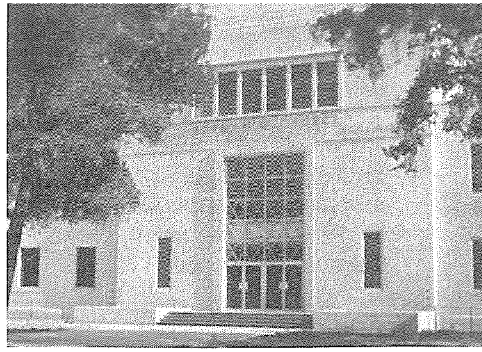
The Management Development Center

The increasing complexity of business operations has emphasized the fact that a manager must not only know how to do the work being supervised but must also know how to supervise—a separate and distinct function. The expanding demand for training in the knowledge and skills required for supervision caused the establishment of the Management Development Center in 1957 as a part of the Industrial Relations Section.

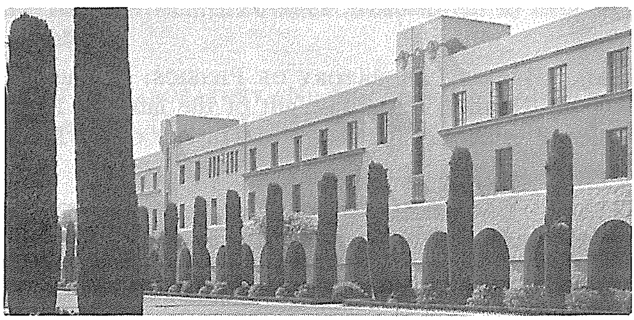
This Center offers training in the field of management in general and in the specialized field of personnel administration. A wide range of courses is presented: on campus or off campus, full-time or part-time, for representatives of a variety of companies or specially designed for the management of a specific company. The courses do not carry academic credit.

Detailed information about the courses, conferences, and other services available through this Center can be secured from the Management Development Center, Culbertson Hall.

Throop Hall

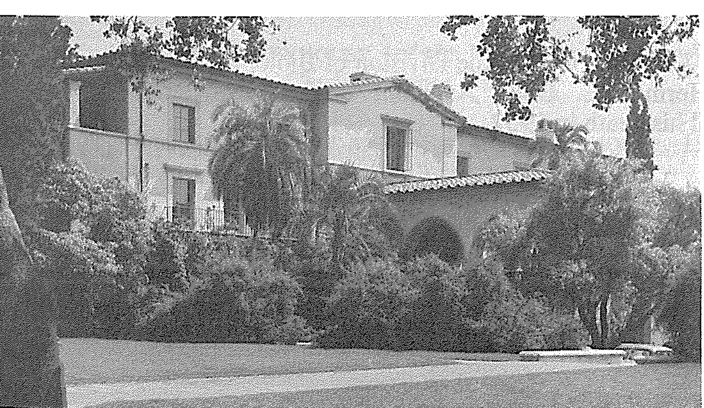


Church Laboratory for Chemical Biology

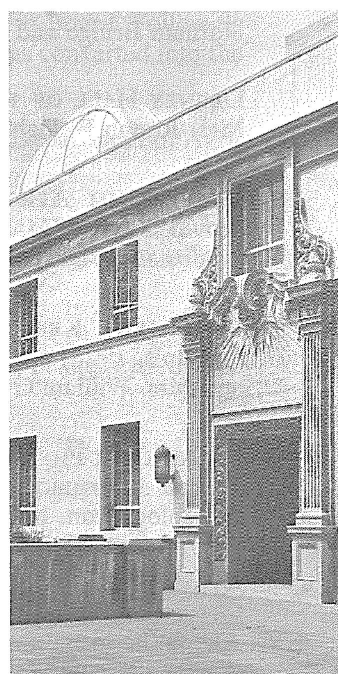


Kerckhoff Laboratories of the Biological Sciences

Spalding Laboratory of Engineering



Athenaeum



Robinson Laboratory of Astrophysics

BUILDINGS AND FACILITIES

THROOP HALL, 1910. The administration building; erected with funds supplied by a large number of donors, and named for the Honorable Amos G. Throop, founder of Throop Polytechnic Institute from which California Institute developed.

GATES AND CRELLIN LABORATORIES OF CHEMISTRY: first unit, 1917; second unit, 1927; third unit, 1937. The first two units were the gift of the late Messrs. C. W. Gates and P. G. Gates of Pasadena; the third unit was the gift of the late Mr. and Mrs. E. W. Crellin of Pasadena.

CULBERTSON HALL, 1922. The Institute auditorium; named in honor of the late Mr. James A. Culbertson of Pasadena, Vice President of the Board of Trustees of the Institute, 1908-1915.

NORMAN BRIDGE LABORATORY OF PHYSICS: first unit, 1922; second unit, 1924; third unit, 1925. The gift of the late Dr. Norman Bridge of Los Angeles, President of the Board of Trustees of the Institute, 1896-1917.

ALFRED P. SLOAN LABORATORY OF MATHEMATICS AND PHYSICS, 1923. Formerly the High-Voltage Research Laboratory erected with funds provided by the Sounthern California Edison Company. Rebuilt in 1960 with funds provided by the Alfred P. Sloan Foundation, Inc.

HEATING PLANT, 1926. Erected with funds provided in part by the late Dr. Norman Bridge and in part from other sources.

DABNEY HALL OF THE HUMANITIES, 1928. The gift of the late Mr. and Mrs. Joseph B. Dabney of Los Angeles.

GUGGENHEIM AERONAUTICAL LABORATORY, 1929. Erected with funds provided by the Daniel Guggenheim Fund for the Promotion of Aeronautics. A substantial addition was erected in 1947.

WILLIAM G. KERCKHOFF LABORATORIES OF THE BIOLOGICAL SCIENCES: first unit, 1928; second unit, 1939; annex, 1948. The gift of the late Mr. and Mrs. William G. Kerckhoff of Los Angeles.

DOLK PLANT PHYSIOLOGY LABORATORY (of the Division of Biology), 1930. Named in memory of Herman E. Dolk, Assistant Professor of Plant Physiology from 1930 until his death in 1932.

ATHENAEUM, 1930. The gift of the late Mr. and Mrs. Allan C. Balch of Los Angeles, President of the Board of Trustees of the Institute, 1933-1943. A clubhouse for the use of the staffs of the California Institute, the Huntington Library, and the Mt. Wilson Observatory; and the California Institute Associates.

STUDENT HOUSES, 1931.

Blacker House. The gift of the late Mr. and Mrs. R. R. Blacker of Pasadena.

Dabney House. The gift of the late Mr. and Mrs. Joseph B. Dabney of Los Angeles.

Fleming House. Erected with funds provided by some twenty donors, and named in honor of the late Mr. Arthur H. Fleming of Pasadena, President of the Board of Trustees of the Institute, 1917-1933.

Ricketts House. The gift of the late Dr. and Mrs. Louis D. Ricketts of Pasadena.

CENTRAL ENGINEERING MACHINE SHOP, 1931. Erected with funds provided by the International Education Board and the General Education Board. Formerly the Astrophysical Instrument Shop until the completion of the Palomar Observatory.

W. K. KELLOGG RADIATION LABORATORY (Nuclear Physics), 1932. The gift of the late Mr. W. K. Kellogg of Battle Creek, Michigan.

HENRY M. ROBINSON LABORATORY OF ASTROPHYSICS, 1932. Erected with funds provided by the International Education Board and the General Education Board, and named in honor of the late Mr. Henry M. Robinson of Pasadena, member of the Board of Trustees, 1907-1937, and the Executive Council of the Institute.

SYNCHROTRON LABORATORY, 1933. Erected with funds provided by the International Education Board and the General Education Board. Following completion of the Palomar Observatory, this building was converted into the Synchrotron Laboratory.

SEDIMENTATION LABORATORY, 1936. Provided by the Department of Agriculture of the United States Government.

CHARLES ARMS LABORATORY OF THE GEOLOGICAL SCIENCES, 1938. The gift of the late Mr. and Mrs. Henry M. Robinson of Pasadena, in memory of Mrs. Robinson's father, the late Mr. Charles Arms.

SEELEY W. MUDD LABORATORY OF THE GEOLOGICAL SCIENCES, 1938. The gift of the late Mrs. Seeley W. Mudd of Los Angeles, in memory of her husband.

CLARK GREENHOUSE (of the Division of Biology), 1940. The gift of Miss Lucy Mason Clark of Santa Barbara.

RECEIVING ROOM AND CENTRAL WAREHOUSE, 1944.

HYDRODYNAMICS LABORATORY, 1944.

ENGINEERING BUILDING: first unit, 1945; second unit, 1950. Funds for the erection of the first unit were allocated from the Eudora Hull Spalding Trust with the approval of Mr. Keith Spalding, Trustee.

EARHART PLANT RESEARCH LABORATORY (of the Division of Biology), 1949. The gift of the Earhart Foundation of Ann Arbor, Michigan.

COSMIC RAY LABORATORY, 1952.

ALUMNI SWIMMING POOL, 1954. Provided by the Alumni Fund through contributions by members of the Alumni Association of the Institute.

SCOTT BROWN GYMNASIUM, 1954. The funds for this building were provided by a trust established by the late Mr. Scott Brown of Pasadena and Chicago, a member and director of the California Institute Associates.

NORMAN W. CHURCH LABORATORY FOR CHEMICAL BIOLOGY, 1955. The funds for the erection of this laboratory were provided through gift and bequest by the late Mr. Norman W. Church of Los Angeles, a member of the California Institute Associates.

EUDORA HULL SPALDING LABORATORY OF ENGINEERING, 1957. Erected with funds allocated from the Eudora Hull Spalding Trust.

ARCHIBALD YOUNG HEALTH CENTER, 1957. The gift of Mrs. Archibald Young of Pasadena, in memory of her husband, a member and director of the California Institute Associates.

PHYSICAL PLANT BUILDING AND SHOP, 1959.

CAMPBELL PLANT RESEARCH LABORATORY, 1960. Erected with funds given by the Campbell Soup Company of Camden, New Jersey, and by the Health Research Facilities Branch of the National Institutes of Health, Bethesda, Maryland.

GORDON A. ALLES LABORATORY FOR MOLECULAR BIOLOGY, 1960. Erected with the gift of Dr. Gordon A. Alles of Pasadena, Research Associate in Biology at the Institute, an alumnus and a member of the California Institute Associates; and with funds provided by the Health Research Facilities Branch of the National Institutes of Health.

HARRY CHANDLER DINING HALL, 1960. The gift of the Chandler family, the Pfaffinger Foundation, and the Times-Mirror Company of Los Angeles.

W. M. KECK ENGINEERING LABORATORIES, 1960. The gift of the Superior Oil Company of Los Angeles.

LIBRARIES

The General Library, as the center of the Institute library system, houses the administrative office, which serves nine departmental libraries located in as many buildings on the campus. The departmental libraries house the collection of books, periodicals, and basic reference works in aeronautics, astronomy and astrophysics, biology, chemistry, chemical engineering, geology, humanities, industrial relations, and physics. The General Library houses the collections in mathematics and engineering, as well as the master catalog for the entire system. The bookstacks throughout the libraries are open to all readers. The collections constitute strictly a working library, including subscriptions to more than 3000 periodicals.

OFF-CAMPUS FACILITIES

KRESGE SEISMOLOGICAL LABORATORY, 1928, and DONNELLEY SEISMOLOGICAL LABORATORY (of the Division of the Geological Sciences), North San Rafael Avenue, 1957.

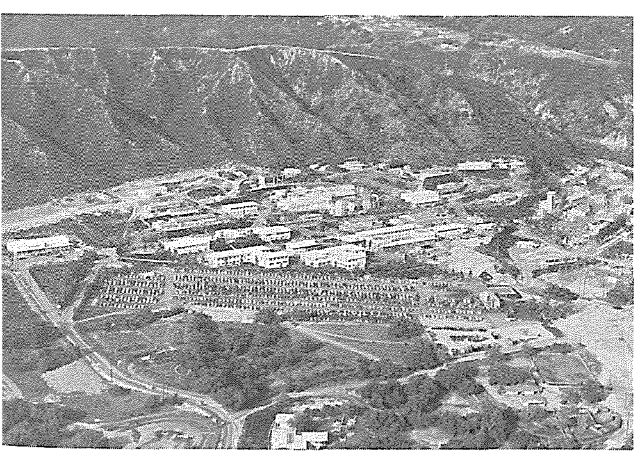
The second laboratory was the gift of Mr. and the late Mrs. C. Pardee Erdman of Santa Barbara, The Kresge Foundation of Detroit, Michigan, and the James Irvine Foundation of San Francisco; and named in honor of Mrs. Erdman's father, the late Mr. Reuben H. Donnelley.

WILLIAM G. KERCKHOFF MARINE BIOLOGICAL LABORATORY (of the Division of Biology), Corona del Mar, 1930.

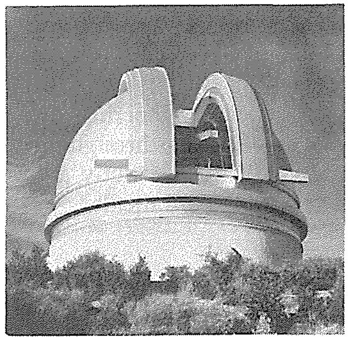
JET PROPULSION LABORATORY, 4800 Oak Grove Drive, 1944. Owned and sponsored by the National Aeronautics and Space Administration and operated by the Institute.

PALOMAR OBSERVATORY, 1948. Owned by the Institute and, with the Mount Wilson Observatory, jointly operated by the Carnegie Institution of Washington and the Institute.

RADIO-ASTRONOMY OBSERVATORY, Bishop, 1958.



The Jet Propulsion Laboratory, operated by Caltech for the National Aeronautics and Space Administration



The 200-inch telescope at the Palomar Observatory

STUDY AND RESEARCH
AT THE CALIFORNIA INSTITUTE

1. The Sciences

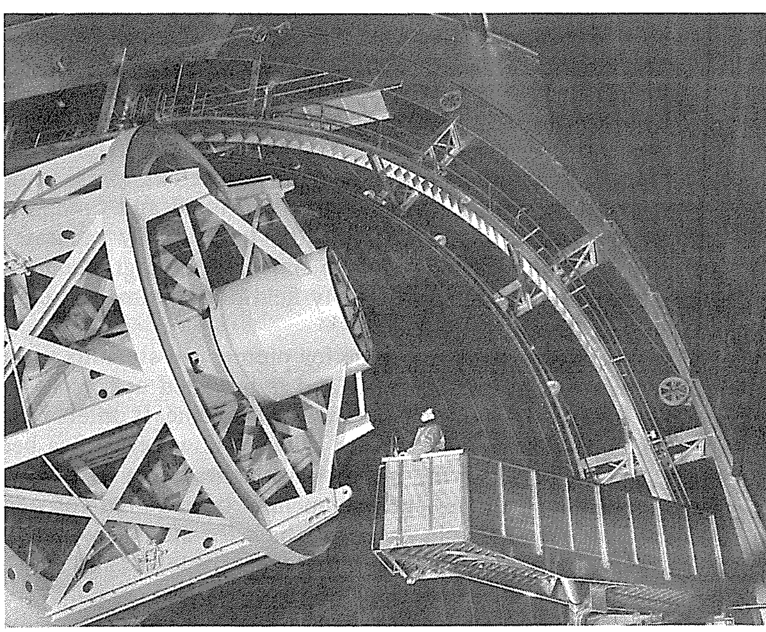
Astronomy

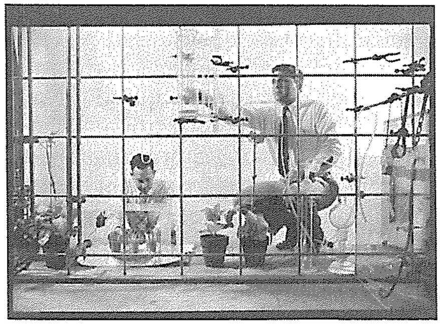
The Rockefeller Boards provided in 1928 for the construction by the Institute of an astronomical observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, 48-inch and 18-inch schmidt wide-angle telescopes and other auxiliary instruments, together with an astrophysical laboratory, on the Institute campus. The purpose of this observatory is to supplement, not to duplicate, the facilities of the Mount Wilson Observatory of the Carnegie Institution of Washington, which, while not a part of the California Institute, is located even closer to Pasadena than is Palomar Mountain. The increased light-collecting power of the 200-inch telescope permits further studies of the size, structure, and motion of the galactic system; of the distance, motion, radiation, composition, and evolution of the stars; the interstellar gas; the distance, motion, and nature of remote nebulae; and of many phenomena bearing directly on the constitution of matter. The 48-inch Schmidt has made possible a complete survey of the sky as well as an attack upon such problems as the structure of clusters of nebulae, the luminosity function of nebulae and absolutely faint stellar systems, intergalactic matter, extended gaseous nebulae, and the stellar contents of the milky way. These two unique instruments supplement each other as well as the telescopes on Mount Wilson; the one reaches as far as possible into space in a given direction, while the other photographs upon a single plate an entire cluster of distant nebulae or a star cloud in our own galaxy.

The Mount Wilson and Palomar Observatories constitute a unique and unprecedented concentration of scientific facilities in astronomy. Outstanding scientific talent is present both in the field of astronomy and in the neighboring field of physics and mathematics. The California Institute of Technology and the Carnegie Institution of Washington have recognized the advantages implicit in the creation of a great astronomical center in which a unitary scientific program would be pursued under highly favorable circumstances, that would attract distinguished investigators to collaborate with the staff of the observatories in scientific matters, and that would draw young men of great ability to graduate studies where they might enjoy the inspiration of leading minds and familiarize themselves with powerful tools of exploration. For this purpose a plan for the unified operation of the two observatories, in which they function as a single scientific organization under the direction of Dr. I. S. Bowen, was approved by the Trustees of the two institutions. Under this plan all the equipment and facilities of both observatories are made available for the astronomical investigations of the staff members of the combined observatories and the unified research program is paralleled by undergraduate and graduate training in astronomy and astrophysics in which members of the Staff of Mount Wilson Observatory join with the Institute Faculty.

In 1956 work started in radio astronomy and advanced study and research in this field are now under way. The first instrument was a 32-foot paraboloid for 21 cm research. Two new, precision, 90-foot diameter steerable paraboloids suitable for high frequencies are now in operation at a field station near Bishop. The two may also be used together as an interferometric radio telescope for exact position finding. In addition, a large interferometer array is operating at low frequency. This is one of the most advanced installations in this new and rapidly growing field. The radio astronomy group works in close cooperation with the optical astronomers in Pasadena; the program of study in the two fields is essentially the same, except for specialized advanced courses.

As a result of the cooperation possible over a broad range of astronomy, astrophysics, and radio astronomy unusual opportunities exist at the California Institute for advanced study and research. The instructional program is connected with a broad and thorough preparation in physics, mathematics, and relevant subjects, as well as instruction in astronomy, radio astronomy, and astrophysics.





Biologists produce synthetic climatic conditions in studies of greenhouse plants

Biological Sciences

UNDERGRADUATE WORK AND GRADUATE WORK

Biology is today one of the most rapidly expanding and exciting of the sciences. Advances of a spectacular kind are being made in our understanding of living things. This is in large part so because it has been found possible to apply the methods, concepts, and approaches of mathematics, physics and chemistry to the investigation of such biological problems as the manner in which molecules, genes, and viruses multiply themselves, the nature of enzyme reaction and of enzymatic pathways, the mechanisms of growth and development, and the nature of nerve activity, brain function and behavior. There is great and increasing demand for experimental biologists, and qualified individuals will find opportunities for challenging work in basic research and in the applied fields of medicine, agriculture and chemical industry.

Because of the preeminent position of the California Institute of Technology in both the physical and biological sciences, students at the Institute have an unusual opportunity to be introduced to modern biology. The undergraduate option is designed to give the student an understanding of the basic facts, techniques and logic of biology as well as a solid foundation in physical science. Emphasis is placed on the general and fundamental properties of living creatures, thus unifying the traditionally separate fields of botany, zoology, microbiology and so on. The undergraduate option serves as a basis for graduate study in any field of experimental biology or for admission to the study of medicine.

The undergraduate course for premedical students is essentially the same as that for biology students and is intended as a basis for later careers in research as well as in the practice of medicine. It differs in some respects from premedical curricula of other schools; however, it has been quite generally accepted as satisfying admission requirements of medical schools. Slight modifications in the curriculum may be required for admission to certain medical schools or in cases in which the student wishes to try to complete admission requirements in three years instead of four. The student should consult with the premedical adviser about this.

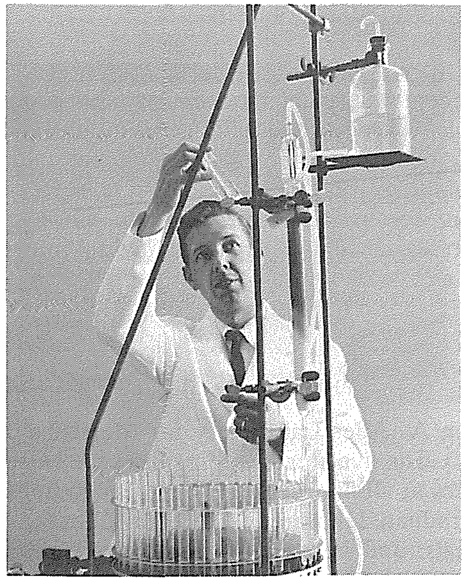
Graduate work leading to the Ph.D. degree is chiefly in the following fields: animal biochemistry, plant biochemistry, bio-organic chemistry, experimental embryology, animal and plant genetics, chemical genetics, immunology, biophysics, mammalian physiology, comparative physiology, plant physiology, psychobiology, and virology. These represent the fields in which active research is now going on in the Division. The emphasis in graduate work is placed on research. This is supplemented by courses and seminars in advanced subjects aimed to develop the student's insight and critical ability as an investigator.

PHYSICAL FACILITIES

The new Gordon A. Alles Laboratory for Molecular Biology was completed in May 1960. The five-story building links the existing Kerckhoff and Church Laboratories at all floor levels. The three laboratories contain classrooms and undergraduate laboratories, a biology library, an annex housing experimental animals, and numerous laboratories equipped for biological, biochemical, and physiological research at the graduate and doctoral level. The constant temperature equipment includes rooms for the culturing of the Institute's valuable collection of mutant types of Drosophila and Neurospora and complete facilities for plant and animal tissue culture.

Adjacent to the campus is the Plant Research Center consisting of the newly constructed Campbell Plant Research Laboratory, the Earhart Plant Research Laboratory and the Dolk, Clark and Batson Greenhouses. In the Earhart Laboratory all the elements of climate, such as light, temperature, humidity, wind, rain, and gas-content of air can be controlled simultaneously. These laboratories offer the opportunity to study plants under different synthetic climatic conditions, yet with reproducibility of experimental results.

About 50 miles from Pasadena, at Corona del Mar, is the William G. Kerckhoff Marine Laboratory. The building houses several laboratories for teaching and research in marine zoology, embryology, and physiology. It is equipped with its own shop, has boats and tackle for collecting marine animals, and running sea-water aquaria for keeping them. The proximity of the marine station to Pasadena makes it possible to supply the biological laboratories with living material for research and teaching. The fauna at Corona del Mar and at Laguna Beach, which is nearby, is exceptionally rich and varied, and is easily accessible.



Chemist, studying molecular diseases, separates the different components of human hemoglobin

Chemistry and Chemical Engineering

The Gates and Crellin Laboratories of Chemistry consist of three adjacent units. The first two are the gift of the late Messrs. C. W. Gates and P. G. Gates. The third unit, which was completed in 1937 and affords space approximately equal to that of the first two units, is the gift of the late Mr. and Mrs. E. W. Crellin. In addition, the Division of Chemistry and Chemical Engineering occupies the East half of the new Norman W. Church Laboratory of Chemical Biology.

These four units include laboratories used for undergraduate instruction in inorganic, analytical, physical, and organic chemistry; they also include classrooms, lecture rooms, and a chemistry library. The remaining space in these buildings is largely devoted to facilities for research. There are numerous laboratories for inorganic, physical, and organic research, providing space for over one hundred research fellows and advanced students. The laboratories in the Norman W. Church Laboratory of Chemical Biology are used for research in immunochemistry and on the application of chemistry to biological and medical problems.

The Chemical Engineering Laboratory is located in the new Eudora Hull Spalding Laboratory of Engineering and in the adjoining Engineering Building. This laboratory is well equipped for making the accurate measurements needed in engineering investigations of quantitative character. It is especially well provided with equipment for determination of the phase relations and thermodynamic properties of fluids at moderately high pressures. Research equipment is available for intensive study of reaction kinetics and transfers of matter and energy in systems involving fluids.

UNDERGRADUATE WORK

The Division offers two undergraduate options, which are identical in the first two years. One is in Chemistry and the other in Chemical Engineering. These options, especially when followed by graduate work in these subjects, prepare the students for teaching and research in colleges and universities, for research in government and industry, for operation and control of manufacturing processes, and for management and development positions in chemical industry.

The first-year general chemistry course, which is taken by all freshman students, emphasizes fundamental principles and their use to systematize descriptive chemistry. In the laboratory the student executes many experiments involving quantitative techniques of high precision; the third-term laboratory work involves a system of qualitative and semi-quantitative analysis.

During the second year the Chemistry and Chemical Engineering Options are identical and prescribe studies of the properties and reactions of organic compounds and of laboratory work in which fundamental manipulative techniques are acquired through preparations of important pure organic compounds by useful general reactions. Sophomore electives can be so chosen by the student as to broaden his view of science and engineering.

In the third year the Chemistry Option prescribes courses in physical and analytical chemistry, and offers a wide variety of elective subjects as described on page 213.

The fourth year of the Chemistry Option consists mainly of electives; courses in other scientfic and engineering subjects are acceptable electives.

In the third year the Chemical Engineering Option includes courses in analytical and physical chemistry, chemical engineering thermodynamics, engineering mathematics, and introductory electronics.

Required courses in the fourth year of the Chemical Engineering Option are industrial chemistry, dynamics, strength of materials, chemical engineering unit operations, chemical engineering laboratory, and continued work in chemical engineering thermodynamics. Electives are also available during the fourth year.

Throughout the undergraduate years qualified students in either option are encouraged to participate in research.

GRADUATE WORK

A fifth year of work leading to the degree of Master of Science in Chemistry is available. Research constitutes a substantial proportion of the work required for this degree.

The fifth-year course in chemical engineering leads to the degree of Master of Science in Chemical Engineering. This curriculum contains a laboratory course in engineering measurements and research methods, an elective in the humanities, and elective studies in science and engineering. Upon completion of the fifth-year course the student becomes eligible to be considered for sixth-year work leading to the degree of Chemical Engineer. Approximately one-half of the work of the sixth year is devoted to research in chemical engineering, the other half being occupied with approved graduate courses.

Opportunities for study and research leading to the degree of Doctor of Philosophy are offered in the various fields of chemistry and chemical engineering and in such borderline fields as chemical biology, geochemistry, and chemical physics. Some of the fields of research in which members of the staff are engaged and which are available to qualified students are listed on pages 247 and 253.

Geological Sciences

The Division of Geological Sciences is closely allied with the other active and creative fields of science and engineering at Caltech. Accordingly, a favorable intellectual atmosphere exists for education and research in geology, geobiology, geochemistry, and geophysics. The geographic position and geological setting of the Institute are nearly ideal for students and research workers, who can derive materials, ideas, and inspiration from the wide variety of easily accessible field environments. The staff as listed on an earlier page of this catalog represents a variety of allied and integrated interests and is active in both teaching and research.

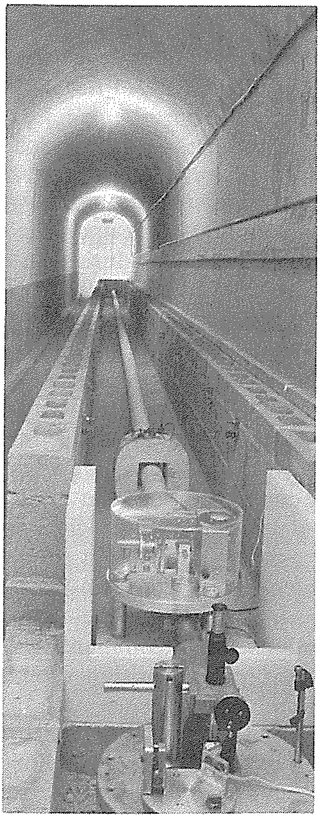
Physical facilities, both natural and man-made, are excellent. All the classroom instruction and most of the laboratory research in geology and geochemistry, as well as part of that in geophysics, are carried on in the Arms and Mudd Laboratories. These are modern, five-story buildings which were specifically designed for these activities and to provide office space for the staff and students. They also house the Division Library; paleontologic, rock, and mineral collections; spectographic and X-ray equipment; and laboratories for rock and mineral analyses, sedimentation studies, thin and polished section work, and other tools required for comprehensive studies in the earth sciences. A new suite of laboratories for mineral separation and analyses is available for student use.

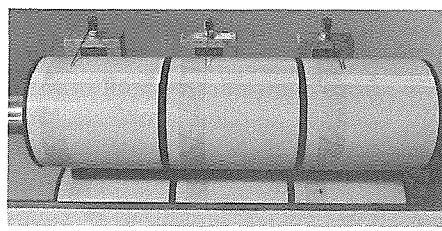
Extensive facilities are available for the application of techniques of nuclear chemistry to problems in the earth sciences. These facilities include chemical laboratories for trace-element studies, a silicate analysis laboratory, and mass spectrometric and counting facilities for isotopic work. Available equipment includes mass spectrometers, emission counters, an induction furnace, and extensive mineral separation facilities in addition to the usual geological and chemical items.

Favorable opportunity for study of dynamic aspects of paleontology and evolution as revealed by morphology, ecology, and biogeochemistry is provided by the combination of personnel, reference collections, and modern geochemical tools and techniques available here. Biologic principles and processes, past and present, of significance to geology may be interpreted from experimentation and studies at the Kerckhoff Marine Laboratory at Corona del Mar, operated under auspices of the Division of Biology.

The Seismological Laboratory of the California Institute, with ample space and excellent facilities in the Donnelley and Kresge Laboratories, is located about three miles west of the campus on a crystalline bedrock ridge affording firm foundation for the instrument piers and tunnels. The central laboratory, together with seventeen outlying auxiliary stations in southern California—built and maintained with the aid of cooperating companies and organizations—constitutes a fine center for education and research in seismology. Other phases of geophysical training and investigation are carried on in the regular campus buildings.

Conditions for field study and research in the earth sciences in southern California are excellent. A great variety of rock types, geologic structures,





The Seismological Laboratory

active geologic processes, physiographic forms, and geologic environments occur within convenient reach of the Institute. The relatively mild climate permits field studies throughout the entire year, consequently year-around field training is an important part of the departmental program.

The student body is purposely kept small and usually consists of 40 to 50 graduate students and 20 to 30 undergraduates. The small size of the student group and large size of the staff give a highly favorable ratio of students to staff and result in close associations and contacts which enhance the value of the educational program.

UNDERGRADUATE WORK

The aim of the undergraduate program in the Geological Sciences is to provide thorough training in basic geological disciplines and, wherever possible, to integrate the geological studies with and build upon the courses in mathematics, physics, chemistry, and biology taken during the earlier years at the Institute. Special emphasis is also placed on field work because it provides first-hand experience with geological phenomena that never can be satisfactorily grasped or understood solely from classroom or laboratory treatment. Options are offered in geology (including paleontology and paleoecology), geophysics, and geochemistry. Sufficient flexibility in electives is provided to permit a student to follow lines of special interest in related scientific or engineering fields. Men who do well in the basic sciences and at the same time have a compelling curiosity about the earth and its natural features are likely to find their niche in the Geological Sciences, especially if they possess a flexible and imaginative mind that enables them to grapple with complex problems in which it is difficult to get sufficient data on all the unknowns.

The Geochemistry and Geophysics options are recommended only for those students who anticipate continuing their training at the graduate level.

Men trained in the earth sciences find employment in research, teaching, and a wide variety of other professional activities. Many work for the petroleum industry both in the field and in the laboratory on theoretical as well as applied problems. Some eventually become administrators and executives. Mining companies, railroads, large utilities, and other organizations engaged in development of natural resources, employ men trained in the geological sciences, as do a number of Federal and state bureaus, such as the U. S. Geological Survey and the Bureau of Reclamation.

GRADUATE WORK

The number of courses required within the Division for an advanced degree is purposely held to a minimum to permit individuality and flexibility in the various programs. Facilities are available for research and study in such subjects as geochemistry, geophysics, seismology, paleoecology, paleontology, petrology, geomorphology, glaciology, structural geology, stratigraphy, sedimentation, tectonophysics, and mineral deposits.

The Division is especially interested in graduate students who not only have a good background in geology, but also have sound and thorough training in physics, chemistry, biology, and mathematics. Applicants with majors in these subjects and with a strong interest in the earth sciences will be given consideration for admission and appointment along with geology majors.

MATHEMATICS

UNDERGRADUATE WORK

The four-year undergraduate program in mathematics leads to the degree of Bachelor of Science. The purpose of the undergraduate option is to give the student an understanding of the broad outlines of modern mathematics, to stimulate his interest in research, and to prepare him for later work, either in pure mathematics or allied sciences. Unless a student has done exceptionally well in his freshman and sophomore years, he should not contemplate specializing in mathematics. An average of at least "B" in his mathematics courses is expected of a student intending to major in mathematics.

Since the more interesting academic and industrial positions open to mathematicians require training beyond a Bachelor's degree, the student who expects to make mathematics his profession must normally plan to continue either here or elsewhere, with graduate work leading to the degree of Doctor of Philosophy. The undergraduate should bear this in mind in choosing his course of study. In particular he is urged to include at least one year, and preferably two years, of language study in his program. Overloads in course work are strongly discouraged; students are advised instead to deepen and supplement their course work by independent reading. The excellent mathematics library with its large collection of journals is housed in the general library in the Norman Bridge Laboratory. In addition, there is a reference library of duplicate books and periodicals located on the third floor of the Sloan Laboratory for Mathematics and Physics. Books, not on reserve for special courses, may be borrowed from the general library. Current periodicals may be consulted in either library.

Normally the undergraduate will have joined the option by the beginning of his sophomore year. He is required to take the course Ma 5 abc during his second year. Students transferring from another option at the end of the sophomore year who have not as yet taken this course will take it as their selected course in mathematics during their junior year concurrently with Ma 108, and will take two selected courses in Mathematics during their senior year.

The schedule of courses in the undergraduate mathematics option is flexible. It enables the student to adapt his program to his needs and mathematical interests and gives him the opportunity of becoming familiar with creative mathematics early in his career. Each term during his junior and his senior year the student will normally take 18 units of courses in mathematics, including the required course Ma 108. These courses are chosen from the subjects of instruction listed under A in section VI of this catalog. The courses Ma 102, 103, 105, 109, 112, 116 are recommended to juniors and seniors. The other courses demand more maturity and prerequisites. They are recommended to seniors only.

GRADUATE WORK

Graduate work in mathematics is planned to give the student a broad knowledge of classical and modern mathematics and to stimulate him to do creative and independent work. The normal course of study leads to the Ph.D. degree and requires three or four years. Exceptional ability and graduate work done elsewhere may shorten this time.

Entering graduate students are normally admitted directly to the Ph.D. program. A master's degree is awarded in exceptional cases. General requirements are listed under A and B of section IV. The program of study for a master's degree must include 27 or more units of graduate humanities electives, at least 135 units of graduate course work in mathematics, and the submission of a thesis. The thesis requirement may be waived at the discretion of the department.

The general Institute requirements for the Ph.D. degree are listed in section IV under A and D. Additional requirements for mathematics are found on page 199; they give information on placement examinations, admission to candidacy and final examinations.

Courses. The graduate courses which are offered are listed in section VI. They are divided in three categories. The courses numbered between 100 and 199 are basic graduate courses open to all graduate students. The course Ma 108 is the fundamental course in Analysis. It is a prerequisite to most courses and its equivalent is expected to be part of the undergraduate curriculum of the entering graduate student. The basic course in Algebra, Ma 120, presupposes an undergraduate introductory course in modern algebra similar to Ma 5 abc. Particular mention is made of Ma 190. It is a seminar required of all first year graduate students and restricted to them. It is intended to stimulate independent work, to train students in the presentation of mathematical ideas and to develop an independent critical attitude.

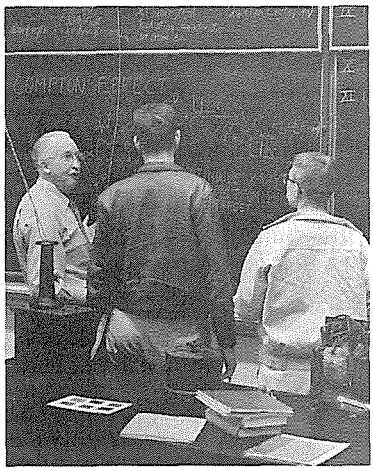
The courses in the second category are numbered between 200 and 299. They are taken normally by second year and more advanced graduate students. They are usually given in alternate years. The 300 series includes the more special courses, the research courses and the seminars. They are given on an irregular basis depending on demand and interest.

The program of a first year graduate program, in addition to the elementary seminar Ma 190, will consist as a rule of two or three 100-series courses. The student is reminded of the language requirements and of the requirements for a minor or course work outside of his main field of interest. It is advisable for a student to satisfy these requirements as early as possible. In particular, the student should fill out early the form listing his intended courses outside of mathematics and secure approval for this part of his plan of study.

Beginning at the latest with the second year the student will be expected to begin his independent research work and be strongly encouragd to participate in seminars.

Research. Although supervision and guidance will be provided by members of the staff of the Institute, the thesis research including the choice of a topic is the responsibility of the student. Proper guidance can be given in about any field, in pure or applied mathematics and is not restricted to the immediate interests of the staff in mathematics. These include: group theory, matrix theory, lattice theory; algebraical and analytic theory of numbers; topology; and in analysis: differential equations, asymptotic expansions, special functions, functional analysis and mathematical problems of classical mathematical physics.

Financial Aid. Besides the help provided by the nationwide fellowship programs financial assistance is provided by tuition scholarships and research or teaching assistantships. A scholarship and an assistantship may be held concurrently. As a rule the teaching duties of a teaching assistantship is limited to one four-hour-a-week course. The present stipend ranges from $1540 to $1960 for more advanced and experienced instructors. This light teaching load allows the student to carry a full program of study.



PHYSICS

UNDERGRADUATE WORK

The distinctive feature of the undergraduate work in physics at the California Institute is the creative atmosphere in which the student at once finds himself. This results from the combination of a large and very productive graduate school with a small and carefully selected undergraduate body.

Since the best education is that which comes from the contact of youth with creative and resourceful minds, the members of the staff of the Norman Bridge Laboratory of Physics have been from the beginning productive physicists dividing their time between basic research and teaching. The instruction in the freshman and sophomore years is done by the small group method, twenty to a section, save for one demonstration lecture every other week throughout the freshman and sophomore years. Most of the members of the staff participate in these lectures. The entering freshman thus makes some contact in his first year with many senior members of the staff, and he has the opportunity to maintain that contact throughout his four undergraduate years, and his graduate work as well, if he elects to go on to the higher degrees.

In order to provide the thorough training in physics required by those who are going into scientific or engineering work, two full years of general physics are required of all students. Those who desire to major in physics take during their junior and senior years intensive courses that provide a more than usually thorough preparation for graduate work. Elective courses during the junior and senior years provide flexibility which enables the student to select a program to fit his individual requirements. Many of the undergraduate students who elect physics are given also an opportunity to participate in some of the thirty to sixty research projects which are always underway and the graduate seminars are open to undergraduates at all times.

GRADUATE WORK

Graduate students working toward the Ph.D. degree should complete the requirements for admission to candidacy for the doctor's degree as soon as possible. (See page 198.) The courses required to be passed either regularly or by examination provide an unusually thorough grounding in the fundamentals of physics, and the student learns to use these principles in the solution of problems. After the first year of graduate work, students with special technical training will find it comparatively easy to obtain part-time work during the summer on one or another research projects in physics. Students so employed are also expected to register for 15 or more units of research.

The Norman Bridge Laboratory of Physics is equipped to carry on research in most of the principal fields of physics. An addition to this laboratory has been especially constructed for the work in cosmic rays and the study of elementary particles. Special facilities for research in nuclear physics are also provided in the W. K. Kellogg Radiation Laboratory which is equipped with three electrostatic generators and a variety of auxiliary equipment. The Alfred P. Sloan Laboratory of Mathematics and Physics will be open in the fall of 1960 with new laboratories for nuclear physics and a 10 Mev tandem electrostatic accelerator. There will also be new and enlarged facilities for work in the properties of matter at low temperature down to the milli-degree range. The Synchrotron Laboratory houses an electron accelerator which is now operating at energies up to 1.3 billion electron volts. Work in high-energy physics bridges the gap between the nuclear physics research in the Kellogg Laboratory and the cosmic ray and elementary particle investigations that have been carried on for many years in the Norman Bridge Laboratory. Special facilities are available in the Norman Bridge Laboratory for the precision investigation of X-rays and gamma rays and the study of beta ray spectra. Opportunities for study in theoretical physics in any one of a number of fields are particularly good for a limited number of students whose ability and background qualify them for theoretical work.

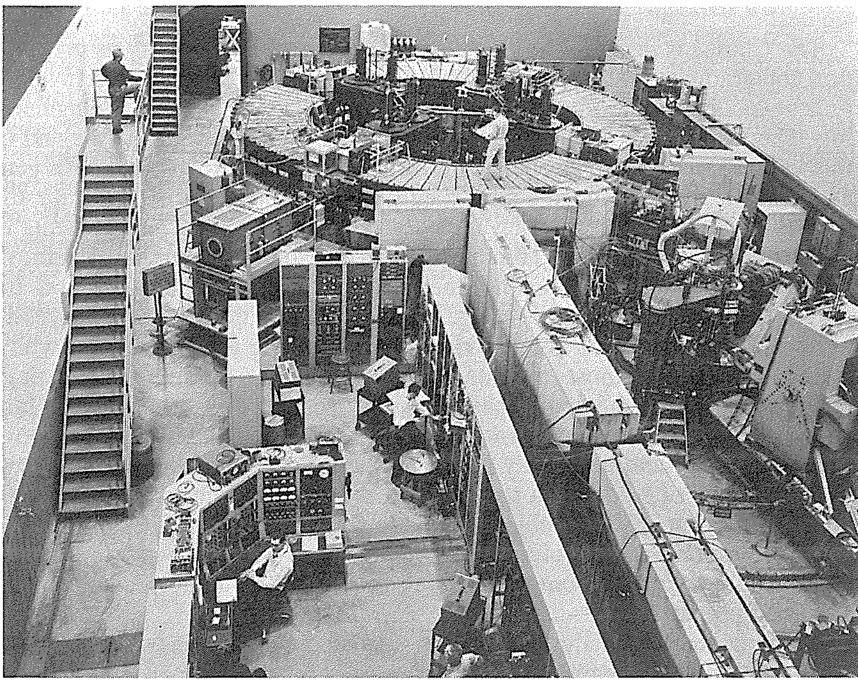
The student either may select his own problem in consultation with the department or may work into some one of the research projects already under way. The average yearly output of the laboratory for many years has been from fifty to sixty major papers.

There is a general seminar or research conference each week which is regularly attended by all research workers and graduate students. In addition, a weekly theoretical seminar is conducted for the benefit of those interested primarily in mathematical physics and there are several seminars on special fields of work such as nuclear physics, X-rays, and high energy physics.

For graduates in physics the main outlets are positions in colleges and universities, in the research laboratories of the government, and in the increasing number of industrial research laboratories of the country.

There is at present a continuing demand for physicists in the National Defense activities of the government, and many graduates are engaged in such work.

In order to make it possible for students to carry on their researches even after they have satisfied the requirements for the doctor's degree, a number of post-doctoral research fellowships are available.



The 1.3 billion-volt Caltech synchrotron is used to study the photoproduction of mesons and hyperons from the proton and neutron

2. Engineering

UNDERGRADUATE WORK

"The four-year Undergraduate Course in Engineering," as prescribed in the Educational Policies of the Institute, "shall be of general, fundamental character, with a minimum of specialization in the separate branches of engineering. It shall include an unusually thorough training in the basic sciences of physics, chemistry, and mathematics, and a large proportion of cultural studies."

The Course is designed to give the greatest possible flexibility as preparation for graduate study and for professional practice. The Course involves four years of study leading to the degree of Bachelor of Science in Engineering. The first year is common for all students at the Institute. At the end of this year a student who elects Engineering is assigned an Advisor in his general field of interest and together they develop a program of study for the next three years. This program includes the Institute-wide requirements in Physics, Mathematics and Humanities and an additional, or third year, of advanced mathematics. Beyond these specifications the student and his Advisor choose from a wide range of engineering and science electives to build a solid foundation for the kind of engineering activity toward which a student aims. For most students graduate study in a specialized branch of engineering will be the goal. These men may wish to elect some foreign language also as graduate preparation. For others, immediate industrial work is the objective, and ultimately administration. Such students will be able to build a course of study from specialized professional courses and more general engineering science subjects suitable for more immediate engineering practice. Among such professional courses are a number which are nominally graduate subjects but which may be elected by undergraduates with adequate preparation.

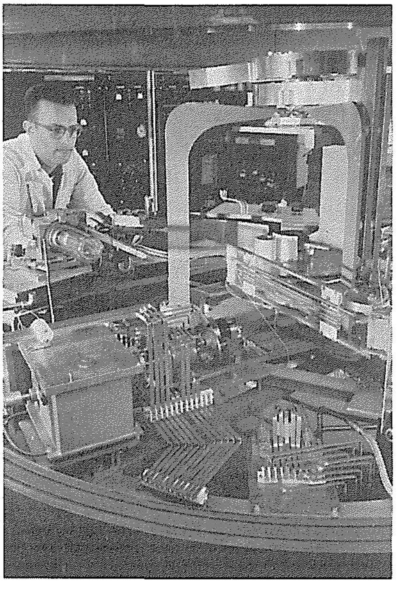
The engineering curriculum is thus extremely flexible and a student will be advised to seek breadth as well as reasonable concentration in a technical area. No one rigidly prescribed curriculum can serve the needs of all students. Nor do the traditional curricula of the specialized branches of engineering properly reflect the interdisciplinary character of modern engineering. Consequently the California Institute of Technology has adopted a single engineering curriculum strong in the sciences and humanities with great flexibility of choice among the engineering sciences. This four year bachelor's program leads logically toward graduate study in some specialized engineering field. It recognizes the increasing national growth in graduate engineering education and through good counseling and elective freedom builds an adequate preparation.

GRADUATE STUDY AND RESEARCH IN ENGINEERING

Graduate study and research opportunities in Engineering exist in aeronautics, civil, mechanical, electrical, and chemical engineering, with courses broadly outlined, leading to the degree of Master of Science. These courses normally require one year of work following the Bachelor's degree and are designed to prepare the engineer for professional work of more specialized and advanced nature. A sixth year leads to the degree of Aeronautical

Engineer, Chemical Engineer, Civil Engineer, Electrical Engineer, or Mechanical Engineer. In addition, advanced work is offered in Aeronautics, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, and Engineering Science leading to the degree of Doctor of Philosophy. In all phases of the graduate program students are encouraged to include in their courses of study a considerable amount of work outside of their specialized fields, particularly in mathematics and physics.

The Division of Engineering includes those curricula and facilities which are a part of the options of Civil, Electrical, Mechanical Engineering and Aeronautics and Engineering Science in which degrees designated with these options are given. In addition, the Division includes subjects and research facilities in which no specific degree is offered, but which form a part of a student's course of study or are available to him as optional work. These subjects are Applied Mechanics, Hydraulics and Hydrodynamics, Jet Propulsion, Nuclear Energy Technology, and Physical Metallurgy. Some of the specialized laboratory facilities available for instruction and research are the various wind tunnels, the Computer Center, which includes the Analog and Digtal Computers, the Dynamics Laboratory, a Nuclear Measurements Laboratory, and the several facilities for work in Hydraulic Structures, Hydrodynamics, Physical Metallurgy and Properties of materials.



A graduate student in mechanical engineering uses a high temperature spectrometer to study the X-ray diffraction patterns of metals

Aeronautics

The graduate school of Aeronautics and the Guggenheim Aeronautical Laboratory, widely known as the GALCIT, were established in 1928 at the California Institute with the aid of the Daniel Guggenheim Fund for the Promotion of Aeronautics. In 1948, a Jet Propulsion Center, to provide facilities for study in that field, was established by the Daniel and Florence Guggenheim Foundation (see page 127). The staffs of these three facilities are actively engaged in the fields of Aeronautics, Astronautics and the allied sciences. The following program of instruction at the postgraduate level and of advanced research is now in progress:

1. A comprehensive series of theoretical courses in aerodynamics, fluid mechanics (including magneto-hydrodynamics), dynamics and thermodynamics of space flight, elasticity and plasticity, with the underlying mathematics, mechanics, thermodynamics, and physics.

2. A group of practical courses in the fundamentals of design of aircraft, missiles and space vehicles conducted by the Institute's staff in cooperation with practicing engineers in the vicinity.

3. Experimental and theoretical researches on:

a. The basic problems of fluid mechanics with particular emphasis on the effects of viscosity, compressibility, low density, and electromagnetic fields.

b. The fundamentals of solid mechanics relating to the properties of materials and to the elastic or plastic behavior of structures and structural elements, primarily for aircraft, missiles, and space vehicles and their boosters.

c. The concepts of aeroelasticity in which the dynamical structural deformations are correlated with their attendant aerodynamic effects.

d. The performance, stability, and dynamical behavior of aircraft, guided missiles and space vehicles.

e. Problems in jet propulsion with special emphasis on the underlying fluid mechanics, thermodynamics, dynamics, and chemistry. (See page 127.)

The campus laboratory houses a wind tunnel of the closed circuit type with a working section 10 feet in diameter. A 750 horsepower motor and propeller produce test section wind velocities in excess of 200 miles per hour. A complete set of balances permits the rapid testing of aircraft models as well as the undertaking of many types of scientific investigation in this tunnel. A fluid mechanics laboratory contains several smaller wind tunnels and a considerable amount of auxiliary apparatus especially suitable for the study of the basic problems connected with turbulent flows. The problems of transonic, supersonic, and hypersonic flows may be investigated in other wind tunnels specifically designed for such purposes. In these tunnels, flow velocities up to approximately 10 times the velocity of sound may be studied. These tunnels are equipped with optical apparatus which can be used for the study of shock wave phenomena. Shock tubes and plasmajets are available for the study of extreme temperature, low density, and magnetohydrodynamic effects. A structures laboratory is equipped with standard and special testing machines for research in the field of aircraft structures. Fatigue machines are also available for investigating the fatigue properties of materials. Photoelastic equipment is available for the study of stress distribution by optical methods. The laboratory is also equipped with excellent shop facilities for the manufacture of testing equipment, an extensive reference library of books and periodicals on aeronautical and allied topics and research instrumentation.

An activity which had its origin at the GALCIT, and with which the Aeronautics Department continues to maintain close contact, is the Jet Propulsion Laboratory which has a staff of about 2700 persons of whom about 700 are professional engineers and scientists. The JPL is supported by the National Aeronautics and Space Administration and is administered under the auspices of the Institute. Its primary responsibility is the "development of operations of space craft for lunar and interplanetary exploration," which includes an extensive supporting research program on the fundamental problems of jet propulsion, missiles, and space vehicles, with emphasis on supersonic aerodynamics, fuels and combustion, high-temperature materials, rocket motor design, and electronic instrumentation for telemetering and missile guidance. Among the experimental facilities are: two supersonic wind tunnels (a 20-inch tunnel capable of speeds of 4.8 times the velocity of sound and a 21-inch hypersonic wind tunnel capable of speeds of 7 to 9 times sound velocity); over a dozen rocket and thermal jet test cells, large laboratories devoted to space sciences, refractory materials, hydraulics, instrumentation, chemistry, combustion, heat transfer; and a REAC electronic analog computer. The Laboratory extends the use of these facilities to properly accredited Institute students who are doing thesis work.

The facilities of the Institute are available to students working towards advanced degrees, and to qualified workers who wish to carry out researches in the fields outlined above. In some cases the off-campus facilities can also be made available for such purposes. A few fellowships can be granted to selected men.

As in the fields of physics, chemistry, and mathematics, emphasis is placed primarily upon the development of graduate study and research; but provision has also been made in the four-year undergraduate course in engineering for work leading to such graduate study and research. This affords a broad and thorough preparation in the basic science and engineering upon which aeronautics rests.

The graduate courses may be taken either by students who have completed a four-year course at the Institute, or by students from other colleges who have had substantially the same preparation. The field of aeronautics is so many-sided that a student who has completed the undergraduate course either in engineering or in applied science will be admitted to the fifth-year course. The sixth-year work, however, may be taken only by students who have completed the fifth-year course at the Institute or who have had substantially the same preparation elsewhere.

Still more advanced study and research are offered for the degree of Doctor of Philosophy. This degree is given under the same general conditions as those that obtain in the other courses offered at the Institute.

Chemical Engineering

(See pages 108-109)

Civil Engineering

In Civil Engineering instruction is offered leading to the degrees of Master of Science, Civil Engineer, and Doctor of Philosophy.

The fifth year of study at the Institute is organized to be a logical continuation of the first four years of study. The emphasis during the first four years at the Institute is on the basic subjects in science and engineering. In particular, strong emphasis is placed on physics, mathematics, and solid and fluid mechanics. The fifth year of study involves more specialized engineering subjects but the student is not encouraged to overspecialize in one particular field of civil engineering.

Greater specialization is provided by the work for the engineer's and for the doctor's degree. The candidate for these degrees is allowed wide latitude in selecting his program of studies, and is encouraged to elect related course work of advanced nature in the basic sciences. The engineer's degree of Civil Engineer is considered to be a terminal degree for the student who desires advanced training more highly specialized and with less emphasis on research than is appropriate to the degree of Doctor of Philosophy. Research leading to a thesis is required for the engineer's degree and for the doctor's degree.

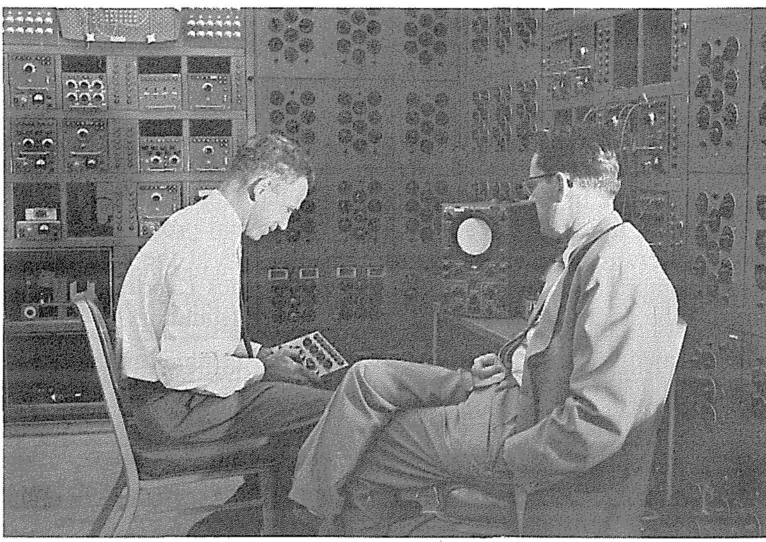
In some instances a student who has not specialized in civil engineering as an undergraduate will be admitted for graduate study in Civil Engineering if he intends to pursue a program of study leading toward the Civil Engineer or Ph.D. degree. As preparation for advanced study and research, a good four-year undergraduate program in mathematics and the sciences may be substituted for a four-year undergraduate engineering course with the approval of the faculty. The qualifications of each applicant will be considered individually, and, after being enrolled, the student will arrange his program in consultation with a member of the faculty. In some cases, the student may be required to make up deficiencies in undergraduate work. However, in every case the student will be urged to take some courses which will broaden his understanding of the overall field of civil engineering, as well as courses in his specialty. In addition, most graduate students are required to take further work in applied mathematics.

The general areas of civil engineering in which advanced work is offered are (1) structural engineering and applied mechanics, (2) soil mechanics and foundation engineering, (3) hydraulics (hydrodynamics, hydraulic engineering and hydrology), and (4) environmental health engineering. Emphasis is placed on the application of mathematics and basic scientific principles to the solution of civil engineering problems, and the student is discouraged from depending on handbooks and empirical formulas.

Excellent research facilities are available to qualified graduate students in all the fields above. Laboratories for structural engineering and soil mechanics are located in the Engineering Building. Hydraulic research is carried on in the Laboratory of Hydraulics and Water Resources which is located in the W. M. Keck Engineering Laboratories and is described in detail under the section "Hydrodynamics" below. The Laboratory for Environmental Health Engineering is also located in the W. M. Keck Engineering Laboratories, and some of this work is closely integrated with the research work in hydraulics and water resources.

In recent years, graduate students and members of the staff have pursued a variety of research programs such as analysis of structures subjected to dynamic loadings (such as earthquakes); compaction of soil by vibration; design criteria for various hydraulic structures; investigation of laws of sediment transportation by streams and settling in sedimentation tanks; water quality criteria; and sterilization of sewage.

Field trips to many unusual civil engineering works in this region are a regular part of the fifth-year program. The annual 6-day trip along the lower Colorado River during the spring vacation provides an unusually fine opportunity to inspect large hydraulic projects and to study the problems of integrated multiple-purpose development of a large river basin.



Electrical engineers use the analog computer to simulate such problems as aircraft flutter or ship vibrations

Electrical Engineering

In Electrical Engineering instruction is offered leading to the degrees of Master of Science, Electrical Engineer, and Doctor of Philosophy.

Electrical engineering affords opportunity for many choices of life work relating to research, design, production, operation, and management. Some phases of these activities and the commercial semi-technical phases of the electrical industry require only the preparation of the four-year course, but the better, or more normal, preparation for an electrical engineering career requires the completion of the five-year course leading to the degree, Master of Science.

The instruction pattern for electrical engineering is therefore designed on a five-year basis, the fifth year courses being open to qualified students who have completed the four-year engineering course for the Bachelor of Science degree from the Institute, or have had substantially the same preparation in other colleges.

Other fields of endeavor call for a knowledge of mathematics, physics, and electrical engineering in excess of that obtainable in the five-year curricula. To meet this need the Institute has provided courses of graduate study and research in electrical engineering leading to the degrees of Electrical Engineer and Doctor of Philosophy. These courses provide for advanced work in the application of mathematical analysis and physical laws to mechanical and electrical problems and may be taken by a limited number of exceptional students who have completed the five-year electrical engineering course at the Institute, or less frequently by students from other colleges who have substantially the same preparation.

The distinctive features of undergraduate work and graduate work in electrical engineering at the California Institute of Technology are the creative atmosphere in which the student finds himself and the large amount of physics and mathematics courses included in the engineering curricula. The graduate work in electrical engineering in particular brings graduate students into close touch with research men and current problems.

Of the several electrical engineering laboratories at the California Institute, the Computing Center, the Solid State Physics Laboratories, and the Electron Tube and Microwave Laboratory are outstanding.

The *Computing Center* provides comprehensive facilities for research and instruction in the development and application of large scale machine computation to the solution of the more complex mathematical problems of science and engineering. The computers in the laboratory include a large-scale direct analogy electric analog computer, a Burroughs 220 general purpose digital computer, LGP-30 digital computer, and several digital and analog computers developed by the Institute.

The Computing Center serves as a general service facility to all campus research requiring such mathematical aids.

The *Electron Tube and Microwave Laboratory* has special facilities for conducting research and instruction in the behavior of microwave electron tubes and broadly related fields. A small but complete laboratory for processing vacuum tubes of almost any kind is available. Microwave and low-frequency test equipment, which make it possible to conduct investigations in nearly any part of the frequency spectrum, are also available.

The *Antenna Laboratory* is devoted to theoretical and experimental studies of electromagnetic wave phenomena. It provides facilities for the investigation of basic problems arising principally, but not exclusively, from recent developments in antenna theory and design. A major part of the research program now in progress concerns the mathematical theory of diffraction, the propagation of waves in anisotropic inhomogeneous media, artificial dielectrics, broad-band antennas, and surface-wave antennas.

The *Solid State Physics Laboratory* has facilities for research in semiconductor materials and devices, ferromagnetism, and superconductivity.

A *Servomechanism Laboratory* has been established for instruction and research on feedback control systems. The facilities of this laboratory provide excellent opportunities for research leading to all graduate degrees. One important feature is an electric analog computer suitable for general mathematical analysis and detailed studies of control system components in a complete system.

Other laboratories and equipment for research work in electronics, communications, information theory, and circuit synthesis are available. Facilities for research in dynamo-electric machinery are also available.

Engineering Science

Advanced programs of study leading to the degree of Doctor of Philosophy in Engineering Science are offered by the Division of Engineering. These programs are complementary to those leading to the degrees of Doctor of Philosophy in Civil, Mechanical, Electrical, and Aeronautical Engineering and are designed to meet the needs of currently developing fields of engineering that are not included in the already established engineering disciplines. The general requirements for the doctorate in Engineering Science are similar to those for the degree in the other fields of engineering, including the completion of satisfactory thesis research. The fields of study may include topics in engineering and science, such as applied mechanics, fluid mechanics, physical metallurgy, reactor physics, and other applications of modern physics and chemistry to engineering.

Note: Students who have majored in physics, mathematics, or engineering science as undergraduates and who are applicants for AEC Special Fellowships in Nuclear Science and Engineering should apply for admission to graduate study in this option.

Mechanical Engineering

In Mechanical Engineering instruction is offered leading to the degrees of Master of Science, Mechanical Engineer, and Doctor of Philosophy.

The general program of instruction in mechanical engineering is organized on a five-year basis in which the fifth-year schedule is open to qualified students who have completed the four-year engineering course for the Bachelor of Science degree from the Institute, or have had substantially the same preparation in other colleges. The first four years at the Institute are concerned with basic subjects in science and engineering and in the humanities. The fifth year, therefore, is somewhat more specialized, with options in general mechanical engineering, jet propulsion, physical metallurgy, and nuclear engineering. A schedule of subjects is specified for each of the fifth-year options which may be modified by petition to the staff in mechanical engineering to satisfy the special interest of the student.

Determination of neutron flux distribution in a sub-critical nuclear reactor

Greater specialization is provided by the work for the engineer's or doctor's degree. The student is allowed considerable latitude in selecting his course of subjects, and is encouraged to elect related course work of advanced character in the basic sciences. The engineer's degree of Mechanical Engineer is considered as a terminal degree for the student who wishes to obtain advanced training more highly specialized than is appropriate to the degree of Doctor of Philosophy. Research work leading to a thesis is required for the engineer's degree and for the doctor's degree.

In advanced work in Mechanical Engineering facilities are provided in five general areas: (1) hydrodynamics, (2) design, mechanics, and dynamics, (3) physical metallurgy and mechanics of materials, (4) thermodynamics and heat power, and (5) nuclear energy. In hydrodynamics extensive facilities are available as described under a separate section of the catalog. A Dynamics Laboratory is provided for the study of problems in vibration, transient phenomena in mechanical systems, and experimental stress analysis by means of special mechanical and electronic equipment. Instruction and research in physical metallurgy is made possible by a well-equipped metallography laboratory in which alloys may be prepared, heat-treated, analyzed, and studied microscopically. Extensive laboratory facilities have been developed for the study of mechanics of materials, particularly under conditions of dynamic loading, which are located in a special laboratory. Work in the field of thermodynamics and heat power is implemented by laboratories containing internal combustion engines and heat-transfer apparatus. Work is in progress on certain phases of gas turbines which provides problems and facilities for research in this field.

An additional activity of interest to all advanced students in engineering is the Analysis Laboratory. This laboratory is built around an analog computer, which merges the various interests in applied mechanics, applied mathematics, and electrical engineering in the solution of problems. The computer is valuable not only for solution of specific research problems but also as research in itself in the development of new elements to extend the usefulness of the computer to more general mathematical analysis.

Close connections are maintained by the Mechanical Engineering staff with the many industries and governmental research agencies in the area which provide new, basic problems and facilities for study and research in the broad field of mechanical engineering.

GUGGENHEIM JET PROPULSION CENTER

During 1948 at the California Institute of Technology, a Jet Propulsion Center was established by the Daniel and Florence Guggenheim Foundation. This Center was created specifically to provide facilities for postgraduate education and research in jet propulsion and rocket engineering, with particular emphasis on peace-time uses. The objectives of this Center are to provide training in jet propulsion principles, to promote research and advanced thinking on rocket and jet-propulsion problems, and to be a center for peace-time commercial and scientific uses of rockets and jet propulsion. The Guggenheim Jet Propulsion Center is a part of the Division of Engineering of the California Institute of Technology. All instruction in the Guggenheim Center is on the graduate level.

The solution of the engineering problems in jet propulsion draws on the knowledge and practice of the older branches of engineering, in particular, mechanical engineering and aeronautics. Thus, it is proper that the program of instruction in jet propulsion include material from both of these engineering fields. In general, students entering the course work in jet propulsion will have had their undergraduate preparation in mechanical engineering or aeronautics, but the courses are also available to students whose preparation has been in engineering science and physics. For the complete program of instruction in jet propulsion there are two separate options, allowing men from both aeronautics and mechanical engineering to follow their previous inclinations and developments. The Mechanical Engineering option leads to the degree of Master of Science upon completion of the fifth-year program. For men in the Aeronautics Option, the degree of Aeronautical Engineer will be given upon completion of a sixth-year program. Similarly, the degree of Mechanical Engineer will be given to men upon the completion of the sixth-year program of the Mechanical Engineering Option.

Students from the Aeronautics Option may be admitted to work for the degree of Doctor of Philosophy in Aeronautics and a minor field. Students from the Mechanical Engineering Option may be admitted to work for the degree of Doctor of Philosophy in Mechanical Engineering and a minor field. No designation specifying the field of jet propulsion will be given. In addition, students admitted to work for the degree of Doctor of Philosophy in Engineering Science and a minor field may take part of their courses of instruction in jet propulsion and may choose a research problem in jet propulsion.

The facilities of the Institute, in particular those in Aeronautics and in Mechanical Engineering, as well as those of the Jet Propulsion Center are available to students working towards advance degrees. Under the present regulations, students who wish to use the facilities of the Jet Propulsion Laboratory must, however, first obtain clearance from the Armed Services.

HYDRODYNAMICS

Hydrodynamics and hydraulic engineering represent subjects in Fluid Mechanics which complement other Institute work in Aerodynamics and in which a vigorous program of research and instruction is maintained. While no specific degree in Hydrodynamics is given, advanced students in any of the several options of the Engineering Division may elect to do a thesis problem in this field. The several specialized laboratories provide excellent facilities for graduate student research.

Hydraulic Machinery Laboratory. This laboratory is designed for carrying out basic and precise research studies in the hydrodynamics of centrifugal and propeller pumps, turbines, and allied flow problems. Dynamometers with precision speed controls are available up to 450 horsepower output or input, and for speeds up to 5,000 r.p.m. Accurate instruments for measuring pressures, flow rates, speeds, and torques are provided. Special equipment for the study of cavitation has been developed. Special test facilities serve for the detailed study of flow characteristics of individual components of hydraulic machinery designed with the object of comparing the theoretical and actual flow patterns.

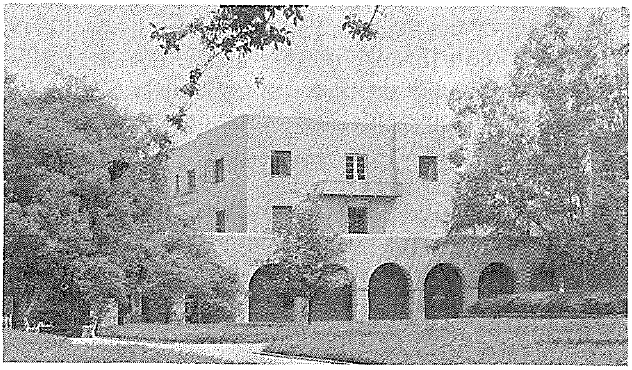
Hydrodynamics Laboratory. This laboratory is a three-story wing adjoining the Hydraulic Machinery Laboratory. Its equipment is designed for the determination of the dynamics of the motion of underwater bodies. Major research programs are now being carried on under the sponsorship of the Bureau of Ordnance of the Navy. The facilities are also available for graduate research. The equipment includes (a) a High Speed Water Tunnel with a 14-inch working section and velocities up to 100 feet per second, (b) a Free Surface Water Tunnel, (c) a large Controlled Atmosphere Launching Tank, and (d) a Polarized Light Flume. Force balance and pressure distribution measuring equipment are available for the tunnels. Much additional auxiliary equipment has been developed, including a flash-type motion picture camera for work up to 30,000 exposures per second. Well-equipped photographic dark rooms and a precision instrument shop are part of the laboratory facilities.

Special equipment for study of cavitation and wave propogation in fluids and solids has been developed. This includes a camera capable of one million six hundred thousand pictures per second at exposure times as short as 30 billionths of a second. Photoelastic and Schlieren photographs may also be taken with this device. Improved apparatus for studying cavitation damage and generating high frequency waves has been designed and constructed.

In the Hydrodynamics Laboratory, an investigator works on a fundamental flow problem in fluid mechanics

W. M. Keck Laboratory of Hydraulics and Water Resources. The recently completed laboratory building provides space and facilities for an expanded basic research program in the fields of sedimentation, hydraulic structures, coastal engineering, and flow through porous media. The main laboratory at sub-basement level occupies a floor space approximately 50 ft. x 200 ft. and contains (a) three tilting flumes for sedimentation studies ranging in size from 10 inches wide by 40 feet long to 42 inches wide by 130 feet long, (b) water tunnel with 12 in. x 12 in. working section, (c) glass-wall tank for settling tank studies, (d) constant level tank and a flexible water distribution system for general experiments, (e) complete equipment for analysis of sediments, (f) shops for constructing and maintaining research equipment, (g) laboratory facilities for teaching fluid mechanics and (h) workrooms for researchers and assistants. Two laboratory rooms at basement level are reserved for research in flow through porous media and for other studies which do not require large flows or apparatus. Space is also provided in the building for offices of the staff, graduate students and assistants.

Facilities of this laboratory are available to graduate students carrying out research required for the Engineer or Ph.D. degrees. Because these facilities are suitable for studying problems of interest to Civil Engineers they are used primarily by students in this group.



Dabney Hall of the Humanities

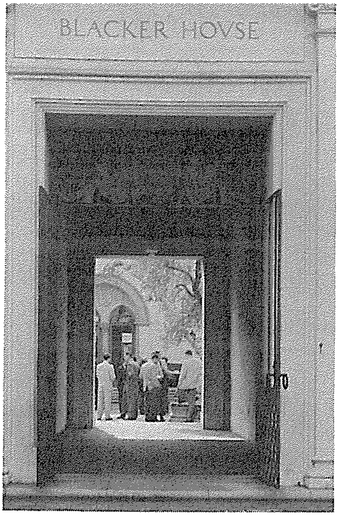
3. The Humanities

One of the distinctive features of the California Institute is its emphasis upon the humanistic side of the curriculum. The faculty is in thorough sympathy with this aim and gives full support to it. Every student is required to take, in each of his four undergraduate years, one or more humanistic courses. These courses in the Division of the Humanities include the subjects English and foreign literatures, European and American history, philosophy and social ethics, economics (including industrial relations), and government. All of them are so planned and articulated that the student obtains a solid ground and not merely the superficial acquaintance which is too often the outcome of a free elective system. The standards of intellectual performance in these studies are maintained on the same plane as in the professional subjects.

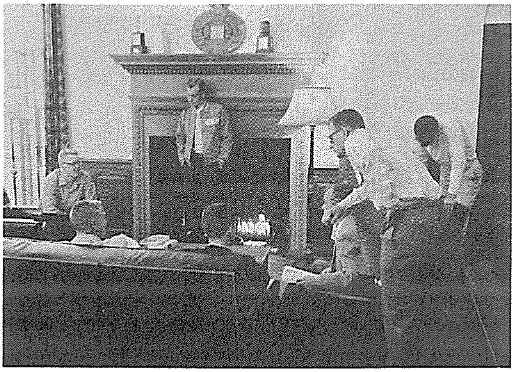
Ample quarters for the work in humanities are provided in Dabney Hall, which was given to the Institute by the late Mr. and Mrs. Joseph B. Dabney of Los Angeles as an evidence of their interest in the humanities program of the Institute and their desire to support it. Besides the usual class and lecture rooms, Dabney Hall of the Humanities contains a divisional library and reading room, offices for members of the humanities faculty, a Public Affairs Room, and a student lounge which opens upon a walled garden of olive trees.

In connection with the acceptance of the gift of Dabney Hall, a special fund of $400,000 for the support of instruction in the humanistic fields was subscribed by several friends of the Institute. In 1937 the late Mr. Edward S. Harkness gave the Institute an additional endowment fund of $750,000 for the same purpose.

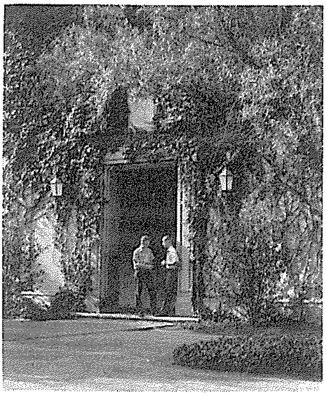
In addition to the regular staff of the Institute, scholars from other institutions give instruction or lectures in the Division of the Humanities. The proximity of the Huntington Library, with its unique opportunities for research in literature, history, and economics, is assurance that the instruction given at the Institute in these fields will continue in the future, as in the past, to be strengthened by the association of visiting scholars.



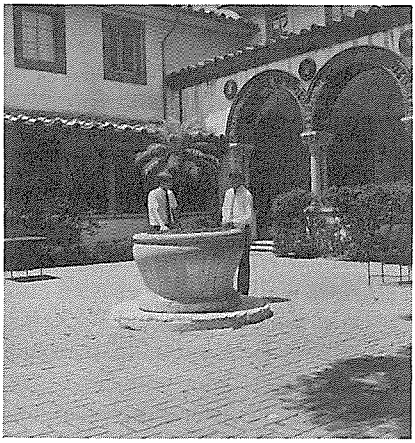
Blacker



Dabney

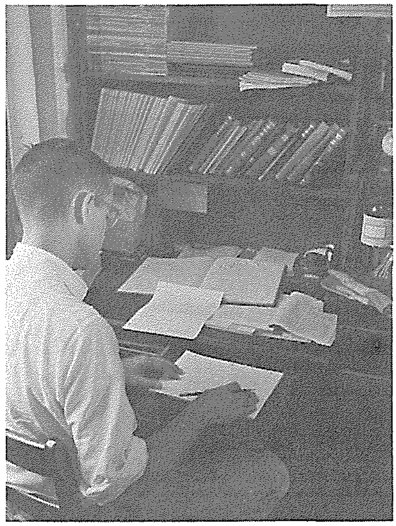


Fleming



Ricketts

The Student Houses are pleasantly located in the east campus



STUDENT LIFE

Student Houses. The seven Student Houses are situated on both sides of the Olive Walk near the eastern end of the campus. The original four—Blacker, Dabney, Fleming, and Ricketts—were built in 1931 from the plans of Mr. Gordon B. Kaufmann in the Mediterranean style to harmonize with the adjacent Athenaeum. The other three, designed by Smith, Powell, and Morgridge and generally consistent in appearance with the older group, were completed in 1960, and are as yet un-named. Each of the seven is a separate unit providing accommodations for about seventy-five students, with its own dining room and lounge.

All seven Houses have their own elective officers and are given wide powers in the matter of arranging their own social events, preserving their own traditions, and in promoting the general welfare. The immediate supervision of the activities of each House is the responsibility of the House Resident Associate, generally a graduate student or unmarried Faculty member. All Houses are under the general supervision and control of a member of the Faculty known as the Master of the Student Houses.

Since the demand for rooms often exceeds the supply, newly entering students are advised to file room applications with the Master of Student Houses immediately upon being notified by the Dean of Admissions of admittance to the Institute. All Freshmen are expected to live in the Houses. Those who have reason to believe they should live elsewhere should discuss the matter with the Dean of Freshmen. Students failing to obtain admission to the Student Houses, who wish to avoid commuting, can find comfortable rooms for rent in private homes near the Institute campus.

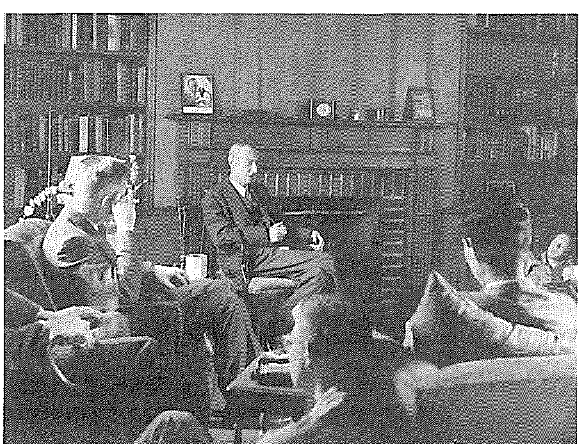
Off Campus Housing. The Housing Office, 203 Throop, maintains a file of listings for rooms, apartments, and houses. Assistance will be given upon arrival, but no arrangements or reservations can be accomplished in advance. If specific information is desired, it should be requested through this office, and not through the office of the Master of Student Houses.

Interhouse Activities. The presidents and vice-presidents of the Student Houses make up the Interhouse Committee, which determines matters of general policy for all seven organizations. While each sponsors independent activities, there is at least one joint dance held each year. The program of intramural sports is also carried on jointly. At present it includes touch football, softball, cross-country, swimming, basketball, tennis, track, and volleyball.

Interhouse Scholarship Trophy. A trophy for annual competition in Scholarship among the seven Student Houses has been provided by an anonymous donor. With the approval of the donor the trophy has been designated as a memorial to the late Colonel E. C. Goldsworthy who was Master of the Student Houses and commemorates his interest and effort in the field of undergraduate scholarship.

"*ASCIT.*" The undergraduate students are organized as the "Associated Students of the California Institute of Technology, Incorporated," (ASCIT). All students pay the student body fees and are automatically members of this organization, which deals with affairs of general student concern and with such matters as may be delegated to it by the faculty. Membership in the corporation entitles each student to (a) admission to all regular athletic or forensic contests in which Institute teams participate, (b) a subscription to The California Tech, (c) one vote in each corporate election, and (d) the right to hold a corporate office.

Board of Directors. The executive body of the ASCIT corporation is the Board of Directors, which is elected by the members in accordance with the provisions of the By-Laws. The Board interprets the By-Laws, makes awards for athletic and extra-curricular activities, authorizes expenditures from the corporation funds, and exercises all other powers in connection with the corporation not otherwise delegated.



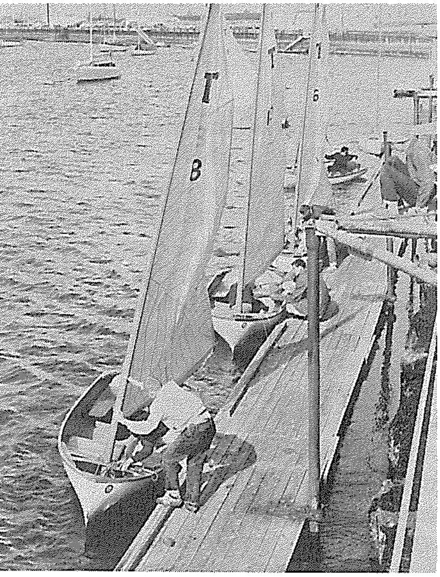
An informal discussion
with a distinguished visitor to the campus

Board of Control. The Honor System is the fundamental principle of conduct of all students. More than merely a code applying to conduct in examinations, it extends to all phases of campus life. It is the code of behavior governing all scholastic and extra-curricular activities, all relations among students, and all relations between students and faculty. The Honor System is the outstanding tradition of the student body, which accepts full responsibility for its operation. The Board of Control, which is composed of elected representatives from each of the four undergraduate classes, is charged with interpreting the Honor System. If any violations should occur, the Board of Control considers them and may recommend appropriate disciplinary measures to the Deans.

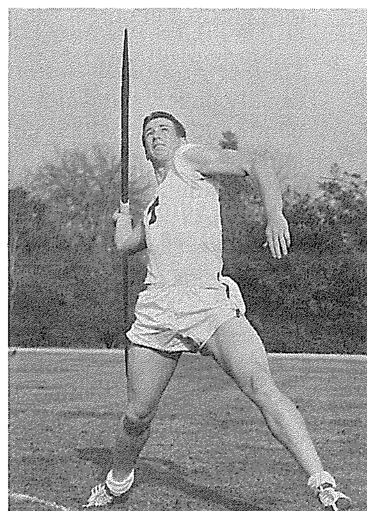
Faculty-Student Relations. Faculty-student coordination and cooperation with regard to campus affairs is secured through periodic joint meetings of the Faculty Committee on Student Relations and certain student body officers and elected representatives. These conferences serve as a clearing house for suggestions as to policy, organization, etc., originating with either students or faculty.

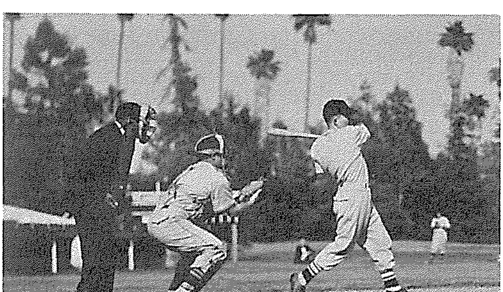
Option Advisers. Each member of the three undergraduate upper classes is assigned to an Option Adviser, a Faculty member in the option in which the student is enrolled. The adviser interests himself in the student's selection of optional courses, progress toward his degree, and, eventually, in assisting the student toward satisfactory placement in industry or in graduate school. Normally, the association between student and adviser, which is primarily professional, is established before the beginning of the sophomore year and continues through graduation.

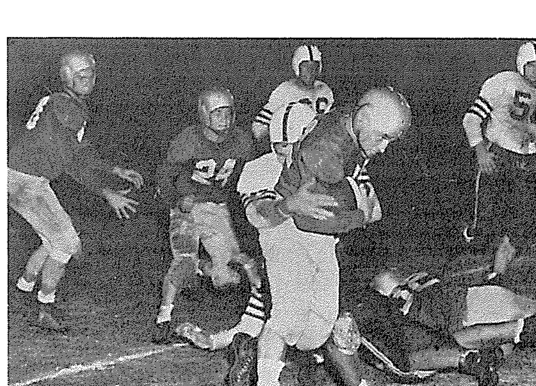
Athletics. The California Institute maintains a well-rounded program of athletics, and as a member of the Southern California Intercollegiate Athletic Conference, schedules contests in nine sports with the other members of the Conference—Occidental, Pomona, Redlands, Whittier, and Claremont-Harvey Mudd—as well as with many other neighboring colleges. In addition, the Caltech Sailing Club sails a fleet of Institute-owned dinghies based at Los Angeles Harbor.




53
55
56
51
54






24

The California Institute Athletic Field, of approximately twenty-three acres, includes football field, standard track, baseball stadium, and championship tennis courts. The Scott Brown Gymnasium and the Alumni Swimming Pool, completed early in 1955, provide attractive modern facilities for intercollegiate, intramural, or recreational competition in badminton, basketball, volleyball, swimming, and water polo. Funds for the pool were contributed by the Alumni of the California Institute; construction of the gymnasium was made possible through a bequest of the late Scott Brown.

The Institute sponsors an increasingly important program of intramural athletics. There is spirited competition among the five groups composed of the Student Houses and the Throop Club for the possession of three trophies. The Interhouse Trophy is awarded annually to the group securing the greatest number of points in intramural competition during the year. The Varsity and Freshman Rating Trophy is presented to the group having the greatest number of men participating in intercollegiate athletics. The third trophy, "Discobolus," is a bronze replica of Myron's famous statue of the discus thrower. "Discobolus" is a challenge trophy, subject to competition in any sport. It remains in the possession of one group only so long as that group can defeat the challengers of any of the other groups.

Student Body Publications. The publications of the student body include a weekly paper, the *California Tech;* an annual; a literary magazine; and a student handbook, which gives a survey of student activities and organizations and serves as a campus directory. These publications are staffed entirely by undergraduates. Through them ample opportunity is provided for any student who is interested in obtaining valuable experience not only in creative writing, art work, and in the journalistic fields of reporting and editing, but in the fields of advertising and business management as well.

Musical Activities. The Institute provides qualified directors and facilities for a band and glee club. A series of chamber music concerts is given on Sunday evenings in the lounge of Dabney Hall. The Musicale is an organization which encourages interest and appreciation for classical recordings. The extensive record library of the Institute provides opportunity for cultivation of this interest and for the presentation of public programs. From a special loan library, records may be borrowed for students' private use.

Student Societies and Clubs. There is at the Institute a range of undergraduate societies and clubs wide enough to satisfy the most varied interests. The American Institute of Electrical Engineers, the American Society of Civil Engineers, and the American Society of Mechanical Engineers all maintain active student branches.

The Institute has a chapter (California Beta) of Tau Beta Pi, the national scholarship honor society of engineering colleges. Each year the Tau Beta Pi chapter elects to membership students from the highest ranking eighth of the junior class and the highest fifth of the senior class.

The Institute also has a chapter of Pi Kappa Delta, the national forensic honor society. Members are elected annually from students who have represented the Institute in intercollegiate debate, or in oratorical or extempore speaking contests.

In addition to the national honorary fraternities there are four local honorary groups: the Beavers, membership in which is a recognition of service to the student body; the Varsity Club, which is composed of students who have earned letters in intercollegiate athletics; the Press Club, which elects members who are active in student publications; and the Drama Club, in which membership is conferred as an award for student dramatic talent. Another service group, the Instituters, is composed of those students who volunteer their assistance in support of various activities of general undergraduate interest.

Special interests and hobbies are provided for by the Chemistry, Mathematics, and Physics Clubs, the Radio Club, the Sailing Club, and the Ski Club. The Christian Fellowship Group, Christian Science Group, Episcopal Group, the Newman Club are organized on the basis of religious interests. The Inter-Nations Association is an organization composed of foreign students from various countries, as well as interested Americans. Its object is to make the students' stay at Caltech more valuable by introducing them to Americans, their customs and way of life. Conferences, weekly teas, and trips to points of interest in the vicinity are among the activities.

Student Shop. The Student Shop is located temporarily in quarters just southeast of the Sloan Laboratory. Ultimately it will be housed in the new Winnett Student Center. It was equipped by the Institute, largely through donations, and is operated by the students under faculty supervision. It has no connection with regular Institute activities, and exists only as a place where qualified students may work on private projects that require tools and equipment not otherwise available. All students are eligible to apply for membership in the Student Shop; applications are acted on by a governing committee of students. Members who are not proficient in power tools are limited to hand tools and bench work; however, instruction in power tools will be given as needed. Yearly dues are collected to provide for maintenance and replacement.

Speech Activities. Practical training in public speaking is the keynote of the Institute's forensic program. A variety of experiences ranging from intercollegiate debate tournaments to local speech events can be had by all who wish to improve their abilities. Debaters take part in an average of six intercollegate tournaments during the year. These tournaments, including extempore speaking, oratory, impromptu speaking and discussion, comprise such events as the Western Speech Association tournament, the regional Pi Kappa Delta tournament, and the annual Caltech invitational debate tournament held on the Institute's campus. Bi-annually the Institute is represented at the National Pi Kappa Delta Speech tournament. Local activities include the annual Conger Peace Prize oration contest, and the inter-house speech contest for the Lincoln trophy. Student toastmasters' clubs, panels, and students competing for public speaking prizes of the national engineering societies are given guidance.

Y.M.C.A. The California Institute Y.M.C.A. is a service organization whose purpose is to supplement a technical and scientific education with a program emphasizing social and religious values. The "Y" is one of the most active student organizations on the campus and welcomes as members all students taking an active part in its regular program of activities. The program includes weekly luncheon clubs, discussion groups which bring speakers representing many interests to the campus, forums and lectures, student-faculty firesides, inter-collegiate conferences, and work with local church groups. It also sponsors an annual freshman tea dance. The "Y" services to the student body include a used textbook exchange, a loan fund, an all-year calendar of student events and the use of the lounge and offices. Friends of the Institute "Y" have provided a residence near the campus for the executive secretary, especially built to accommodate informal meetings of discussion groups.

Bookstore. The Student Store serving students, faculty and staff is located on the ground floor of Throop Hall. The store, which is owned and operated by the Institute, carries a complete stock of required books and supplies, many reference books and many extra-curricular items—athletic supplies, stationery, fountain pens, etc. Net income from operation of the store is used for undergraduate scholarships and for payment of a dividend to the Associated Students for student body activities.

AIR FORCE RESERVE OFFICERS TRAINING CORPS

THE California Institute has a unit of the Air Force ROTC. Membership in the unit is voluntary. Students may join at any time up to the beginning of the Freshman third quarter, and all freshmen are eligible regardless of the academic option they plan to choose. Students with prior military service may be given credit for basic course. Students completing the 4-year program are commissioned 2nd Lieutenants in the Air Force Reserve, and will enter on active duty with the Air Force for the periods specified at time of graduation.

Students may enroll in any of four categories: Category I, flying training candidates; Category II, technical and scientific fields; Category III, administrative fields; and Category IV, veterans only. No test, either mental or physical, other than those necessary for entrance to the California Institute, are required to enter the basic course, which covers the first two years. Admission to the advanced course, covering the Junior and Senior years, is dependent upon passing a physical examination given by military authorities.

The basic course consists of one hour weekly in Leadership Laboratory (drill) in each academic quarter, and two hours weekly in AFROTC classrooms during the third quarter of the Freshman year and the first two quarters of the Sophomore year.

The advanced course consists of one hour weekly in Leadership Laboratory plus three hours of classroom work; however, Institute courses are acceptable for AFROTC substitutions so the net effect is that no academic overload results. This phase emphasizes leadership development, and instilling individual confidence and ability.

Students entering the basic course normally continue in the program through graduation. However, a student may voluntarily leave the program at any time prior to commissioning. Deferment from Selective Service is granted to all who remain in good standing with the Institute and AFROTC. Uniforms and textbooks are furnished. Students in the basic course receive no pay; those in the advanced course receive about $27.00 per month subsistence allowance.

For AFROTC course requirements for the first year see page 206.

Section III

INFORMATION AND REGULATIONS FOR THE GUIDANCE OF UNDERGRADUATE STUDENTS

REQUIREMENTS FOR ADMISSION TO UNDERGRADUATE STANDING

THE California Institute is not coeducational and applications are accepted from men students only. The academic year consists of one twelve-week term and two eleven-week terms, extending from late September until the middle of June. There are no summer sessions, except that graduate students are permitted to register for summer research. Undergraduates are admitted only once a year—in September. All undergraduates at the California Institute are expected to carry the regular program leading to the degrees of Bachelor of Science in Science or Bachelor of Science in Engineering. Special students who wish to take only certain subjects and are not seeking a degree cannot be accepted.

ADMISSION TO THE FRESHMAN CLASS

Students are selected from the group of applicants on the basis of (a) high grades in certain required high school subjects (b) results of the College Entrance Examination Board tests, and (c) recommendation forms, and a personal interview when this is feasible. The specific requirements in each of these groups are described below. An application fee of $10 is due at the time an application for admission is submitted. No application will be considered until this fee is paid. The fee is not refundable whether or not the applicant is admitted or cancels his application, but it is applied on the first term bills of those who are admitted and who register in September.

APPLICATION FOR ADMISSION

Two applications are needed. One, for admission, is made on a form furnished by the California Institute on request, and is returned directly to the Institute together with an application fee of $10. The other, to take examinations, may be secured by writing to the College Entrance Examination Board either in Los Angeles or Princeton (see below).

Completed admission application blanks, the $10 application fee, and high school records including courses that may be in progress must reach the Admissions Office not later than March 1, 1961. (Application to take entrance examinations must be made directly to the College Board at an earlier date, for which see page 140.)

Applicants living outside of the United States must submit their credentials by December 1, 1960.

Transcripts of records covering three and a half years of high school should be submitted as soon as the grades of the first semester of the senior year are available. Those attending schools which operate on the quarter system should submit records covering the first three years and the first quarter of the senior year. They must also arrange for a supplementary transcript showing the grades for the second quarter to be sent as soon as possible. Applicants must be sure to list in space provided on the application blank the subjects they will take throughout the senior year.

Arrangements to take the tests must be made by writing to the College Entrance Examination Board in advance of the closing dates and according to the instructions listed below.

HIGH SCHOOL CREDITS

Each applicant must be thoroughly prepared in at least fifteen units of preparatory work, each unit representing one year's work in a given subject in an approved high school at the rate of five recitations weekly. Each applicant must offer all of the units in Group A and at least five units in Group B.

Group A:	English	3
	Mathematics	4
	Physics	1
	Chemistry	1
	United States History and Government	1
Group B:	Foreign Languages, Shop, additional English, Geology, Biology or other Laboratory Science, History, Drawing, Commercial subjects, etc.	5

The three units of English are a minimum and four units are strongly recommended.

The four-year program in mathematics should cover the principal topics of first-year algebra, intermediate algebra, trigonometry, and plane geometry, preferably including the basic notions of solid geometry. An introduction to elementary analytic geometry and the calculus is desirable but not necessary.

The Admissions Committee recommends that the applicant's high school course include at least two years of foreign languages, a year of geology or biology, basic elementary shop work, and as much extra instruction in English grammar and composition as is available in the high school curriculum.

ENTRANCE EXAMINATIONS

In addition to the above credentials, all applicants for admission to the freshman class are required to take the following entrance examinations given by the College Entrance Examination Board: the Scholastic Aptitude Test (morning program); the afternoon program consisting of achievement tests in advanced mathematics and any two of the following: physics, chemistry, English. Note that the Scholastic Aptitude and the Advanced Mathematics tests must be taken, and that the choice lies only among physics, chemistry, and English of which two must be taken. No substitution of other tests can be permitted.

For admission in 1961 the Scholastic Aptitude Test must be taken no later than the February 4 College Board Test date and the Achievement Tests no later than the March 18 date. *It is important to note than no applicant can be considered with the original group to be admitted in 1961 who has not taken the Scholastic Aptitude Test by February 14 and the required Achievement Tests by March 18.* No exception can be made to the rule that all applicants must take these tests and no substitution of other tests for those listed above can be permitted.

Full information regarding the examinations of the College Entrance Examination Board is contained in the *Bulletin of Information* which may be obtained without charge by writing to the appropriate address given below. The tests are given at a large number of centers, but should any applicant be located more than 65 miles from a test center, special arrangements will be made to enable him to take the tests nearer home.

Applicants who wish to take the examinations in any of the following states, territories, or foreign areas should address their inquiries by mail to College Entrance Examination Board, P.O. Box 27896, Los Angeles 27. California:

Alaska	Nevada	Province of British Columbia
Arizona	New Mexico	Province of Manitoba
California	Oregon	Province of Saskatchewan
Colorado	Utah	Republic of Mexico
Hawaii	Washington	Australia
Idaho	Wyoming	Pacific Islands, including
Montana	Province of Alberta	Japan and Formosa

Candidates applying for examination in any state or foreign area not given above should write to College Entrance Examination Board, P.O. Box 592, Princeton, New Jersey.

Each examination application submitted for registration must be accompanied by the examination fee of $4 for the Scholastic Aptitude Test and $6 for the three Achievement Tests. Please note that the examination fee is *not* sent to the California Institute, but to the appropriate College Board office. The application fee of $10 is the only fee sent to the California Institute at the time an application is made.

For admission to the California Institute in 1961 a candidate has only two dates on which he can take the required Achievement Tests. These are December 3, 1960, and March 18, 1961. The Scholastic Aptitude Test may be taken on December 3 as well. Most applicants will find that they will be better prepared for the achievement tests if they wait until March 18. The College Board will offer the Scholastic Aptitude Test on January 14 and February 4 in addition, but no Achievement Tests will be offered on these latter dates. An applicant must be sure to put the California Institute's name in the appropriate blank on the College Board examination application form which he fills out for *each* of the dates he chooses.

All examination applications and fees should reach the appropriate office of the Board not later than the dates specified below.

To take tests on	*For examination centers located* In the United States, Canada, the Canal Zone, Mexico, or the West Indies, applications must be received by	*For examination centers located* In Europe, Asia, Africa, Central and South America, and Australia, applications must be received by
Dec. 3, 1960	November 5	October 15
Jan. 14, 1961 (Aptitude Test only)	December 17	November 26
Feb. 4, 1961 (Aptitude Test only)	January 7	December 17
Mar. 18, 1961	February 18	January 28

Candidates are urged to send in their examination applications and fees to the Board as early as possible, preferably at least several weeks before the closing date, since early registration allows time to clear up possible irregularities which might otherwise delay the issue of reports. Under no circumstances will an examination application be accepted if it is received at a Board office later than one week prior to the date of examination. No candidate will be permitted to register with the supervisor of an examination center at any time. Only properly registered candidates, holding tickets of admission to the centers at which they present themselves, will be admitted to the tests. Requests for transfer of examination center cannot be considered unless these reach the Board office at least one week prior to the date of the examination.

Please note that requests to take the examinations and all questions referring exclusively to the examinations are to be sent to the College Entrance Examination Board at the appropriate address as given above, and not to the California Institute.

PERSONAL INTERVIEWS AND RECOMMENDATION FORMS

By March 1, recommendation forms will be sent out for each applicant who has an application on file. These forms are sent directly to the principal or headmaster of the school which the applicant is attending, with the request that they be filled out and returned directly to the California Institute. These recommendation forms provide valuable information on candidates. The College Board scores, the last of which will be received by about April 15, provide further important data. Since, however, there are many more applicants to the California Institute than our facilities can accommodate, as much information as possible is desired on each candidate for admission. Wherever preliminary information shows that an applicant has a chance of gaining admission, an attempt is made to hold a personal interview with him at the school he is attending. It is not possible to visit all of the schools involved; but if a personal interview cannot be held, this in no way prejudices an applicant's chances of admission. The applicant has no responsibility with regard to the personal interview unless and until he receives a notice giving the time and date when a representative will visit his school. These visits occur beween March 15 and May 1.

NOTIFICATION OF ADMISSION

Final selections will ordinarily be made and the applicants notified of their admission or rejection well before May 24, 1961 which is the date before which most College Board member colleges have agreed that they will not require any candidate to give final notice of acceptance of admission or of a scholarship. Upon receipt of a notice of admission an applicant should immediately send in the registration fee of $10. In the event of subsequent cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute. Places in the entering class will not be held after May 24, if the applicant could reasonably be expected to have received notice of acceptance at least ten days before this date. Otherwise, places will be held not more than ten days after notification. When the registration fee has been received, each accepted applicant will be sent a registration card which will entitle him to register, provided his physical examination is satisfactory. The registration card should be presented at Dabney Hall Lounge on the date of registration.

Checks or money orders should be made payable to the California Institute of Technology.

ADVANCED PLACEMENT PROGRAM

A number of high schools and preparatory schools offer selected students the opportunity to accelerate and to take in the senior year one or more subjects which are taught at the college level and cover the material of a college course. The College Entrance Examination Board gives each year in May a set of Advanced Placement examinations covering this advanced work. The regulations governing Advanced Placement at the California Institute in the subjects concerned are as follows:

Chemistry. The freshman chemistry course now contains a good deal of material formerly given in the sophomore year and not usually covered in advanced placement courses in the schools. For this reason all freshmen must take the first term work (Chemistry 1 a). Those who took the College Board Advanced Placement examination in Chemistry and received a score of 5 or 4 and who received a grade of B or better in Chemistry 1 a may be excused from the lecture portion the last two terms (Chemistry 1 bc) if the advanced course they took in school covered the substantial equivalent of the work given here in these terms. They may also be excused from the laboratory portion of Chemistry 1 bc if they have covered the substantial equivalent, but it is less likely that they will have done so. Anyone who feels that prior to entrance he has covered the equivalent of the freshman chemistry but who has not taken the College Board Advanced Placement examination may take the California Institute transfer examination in chemistry covering the work of the freshman year. Units from which a student has been excused by reason of advanced placement courses must be made up before graduation and may be taken in any subject offered in any division for which the student has the necessary prerequisites, except that those who wish to major in chemistry or chemical engineering may be required to make up the units by additional work in chemistry.

English. No advanced placement or credit will be given in English because the freshman course at the Institute (En 1 abc) is an advanced course of a level formerly (before 1959-60) given in the junior year.

History. An entering freshman may be excused from freshman history (H 1 abc: History of European Civilization) on the basis of a one-year college-level course, completed with a high mark, and a high score in the College Advanced Placement examination in that subject; units must be made up by Advanced Placement in any of the Senior Humanities Electives. He may be excused from sophomore history and government (H 2 abc: History and Government of the United States) on the same basis; units must be made up by Advanced Placement in any of the Senior Humanities Electives. (Note: Because of a California State law requiring colleges to give instruction in the Constitution of the United States and of the State of California, it will be necessary for students to do a small amount of supplementary reading if they are excused from H 2 abc.)

Mathematics. An entering freshman who has achieved a sufficiently high score on the College Board Advanced Placement test in Mathematics will be sent during the summer a questionnaire concerning the advanced work in mathematics which he has taken. If an entering freshman believes that he has covered the equivalent of the first year mathematics but has not taken the College Board Advanced Placement test he may take the California Institute transfer mathematics examination covering the first year work. On the basis of the College Board test or the transfer examination and of the information in the questionnaire he may be placed in a special mathematics section which will cover some topics of the freshman course not usually touched on in advanced placement courses and will cover in addition the material of the first two terms of the sophomore year (Mathematics 2 ab). He will then take the third term sophomore work (Mathematics 2 c) in either the first or third terms of the sophomore year. In exceptional cases an entering freshman may be placed immediately in the sophomore course (Mathematics 2 abc). The special mathematics course in the freshman year is taken in place of the regular freshman Mathematics 1 abc and upon successful completion of this special course full credit is given for Mathematics 2 ab. Those who are permitted to enter immediately the sophomore Mathematics 2 abc will receive full credit for Mathematics 1 abc.

Physics. An entering freshman may apply for advanced standing in physics on the basis of the results of the College Board Advanced Placement test in physics or of the California Institute transfer physics examination covering the work of the first year. If he has been accorded a score of 5 or 4 on the Advanced Placement Calculus option Physics test or a satisfactory grade on the transfer examination he will be considered favorably for advanced work. Those who took the Non-calculus option test or who made a score of 3 on the Calculus option test must take the transfer examination if they wish to be considered for advanced work. Those with scores below 3 on the Advanced Placement test will not be considered for advanced work. Those with satisfactory scores on the Advanced Placement test or the transfer examination will consult with a member of the physics department and if the result of this interview is satisfactory they may enter the sophomore physics course (Physics 2 abc), but unless there are good reasons to the contrary they will be expected to take the freshman physics laboratory consisting of one 3-hour laboratory period per week amounting to 3 units per term. Credit for the remaining 27 units of freshman physics (9 units per term) will be granted only after satisfactory completion of the sophomore course. Those who commence Physics 2 abc but find the work is beyond their capacity at that time may drop back to Physics 1 abc without penalty.

NOTE: The Advanced Placement tests are in no way a substitute for the College Board aptitude and achievement tests at the ordinary high-school level required for admission. The latter are the only tests considered in granting freshman admission. After admission those who offer advanced credits and examinations will be considered for credit and advanced placement in the subjects involved.

PHYSICAL EXAMINATION

Prior to final acceptance for admission, each applicant is required to submit a report of physical examination on a form which will be sent him at the time he is notified of admission. It is the applicant's responsibility to have this form filled out by a Doctor of Medicine (M.D.) of his own choosing. (See page 157.) Admission is tentative pending such examination, and is subject to cancellation if the results of the examination are unsatisfactory.

Vaccination at the time of the examination is a requirement. Students will not be admitted unless the physical examination form bears evidence of such vaccination.

Students who have been on leave of absence for three terms or more must submit reports of a physical examination under the same conditions as for new students.

SCHOLARSHIPS AND LOANS

For information regarding scholarships for entering freshmen see pages 164-173. Note that there is a distinction between Honors at Entrance and scholarship grants and that the latter are awarded on the basis of financial need as well as high standing on the entrance examinations. No one can be considered for a scholarship grant who has not sent in a scholarship form according to the instructions on page 164. For information on tuition and other costs and on loans and the deferred payment plan see pages 160-163.

NEW STUDENT CAMP

All undergraduate students entering the Institute for the first time, either as freshmen or as transfer students, are required to attend the New Student Camp as part of the regular registration procedure. This meeting occupies three days of registration week preceding the fall term, and is usually held at Camp Radford, a large well-equipped camp owned by the city of Los Angeles and located in the San Bernardino mountains east of Redlands.

A large number of faculty members and student leaders attend the camp. During the three-day program the new students hear what life at the Institute is like. They learn what is expected of them and what aids are available to them to help them live up to these expectations. Because of the comparatively small student body and the pressure of work once academic activity starts, it is important both to the student and to the Institute that new students become, at the very beginning, part of a homogeneous group sharing a common understanding of purpose and a common agreement on intellectual and moral standards. The three days at the camp afford the best possible opportunity for achieving this necessary unity.

STUDENTS' DAY

The California Institute holds an annual invitational Students' Day on the first Saturday in December of each year. This popular event is conducted by invitation to allow a more intimate view of the work in the laboratories of science and engineering with the hope that this contact will assist the student in his choice of a future career. Science students and their teachers are invited, upon nomination by secondary schools throughout Southern California, to view exhibits of the work in the various Divisions of the Institute and to attend selected demonstration lectures given by students and faculty members. Student life on the campus is an important feature of Students' Day with the undergraduate student body serving as host and responsible for the actual operation under the direction of a joint faculty-student committee. To avoid overcrowding at the exhibits and lectures it is necessary to limit attendance at this event to those who have been selected by their schools and whose names have been sent to the Students' Day Committee in advance.

AIR FORCE ROTC

For details of admission to the AFROTC see page 138.

Admission to Upper Classes by Transfer From Other Institutions

The Institute admits to its upper classes (i.e., sophomore year and beyond) a limited number of able men who have made satisfactory records at other institutions of collegiate rank. In general only students whose grades, especially those in mathematics and science, are above average can expect to be permitted to take the entrance examinations.

A student who is admitted to the upper classes pursues a full course in engineering or in one of the options in science, leading to the degree of Bachelor of Science. The Institute has no special students. Men are admitted either as freshmen in accordance with the regulations set forth on pages 139-143 or as upper classmen in the manner described below. Those who have pursued college work elsewhere, but whose preparation is such that they have not had the substantial equivalent of the following freshman subjects, English, mathematics, and physics, will be classified as freshmen and should apply according to the instructions on pages 139-143. They may, however, receive credit for the subjects which have been completed in a satisfactory manner.

An applicant for admission must write to the Office of Admissions, California Institute of Technology, Pasadena, California stating his desire to transfer, his choice of engineering or one of the options in science, and the number of years of college he will have completed by the date of transfer. At the same time he must present a transcript of his record to date showing in detail the character of his previous training and the grades received both in high school and college. If the college transcript does not list subjects *and grades* for high school work, the applicant must see that his high school sends the Office of Admissions a transcript of this work. After the transcripts have been evaluated by the Admissions Office an application blank will be sent provided the grades and subjects on the transcripts meet the transfer requirements.

Please note that an application blank is not sent until the transcripts have been received and evaluated, and that the applicant must write a letter giving the information outlined in the preceding paragraph. Transcripts are held in the files until such a letter is received.

Application blanks must be on file in this office by April 15. Transcripts should, therefore, be sent no later than April 1. Applicants living in foreign countries must have applications and transcripts on file by March 1 at the latest and should understand that no information with regard to acceptance or rejection can be sent before June 20.

Applicants who are enrolled in a college at the time applications are made do not ordinarily complete the academic year until May or June. Such applicants should make sure that a list of subjects being taken during the final semester is included in the transcript sent for evaluation and that a supplementary transcript showing the grades for the final semester is sent at the end of the academic year as soon as these grades are available.

Before their admission to the upper classes of the Institute all students are required to take entrance examinations in mathematics, physics, and English composition covering the work for which they desire credit, except that in addition an examination in chemistry is required of those desiring to major in chemistry or chemical engineering. Students must offer courses, both professional and general, substantially the same as those required in the various years at the Institute (see pages 206-218) or make up their deficiencies as soon as possible after admission.

It is not possible to answer general questions regarding the acceptability of courses taken elsewhere. The nature of the work at the Institute is such as to demand that all courses offered for credit be scrutinized individually. Even when a transcript of record is submitted it is not always possible to tell whether the courses taken are equivalent to the work at the Institute. In case the standard of the work taken elsewhere is uncertain additional examinations may be required before the question of credit is finally determined.

Applicants are advised to read the descriptions of the freshman and sophomore courses, particularly those in physics, mathematics, and chemistry, and to note that the work in freshman mathematics includes differential and integral calculus, vector algebra and infinite series. If an entering sophomore has not had the last two topics he will enroll in a special section of the sophomore mathematics course. Note also the references to freshman and sophomore chemistry on page 148.

Two examinations of a comprehensive character are offered in each of the three subjects, mathematics, physics, and chemistry. One examination in each subject covers the work of the first year, the other examination that of the first and second years. Representative examination papers will be sent to approved applicants upon request. The English examination covers composition only and is the same, regardless of the level at which the applicant is seeking admission. The Institute courses for which those admitted will receive credit will be determined by the Committee on Admission to Upper Classes and the departments concerned on the basis of the applicants' previous records and of the results of their examinations.

It is not possible to give definite assurance that a transfer student entering the sophomore year will graduate in three years or that one entering as a junior will graduate in two years. Much depends on the amount and nature of the credit granted at the time a student registers in September and on the possibility of fitting deficiency make-ups into the regular schedule.

Applications will not be considered unless the applicant has had the substantial equivalent of the following courses—mathematics, physics, and English—given at the California Institute at the first-year level for sophomore standing, and at the first- and second-year levels for junior standing in the option of the applicant's choice.

The first-year chemistry course at the California Institute differs from those given at many other colleges because of the inclusion of a substantial amount of quantitative analysis in the laboratory work. A transfer student who has had a one-year college course in inorganic chemistry and qualitative analysis will be considered to have met the first year chemistry requirements provided, of course, that his grades have been satisfactory, except that those wishing to major in biology or chemistry will be required to take certain portions of freshman chemistry if they have not had the equivalent laboratory work elsewhere.

The transfer examination in chemistry is required only of those wishing to major in chemistry. For admission to the sophomore year this examination will cover general chemistry and qualitative analysis. The examination for admission to the third year is a comprehensive test covering general chemistry, qualitative and quantitative analysis. Transfer students entering the junior year in chemistry will be able to take the sophomore organic chemistry course during their first year at the Institute.

No application fee is charged in the case of transfer students, but only those whose records are good will be permitted to take the tests.

Applicants should not come to the Institute expecting to be admitted to the examinations, without first receiving definite permission to take them.

The schedule for the examinations for admission to upper classes September 21, 1961, is as follows:

Chemistry	(3 hours)	1:00 P.M.	June 2, 1961
English	(1 hour)	9:00 A.M.	June 3, 1961
Mathematics	(2 hours)	10:30 A.M.	June 3, 1961
Physics	(3 hours)	2:00 P.M.	June 3, 1961

No other examinations for admission to upper classes will be given in 1961.

Applicants residing at a distance may take the examinations under the supervision of their local college authorities, provided definite arrangements are made well in advance. Arrangements for examinations in absentia should include a letter to the Dean of Admissions from the person directing the tests stating that the required supervision will be given.

The attention of students planning to transfer to junior standing is called to the fact that, until they have satisfactorily completed three full terms of residence at the Institute, they are subject to the same scholastic requirements as are freshmen and sophomores. (See pages 152-156.) In addition, they should note that to be permitted to register for any science or engineering options during their junior and senior years they must meet the scholastic requirements of the divisions concerned. (See page 154.)

Physical examinations and vaccination are required as in the case of students entering the freshman class. (See page 145.) Admission is conditional upon a satisfactory report on the physical examination.

Transfer students are required to pay a registration fee of $10 upon notification of admission to the Institute. In the event of subsequent cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute. Transfer students are expected to attend the new Student Camp for information on which see page 145.

Scholarship grants for transfer students are awarded on the same basis as are those for freshmen; namely high standing on the entrance examinations and demonstrated financial need. To secure consideration for a scholarship a transfer student must file a special form which will be sent on request and must be completely filled out by the parent or guardian responsible for the applicant's support. This form must reach the Admissions Office no later than April 15, and no applicant will be considered for a scholarship grant who does not have such a form on file here by that date.

THE 3-2 PLAN

Arrangements exist between the California Institute and certain liberal arts colleges, whereby students enrolled in these liberal arts colleges may follow a certain prescribed course for the first three years and then transfer into the third year of one of the engineering options at the California Institute without further formality provided that they have the unqualified recommendation of the officials at the liberal arts college which they are attending. After satisfactorily completing in two years at the California Institute all remaining work required for a bachelor's degree in engineering they will be awarded a bachelor of arts degree by the college from which they transferred and a bachelor of science degree in engineering by the California Institute. Application for admission at the freshman level under this plan should be made to the liberal arts college.

The list of colleges with which these arrangements exist is as follows:

- Bowdoin College, Brunswick, Maine
- Brandeis University, Waltham, Massachusetts
- Grinnell College, Grinnell, Iowa
- Occidental College, Los Angeles, California
- Ohio Wesleyan University, Delaware, Ohio
- Pomona College, Claremont, California
- Reed College, Portland, Oregon
- Wesleyan University, Middletown, Connecticut
- Whitman College, Walla Walla, Washington

REGISTRATION REGULATIONS

	Registration Dates	*Fees Payable*	*Instruction Begins*
Freshman and Transfer Students	Sept. 22, 1960	Sept. 22, 1960	Sept. 27, 1960
Upperclassmen and Graduate Students	Sept. 26, 1960	Sept. 26, 1960	Sept. 27, 1960

For Second and Third Term dates refer to the Institute Calendar.

Fees for Late Registration

Registration is not complete until the student has personally turned in the necessary registration and class assignment cards for a program approved by his registration officer and has paid his tuition and other fees. A penalty fee of four dollars is assessed for failure to register on the scheduled date, and a similar fee is assessed for failure to pay fees within the specified dates. These requirements apply to all three terms.

Special Students

Applicants who wish to take a special program without working toward a degree are not accepted for undergraduate admission. Registered undergraduates who register for programs which make it appear that they are no longer candidates for a B.S. degree may be refused further registration by the Registration Committee.

Changes of Registration

All changes in registration must be reported to the Registrar's Office by the student. Such changes are governed by the last dates for adding or dropping courses as shown on the Institute calendar. A grade of F will be given in any course for which a student registers and which he does not either complete satisfactorily or drop. A course is considered dropped only after the student has turned in to the Registrar's Office a drop card properly filled out and signed by the instructor concerned and any other required persons. A student may not at any time withdraw from a course which is required for graduation in his option without permission of one of the Deans. Senior students must also have the approval of the Registrar. A student may not withdraw from a course after the last date for dropping courses without, in addition to his instructor's consent, the approval of the Registration Committee. A student may, with the consent of the instructor concerned, add a course after he has completed his regular registration provided the addition does not bring the total units for which he is registered above 58 including Physical Education or ROTC. To carry excess units he must obtain the recommendation of his Departmental Adviser and the approval of the Registration Committee (see page 156). A student may not add a course after the last date for adding courses without, in addition to his instructor's consent, the approval of the Registration Committee. Registration for added courses is complete only after a student has turned in to the Registrar's Office an add card properly filled out and signed by the instructor concerned. No credit will be given for a course for which a student has not properly registered.

General Regulations

Every student is expected to attend all classes and to satisfy the requirements in each of the courses in such ways as the instructor may determine.

Students are held responsible for any carelessness, willful destruction, or waste. At the close of the year, or upon the severance of their connection with any part of the work of the Institute, students are required to return immediately all locker keys and other Institute property.

It is taken for granted that students enter the Institute with serious purpose. The moral tone is exceptionally good; the honor system prevails in examinations, and in all student affairs. A student who is known to be engaging in immoral conduct or exercising a harmful influence on the student life of the Institute may be summarily dismissed, whatever be his scholastic standing.

Auditing of Courses

Persons not regularly enrolled in the Institute may, with the consent of the instructor in charge of the course and the Chairman of the Division concerned, be permitted to audit courses upon payment of a fee in the amount of $21.00 per term, per lecture hour. Registration cards for auditing of courses may be obtained in the Registrar's office. Regularly enrolled students and members of the Institute staff are not charged for auditing. No grades for auditors are turned in to the Registrar's office and no official record is kept of the result of work done.

SCHOLASTIC GRADING AND REQUIREMENTS

Scholastic Grading

The following system of grades is used to indicate the character of the student's work in his various subjects of study:

A denotes Excellent, B denotes Good, C denotes Satisfastory,* D denotes Poor, E denotes Conditioned, F denotes Failed, inc denotes Incomplete.

In addition, grades of A+ and A−, B+ and B−, C+ and C−, and D+ may, where appropriate, be used for undergraduates only.

In certain designated courses (see p. 153), the grade of "P" indicating Pass may be given, but it is not counted in computing grade-point average of an undergraduate student. The grade of "H" is a grade given for satisfactory completion of freshman honor elective courses and is not used in computing the grade-point average.

"Conditions" indicate deficiencies that may be made up without actually repeating the subject. Grade of "D" is given when the work is completed.

The grade "incomplete" is given only in case of sickness or other emergency which justifies the non-completion of the work at the usual time. An "*incomplete*" will be recorded only if the reasons for giving it are stated by the instructor on a form which will be sent with each grade sheet and only if, in the opinion of the appropriate committee (Registration Committee for Undergraduates, and Graduate Study for Graduate Students), the reasons justify an incomplete. If, in the opinion of the appropriate committee, the incomplete is not justified, a condition will be recorded.

An incomplete or a condition in any term's work must be removed during the next term in residence by the date fixed for the removal of conditions and incompletes. Each student receiving such grades should consult with his instructor at the beginning of his next term in residence. Any condition or incomplete not so removed automatically becomes a failure unless otherwise recommended in writing to the Registrar by the instructor prior to the date for removal of conditions and incompletes.

Failed means that no credit will be recorded for the course, the units, however, count in the student's grade-point average. He may register to repeat the subject in a subsequent term and receive credit without regard to his previous grade, the new registration and units being counted as for any other course. In special cases the Registration Committee may, with the instructor's approval, authorize the completing of a *failed* course by three 3-hour examinations, the units and new grade being recorded as in the event of repeating the subject. The original "F" and units for the course remain on the record and are counted in computing the grade-point average.

Scholastic Requirements

All undergraduates and Master of Science candidates are required to meet certain scholastic standards as outlined below. In addition, students who have been reinstated to senior standing after having failed to make the required number of credits in the junior year are subject to these scholastic requirements in the senior year.

Each course in the Institute is assigned a number of units corresponding to the total number of hours per week devoted to that subject, including

*Excepting that C— is considered poor.

classwork, laboratory, and the normal outside preparation.* *Credits* are awarded on the basis of the number of units multiplied by four if the grade received is "A," three if "B," two if "C," and one if "D"; thus, a student receiving a grade of "B" in a twelve-unit course receives 36 credits for this course.†

Credits are not given for work in physical education. The following system of grades is used: P denotes Passed, H denotes Intercollegiate Team Participation and F denotes Failed.

Grade-point average is computed by dividing the total number of credits earned in a term or an academic year by the total number of units taken in the corresponding period. Units for which a grade of 'F" has been received are counted, even though the "F" may have subsequently been removed. (See above.) Units and credits in military subjects taken by Air Force ROTC students are counted in computing grade-point average. Physical education units, and units for honor elective courses are not included in computing grade-point average. A grade of Pass may be given for courses bearing a number 200 or greater, for Ph 172 and Ph 177, for research conferences and undergraduate research, and is not used in computing the grade point average.

Ineligibility for registration. Any undergraduate student or Master's candidate is ineligible to register:

(a) If he fails during any one term to obtain a grade-point average of at least 1.4.

(b) If he fails to obtain a grade-point average of at least 1.9 for the academic year. A student who has completed at least three full terms of residence at the Institute and has been registered for his senior or Master's year shall no longer be subject to the requirement that he make a grade-point

TABLE OF CREDITS CORRESPONDING TO GRADE AND NUMBER OF UNITS

No. of Units	*Grade*											
	A+	A	A−	B+	B	B−	C+	C	C−	D+	D	F
1	4	4	4	3	3	3	2	2	2	1	1	0
2	9	8	7	7	6	5	5	4	3	3	2	0
3	13	12	11	10	9	8	7	6	5	4	3	0
4	17	16	15	13	12	11	9	8	7	5	4	0
5	22	20	18	17	15	13	12	10	8	7	5	0
6	26	24	22	20	18	16	14	12	10	8	6	0
7	30	28	26	23	21	19	16	14	12	9	7	0
8	35	32	29	27	24	21	19	16	13	11	8	0
9	39	36	33	30	27	24	21	18	15	12	9	0
10	43	40	37	33	30	27	23	20	17	13	10	0
11	48	44	40	37	33	29	26	22	18	15	11	0
12	52	48	44	40	36	32	28	24	20	16	12	0
13	56	52	48	43	39	35	30	26	22	17	13	0
14	61	56	51	47	42	37	33	28	23	19	14	0
15	65	60	55	50	45	40	35	30	25	20	15	0

*The units used at the California Institute may be reduced to semester hours by multiplying the Institute units by the fraction 2/9. Thus a twelve-unit course taken throughout the three terms of an academic year would total thirty-six Institute units or eight semester hours. If the course were taken for only one term, it would be the equivalent of 2.6 semester hours.

†For the assignment of credits to undergraduate grades with plus or minus designations see the following table.

average of at least 1.9 for the academic year except that a student who is *reinstated* to enter the senior year is subject to this requirement during his senior year. Seniors and Master's candidates are subject to the requirement that they must receive a grade-point average of at least 1.4 each term to be eligible for subsequent registration. (Special note should be made of the graduation requirement described below.)

(c) Any undergraduate student who is *reinstated* and who fails to make a grade-point average of at least 1.9 for the following term is ineligible to register.

(d) An undergraduate student is ineligible to register for any term if he fails during the preceding term to remove a deficiency in physical education from an earlier term.

A student ineligible for registration because of failure to meet the requirements stated in the preceding paragraphs may, if he desires, submit immediately to the appropriate Dean a petition for reinstatement, giving any reasons that may exist for his previous unsatisfactory work and stating any new conditions that may lead to better results. Each such application will be considered on its merits. If this is the first such occurrence the Dean can, after consultation with the student and examination of his record, reinstate him or at the Dean's discretion refer special cases to the Registration Committee. A reinstated student who again fails to fulfill the scholastic requirements for registration must petition the Registration Committee through the appropriate Dean. In any case the student may, if he wishes, appear before the committee and may at the discretion of the Dean be required to appear. A second reinstatement will be granted only under very exceptional conditions.

Deficiency. Any freshman whose grade-point average during a term falls between 1.4 and 1.9 must obtain the approval of the Dean of Freshmen before registering. Any upperclassman whose grade-point average during a term falls between 1.4 and 1.9 shall receive the usual letter of warning that his work is below the satisfactory minimum, but he shall not be required to obtain the approval of the Dean of Students before registering.

Leave of Absence. Leave of absence involving non-registration for one or more terms must be sought by written petition. Such leave up to one year can be granted by the appropriate Dean for a student whose grade-point average is 2.3 or more. Other petitions should be addressed to the Registration Committee, and the student must indicate the length of time, and the reasons, for which absence is requested. In case of brief absences from any given exercise, arrangements must be made with the instructor in charge.

Departmental regulations. Any student whose grade-point average (credits divided by units) is less than 1.9 in the subjects listed under his division* may, at the discretion of his department, be refused permission to continue

*The curriculum of the Institute is organized under six divisions, as follows:
Division of Physics, Mathematics and Astronomy.
Division of Chemistry and Chemical Engineering.
Division of Civil, Electrical and Mechanical Engineering, and Aeronautics.
Division of Geological Sciences.
Division of Biology.
Division of Humanities.

the work of that option. (See note at head of each option in schedules of undergraduate courses, for special departmental applications of this rule.) Such disbarment, however, does not prevent the student from continuing in some other option provided permission is obtained, or from repeating courses to raise his average in his original option.

Graduation requirement. To qualify for graduation a student must complete the prescribed work in the course in engineering or in some one option of the course in science with a passing grade in each required subject and with a grade-point average of 1.90. A grade of "F" in an elective course need not be made up, provided the student has received passing grades in enough other accepted units to satisfy the minimum total requirements of his option. In addition to the above requirement, a member of the Air Force ROTC unit must satisfactorily complete the basic course unless relieved of this obligation by the Air Force. If a member of the AFROTC has entered the advanced course or if he has at any time at the California Institute secured deferment under Selective Service by reason of his membership in the AFROTC, he must satisfactorily complete the AFROTC course and must accept a commission in the Air Force if one is offered unless excused from these obligations by action of the Air Force.

Graduation in the normally prescribed time. Any undergraduate student who fails to complete the requirements for graduation at the end of the normally prescribed time must petition the Registration Committee for approval to register for further work.

Residence Requirement. All transfer students who are candidates for the Bachelor of Science degree must complete at least one full year of residence in the undergraduate school at the Institute immediately preceding the completion of the requirements for graduation. At least ninety of the units taken must be in subjects in professional courses. A full year of residence is interpreted as meaning the equivalent of registration for three terms of not less than 49 units each.

Honor standing. At the close of each academic year the Committee on Undergraduate Scholarships and Honors awards Honor Standing to fifteen or twenty students in each of three classes remaining in residence. These awards are based on the scholastic records of the students. A list of these students attaining Honor Standing on the basis of their academic records for 1958-59 appears on page 312.

Graduation with honor. Graduation *with honor* will be granted a student who has received on the average throughout his course 130 credits per term which result from grades of "A" and "B" exclusively, provided also that he achieves such an average in the senior year. In addition, a student may be graduated with honor under joint recommendation of his division and the Committee on Undergraduate Scholarships and Honors and approval of the Faculty.

Term examinations will be held in all subjects unless the instructor in charge of any subject shall arrange otherwise. No student will be exempt from these examinations. Permission to take a term examination at other than the scheduled time will be given only in the case of sickness or other emergency and upon the approval of the instructor in charge and of one of the Deans. A form for applying for such permission may be obtained in the Registrar's Office. Another form must be filled out when conflicts exist in a student's examination schedule. It is the student's responsibility to report the conflict to the instructor in charge of one of the conflicting examinations and to request the instructor to leave a copy of the examination in the Registrar's Office to be given at the time and place scheduled for conflict examinations.

Excess or fewer than normal units. Undergraduates who wish to register in any term for more than 58 units inclusive of Physical Education or Air Science must obtain the recommendation of the Option Adviser and the approval of the Registration Committee. Master's candidates, see page 179.

Registration for fewer than 33 units must be approved by the Registration Committee. See page 177 for Graduate Students.

Freshman honor electives. A freshman with a grade-point average for the previous term greater than 1.9 may register in the second or third term for one "Honor Elective" (3 units) in one field, providing he earned at least a B— the previous term in the prescribed course in the chosen field or obtains the approval of the instructor in such course. Registration for an "Honor Elective" is entirely voluntary. If satisfactory work is done, a grade of "H" will be recorded and three units of credit will be allotted on the record; however, these units will not be included in the computation of grade-point average.

Selection of course and option. Students who wish to enter one of the options in science must select their options and notify the Registrar's Office thereof shortly before the close of the freshman year. Students who wish to enter the engineering course must also notify the Registrar's Office thereof shortly before the close of the freshman year and should select some specialty in engineering.

Graduation in two different options. Students who wish to receive a second degree of Bachelor of Science in another option are required to have one additional year of residence (three terms of study involving at least 45 units per term) beyond the first Bachelor of Science degree.

Candidacy for the Bachelor's Degree

A student must file with the Registrar a declaration of his candidacy for the degree of Bachelor of Science on or before the first Monday of November preceding the date at which he expects to receive the degree. His record at the end of that term must show that he is not more than 21 units behind the requirement in the regular work of his course as of that date. All subjects required for graduation, with the exception of those for which the candidate is registered during the last term of his study, must be completed by the second Monday of May preceding commencement.

STUDENT HEALTH AND PHYSICAL EDUCATION

Physical Education

All undergraduate students except members of the Air Force ROTC are required to participate in some form of physical training for at least one hour a day three days a week. This requirement may be satisfied by engaging in organized sports, which include both intercollegiate and intramural athletics, or by regular attendance at physical education classes. Men who drop Air Force ROTC are required to register for Physical Education immediately.

Men may be excused from the requirement of physical education by petitioning the Physical Education Committee for such excuse when they become 24 years of age, or can show credit for 4 years of P.E. at the college level. It is the responsibility of students who wish to be excused and who are eligible under this ruling to make application for excuse at the Athletic Office.

For Graduate Students there is no required work in physical education, but opportunities are provided for recreational exercise.

Student Health

PHYSICAL EXAMINATION AND VACCINATION

All admissions, whether graduate or undergraduate, are conditional until a report of physical examination and vaccination is received and approved by the Director of Student Health. See page 145.

THE DISPENSARY AND INFIRMARY

The new Archibald Young Health Center is located on Arden Road, 50 feet south of California Street and opposite the Student Houses. The services offered by the dispensary are available to graduate students, undergraduate students, and faculty. The service offered to employees is for emergencies only and not for continuing care. Only graduate and undergraduate students (and male employees for emergencies) are admitted to the infirmary. Ten beds are maintained and six emergency beds are available in the infirmary.

The staff consists of attending physicians, retained consultants, and nurses. A medical consultant in radiological safety is on the consulting staff. Diagnostic psychiatric and psychologic service is provided with limited treatment opportunity. Long term or cases requiring sanitarium care are referred to private outside physicians.

The infirmary is operated twenty-four hours a day, seven days a week during the academic year except during holidays (Thanksgiving, Christmas and spring recess). The dispensary is open during the academic year from 9 a.m. to 5 p.m. Monday through Friday, and 9 a.m. to noon on Saturday. During the vacation periods, a somewhat restricted dispensary service is offered.

General office medical care is provided, minor emergency surgery is performed, and complete laboratory facilities are available at the dispensary through the Pasadena Clinical Laboratory. Close co-operaton is maintained with medical specialists in all fields in the community of Pasadena. The services of these doctors are used freely in maintaining high standards of modern medical care. The medical services do not include optometric or dental care.

EMERGENCY HEALTH SERVICES

Over and above the routine medical services available to students at the Health Center, the Institute maintains and supervises a fund to assist both undergraduate and graduate students in meeting the costs of emergency medical, surgical, and hospitalization services in case of an accident or illness. The funds that allow the Institute to support this phase of its health program are derived from the Emergency Health Fund to which the following regulations appertain:

1. The sum of ten dollars of the student's tuition is annually credited to a special account. The Institute, as the custodian, invests these funds and credits the Emergency Health Fund with the income earned. The Fund will not be used for any other purpose than for the payment of the student's medical, surgical, and hospital expenses, including infirmary charges. Whether a case is one within the scope of the Fund will be decided by the Medical Director in consultation with the Faculty Committee on Student Health.

Whenever the expenses for emergency care in any one fiscal year are less than the total deposited in the account for that year, the balance remaining shall be kept in the Fund, and shall remain invested. A balance kept over from one year will be used to render emergency medical and surgical aid to students in later years. The Fund is now stabilized at near $20,000.

2. The Fund is not, in general, applicable to accidents, as distinguished from other emergency medical conditions, which occur away from the grounds of the Institute, unless these occur during authorized activities of the Institute.

3. Each student is insured up to $500 in case of an accident suffered while on Institute property or while engaged in a recognized Institute activity. This coverage is provided by a policy contracted by the Institute and financed by the Emergency Health Fund.

4. The Fund does not cover conditions requiring treatment which arise during the vacation period.

5. The Fund does not cover conditions which existed at the time of admission to the Institute; nor does it cover chronic disease conditions which may develop while the student is at the Institute.

6. The Fund does not cover injuries incurred in connection with authorized inter-collegiate athletics. However, the student is aided by the Department of Physical Education in defraying the cost of any treatment required for such injuries. The normal maximum allowance of a single injury is $250. However, at the discretion of the Physical Education Committee, this maximum may be increased, for any one injury, to an amount not exceeding $500.

7. The Fund does not provide for the families of graduate or undergraduate students.

8. The maximum that has been allowed from the Fund for any one illness or injury is $250, but the Fund is not obligated to pay this maximum, nor is there any obligation to pay for such expenses beyond the available balance of the Fund. The Faculty Committee on Student Health reviews each case

with the Medical Director and determines the amount of assistance to be granted from the Fund.

ELIGIBLE EXPENSES

1. The cost of a student's stay in the infirmary is charged to the Emergency Health Fund.

2. The costs of all medical and surgical services and hospitalization which need to be secured outside of the infirmary and dispensary are the responsibility of the student, although the Fund may help defray these costs.

3. Accidents occurring off the campus and out of the jurisdiction of the Institute (e.g. non-authorized athletics or automobile accidents) may be cared for in the infirmary but the charges will be borne by the student.

4. Medical services not falling within the purview of the Institute's health program may be obtained by students on a non-profit basis at the infirmary. A schedule of charges for cost of medicines, injections, and laboratory work is posted in the dispensary.

SUMMER HEALTH COVERAGE

By action of the Board of Trustees, all students registered for summer work will be charged a Health Fee of about $2.00. This will make them eligible for benefits from the Emergency Health Fund to assist in defraying expenses contracted during the summer vacation period between Commencement Day in June and Registration Day in September for treatment and hospitalization necessitated by accidental bodily injury while on the Institute campus or while participating in school activities.

During the summer vacation, graduate and undergraduate students pay a fee of $2.00 per visit to the Health Center, plus cost of medicine and laboratory services.

RESPONSIBILITY OF THE STUDENT

The responsibility for securing adequate medical attention in any contingency, whether an emergency or not, is solely that of the student, whether the student is residing on or off campus. Apart from providing the opportunity for consultation and treatment at the dispensary and infirmary as described above, the Institute bears no responsibility for providing medical attention.

Any expenses incurred in securing medical advice and attention in any case are entirely the responsibility of the student, except as specified above.

EXPENSES

ANNUAL EXPENSE SUMMARY

I. Undergraduate Students

*Registration Fee (freshmen and transfer students)		$ 10.00	
Tuition (3 terms)		1,275.00	
General Deposit		25.00	
Student Body Dues		19.00	
Subscription to California Tech		1.50	
Books and Supplies (approx.)		80.00	
Total for Academic Year			$1,410.50
Student House Living Expenses	Board $520.00		
	Room $365.00	885.00	
	Dues	21.00	906.00
Total for Academic Year with Board and Room			$2,316.50

II. Graduate Students

Tuition (3 terms)	1,275.00	
General Deposit	25.00	
Books and Supplies (approx.)	80.00	
Total for Academic Year		$1,380.00

*For freshmen applying for admission, there well be a $10.00 Application Fee, not refundable, but applicable, upon registration to the Tuition Fee.

The following is a list of Student Expenses at the California Institute of Technology for the Academic Year 1960-61, together with the dates on which the various fees are due. These charges are subject to change at the discretion of the Institute.

Undergraduate Students

Date Due			*Fee*
Upon notification of admission	Registration Fee		$ 10.00[1]
Sept. 22, 1960: Freshmen and transfer students	General Breakage Deposit		25.00
	Tuition, 1st term		425.00
Sept. 26, 1960: All others	Board and Room, 1st term 21 meals per week		318.00[2]
	First Term Incidental Fees:		
	Associated Student Body Dues	5.50	
	Subscription to Calif. Tech for 1960-61	1.50	
	Total		7.00
	Student House Dues, 1st term		7.00
January 3, 1961	Tuition, 2nd term		425.00
	Board and Room, 2nd term 21 meals per week		288.00[2]

	Second Term Incidental Fees:		
	Associated Student Body Dues		6.75
	Student House Dues, 2nd term		7.00
March 27, 1961	Tuition, 3rd term		425.00
	Board and Room, 3rd term 21 meals per week		279.00[2]
	Third Term Incidental Fees:		
	Associated Student Body Dues		6.75
	Student House Dues, 3rd term		7.00

Graduate Students

	First Term:		
September 26, 1960	Tuition	425.00	
	General Deposit (see page 162)	25.00	
	Second Term:		
January 3, 1961	Tuition	425.00	
	Third Term:		
March 27, 1961	Tuition	425.00	
	*Summer Health Fee	1.00	
Total for Academic Year			1,301.00

Tuition Fees for fewer than normal number of units:

- Over 32 units Full Tuition[3]
- 32 to 25 units .... $318.75 per term
- 24 to 10 units .... $12.75 per unit per term
- Minimum per term .... $127.50[4]
- Auditor's Fee .... $21.00 per term, per lecture hour

*A Health Fee of $1 will be charged to all students taking summer research.

Withdrawals: Students withdrawing from the Institute during the first three weeks of a term, for reasons deemed satisfactory to the Institute, are entitled to a refund of tuition fees paid, less a reduction of 20% and a pro rata charge for time in attendance.[5] No portion of the Student Body Dues, or Subscription to California Tech, is refundable upon withdrawal at any time.

[1] Paid by all freshmen and transfer students (veteran and non-veteran); constitutes fee to cover expense of New Student Camp. Not refundable if admission cancelled by applicant.

[2] There are a few large single rooms available in the new houses which will rent for $425.00 per year. Rates for room and board subject to revision prior to beginning of any term upon notice to student.

[3] Although the Institute charges full tuition for over 32 units, the Veterans Administration allows the following subsistence percentages: 25% for 10 through 20 units per term; 50% for 21 through 29; 75% for 30 through 41; and 100% for 42 and over. See footnote page 201.

[4] Graduate Students see pages 177-178.

[5] Pro rata refunds are allowed students who are drafted (not volunteers) at any time in the term provided the period in attendance is insufficient to entitle student to receive final grades.

Associated Student Body Fee. The Associated Student Body Fee of $19.00 is payable by all undergraduate students. This fee is used for the support of athletics, the BIG T, and any other student activity that the Board of Directors of the Associated Students of the California Institute of Technology may deem necessary. The subscription to the CALIFORNIA TECH, $1.50 per year, is collected from every undergraduate.

General Deposit. Each student is required to make a general deposit of $25, to cover possible loss and/or damage of Institute property. Upon his graduation or withdrawal from the Institute, any remaining balance of the deposit will be refunded.

Student Houses. Students in the Houses must supply their own blankets but bed linen and towels are furnished and laundered by the Institute.

Application for rooms in the Student Houses may be made by addressing the Master of Student Houses.

Special Fees. Students taking the Spring Field Trip in Geology (Ge 122) and the Summer Field Geology course (Ge 123) are charged for travel at an estimated rate of one cent per automobile mile plus reasonable subsistence expense.

The fee for auditing courses (see page 151) is $21.00 per term, per lecture hour.

Unpaid Bills. All bills owed the Institute must be paid when due. Any student whose bills are delinquent may be refused registration for the term following that in which the delinquency occurs. Students who have not made satisfactory arrangements regarding bills due and other indebtedness to the Institute by the date of graduation will be refused graduation.

Loans. Loans are available to members of all undergraduate classes including entering freshmen. They are made upon application subject to the approval of the Faculty Committee on Student Aid and the extent of the available funds. There are two sources of loan funds and the conditions governing each are described below.

California Institute loan funds are available in amounts not to exceed $500 in any one year and a maximum of $2000 during undergraduate residence. No interest is charged and no repayment of principal is required during undergraduate residence as long as residence is continuous (the term "residence" includes the usual vacation periods). For those who do not go on to graduate school repayment commences after the graduation of the class of which the borrower has been a member and is at the rate of $50 a month including simple interest at 4 per cent per annum on the unpaid balance. For those who go on to graduate school at Caltech or elsewhere no later than the fall following their class's graduation, interest is charged at the rate of 3 per cent per annum but no repayment on principal is required until the final advanced degree is earned provided that the borrower remains in continuous residence. After the final degree has been earned repayment commences at the rate of $50 a month including interest at 4 per cent on the unpaid balance. If the borrower withdraws from undergraduate or graduate registration at any time before receiving the degree for which he has been working, the total amount owed the Institute becomes due and payable at once unless the Committee on Student Aid agrees to some exception to this rule.

Federal loans under the National Defense Education Act are available in amounts not to exceed $1000 for any individual in a single year up to a total of $5000. The borrower must demonstrate financial need, must be an above average student and must be willing to sign a loyalty oath and an affidavit that he neither believes in, is a member of or supports any organization that advocates overthrow of the United States government by violence or any illegal or unconstitutional means. No interest is charged on these loans nor is any repayment of principal required until one year after the final degree has been earned. At that time repayment commences and interest is charged at the rate of 3 per cent per annum on the unpaid balance.

To the extent of available funds students who wish to borrow and who meet the stipulated requirements will be given their choice of the foregoing sources of loans.

Deferred Payment Plan. In addition to loans there is available a plan under which any student in good standing may defer up to $1000 of his college bills each year to a total of $4000 and may pay the deferred portion in installments after the graduation of his class. The sum of $38.00 a year is added to the deferred portion and represents the premiums on a life insurance policy in the amount of any balance due the Institute under this plan. The insurance policy covers the life of the student for the duration of the obligation, and during the four undergraduate years it covers in addition the life of the parent or guardian responsible for the student's support. Interest on the amount deferred is charged at the rate of 6 per cent per annum payable quarterly. The interest is the only payment made on this plan during the undergraduate years. The interest payments are as follows: freshman year $46.71, sophomore year $108.99, junior year $171.27, senior year $233.55. Commencing November 1 following his class's graduation the student commences repayment on the deferred portion at the rate of $55 a month including interest at 6 per cent on the unpaid balance. For those who go on to graduate school more favorable repayment arrangements may be made for the duration of graduate work. As in the case of loans, the total of any balance owed the Institute under this plan becomes due and payable at once if continuous residence is not maintained unless in the opinion of the Committee on Student Aid some exception to this rule should be made.

Loans and the Deferred Payment Plan may not be used in combination and the total that may be borrowed or deferred may not exceed $1000 in any year.

Entirely aside from loans and the Deferred Payment Plan a student may arrange with the business office to pay his college bills monthly rather than at the beginning of each term as is customary. No interest is charged on such monthly payments, but arrangements with the business office must be made in advance.

SCHOLARSHIPS, STUDENT AID, AND PRIZES*

Freshman Honors and Scholarship Grants

In order that appropriate awards may be made to students as they most deserve or need them, the California Institute makes a clear distinction between recognition of academic honor and achievement and recognition of need for financial assistance. This distinction is made with two types of awards: Honors at Entrance and Scholarship Grants.

Honors at Entrance

In recognition of distinguished academic achievement Honors at Entrance are awarded to the top ten percent of those admitted to the freshman class. They are awarded without regard to financial need, and carry no monetary grant. No application for consideration for Honors at Entrance is needed.

Freshman Scholarship Grants

The recipients of scholarship grants are selected by the Admissions Committee from the candidates who have stood sufficiently high on the entrance examinations, and have otherwise satisfied the entrance requirements of the Institute, and have submitted a **Parent's Confidential Statement.** (See below).

Scholarship grants are awarded to the extent of available funds where financial need is demonstrated. Awards are made on the basis of all the information available in regard to the applicants—the results of their examinations, their high school records and recommendations, the statements submitted as to their student activities and outside interests, and the result of personal interviews where these are possible. A list of scholarship grants will be found on pages 166 to 172. Where the amount of a grant is not specified there is a certain total sum available each year to be distributed among several scholarship holders in any proportion. Grants from these funds are usually for full tuition, or less if the need of the recipient is less.

The California Institute uses a uniform scholarship grant application which has been adopted by many colleges in the United States. All applications for scholarship grants where financial need exists must be made on this form. The form, called a **Parent's Confidential Statement,** may be obtained in nearly all cases at the school where the applicant is attending. If his school does not have a supply, he should write to the College Scholarship Service at one of the College Board offices, the addresses of which are given on page 141. The form is put out by the College Scholarship Service of the College Entrance Examination Board and is to be returned directly to the appropriate office of the College Board (see page 141) and not to the California Institute. Space is provided on the form for the applicant to indicate that he wishes a copy sent to the California Institute and to such other colleges as he may desire. A fee of two dollars is charged by the service for sending a copy of the form to one college, and an additional two dollars each for copies sent to additional colleges. This fee must accompany the form when it is returned to the College Board.

*For further information on Graduate Scholarships and Fellowships, see page 200.

Parent's Confidential Statement forms must be sent to the appropriate College Board office not later than March 1 of the year in which admission is desired. All applicants who have submitted this form by the above date are considered for scholarship grants. It is not necessary to apply for any particular scholarship by name.

Honorary Scholarships

In addition to the above there are three honorary awards which carry stipends. The Sloan scholarships, the General Motors College scholarships, and the Regional scholarships described below are given without consideration of financial need. All applicants for admission are automatically considered for the Sloan and General Motors College scholarships. Candidates for Regional scholarships are nominated by the principals or headmasters of their schools. Only when need exists is it necessary to file a **Parent's Confidential Statement** in connection with these awards.

State and National Scholarship Contests

Candidates for freshman scholarships are urged to make exhaustive inquiry of their school advisers and to watch their school bulletin boards for announcements of scholarship contests the winners of which may use the awards at the college of their choice. The State of California, for example, awards such scholarships annually to residents of the state who wish to attend a college within the state. Among the nationwide awards are the National Merit Scholarships, the General Motors National Scholarships, and the Westinghouse Talent Search Awards. Applicants in need of financial assistance should enter any such contest for which they are eligible in addition to applying for California Institute Scholarship grants. While duplicate awards will not be given beyond the actual extent of need, the more sources to which a candidate applies the greater are his chances of receiving scholarship assistance.

Regulations and Renewals

Recipients of honorary scholarships and of scholarship grants are expected to maintain a satisfactory standing in their academic work during the year for which the scholarship is granted. If the recipient fails to maintain such an academic standing, or if, in the opinion of the Committee on Undergraduate Scholarships and Honors, the recipient in any other way fails to justify the confidence placed in him, the Committee may cancel the scholarship for the balance of the academic year. Recipients of scholarships which run for more than one year are in general expected to maintain a rank in the upper half of the class. The amount of the award carried by these scholarships may be increased or decreased at the beginning of any year if the financial need has changed. Freshmen who receive scholarship awards for the freshman year only will be considered for scholarship aid in subsequent years on the basis of need according to the regulations in the following paragraph.

Upper Class Scholarships

Sophomores, juniors, and seniors are considered for scholarships if need is demonstrated and if throughout the preceding year they have carried at least the normal number of units required in their respective options, and if they have completed the preceding academic year with a grade-point average of at least 2.0. Awards are made in order of rank in class to the extent of the funds available. Most awards are for full or part tuition. When individual scholarships carry amounts in excess of full tuition this fact is noted in the list of scholarships below. A student who ends the academic year with a grade-point average of 2.0 or higher and who wishes to apply for a scholarship grant for the next year should obtain a scholarship form from the Admissions Office in June. This form is to be filled out by the student and his parents (or guardian) and returned to the Admissions Office by September 15. No one will be considered for a scholarship grant unless a scholarship form completely filled out and signed by parents (or guardian) is submitted by the proper date. If a scholarship applicant feels that his parents should no longer be responsible for his support he may attach an explanatory note to the form, but the form must be filled out.

It is expected that students to whom awards are made will maintain a high standard of scholarship and conduct. Failure to do so at any time during the school year may result in the termination of the award.

Scholarship Funds

Funds for Freshman and Upperclass Scholarships are provided in large part from the special scholarship funds named below. It is not necessary, however, to apply for any particular scholarship by name. Applicants for admission who have a **Parent's Confidential Statement** on file will be considered for the best award to which their relative need and standing on the entrance examinations entitle them. For Honorary Scholarships see above.

Alumni Scholarships: The Alumni Association of the California Institute provides scholarships covering full tuition to be awarded to entering freshmen. The recipients of these scholarships can expect to receive this amount for four years provided their conduct and grades continue to be satisfactory.

ARCS Foundation (Achievement Rewards for College Scientists) of Los Angeles: The ARCS Foundation has established a fund for the award of several undergraduate and graduate scholarships.

The Automotive Council Scholarship: The Automotive Council of Los Angeles, Inc. is providing a $900 scholarship for the 1960-61 academic year for a junior or senior in engineering.

R. C. Baker Foundation Scholarship: The R. C. Baker Foundation of Los Angeles has given four undergraduate scholarships of $1900 each in engineering for the 1960-61 academic year.

Edward C. Barrett Scholarship: Friends of Edward C. Barrett, who for forty-one years was Secretary of the California Institute, have established in his name a scholarship to be awarded annually to an undergraduate student.

Bechtel Foundation Scholarships: The Bechtel Foundation of San Francisco has provided funds for two scholarships to be awarded to juniors or seniors in engineering.

Meridan Hunt Bennett Scholarships and Fellowships: Mrs. Russell M. Bennett of Minneapolis, in January, 1946, made a gift of approximately $50,000 to the Institute to constitute the Meridan Hunt Bennett Fund, as a memorial to her son, Meridan Hunt Bennett, a former student at the Institute. The income of this fund is to be used to maintain scholarships which shall be awarded to undergraduate and graduate students of the Institute, the holders of such scholarships to be known as Meridan Hunt Bennett Scholars.

Blacker Scholarships: Mr. and Mrs. Robert Roe Blacker of Pasadena, in 1923, established the Robert Roe Blacker and Nellie Canfield Blacker Scholarship and Research Endowment Fund. A portion of the income of this fund, as determined by the Board of Trustees, may be used for undergraduate scholarships.

C. F. Braun and Company Scholarships: C. F. Braun and Company of Alhambra, California, has established three scholarships of $1000 each to be awarded to entering freshmen for the 1960-61 academic year. In selecting candidates preference will be given to those who indicate that they wish to pursue a course in engineering.

Caltech Bookstore Scholarships: The profits from the Caltech Bookstore on the California Institute campus are used to furnish a number of scholarships for undergraduates in all options.

California Scholarship Federation Scholarship: The California Institute will each year award a scholarship to a C.S.F. member who is also a sealbearer provided that such a candidate is available who has met the Institute's requirements for a freshman scholarship grant. Sealbearer status must be verified by the C.S.F. adviser at the time of submitting the regular application for a scholarship grant.

Chisholm Scholarship: The late William Duncan Chisholm made provision for an annual scholarship to be awarded to an undergraduate.

Class of 1927 Scholarship: The Class of 1927 has established the Class of 1927 Scholarship Endowment Fund. The income from this fund is to be used for an undergraduate scholarship.

Lewis Crank Scholarship: Loma Vista Investment, Inc., of Culver City, California, has established a $1000 scholarship to be awarded to a sophomore in one of the science options. The holder of this scholarship may expect it to be renewed for each of his last two years subject to the regulations on page 165.

Crellin Scholarships: The late Amy H. Crellin made provision for annual scholarships to be awarded to undergraduates.

Crown Zellerbach Foundation Scholarships: The Crown Zellerbach Foundation provides two scholarships of $900 each for juniors or seniors majoring in a science option.

Cyprus Mines Corporation Scholarships: The Cyprus Mines Corporation of Los Angeles has given $1000 to be used for undergraduate scholarships.

Dabney Scholarships: The late Mrs. Joseph B. Dabney made provision for annual scholarships to be awarded at the discretion of the Institute to members of the undergraduate student body. The recipients are designated Dabney Scholars.

Douglas Aircraft Company Scholarship: The Douglas Aircraft Company has made provision for a $1350 scholarship for the 1960-61 academic year to be awarded to a junior or senior in engineering, or physics in that order of preference.

Downs and Company Scholarship: Downs and Company of Beverly Hills provide a $500 scholarship for undergraduates.

Drake Scholarships: Mr. and Mrs. A. M. Drake of Pasadena have made provision for an annual scholarship available for a graduate of the high schools of St. Paul, Minnesota, and a similar annual scholarship available for a graduate of the high school of Bend, Oregon. If there are no such candidates, the Institute may award the scholarships elsewhere. Mr. and Mrs. Drake, by a Trust Agreement of July 23, 1927, also established the Alexander McClurg Drake and Florence W. Drake Fellowship and Scholarship Fund, the income of which may be used for fellowships and scholarships as determined by the Board of Trustees of the Institute.

Robert S. and Nellie V. H. Dutton: The late Mrs. Robert S. Dutton established a fund the interest from which is used for undergraduate scholarships.

Electric Club Scholarship: The Electric Club of Los Angeles awards a $500 scholarship every other year to a senior in engineering.

Garrett Corporation Scholarships: The Garrett Corporation of Los Angeles has given $3000 for scholarships to be awarded to juniors or seniors majoring in engineering or chemical engineering, and to fifth-year students in mechanical engineering and chemical engineering.

General Motors Corporation Scholarship: The General Motors Corporation has established a scholarship at the California Institute to be awarded to an entering freshman. The award may range from a prize scholarship of $200 for a student not in need of financial assistance to an amount as high as $2000 a year depending on need. Holders of this scholarship may expect it to be renewed in each of the three upper-class years provided the holder's grades and conduct remain satisfactory.

The Gnome Club Scholarship: The alumni of the Gnome Club have established at the California Institute a scholarship to be awarded to a student in the junior class.

Goodyear Scholarship: The Goodyear Foundation, Inc., has established a scholarship of $1000 to be awarded to a junior or senior in engineering who may be interested in a career in business or industry.

Graham Brothers Foundation Scholarship: The Graham Brothers Foundation of Long Beach has made possible the award of a scholarship for the 1960-61 academic year.

Harriet Harvey and Walter Humphry Scholarships: The late Miss Harriet Harvey and the late Mrs. Emily A. Humphry made provision for two scholarships. The first of these, the Harriet Harvey Scholarship, is to be awarded preferably to a well-qualified candidate from the state of Wisconsin. If there is no such candidate the Institute may award the scholarship elsewhere. The second, the Walter Humphry Scholarship, is to be awarded preferably to a well-qualified candidate from the state of Iowa. If there is no such candidate, the Institute may award the scholarship elsewhere.

Robert Haufe Memorial Scholarship: This scholarship is supported by a fund established in 1950 by Mr. and Mrs. J. H. Haufe as a memorial to their son, Robert Haufe.

The Holly Scholarship: The Holly Manufacturing Company has established a half-tuition scholarship to be awarded to a senior in any engineering option.

Walter Humphry Scholarships: The late Mr. Walter Humphry established a fund the interest from which is used for undergraduate scholarships.

International Nickel Company Scholarship: The International Nickel Company has provided a two-year scholarship in the amount of $1600 each year for a student transferring to the California Institute under the 3-2 Plan (see page 149). The holder of this award must be a major in geology or in one of the engineering options.

International Telephone and Telegraph Corporation Scholarship: The International Telephone and Telegraph Corporation has given a $1000 scholarship for a junior majoring in electrical engineering, mathematics, or physics. This award is renewable in the senior year.

J. B. Keating Scholarships: Mr. John B. Keating has made possible the award of two scholarships for undergraduate juniors or seniors.

Kelman Scholarship: Mr. J. N. Kelman of Los Angeles and the I. T. E. Foundation of Philadelphia have made possible the award of a full tuition scholarship for an entering freshman. The recipient of this scholarship can expect to receive this amount each year for four years provided his conduct and grades continue to be satisfactory.

Kennecott Copper Corporation Scholarship: The Kennecott Copper Corporation has given a $1000 scholarship for a junior or senior student majoring in chemical engineering.

Ladish Company Scholarship: The Ladish Company has given two scholarships in the amount of $300 each and two in the amount of $350 each for the 1960-61 academic year.

Lockheed National Engineering Scholarship: The Lockheed Aircraft Corporation of Burbank, California, has established a scholarship covering tuition and certain other expenses totaling $1800 a year. This scholarship is to be awarded to an entering freshman who indicates that he intends to pursue a course in engineering. The recipient of this scholarship may expect to continue to receive this award during each of the three upper-class years, provided that his grades and conduct remain satisfactory.

Los Angeles Philanthropic Foundation Scholarship: The Los Angeles Philanthropic Foundation has given a scholarship for a junior majoring in physics. Preference is given to students whose homes are in Southern California.

Management Club of California Institute of Technology Scholarship: The Management Club at the Institute has established a tuition scholarship to be awarded to an undergraduate student in one of the three upper classes.

Mayr Foundation Scholarships: The George H. Mayr Foundation of Beverly Hills granted funds for twenty undergraduate scholarships for the academic year 1960-61. Not open to freshmen.

Mobil Oil Company has established a scholarship of $1675 for a junior or senior student in engineering.

Seeley Wintersmith Mudd Scholarships: The Seeley W. Mudd Foundation of Los Angeles has provided funds for two scholarships to cover non-tuition expenses of students in the physics or geology options.

David Lindley Murray Educational Fund: Mrs. Katherine Murray of Los Angeles, by her will, established the David Lindley Murray Educational Fund, the income to be expended in assisting worthy and deserving students to obtain an education, particularly in engineering courses.

Neely Enterprises Scholarship: Neely Enterprises has given a $1000 scholarship for a sophomore student majoring in physics or engineering whose home is in Arizona, California, Nevada, or New Mexico.

Frances W. Noble Scholarship: This scholarship has been established from funds given to the Institute by Mrs. Frances W. Noble.

La Verne Noyes Scholarship: Under the will of the late La Verne Noyes, of Chicago, funds are provided for paying the tuition, in part or in full, for deserving students needing this assistance to enable them to procure a university or college training. This is to be done without regard to differences of race, religion, or political party, but only for those who shall be citizens of the United States of America and either: first, shall themselves have served in the army or navy of the United States of America in the war into which our country entered on the 6th of April, 1917, and were honorably discharged from such service, or second, shall be descended by blood from some one who has served in the army or navy of the United States in said war, and who either is still in said service or whose said service in the army or navy was terminated by death or an honorable discharge. The recipients are designated La Verne Noyes Scholars.

Pasadena Optimists Club Scholarship Endowment Fund: The Pasadena Optimists Club has given a fund the interest from which is to be used for undergraduate scholarships.

Edgar H. Pflager Scholarship Fund: Mr. Edgar H. Pflager has given a sum of money the income from which is to be used for undergraduate scholarships.

Procter and Gamble Scholarship: The Procter and Gamble Fund has provided for two four-year undergraduate scholarships in the amount of $1400 a year each. These four-year awards are open to entering freshmen only.

Radio Corporation of America Scholarship: The Radio Corporation of America has provided funds for an undergraduate scholarship for 1960-61 in the amount of $800. Freshmen are not eligible for this award.

Rayonier Foundation Scholarship: The Rayonier Foundation will provide two scholarships of $500 each in 1960-61 for undergraduates majoring in chemical engineering or engineering.

Regional Prize Scholarships: A Regional Prize Scholarship is awarded to one entering freshman student each year in each of seven regions in the United States. The scholarship carries a stipend of $1400 for the freshman year. Regional Scholarships are an academic honor and are awarded, without regard to financial need, on the basis of high scholastic grades, high scores on the College Board Examinations required for admission, the recommendations of teachers and principals or headmasters, and on the result of a personal interview with a member of the Admissions Committee. To be eligible to compete for these scholarships an applicant must be nominated by the principal or headmaster of his school and must be attending school in one of the following regions: Region I: California; Region II: Idaho, Montana, Oregon, Washington, Wyoming; Region III: Arizona, Colorado, Nevada, New Mexico, Texas, Utah; Region IV: Illinois, Iowa, Minnesota, Missouri, Nebraska, Wisconsin; Region V: Indiana, Michigan, Ohio; Region VI: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Region VII: Delaware, Maryland, New Jersey, New York, Pennsylvania. Nomination forms will be sent on request to principals or headmasters of schools in these regions.

Alfred P. Sloan National Scholarships: The Alfred P. Sloan Foundation of New York has established at the California Institute a minimum of six scholarships to be awarded to entering freshmen without restriction as to the field of study to be pursued. Original selection of the holders of these scholarships is made without regard to financial need. Once selection has been made, awards will range from a prize scholarship of $200 per year for students not in need of financial assistance to amounts as high as $2000 per year to those whose need warrants such consideration. Holders of these scholarships may expect them to be renewed in each of the three upper-class years provided the holder's grades and conduct remain satisfactory.

Sloan Foundation Scholarship and Loan Fund: The Alfred P. Sloan Foundation has established at the California Institute six scholarship-loan awards under which a recipient receives part of his financial need in the form of an outright grant and part in the form of a loan repayable in installments after graduation. These awards are usually reserved for entering freshmen and are renewable in each of the three subsequent years provided a recipient's grades and conduct remain satisfactory.

Standard Oil Company of California Scholarships: The Standard Oil Company of California has provided a scholarship for an undergraduate majoring in chemical engineering and another scholarship for an undergraduate majoring in engineering.

Elizabeth Thompson Stone Scholarship: Miss Elizabeth Thompson Stone of Pasadena established, by her will, a scholarship known as the Elizabeth Thompson Stone Scholarship.

William W. Stout Scholarship Endowment Fund: Mr. William W. Stout has established a scholarship fund the interest from which is to be used for undergraduate scholarships.

Superior Oil Company Scholarship: The Superior Oil Company of Los Angeles has established a four-year scholarship in the amount of $1000 each year. Preference is given to a student interested in geology or chemical engineering as applied to the petroleum industry.

Ray Tenhoff Memorial Scholarship: Donated by the Society of Experimental Test Pilots in honor of its first president. This scholarship provides up to $1000, depending on need, for the 1960-61 academic year, to be awarded to a student entering the junior class in engineering, or physics, in that order of preference. The holder of this scholarship may expect it to be renewed for his senior year, provided holder's grades and conduct remain satisfactory.

Texaco Scholarships: Texaco, Incorporated has made provision for one or more scholarships to be awarded to juniors or seniors majoring in a field of engineering or science that would prepare them for a career in the petroleum industry.

J. T. Thorpe, Inc. Scholarship: The J. T. Thorpe Company has provided two full-tuition scholarships for 1960-61 to be awarded to juniors in engineering.

Timken-Sturgis Foundation Scholarship: The Timken-Sturgis Foundation of San Diego has made possible the award of one or more undergraduate scholarships.

Western Electronic Manufacturers Association Scholarship: Western Electronic Manufacturers Association of Los Angeles has provided for one or more scholarships for junior and senior students in Engineering. The purpose of these scholarships is to promote interest in the electronics field.

Claudia Wheat Scholarship: Mr. A. C. Wheat has established a full-tuition scholarship in memory of his wife. The award goes to an entering freshman, and preference is given to a graduate of Alhambra High School in Alhambra, California.

Brayton Wilbur-Thomas G. Franck Scholarship: Mr. Brayton Wilbur and

Mr. Thomas G. Franck of Los Angeles have established the Brayton Wilbur-Thomas G. Franck Scholarship Fund, the income to be used for a scholarship for a deserving student at the Institute.

In addition to the foregoing named scholarships, there is a Scholarship Endowment Fund made up of gifts of various donors.

Of the scholarship donors listed above the following include with their scholarship gifts an unrestricted grant to the Institute's general funds to help defray educational costs in excess of that portion covered by tuition.

The R. C. Baker Foundation
Crown Zellerbach Foundation
Cyprus Mines Corporation
Douglas Aircraft Company, Inc.
Garrett Corporation
General Motors Corporation, College Plan
General Motors Corporation, National Plan
Goodyear Foundation, Inc.
Graham Brothers Foundation
The International Nickel Company, Inc.
International Telephone and Telegraph Corporation
Kennecott Copper Corporation
Lockheed Leadership Fund
Mobil Oil Company
The Procter & Gamble Fund
Radio Corporation of America
Alfred P. Sloan Foundation
The Superior Oil Company
Texaco Inc.
The Union Carbide Educational Fund

Student Aid

Loan Funds

Institute Loan Funds

Thanks to funds presented by a number of generous donors, the Institute is enabled to lend money to many students who, without aid, could not complete their education. Each fund is administered according to the wishes of the donor. Borrowers must be making satisfactory progress toward their degrees; and, in general, preference is given to students who have earned part of their expenses. The Institute Loan Funds are named as follows:

The Gustavus A. Axelson Loan Fund
The Olive Cleveland Fund
The Hosea Lewis Dudley Loan Fund
The Dudley Foundation Loan Fund
The Claire Dunlap Loan Fund
The Roy W. Gray Fund
The Raphael Herman Loan Fund
The Vaino A. Hoover Student Aid Fund
The Howard R. Hughes Student Loan Fund
The Thomas Jackson Memoral Fund
The Ruth Wydman Jarmie Loan Fund
The John McMorris Memorial Loan Fund

The Noble Loan and Scholarship Fund
The James R. Page Loan Fund
The Pasadena Optimists Club Fund
The Scholarship and Loan Fund
The Albert H. Stone Educational Fund

National Defense Student Loan Program

All students are eligible to apply for loans from these limited funds provided they are: citizens or permanent residents of the United States; meeting the Institute's academic standards and standards of conduct; and are recommended by the Institute Committee on Student Aid. Students with superior grades take precedence over others.

A student may apply for a maximum of $1000 a year for five years. Beginning one year after he has completed his education, he pays 3 per cent interest per year on the unpaid balance of his loan. He pays no interest as long as he is a full-time student, nor if he is serving in the armed forces (maximum three years).

Applicants must show evidence of need (statement of family income and resources, personal resources, and an estimated annual budget); sign an oath of allegiance and an affidavit disclaiming belief or membership in subversive organizations; and (if applicant is under 21) obtain signature of parent or guardian to the effect that he has read the application.

DEFERRED PAYMENT PLANS FOR TUITION

See detailed information on page 163.

STUDENT EMPLOYMENT

The Institute tries to help students to find suitable employment when they cannot continue their education without thus supplementing their incomes. The requirements of the courses at the Institute are so exacting, however, that under ordinary circumstances students who are entirely or largely self-supporting should not expect to complete a regular course satisfactorily in the usual time. It is highly inadvisable for freshman students to attempt to earn their expenses. Students wishing employment are advised to write, before coming to the Institute, to the Director of Placements.

PLACEMENT SERVICE

The Institute maintains a Placement Office under the direction of a member of the Faculty. With the services of a full-time staff, this office assists graduates and undergraduates to find employment.

During the second and third terms, schedules are arranged for students to be interviewed by representatives of organizations who visit the campus. Students, both graduate and undergraduate, wanting part-time employment during the school year or during vacations, should register at the Placement Office. Assistance will be given whenever possible in securing employment for summer vacations. Alumni who are unemployed or desire improvement in their positions should register at the Placement Office.

A large number of brochures published by industrial organizations and Government agencies are available. These show placement opportunities in the fields of science and engineering. The Director of Placements is always available for consultation and guidance on placement problems.

It should be understood that the Institute assumes no responsibility in obtaining employment for its graduates, although the Placement Office will make every effort to find employment for those who wish to make use of this service.

PRIZES

THE FREDERIC W. HINRICHS, JR., MEMORIAL AWARD

The Board of Trustees of the California Institute of Technology established the Frederic W. Hinrichs, Jr., Memorial Award in memory of the man who served for more than twenty years as Dean and Professor at the Institute. In remembrance of his honor, courage, and kindness, the award bearing his name is made annually to the senior who, in the judgment of the undergraduate Deans, throughout his undergraduate years at the Institute has made the greatest contribution to the welfare of the student body and whose qualities of character, leadership, and responsibility have been outstanding. At the discretion of the Deans, more than one award or none may be made in any year. The award, presented at Commencement without prior notification, consists of $100 in cash, a certificate, and a suitable memento.

THE CONGER PEACE PRIZE

The Conger Peace Prize was established in 1912 by the Reverend Everett L. Conger, D.D., for the promotion of interest in the movement toward universal peace, and for the furtherance of public speaking. The annual income from $1,000 provides for a first and second prize to be awarded at a public contest and announced at Commencement. The contest is under the direction of representatives of the Division of the Humanities.

THE MARY A. EARL MCKINNEY PRIZE IN ENGLISH

The Mary A. Earl McKinney Prize in English was established in 1946 by the late Samuel P. McKinney, M.D., of Los Angeles, a graduate in Civil Engineering of Rensselaer Polytechnic Institute, class of 1884, as a memorial to his mother. It is provided for by the annual income from $3,500.

The contest for this prize is designed to cultivate proficiency in English. Eligibility is limited to the junior and senior classes. Any contestant in his junior year who has not won a prize may again be a contestant in his senior year. Each year the Faculty in English announces the subject for an essay which shall be based on certain prescribed books. The several students submitting the best essays engage in a final discussion before a group of judges, who award a first and a second prize, each consisting of a sum of money and a trophy in the form of a valuable book. Each of the other final contestants also receives such a trophy. The awards are announced at Commencement.

THE DON SHEPARD AWARD

Relatives and friends of Don Shepard, class of 1950, have provided an award in his memory. The award is presented to a student, the basic costs of whose education have already been met but who would find it difficult, without additional help, to engage in extracurricular activities and in the cultural opportunities afforded by the community. The recipient, an upperclassman, is selected on the basis of his capacity to take advantage of and to profit from these opportunities rather than on the basis of his scholastic standing.

THE AMERICAN CHEMICAL SOCIETY PRIZE

A prize of $250 is awarded each year in connection with the annual high school contest of The American Chemical Society, Southern California Section. The prize goes to the highest ranking man in the contest who applies, is admitted, and registers at the California Institute in the fall following his senior high school year, provided that the candidate does not rank below the top five in the contest.

THE SCAAPT PRIZE

A prize of $250 is awarded each year in connection with the annual high school contest of the Southern California Section of the American Association of Physics Teachers. The prize goes to the highest ranking man in the contest who applies, is admitted, and registers at the California Institute in the fall following his senior high school year, provided that the candidate does not rank below the top five in the contest.

THE DAVID JOSEPH MACPHERSON PRIZE IN ENGINEERING

The David Joseph Macpherson Prize in Engineering was established in 1957 by Margaret V. Macpherson in memory of her father, a graduate of Cornell University in Civil Engineering, class of 1878.

A prize of $100 is awarded annually for the winning essay submitted by a senior in the Division of Engineering. The object of the contest is to stimulate interest and excellence in English composition. The subjects of the essays are set by a Faculty Committee of three, appointed annually by the Chairman of the Division. The subjects may include those set by national engineering societies for their annual student-paper contests.

Section IV

INFORMATION AND REGULATIONS FOR THE GUIDANCE OF GRADUATE STUDENTS

A. General Regulations

I. REQUIREMENTS FOR ADMISSION TO GRADUATE STANDING

1. The Institute offers graduate work leading to the following degrees: Master of Science after a minimum of one year of graduate work; the degrees of Aeronautical Engineer, Chemical Engineer, Civil Engineer, Electrical Engineer, Geological Engineer, Geophysical Engineer, and Mechanical Engineer, after a minimum of two years of graduate work; and the degree of Doctor of Philosophy.

2. To be admitted to graduate standing an applicant must in general have received a bachelor's degree representing the completion of an undergraduate course in science or engineering substantially equivalent to one of the options offered by the Institute. He must, moreover, have attained such a scholastic record and, if from another institution, must present such recommendations as to indicate that he is fitted to pursue with distinction advanced study and research. In some cases examinations may be required.

3. Application for admission to graduate standing should be made to the Dean of Graduate Studies, on a form obtained from his office. Admission to graduate standing will be granted *only to a limited number of students of superior ability,* and application should be made as early as possible. Women students are admitted only in exceptional cases. In general, admission to graduate standing is effective for enrollment only at the beginning of the next academic year. If the applicant's preliminary training has not been substantially that given by the four-year undergraduate options at the Institute, he may be admitted subject to satisfactory completion of such undergraduate subjects as may be assigned. Admission sometimes may have to be refused solely on the basis of limited facilities in the department concerned. Students applying for assistantships or fellowships (see page 200) need not make separate application for admission to graduate standing, but should submit their applications before February 15. For requirements in regard to physical examination, see pages 145 and 157.

4. Admission to graduate standing does not of itself admit to candidacy for a degree. Application for admission to candidacy for the degree desired must be made as provided in the regulations governing work for the degree.

5. Foreign students who are admitted to graduate standing may be required to confine their work during their first term of residence to undergraduate courses when this is necessary in order to familiarize them with American teaching methods and vernacular English.

II. GRADUATE RESIDENCE

One term of residence shall consist of one term's work of not fewer than 45 units of advanced work in which a passing grade is recorded. If fewer than 45 units are successfully carried, the residence will be regarded as shortened in the same ratio; but the completion of a larger number of units in any one term will not be regarded as increasing the residence. See pages 179, 181, 185 for special requirements for residence.

Graduate students will be required to carry at least 36 units during each of their first three terms of attendance at the Institute.

Graduate students expecting to receive a degree will be required to maintain their admission status until the degree is obtained, either by continuity of registration or on the basis of approved leave of absence. In case of lapse in graduate standing, readmission must be sought before academic work may be resumed or the degree may be conferred.

Graduate students are encouraged to continue their research during the whole or a part of the summer, but in order that such work may count in fulfillment of the residence requirements, the student must file a registration card for such summer work in the office of the Registrar between May 15 and June 15. Students who are registered for summer research will not in general be required to pay tuition for the research units, but will be required to pay minimum tuition if Ph.D. or engineer's degree thesis requirements are completed during the summer.

A graduate student who undertakes activities related to the Institute (studies, research, and assisting or other employment) aggregating more than 62 hours per week must receive prior approval therefor from the Dean of Graduate Studies. Petition forms for this purpose may be obtained from the Registrar, and must carry the recommendation of the student's major department before submisison to the Graduate Office.

A graduate student will be considered to be ineligible for registration at the beginning of his second term at the Institute unless his photograph for the Registrar's record card is affixed thereto, or a certification from the photographer is obtained to show that such photograph is in course of preparation on the date of registration. The Registrar provides the opportunity to have these photographs made, without cost to the student, on the registration days of the first and second terms of each year. Photographs taken for this purpose at other times are provided by the student at his own expense.

III. TUITION FEES

The tuition charge for all students registering for graduate work is $1275 per academic year, payable in three installments at the beginning of each term. Graduate students who cannot devote full time to their studies are allowed to register only under special circumstances. Except by specific action of the Committee on Graduate Study, graduate students will be required to register for at least 36 units during each of their first three terms of attendance at the Institute. A graduate student who is registered for 36 or more units is classed as a full-time graduate student. Students desiring permission to register for fewer than 33 units should petition therefor on a blank obtained from the Registrar. If such reduced registration is permitted, the tuition is at the rate of $318.75 a term for 32 to 25 units, and at the rate of $12.75 a unit for fewer than 25 units, with a minimum of $127.50 a term. If the courses registered for do not correspond to the full educational facilities made available to the student, additional tuition will be charged.

The payment of tuition by graduate students is required (a) without reference to the character of the work of the student, which may consist in the prosecution of research, in independent reading, or in the writing of a thesis or other dissertation, as well as in attendance at regular classes; (b) without reference to the number of terms in which the student has already been in residence; and (c) without reference to the status of the student as an appointee of the Institute, except that members of the academic staff of rank of Instructor or higher are not required to pay tuition.

The tuition includes the cost of the routine medical services available to students at the Health Center, as well as the sum of ten dollars which is credited annually to the Emergency Health Fund. A summer health fee of about $2 must be paid by graduate students who register for summer work. (See page 161.) Each graduate student is required to make a general deposit of $25 to cover any loss of, or damage to Institute property used in connection with his work in regular courses of study. Upon completion of his graduate work, or upon withdrawal from the Institute, any remaining balance of the deposit will be refunded.

No degrees are awarded until all bills due the Institute have been paid.

In regard to *fellowships and assistantships,* see page 200 of this catalog. In addition, to students of high scholastic attainments there may be awarded *graduate scholarships* covering the whole or a part of the tuition fee. For such students *loans* also may be arranged, for which application should be made to the Student-Aid Committee.

A graduate student is eligible to borrow from any of the funds under the jurisdiction of this committee, provided that his total indebtedness (including the proposed loan) will not exceed $6000.

B. Regulations Concerning Work for the Degree of Master of Science

I. GENERAL REQUIREMENTS

To receive the degree of Master of Science the student must complete in a satisfactory way the work indicated in the schedule of fifth-year courses (see pages 221-228) as well as in the schedule of the four-year course in science or in engineering, except that, in the case of students transferring from other institutions, equivalents will be accepted in subjects in which the student shows by examination or otherwise that he is proficient, and except in so far as substitutions may be approved by special vote of the committee in charge.

Senior students at the Institute desiring to return for a fifth year should consult with the faculty in the field in which they expect to do their major work, and apply for admission to work towards the master's degree on a form obtained from the Dean of Graduate Studies. Such students will be expected to present satisfactory scholarship qualifications, and to have demonstrated a capacity for doing advanced work.

All programs of study, and applications for admission to candidacy for the degree of Master of Science shall be in charge of the Committee on the

Course in Science (in case the advanced work is to be astronomy, biology, chemistry, chemical engineering, geology, geophysics, mathematics, or physics), or of the Committee on the Course in Engineering (in case the work is to be in civil, mechanical, or electrical engineering, in engineering science, or in aeronautics); and recommendations to the Faculty for the award of the degree shall be made by the appropriate one of these committees, all such actions being taken in general after consideration of recommendations by the department concerned.

A student before entering upon work for the degree of Master of Science should, after consultation with the department concerned, submit a plan of study, and make application to the committee in charge for acceptance as a candidate for that degree. Application forms for admission to candidacy for these degrees may be obtained from the Registrar, and must be submitted not later than the sixth week of the academic year in which the degree is to be granted.

II. REGISTRATION

1. The regulations governing registration and student responsibilities as given for undergraduate students on pages 150-154 of the catalog apply also to students working toward the master's degree.

2. Before registering, the graduate student should consult with members of the department in which he is taking his work to determine the studies which he can pursue to the best advantage.

3. A student will not receive credit for a course unless he is properly registered, and at the first meeting of each class should furnish the instructor with a regular assignment card for the course, obtained on registration.

4. Students registering for more than 50 units but fewer than 63 units in any term must have the approval of their department. Registration for more than 62 units must in addition have the approval of the Dean of Graduate Studies.

5. In the case of a student registered for the degree of Master of Science and holding a position as a graduate assistant, the actual number of hours per week required by his teaching or research services shall be deducted from the total number of units for which he might otherwise register. This number of units shall be determined by his department.

III. SCHOLASTIC REQUIREMENTS

1. A minimum of 140 units of graduate residence at this Institute is required for the master's degree, but specific departmental requirements often exceed this number. All or any part of this residence may be acquired prior to the completion of the work for the bachelor's degree provided a total of fifteen terms of acceptable college work equivalent to 45 units per term is completed. Courses used to fulfill requirements for the bachelor's degree may not be counted as graduate residence. A student will not, in general, be admitted to graduate standing until he has completed work equivalent to that required for the bachelor's degree.

2. Scholastic requirements for undergraduate students (see page 152) also apply to students working toward the master's degree. In meeting the graduation requirements on page 155, the following rule will apply for master's degree candidates: only those courses shown on the candidacy

blank and approved by the department representative shall be counted in figuring the grade-point average. Students who become ineligible to register, having failed to meet the scholastic requirements stated on pages 148-149 of the catalog, may submit to the Dean of Graduate Studies a petition for reinstatement. This petition should have the endorsement of the department in which the student is registered. The Dean of Graduate Studies will pass on this petition if he concurs with the departmental recommendation; otherwise the petition will be referred to the Committee on Graduate Study for final action. Changes on the candidacy blank which are not initialed by the proper authority are not to be recognized. No course which appears on the candidacy blank and for which the candidate is registered may be removed after the last date for dropping courses as listed in the catalog.

3. Students admitted to work toward the degree of Master of Science who have completed the senior year at the Institute are subject to the same regulations as are seniors, as listed on pages 150-154.

4. Students admitted to work toward the degree of Master of Science who have completed their undergraduate work at other institutions are subject to the scholastic regulations applying to new transfer students as listed on pages 150-154.

5. Students admitted to work toward the master's degree in the Division of Chemistry and Chemical Engineering are required to take placement examinations. See page 223.

6. Students admitted to work toward the degree of Master of Science in Electrical Engineering must take placement examinations to be used as a guide in selecting the proper course of study. These examinations will cover essentially the content of the courses given to seniors in the Engineering Division, EE 101 a, b and EE 115 a, b. In addition, the examination will cover the field of physical electronics. Undergraduate students at the California Institute of Technology who intend to pursue work for the M.S. in Electrical Engineering should take EE 101 a, b and EE 115 a, b or their equivalent.

7. A written placement examination is required of incoming graduate students in the Division of Geological Sciences. For details see page 193. Candidates for the master's degree in the Division of Geological Sciences should familiarize themselves with, and are expected to meet, certain special requirements concerning basic sciences and field geology. Detailed information on these requirements may be obtained from the Division Secretary.

8. Students admitted to work toward the master's degree in the Division of Physics, Mathematics, and Astronomy are required to take placement examinations to be used as a guide in selecting the proper course of study. (See page 197, section 2a.)

IV. THESIS

In the case of a required thesis two final copies must be filed with the Division concerned ten days before the degree is to be conferred. Instructions for the preparation of theses may be obtained from the office of the Dean of Graduate Studies.

C. Regulations Concerning Work for the Engineer's Degree

1. The work for an engineer's degree must consist of advanced studies and research in the field appropriate to the degree desired. It must conform

to the special requirements established for the degree desired and should be planned in consultation with the members of the faculty concerned. Advanced studies are defined on page 185. Regulations governing registration will be found on page 183.

2. *Residence.* At least six terms of graduate residence (as defined on page 177) subsequent to a baccalaureate degree equivalent to that given by the California Institute are required for an engineer's degree. Of these, at least the last three terms must be at the California Institute. It must be understood that these are minimum requirements, and students must often count on spending a somewhat longer time in graduate work.

To qualify for an engineer's degree a student must complete the work prescribed by his supervising committee with a grade-point average of at least 1.90, considering the grade of P as being equivalent to C and excluding grades for research. Work upon research and the preparation of a thesis must constitute no fewer than 55 units. More than 55 units may be required by certain departments and the student should determine the particular requirements of his department when establishing his program.

In the case of a student registered for work toward an engineer's degree, and holding a position as graduate assistant or other Institute employee, the actual number of hours per week required by his teaching or research services shall be deducted from the total number of units for which he might otherwise register. This number of units shall be determined by his department.

3. *Admission to Candidacy.* Before the end of the second week of the first term of the academic year in which the student expects to receive the degree he must file in the office of the Dean of Graduate Studies an application for admission to candidacy for the degree desired. Upon receipt of this application, the Dean, in consultation with the chairman of the appropriate division, will appoint a committee of three members of the faculty to supervise the student's work and to certify to its satisfactory completion. One of the members of the committee must be in a field outside of the student's major field of study. The student should then consult with this committee in planning the details of this work. The schedule of his work as approved by the committee shall be entered on the application form and shall then constitute a requirement for the degree. Changes in the schedule will not be recognized unless initialed by the proper authority. No course which appears on the approved schedule and for which the applicant is registered may be removed after the last date for dropping courses as listed in the catalog.

The student will be admitted to candidacy for the degree when his supervising committee certifies: (a) That all the special requirements for the desired degree have been met, with the exception that certain courses of not more than two terms in length may be taken after admission to candidacy; (b) That the thesis research has been satisfactorily started and probably can be finished at the expected time.

Such admission to candidacy must be obtained by mid-term of the term in which the degree is to be granted.

4. *Thesis.* At least two weeks before the degree is to be conferred, each student is required to submit to the Dean of Graduate Studies a ribbon copy, a reproduced copy, and the vellum of a satisfactory individual thesis describ-

ing his research, including a one-page digest or summary of the main results obtained. In form, the thesis must satisfy the requirements for theses for the degree of Doctor of Philosophy. (See page 186.)

The use of "classified" research as thesis material for any degree will not be permitted. Exceptions to this rule can be made only under special circumstances, and then only when approval is given by the Dean of Graduate Studies before the research is undertaken.

Before submitting his thesis, the candidate must obtain written approval of it by the chairman of the division and the members of his supervising committee, on a form obtained from the office of the Dean of Graduate Studies.

5. *Examination.* At the option of the department representing the field in which the degree is desired a final examination may be required. This examination would be conducted by a board to be appointed by the candidate's supervising committee.

Special Requirements for the Degree of Chemical Engineer. Students admitted to work for the degree of Chemical Engineer are required to take placement examinations in engineering thermodynamics of one-component systems, the unit operations of chemical engineering, and either physical chemistry or industrial chemistry. See pages 190, 222.

Special Requirements for the Degree of Electrical Engineer. To be recommended for the degree of Electrical Engineer the applicant must pass the same subject requirements as listed for the doctor's degree on page 191, except that a grade of D in Ph 131 is acceptable.

Special Requirements for the Degree of Mechanical Engineer. Each student admitted to work for the degree of Mechanical Engineer shall be required to take an oral placement examination given by the faculty in mechanical engineering before his registration. The results will be used as a guide in planning the student's work.

Not less than a total of 55 units of this work shall be for research and thesis, the exact number of units to be left to the discretion of the supervising committee appointed by the Dean of Graduate Studies. The courses shall be closely related to mechanical engineering, and the specific courses to be taken and passed with a grade of "C" or better by each candidate shall be determined by the supervising committee, but must include one of the following:

AM 125 abc	Engineering Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ph 107 abc	Electricity and Magnetism

A list of possible courses from which a program of study may be organized will be found on page 229.

D. Regulations Concerning Work for the Degree of Doctor of Philosophy

I. GENERAL REGULATIONS

The degree of Doctor of Philosophy is conferred by the Institute primarily in recognition of breadth of scientific attainment and of power to investigate scientific problems independently and efficiently, rather than for the completion of definite courses of study through a stated period of residence. The work for the degree must consist of scientific research and the preparation of a thesis describing it, and of systematic studies of an advanced character primarily in science or engineering. In addition, the candidate must have acquired the power of expressing himself clearly and forcefully both orally and in written language, and he must have a good reading knowledge of at least two foreign languages chosen among French, German, and Russian. With the permission of the department concerned and the Dean of Graduate Studies, another modern language may be substituted for one of these languages.

Subject to the general supervision of the Committee on Graduate Study, the student's work for the degree of Doctor of Philosophy is specifically directed by the department in which he has chosen his major subject. Each student should consult his department concerning special divisional and departmental requirements. See Section VI.

With the approval of the Committee on Graduate Study, any student studying for the doctor's degree whose work is not satisfactory may be refused registration at the beginning of any term by the department in which the student is doing his major work.

II. REQUIREMENTS FOR ADMISSION TO WORK FOR DOCTOR'S DEGREE

With the approval of the Committee on Graduate Study, students are admitted to graduate standing by the department in which they choose their major work toward the doctor's degree. In some cases, applicants for the doctor's degree may be required to register for the master's or engineer's degree first. These degrees, however, are not general prerequisites for the doctor's degree. Students who have received the master's degree and wish to pursue further studies leading toward either the engineer's or the doctor's degree must file a new application to continue graduate work toward the desired degree. Students who have received an engineer's degree will not in general be admitted for the doctor's degree.

During the second or third term of work toward the engineer's degree, a student may apply for admission to work toward the doctor's degree. If this admission is granted, his admission for the engineer's degree will be cancelled.

III. REGISTRATION

1. Students are required to register and file a program card in the Registrar's office at the beginning of each term of residence, whether they are attending regular courses of study, carrying on research or independent reading only, writing a thesis or other dissertation, or utilizing any other academic service.

2. Before registering, the student should consult with members of the department in which he is taking his major work to determine the studies which he can pursue to the best advantage.

3. A student will not receive credit for a course unless he is properly registered. At the first meeting of each class he should furnish the instructor with a regular assignment card for the course, obtained on registration. *The*

student himself is charged with the responsibility of making certain that all grades to which he is entitled have been recorded.

4. The number of units allowed for a course of study or for research is so chosen that one unit corresponds roughly to one hour a week of work throughout the term, for a student of superior ability.

5. In registering for research, students should indicate on their program card the name of the instructor in charge, and should consult with him to determine the number of units to which the proposed work corresponds. At the end of the term the instructor in charge shall decrease the number of units for which credit is given, in case he feels that the progress of the research does not justify the full number originally registered for.

6. Registration, with at least minimum tuition (see page 161), is required for the term or summer period in which the requirements for the Ph.D. degree are completed, including either the final examination or submission of thesis.

7. Graduate students studying for the doctor's degree who are devoting their whole time to their studies will be allowed to register for not more than 60 units in any one term. (See pages 179, 181 with reference to total work load of graduate students.)

IV. GRADES IN GRADUATE COURSES

1. Term examinations are held in all graduate courses unless the instructor, after consultation with the Chairman of the Division, shall arrange otherwise. No student taking a course for credit shall be exempt from these examinations when they are held.

2. Grades for all graduate work are reported to the Registrar's office at the close of each term.

3. The following system of grades is used to indicate class standing in graduate courses: "A" excellent, "B" good, "C" satisfactory, "D" poor, "E" conditioned, "F" failed, "Inc" incomplete. In addition to these grades, which are to be interpreted as having the same significance as for undergraduate courses (see page 152), the grade "P," which denotes passed, may be used at the discretion of the instructor, in the case of seminar or other work which does not lend itself to more specific grading. In graduate research, only the grades "P" and "F" are given.

V. GENERAL REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

1. *Major and minor program of study.* The work for the doctor's degree must consist of scientific research and advanced studies in some branch of science and engineering, called the major program of study; and of additional advanced work outside of this branch, called the minor program of study.

The minor program of study will be at the option of the student, either a general minor or a subject minor.

(a) *General minor.* The work will consist of at least 45 units of advanced work in one or more disciplines in the humanities or science or engineering other than that of the major subject. The choice and scope of this work must be approved by the division in charge of the major subject, on a form obtainable from the Graduate Office.

(b) *Subject minor*. The work is concentrated in one discipline, including at least 45 units of advanced work in this discipline, and must be comprehensive enough to give the student a fundamental knowledge of it. The minor subject may be in the humanities or in any discipline listed in Section VI under special requirements adopted by the various divisions of the Institute. The program must be approved by both major and minor divisions on a form obtainable from the Graduate Office. The candidate will be examined on this work (see page 186). A student who has satisfied the requirements for such a minor program of study will be given recognition for this work by explicit mention on his Ph.D. diploma of the minor subject or minor subjects if the requirements have been satisfied in more than one discipline.

Advanced studies include courses with numbers of 100 or over. However, only in approved cases is graduate residence credit given for such courses when they are required in the undergraduate option corresponding to the student's major field. No residence credit is given for courses with numbers under 100 when they constitute prerequisites to the student's minor subject courses. Credit in the amount to be determined by the Committee on Graduate Study may be allowed for other courses with numbers under 100 when they are outside the student's major field.

2. *Residence*: At least three academic years of residence subsequent to a baccalaureate degree equivalent to that given by the Institute are required for the doctor's degree. Of this at least one year must be in residence at the Institute. It should be understood that these are minimum requirements, and students must usually count on spending a somewhat longer time in residence. However, no student will be allowed to continue work toward the doctor's degree for more than 15 terms of graduate residence, nor more than 18 registrations for full- or part-time academic work, except by special action of the Committee on Graduate Study. In either case graduate study taken elsewhere will be counted when residence credit at the Institute has been allowed. (See page 177 regarding summer registration for research.)

A graduate student who, by special arrangement made in advance, is permitted to conduct a portion of his research in the field, in government laboratories, or elsewhere off the campus, must file in advance a registration card for this work in the office of the Registrar, in order that it may count in fulfillment of residence requirements. This work must be carried out under the direct supervision of a member of the Institute staff. The number of units to be credited for such work shall be determined by the Dean of Graduate Studies in consultation with the Chairman of the Division in which the student is carrying his major work; and a recommendation as to the proportion of the full tuition to be paid for such work shall be made by the Dean to the Vice-President in charge of Business Affairs.

A student whose undergraduate work has been insufficient in amount or too narrowly specialized, or whose preparation in his special field is inadequate, must count upon spending increased time in work for the degree.

3. *Admission to Candidacy*: On recommendation of the Chairman of the Division concerned, the Committee on Graduate Study will admit a student to candidacy for the degree of Doctor of Philosophy after he has

been admitted to work toward the doctor's degree and been in residence at least one term thereafter; has satisfied the several departments concerned by written or oral examination or otherwise that he has a comprehensive grasp of his major and minor (if any) subjects as well as of subjects fundamental to them; has fulfilled the language requirements; has shown ability in carrying on research, with a research subject approved by the Chairman of the Division concerned; and has initiated a program of study approved by his major and minor (if any) departments. For special departmental regulations concerning admissions to candidacy, see Section VI. Members of the Institute staff of rank higher than that of Assistant Professor are not admitted to candidacy for a higher degree.

A regular form, to be obtained from the Dean of Graduate Studies, is provided for making application for admission to candidacy. Such admission to candidacy must be obtained before the beginning of the fourth academic year after admission to graduate standing at the Institute. A student not admitted to candidacy at that time must petition through his Division to the Dean of Graduate Studies for permission to register for further work.

4. *Examinations.* (a) The language requirements are a prerequisite to admission to candidacy for the degree of Doctor of Philosophy. As soon as possible after beginning their graduate study, students are urged to consult with the department of languages to determine the best means of satisfying these requirements early. Graduate students are permitted to audit all courses in languages (page 151). The language requirements in either or both of the approved languages can be met in one of three ways:

I. To pass language examinations. Examinations are given three times a year. The dates are announced on the calendar on pages 4, 5.

II. To pass with a grade of B- or better one of the following courses: L 1 ab in French, L 35 in German, or L 51a in Russian.

III. With the approval of the department of languages, to complete a translation project. A knowledge of the fundamentals of the language is presupposed in such a case.

(b) During his course of study every doctoral candidate shall be examined broadly and orally on his major subject, the scope of his thesis and its significance in relation to his major subject, and if the candidate has a subject minor, on the subject of that program. These examinations, subject to the approval of the Committee on Graduate Study, may be taken at such time after admission to candidacy as the candidate is prepared, except that they must take place at least two weeks before the degree is to be conferred.

The examinations may be written in part, and may be subdivided into parts or given all at one time at the discretion of the departments concerned. The examination relating to the subject minor need not be included in the final examination. It may be given at a time to be determined by agreement between the minor and the major departments. The student must petition for these examinations on a form obtained from the Dean of Graduate Studies. For special departmental regulations concerning candidacy and final examinations, see Section VI, page 187.

5. *Thesis*: Two weeks before the degree is to be conferred, the candidate is required to submit to the Dean of Graduate Studies a ribbon copy, a repro-

duced copy, and the vellum of a satisfactory thesis describing his research. For special departmental regulations concerning theses, see Section VI.

With the approval of the department concerned, a portion of the thesis may consist of one or more articles published jointly by the candidate and members of the Institute staff or others. In any case, however, a substantial portion of the thesis must be the candidate's own exposition of his work. For regulations regarding use of "classified" material, see pages 181, 182.

Regulations and directions for the preparation of theses may be obtained from the office of the Dean of Graduate Studies, and should be followed carefully by the candidate.

Before submitting his thesis to the Dean of Graduate Studies, the candidate must obtain approval of it by the Chairman of his Division and the members of his examining committee. This approval must be obtained in writing on a form which will be furnished at the office of the Dean. *The candidate himself is responsible for allowing sufficient time for the members of his committee to examine his thesis.*

VI. SPECIAL REQUIREMENTS FOR THE DOCTOR'S DEGREE

In agreement with the general requirements for the doctor's degree adopted by the Committee on Graduate Study, as set forth in Section V (page 184), the various Divisions of the Institute have adopted the following supplementary regulations.

Division of Biology

1. *Admission.* Applicants are expected to have studied mathematics, physics, chemistry, and biology to approximately the same extent as covered in the undergraduate option in biology at the California Institute of Technology (see Schedules of Undergraduate Courses). Students with deficient preparation in one or more of these basic sciences may be admitted and required to remedy their deficiencies during the first years of graduate training. No graduate credit will be granted for such remedial study. Applicants intending to specialize in fields bordering between biology and chemistry or between biology and physics may be admitted on the basis of a curriculum equivalent to that offered respectively in the chemistry or physics undergraduate options at the Institute. Applicants are urged to take the Graduate Record Examinations (Aptitude Test and Advanced Tests in Biology, Chemistry, Mathematics, and Physics) and have their test scores submitted to the Institute.

2. *Student Conferences.* During the week preceding registration for the first term, each entering student confers with his *Advisory Committee.* The committee consists of the instructor likely to be in charge of his major subject work and three others representing diverse fields of biology. The committee will advise the student of deficiencies in his training and will be available for consultation and advice throughout his graduate study.

3. *Teaching Requirement for Graduate Fellows.* A graduate student who holds a national fellowship to do graduate work in the Division of Biology may be assigned to assist in teaching undergraduate courses if his advisory committee considers it to be of value for him to gain teaching experience. The amount of teaching may vary, but it will not be more than 15 hours per week for one term per year.

4. *Major Subjects of Specialization.* The fields within the Division of Biology in which a student may pursue major work leading to the doctor's degree are listed herewith. They are divided into three main disciplines for purposes of the regulations concerning minor subjects as stated on page 184.

A. Physiological Biology
- Plant Physiology
- Animal Physiology
- Psychobiology
- Embryology
- Biophysics

B. Genetical Biology
- Genetics
- Immunology
- Virology

C. Chemical Biology
- Biochemistry

5. *Minor Subjects.* A student majoring in one of these fields may elect to take a minor subject either (a) in another discipline of Biology or (b) in another division of the Institute. A student majoring in the Biology Division, whose minor program of study is of the general type, is required to select 45 units of advanced course work in one or more disciplines in the humanities, sciences (other than biology), or engineering, subject to the approval of the Biology Division.

A student majoring in another division of the Institute may, with the approval of the Biology Division, elect as a minor subject any one of those listed above in section 4. He is required to take two examinations, one in either general botany or general zoology and one in his minor subject.

6. *Admission to Candidacy.* To be recommended by the Division of Biology for admission to candidacy for the doctor's degree, the student must have demonstrated his ability to carry out original research and have passed the appropriate candidacy examinations, viz:—

a. A student taking his major subject in the Division of Biology who elects to take a minor subject in the same division is required to take four candidacy examinations. One must be in the field of the major and one in the field of the minor; the two others may be in general botany and general zoology, or in one of these and one of the subjects listed above in section 4, subject to approval of the Biology Division.

b. In case the minor subject is taken outside the Biology Division, the student will be required to fulfill the minor requirement of the outside division and, in addition, will be required to take three candidacy examinations. One must be in the field of the major; the two others may be in general botany and general zoology, or in one of these and one of the subjects listed above in section 4, subject to approval of the Biology Division.

c. A student taking his major subject in the Division of Biology, whose minor program of study is of the general type, is required to take three candidacy examinations. One must be in the field of the major; the two others may be in general botany and general zoology, or in one of these and one of the subjects listed above in section 4, subject to the approval of the Biology Division.

Although grades of C are considered to be passing in candidacy examinations, a grade of B or better is required in the student's major and minor subjects, except in general biology and general type minors in which a C is accepted.

7. *Final Examination and Thesis.* A final oral examination covering principally the work of the thesis will be held at least two weeks before the degree is to be conferred. The original typed copy of the thesis, the vellum copy, and two reproduced copies must be submitted at least two weeks before the date of the final examination. One of the two reproduced copies is retained by the Division Library. The examining committee will consist of such individuals as may be recommended by the Chairman of the Division and approved by the Dean of Graduate Studies.

Division of Chemistry and Chemical Engineering

1a. *Chemistry.* On the Monday and Tuesday preceding General Registration for the first term of graduate study, graduate students admitted to work for the Ph.D. degree will be required to take written placement examinations in the fields of inorganic chemistry, physical chemistry, and organic chemistry. These examinations will cover their respective subjects to the extent that these subjects are treated in the undergraduate chemistry option offered at this Institute and in general will be designed to test whether the student possesses an understanding of general principles and a power to apply these to concrete problems, rather than a detailed informational knowledge. It is expected of graduate students that they will demonstrate a proficiency in the above subjects not less than that acquired by abler undergraduates. Students who have demonstrated this proficiency in earlier residence at this Institute may be excused from these examinations.

In the event that a student fails to show satisfactory performance in any of the placement examinations he will be required to register for a prescribed course, or courses, in order to correct the deficiency at an early date. In general no graduate credit will be allowed for prescribed undergraduate courses. If the student's performance in the required course or courses is not satisfactory he will not be allowed to continue his graduate studies except by special action of the Division of Chemistry and Chemical Engineering on receipt of his petition to be allowed to continue.

To be recommended for candidacy for the doctor's degree in chemistry the applicant, in addition to demonstrating his understanding and knowledge of the fundamentals of chemistry, must give satisfactory evidence of his proficiency, at a higher level, in that field of chemistry elected as his primary field of interest and approved by the Division of Chemistry and Chemical Engineering. In general the applicant will be required to pass an oral examination and to submit to his examining committee one week prior to his examination (1) a written progress report giving evidence of his industry and ability in research and of his power to present his results in clear, concise language and with discrimination as to what is essential in scientific reports, and (2) three propositions (as described on the following pages) which the applicant is prepared to defend during his oral examination.

In the event that any or all of the candidate's propositions are found to be unsatisfactory he will not be recommended for candidacy at that time, but will be required to submit and defend a set of new or revised propositions at an examination to be taken at least three terms prior to his final examintion.

A student admitted to work for the Ph.D. degree in chemistry who fails to satisfy the Division's requirements for candidacy by the end of his fifth term of graduate residence at the Institute will not be allowed to register in a subsequent academic year except by special permission of the Division of Chemistry and Chemical Engineering.

1B. *Chemical Engineering.* The requirements in chemical engineering are essentially the same as those in chemistry except that the placement examinations for students planning to work for the Ph.D. degree will be required in the fields of engineering thermodynamics of one-component systems (on the Wednesday before registration), the unit operations of chemical engineering including fluid flow topics (on Thursday), and either physical chemistry (on Monday) or industrial chemistry (on Friday). Students who have in earlier residence at this Institute demonstrated proficiency in the subjects covered by the placement examinations may be excused from them.

The Division's requirements for candidacy in chemical engineering are in general to be completed by the end of the student's second term subsequent to receiving the master's degree or completing the requirements imposed on the basis of the placement examinations. The candidacy examination covers thermodynamics, chemical engineering unit operations, physical chemistry, and industrial chemistry.

2. It is expected that the applicant will have studied mathematics and physics substantially to the extent that these subjects are covered in the required undergraduate courses in the student's field of interest. In case the applicant's training is not equivalent to this, the Division of Chemistry and Chemical Engineering may prescribe additional work in these subjects before recommending him as a candidate.

3. The units of study offered to satisfy a minor requirement are to consist in general of graduate courses other than research; however, the Division of Chemistry and Chemical Engineering may, by special action, permit up to one-half of these units to consist of appropriate research. If a student elects a minor program of study of the general type, 45 units or more of advanced work are required and must represent an integrated program approved by the Division; for students in Chemistry it must consist of courses other than chemistry; for students in Chemical Engineering it must consist of courses other than chemical engineering. A grade of C or better is required in these courses.

4. The candidate must submit to the Chairman of the Division of Chemistry and Chemical Engineering four copies of his thesis, in final form (the original copy, a copy on vellum, and two copies reproduced from the vellum), at least two weeks before the date of his final examination. Three copies are returned to the candidate after his examination.

5. The final examination will consist in part of the candidate's oral presentation of a brief résumé of his research and its defense against attack, and in part of the defense of a set of propositions prepared by the candidate. The candidate may also expect questions related to his minor program of study.

Five propositions are required. In order to obtain diversity with respect to subject matter not more than two shall be related to the immediate area of the candidate's thesis research. Each proposition shall be stated explicitly and the argument presented in writing with adequate documentation. Propositions of exceptional quality presented at the time of the candidacy examination may be included among the five submitted at the time of the final examination.

The propositions, prepared by the candidate himself, should display his originality, breadth of interest, and soundness of training; the candidate will be judged on his selection and formulation of the propositions as well as on his defense of them. It is recommended that the candidate begin the formulation of his set of propositions early in his course of graduate study.

A copy of the set of propositions in final form must be submitted as part of each copy of the thesis to the Chairman of the Division of Chemistry and Chemical Engineering at least two weeks before the date set for the examination.

6. Graduate students taking chemistry as a subject minor shall complete a program of study which in general shall include Ch 125 or Ch 144 or Ch 148-149 and one or more graduate courses in chemistry so selected as to provide an understanding of at least one area of chemistry. The total number of units shall not be less than 45, and a grade of C or better in each course included in the program will be required.

Division of Engineering

1. *Civil Engineering.* To be recommended for candidacy for the doctor's degree in civil engineering the applicant must pass with a grade of C or better the subjects prescribed and selected for the fifth year, or equivalent substitution satisfactory to the department, and such other advanced subjects related to the contemplated direction of study as the department may require, and must pass special comprehensive oral or written examinations in the field covered by these subjects.

2. *Electrical Engineering.* To be recommended for candidacy the applicant must pass the following subject with a grade of C or better:

Ph 131 abc	Electricity and Magnetism

and one of the following subjects:

Ma 108 abc	Introduction to Real and Complex Analysis
AM 125 abc	Engineering Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ph 129 abc	Methods of Mathematical Physics

An applicant may also satisfy any of the course requirements described above by taking an examination in the subject with the instructor in charge. Every examination of this type will cover the whole of the course specified and the student will not be permitted to take it either in parts (e.g. term by term) or more than twice.

Students working toward the doctorate are required to take three oral examinations. The first of these, which is normally given during the fifth year, may be waived at the discretion of the faculty. The second must be taken prior to admission to candidacy and covers broadly his major field and his minor program of study. The third, which is taken after admission to candidacy, covers his doctorate thesis and its significance in and its relation to his major field. This final examination will be given not less than one month after the thesis has been presented in final form and subsequent to its approval.

3. *Mechanical Engineering.* Before being admitted to work for a doctor's degree in mechanical engineering, a graduate student will be admitted to work toward the degree of Mechanical Engineer. After completion of at least 12 units of research in his chosen field, the student may apply for permission to work toward the doctorate. The required 12 units of research can usually be completed by the end of the first term of the sixth year. Permission to work toward the doctorate will be granted if the student's course work and research show that he is capable of carrying on work at the doctoral level. Notification of the action taken will be given to the applicant not later than the end of the second term. Upon being admitted to work toward the doctor's degree, the student's admission to work for the engineer's degree will be cancelled.

To be recommended for candidacy for the doctor's degree in mechanical engineering, the applicant must pass one of the following subjects with a grade of C or better:

AM 125 abc	Engineering Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ph 107 abc	Electricity and Magnetism

and, in addition, not fewer than 50 units of advanced courses arranged by the student in conference with his supervising committee and approved by the department. If any course submitted for candidacy was taken elsewhere than at the Institute, the candidate may be required to pass special examinations indicating an equivalent knowledge of the subject.

Candidates are required to take two oral examinations after admission to candidacy. The first, termed the general examination, must be taken not later than six weeks after admission to candidacy and shall cover the major and minor subjects. The second, or thesis examination, shall be a defense of the doctoral thesis and a test of the candidate's knowledge in his specialized field of research.

The minor subject of a student in Mechanical Engineering must be chosen outside of the Division of Engineering. This restriction does not apply for a program of study of the general type, although at least a portion of this work should preferably be outside the Division. The choice of program must be approved by the student's advisor and the Faculty in Mechanical Engineering.

A student majoring in another branch of engineering or another division of the Institute may, with the approval of the Faculty in Mechanical Engineering, elect as a minor subject a group of courses that differ markedly from the major subject of study or research. The student shall acquire a thorough knowledge of that particular discipline. Such discipline may be fluid mechanics and thermodynamics, applied mechanics, jet propulsion, or physical metallurgy.

4. *Aeronautics.* In general, a graduate student is not admitted to work for the doctor's degree in aeronautics until he has completed at least 20 units of research in his chosen field. Thus, upon completion of his fifth year's work, he will be admitted to work towards the engineer's degree. If his course work and research during the sixth year show that he is capable of carrying on work at the doctorate level and if he satisfactorily passes a qualifying oral examination, he may then be admitted to work towards the doctor's degree. Upon being admitted to work towards the doctor's degree, his admission to work for the engineer's degree will be cancelled.

To be recommended for candidacy for the doctor's degree in aeronautics the applicant must pass one of the following subjects with a grade of C or better:

AM 125 abc	Engineering Mathematical Principles,
AM 126 abc	Applied Engineering Mathematics,
Ph 129	Methods of Mathematical Physics,
Ph 108 abc	Theoretical Mechanics

and two of the following subjects:

Ae 107 abc	Elasticity Applied to Aeronautics	
Ae 201 abc	Inviscid Fluid Mechanics	
Ae 204 abc	Mechanics of Real Gases	
JP 121 abc	Rocket	considered as one subject
JP 130 abc	Thermal Jets	

If any of the above subjects was taken elsewhere than at the Institute, the candidate may be required to pass special examinations indicating an equivalent knowledge of the subject.

5. *Engineering Science.* The program of study leading to advanced degrees in engineering science must be approved by the Engineering Science Committee.

a. Placement examinations. On the Thursday and Friday preceding the beginning of instruction for his first term of graduate study, a student is required to take placement examinations in basic mathematics and physics.

b. Admission to candidacy. To be recommended for candidacy for the Ph.D. degree in engineering science the student must, in addition to the general Institute requirements, take at least 12 units of research and pass the candidacy examinations. Before the end of his second year of residence, the student must take an examination in applied mathematics and theoretical physics and in addition an examination in one or more specific topics in engineering science such as fluid mechanics, physical metallurgy, principles of jet propulsion, nuclear engineering, electromagnetic wave propagation.

c. Thesis and final examination. A final examination will be given not less than one month after the thesis has been presented in final form. The final examination will cover the thesis and fields related to it.

Division of Geological Sciences

The following statement summarizes the regulations governing the doctorate program. A circular which provides more detail on these matters is available upon request at the Division Office.

1. *Placement Examinations*: Applications for admission to graduate study in the Division of Geological Sciences should be supported by a report of the student's score on both the aptitude test and the advanced test in geology of the Graduate Record Examination. This is not an absolute requirement but compliance is strongly urged. On Wednesday, Thursday and Friday of the week preceding registration for his first term of graduate work, the student will be required to map a small field area and to take written placement examinations covering basic aspects of the earth sciences and including elementary physics, mathematics, chemistry, and biology. These

examinations will be used to determine the student's understanding of basic scientific principles and his ability to apply these principles to specific problems. It is not expected that he possess detailed informational knowledge, but it is expected that he demonstrate a degree of proficiency not less than that attained by abler undergraduate students at the California Institute. A student who has demonstrated proficiency in earlier residence at the Institute may be excused from these examinations.

The student's past record and his performance in the placement examinations will be used to determine whether he should register for certain undergraduate courses. Any deficiencies must be corrected at the earliest possible date. All students who do not demonstrate adequate proficiency in mathematics will be required to register for Ge 108 in their first year of graduate residence.

Each member of the Division faculty serves as an adviser to a small number of graduate students. Each graduate student will be notified, prior to his arrival, as to who his adviser is to be, and prior to registration day in the fall the student should seek the counsel of his adviser in planning his program for the first term.

2. *Recommended Courses*: It is recommended, although not required, that the incoming graduate student take the following courses as early as possible in his program:

Ge 150	The Origin, Evolution, and Nature of the Earth
Ge 151	Laboratory Techniques in the Earth Sciences

These courses are designed to help orient the student and to acquaint him with pertinent problems, processes, and principles; with the kinds of tools employed in earth science studies, their limitations and potentialities; and with the interests and attitudes of the staff.

3. *Field Requirement*: Many problems in the earth sciences require for their solution an understanding of field techniques and field relations. All students in the Division of Geological Sciences will therefore be required to pursue at least a minimal program of study in field geology; a program which develops a competence in the solution of field problems equivalent to that achieved in Ge 120 abc. In general, all entering graduate students should expect to take at least one year of field geology during his first year at the Institute, or to take Ge 123 during the first summer. Graduate students majoring in geology in general will be required to take more than the minimal one-year program; the equivalent of the undergraduate field geology program (Ge 120 abc, GE 121 abc, Ge 123) at the Institute being the basic requirement.

Students who exhibit exceptional ability in physics and mathematics and whose program of study and research is devoted strictly to geophysical problems unrelated to surface or subsurface geology or to the characteristics of rocks and geological relations as they can be observed in the field may be excused from the minimal program of study in field geology. Individual decisions on these matters are made by a special committee appointed by the Division Chairman upon request of the student's advisor.

4. *Major Subject*: The work for the doctorate in the Division of the Geological Sciences shall consist of advanced studies and of research in some discipline in the geological sciences which will be termed the "major

subject" of the candidate. The Division will accept as major subjects any of the disciplines listed herewith, provided that the number of students working under the staff members in that discipline does not exceed the limit of efficient supervision.

Geology	Geochemistry
Geobiology	Geophysics

5. *Minor Requirement*: The purpose of the minor requirement is to give diversification of training and a broadening of outlook. It should involve basic approaches, techniques, and knowledge distinct from those of the major subject. The Division prefers to have its students satisfy the minor requirement by work in other divisions of the Institute as prescribed on pages 184-185 of this catalog. However, the student may propose a concentrated minor in one of the four fields listed in section 4 above, that is different from the major subject, or he may include Geology Division courses within a minor program of general type, if they are pertinent to an intelligently integrated program. These proposals are subject to review and approval by the Division and the Dean of Graduate Studies.

6. *Requirements for Ph.D.:*

In Geochemistry: In addition to the general Institute and Division requirements, the candidate for the Ph.D. in geochemistry must have as a minimum the equivalent of the courses that are required for the Bachelor's Degree in Geochemistry. The candidate will be expected to take a minimum of 45 units of advanced courses in Chemistry and Geochemistry. These same courses cannot be presented to satisfy the requirements for a minor or for a distributed minor.

Substitution for courses equivalent to the undergraduate requirement may be permitted by the Geochemistry Curriculum Committee upon petition. The natures of the substitutions that are permitted will depend upon the abilities and interests of the student.

In Geophysics: Ph.D. candidates in geophysics are required to take and pass with a grade of C or better Ph 129abc plus 45 units selected from the following: Ph 131, Ph 201, Ph 202, Ph 205, Ph 212, Ph 218, Ph 219, Ph 227, Ph 235, Ma 105, Ma 118, Ma 185, Ma 211, Ma 280, Ch 223, and Ch 225. This list is not exhaustive but does give the student an idea of the acceptable level. Mature students may satisfy any or all of these requirements by examinations.

7. *Admission to Candidacy*: An otherwise qualified student is eligible for admission to candidacy for the doctorate in the Division of the Geological Sciences as soon as he has passed his qualifying oral examination. This examination will consist of the oral defense of a set of propositions prepared by the candidate. The propositions should be from 3 to 5 in number and about half of them should relate to the branch of earth sciences of major interest to the candidate. The remaining propositions should cover aspects of the sciences in fields other than that of the major interest. As prepared by the candidate himself, each proposition should represent his grasp of the basic features and his critical evaluation of a significant scientific point or question. The entire group of propositions should display scholarship, originality, and breadth of interest. A clear statement of the basic problem and of the candidate's specific approach to, or evaluation of, it should be

incorporated in a succinct paragraph for each proposition. The candidate will be judged upon his selection and formulation of the propositions and upon his defense of them. In addition the examining committee will ask questions designed to evaluate his basic background in the earth sciences and allied fields as related to the propositions and to determine his capabilities in applying fundamental scientific principles to specific problems.

A copy of a list of propositions which has been drawn from past qualifying examinations is on file in the Division office, for student reference. This list is offered as a guide to satisfactory form and treatment rather than as a yardstick for choice of subject matter and originality.

Three copies of the propositions should be filed in the office of the Division of the Geological Sciences, not later than midterm of the fifth term of graduate residence, for approval by the Division Examining Committee (see page 186). An examining committee will then be appointed and a date will be set for the examination which is mutually agreeable to those concerned. The list of propositions, as approved by the supervising committee, must be filed by the candidate in the Division office at least two weeks in advance of the date set for the examination.

By approval of the Division of the Geological Sciences the candidate may obtain up to 15 units of graduate credit for his preparation of propositions, if these are adequately defended prior to midterm of his third term of graduate residence at the Institute.

A student admitted to work for the Ph.D. degree who fails to satisfy the Division's requirements for candidacy by the end of his fifth term of residence will not be allowed to register in a subsequent academic year except by special permission of the Division of the Geological Sciences. Successful completion of the qualifying examination is a necessary step in admission to candidacy. The remaining steps are outlined on page 185. item 3.

8. *Thesis and Paper for Publication:* The doctoral candidate must complete his thesis and submit it in final form by May 10 of the year in which the degree is to be conferred. The candidate must also prepare a paper for publication embodying the results of his thesis work in whole or in part. He should consult with the member of the staff supervising the major research on the choice of subject and on the scope of the paper. This paper must either be accepted by an agency of publication or be in such form that the examining committee believes that it will be published. A first draft of the thesis must be submitted by March 1 of the year in which it is proposed to take the degree.

9. *Final Examination*: The final oral examination for the doctorate will be scheduled following submission of the thesis and, in conformity with an Institute regulation, it must be scheduled at least two weeks before the degree is to be conferred.

Division of Physics, Mathematics, and Astronomy

1. Major and Minor Fields

The disciplines offered by the Division in which major or minor work may be undertaken, as specified on page 184, are Astronomy, Mathematics, and Physics.

2. PHYSICS

a. *Placement Examinations.* On Thursday and Friday preceding the beginning of instruction for his first term of graduate study, a student admitted to work for an advanced degree in physics is required to take placement examinations to be used as a guide in selecting the proper course of study. These examinations will cover material treated in Electricity and Magnetism; Theoretical Mechanics; Atomic and Nuclear Physics, and Introduction to Real and Complex Analysis approximately as covered in Ph 107, Ph 108, Ph 112, and Ma 108. In general, they will be designed to test whether the student possesses an understanding of general principles and a power to apply these to concrete problems, rather than detailed informational knowledge. In cases in which there is a clear basis for ascertaining the status of the entering graduate student, the placement examinations may be waived.

If the placement examinations reveal a need for courses prerequisite to those listed in section c, the student will be required to register for a prescribed course or courses. If he does not obtain grades of C or better in these courses he will be allowed to continue his graduate studies only by special permission of the Physics Department Graduate Committee.

b. *Course Groups.* In the statements below of courses required for the oral candidacy examination, admission to candidacy, and recommendation for the Ph.D. degree, the courses are divided into groups as follows:

	GROUP I, REQUIRED COURSES	*Units*
Ph 129	Methods of Mathematical Physics	18
Ph 205	Principles of Quantum Mechanics	18
Ph 209	Electromagnetism and Electron Theory	27

	GROUP II, ELECTIVE COURSES
Ph 131	Electricity and Magnetism
Ph 201	Analytical Mechanics
Ph 203	Nuclear Physics
Ph 204	Low Temperature Physics
Ph 207	X- and Gamma-rays
Ph 217	Spectroscopy
Ph 227	Thermodynamics, Statistical Mechanics and Kinetic Theory
Ph 231	High Energy Physics
Ph 234	Topics in Theoretical Physics
Ph 235	Relativity and Cosmology
Ay 131	Astrophysics I
or	
Ay 132	Astrophysics II

Since the purpose of the Group II course requirements is to broaden the student's knowledge of physics and acquaint him with material outside his own field of specialization, no more than two terms of any given course may be counted toward any requirement for courses in Group II.

The student is expected to obtain a grade of C or better in each of his courses. If he obtains grades below C in the courses of Group I and those courses he elects from Group II, or in the courses presented to fulfill the requirements for 45 units in a discipline other than physics, or in the oral candidacy examination, the Physics Department Graduate Committee will review the student's entire record, and, if it is unsatisfactory, will refuse permission for him to continue work for the Ph.D.

c. *Oral Candidacy Examination*: Prior to the oral candidacy examination, a student must have taken at least 18 units of research and should have passed (or passed the written candidacy examination in) 45 units of the courses listed in Group I and in 27 units of the courses in Group II. The requirement for 18 units of research may be waived if the student has clearly demonstrated his familiarity with research in a particular field. The oral candidacy examination will cover those subjects in physics and the minor subject with which the student may be expected to have gained familiarity through course work, independent study, and laboratory research. It may also include material from the advanced undergraduate courses required of physics majors at the California Institute. At the discretion of the examining committee this examination may be supplemented by a written examination and, in special cases, may be broken off early without reaching any decision, adjourning to a later date.

Candidates who have selected a minor subject must pass a special oral examination in their minor subject. It is the responsibility of the candidate to make arrangements for this examination. It should be held as soon as possible after completion of the required course work in the minor.

d. *Admission to Candidacy*. To be recommended for candidacy for the Ph.D. degree in physics, a student must, in addition to the general Institute requirements, pass (or pass the written candidacy examinations in) all 63 units of Group I and 36 units of Group II, pass the Physics oral candidacy examination, and be accepted for thesis research by a staff member.

A student, admitted to work toward the Ph.D. degree, who does not satisfy the Division requirements for 63 units of Group I, 36 units of Group II, and the Physics oral candidacy examination by the end of the second year of graduate study at the Institute will not be allowed to register in a subsequent academic year without special permission of the Physics Department Graduate Committee. When a student is required to take courses prerequisite to those listed in section b, this committee ordinarily will grant at that time a suitable extension of the time allowed to complete the candidacy requirements.

e. *Further requirements for the Ph.D. degree*. In order to be recommended for the Ph.D. degree, each candidate must, in addition to the requirements for candidacy and the general Institute requirements for a Ph.D. degree, pass satisfactorily the 63 units from Group I and a total of 54 units from Group II. In addition to these requirements, the student will normally take other advanced courses, particularly in his field of specialization. In general a student will find it desirable to continue his graduate study and research for two years after admission to candidacy.

A final examination will be given not less than one month after the thesis has been presented in final form. This examination will cover the thesis topic and its relation to the general body of knowledge of physics.

The candidate himself is responsible for completing his thesis early enough to allow the fulfillment of all Division and Institute requirements, having due regard for the impossibility of scheduling by the Division of more than one final oral examination per day.

3. MATHEMATICS

a. Each new graduate student admitted to work for an advanced degree in mathematics will be given an informal interview on Thursday or Friday of the week preceding the beginning of instruction in the fall term. The purpose of this interview is to ascertain the preparation of the student and assist him in mapping out a course of study. The work of the student during the first year will include independent reading and/or research.

b. To be recommended for candidacy for the degree of Doctor of Philosophy in Mathematics the applicant must satisfy the general requirements and pass an oral candidacy examination. This examination will be held at the end of the first term of the second year of graduate study. The student will choose two among the three major fields of mathematics (Algebra, Analysis, Geometry). The candidacy examination will cover (a) the fundamentals of the two chosen fields and (b) the independent work done by the candidate during his first year. At the discretion of the department this examination may be supplemented by a written examination. The department may in special cases change the date of the candidacy examination.

c. In the course of his studies the candidate for the degree of Doctor of Philosophy must pass the equivalent of a full year's course in each of the three major fields of mathematics with a grade of C or better in each term (except that no grade requirements are made for a course taken in the last year). A candidate may satisfy any of these course requirements by passing an examination covering the full course in question.

d. On or before the first Monday in April of the year in which the degree is to be conferred, a candidate for the degree of Doctor of Philosophy must deliver a typewritten or printed copy of his completed thesis, in final form, to his supervisor. The department will assign to the candidate, immediately after the submission of his thesis, a topic of study outside his field of specialization. During the next four weeks the candidate is expected to assimilate the basic methods and the main results of the assigned topic with the aim of recognizing the direction of further research in this field.

e. The final oral examination in mathematics will be held as closely as possible four weeks after the date the thesis has been handed in. It will cover the thesis and fields related to it and the assigned topic of study.

f. Candidates who have selected a minor subject must pass a special examination in their minor subject. It is the responsibility of the candidate to make arrangements for this examination. It should be held as soon as possible after admission to candidacy and completion of the course-work in his minor subject.

4. ASTRONOMY

The Placement Examinations, p. 197, Section 2a, covering the material of Ph 107, Ph 108, Ph 112, and an additional examination in astronomy, covering the material in Ay 2, will be required of first-year students. Their goal is to ascertain whether the background of atomic and nuclear physics, mathematical physics, and astronomy is sufficiently strong to permit advanced study in these subjects.

To be recommended for candidacy for the doctor's degree in astronomy the applicant must complete satisfactorily 18 units of research, Ay 142, pass with a grade of C or better, or by special examination Ay 131abc, Ay 132ab, Ay 210 or Ay 211, and a satisfactory program, approved by the Department, in fields which will depend on the student's specialty.

The student's program during the first two years of graduate study should include a minimum of 63 units of advanced subjects in physics; for those students specializing in radio astronomy or in applied astronomical electronics advanced courses in electrical engineering and applied mechanics can be substituted. This program of study must be planned, and approved by the Department, during the first year, and special permission will be required for further registration if the candidacy course requirement is not satisfactorily completed by the end of the second year of graduate study. For admission to candidacy an oral examination will be given covering the entire field of study.

A final draft of the thesis must be submitted at least six weeks before the commencement at which the degree is to be conferred. At least two weeks after submission of the thesis the student will be examined orally on the scope of his thesis and its relation to current research in astronomy.

Opportunities for Graduate and Scientific Work at the Institute

ATHENAEUM

Graduate students are privileged to join the Athenaeum (Faculty Club), which affords the possibility of contact not only with fellow graduate students but also with others using the Athenaeum, including the Associates of the Institute, distinguished visitors, and members of the professional staffs of the Mount Wilson Observatory, the Huntington Library, and the California Institute. Students may have meals at the Athenaeum, and lodging when space is available. Beginning with the academic year 1961-62, new graduate student houses will provide lodging accommodations for about 160 graduate students.

GRADUATE FELLOWSHIPS, SCHOLARSHIPS, AND ASSISTANTSHIPS

The Institute offers in each of its divisions a number of fellowships, scholarships, and graduate assistantships. In general, scholarships carry tuition grants; assistantships, cash stipends; and fellowships often provide both tuition and cash grants. Graduate assistants are eligible to be considered for scholarship grants.

Forms for making application for fellowships, scholarships, or assistantships may be obtained on request from the Dean of Graduate Studies. In using these forms it is not necessary to make separate application for admission to graduate standing. These applications should reach the Institute by February 15. Appointments to fellowships, scholarships, and assistantships are for one year only; and a new application must be filed each year by all who desire appointments for the following year, whether or not they are already holders of such appointments.

GRADUATE ASSISTANTSHIPS

Graduate Assistants devote during the school year not more than fifteen hours a week to teaching, laboratory assistance, or research of a character that affords them useful experience. This time includes that required in preparation and in marking note-books and papers, as well as that spent in classroom and laboratory. The usual assistantship assignment calls for fifteen hours per week at the most and ordinarily permits the holder to carry a full graduate residence schedule as well.

GRADUATE SCHOLARSHIPS AND FELLOWSHIPS*

Institute Scholarships: The Institute offers a number of tuition scholarships to graduate students of exceptional ability who wish to pursue advanced study and research.

Cole Fellowships: The income from the Cole Trust, established by the will of the late Mary V. Cole in memory of her husband, Francis J. Cole, is used to provide three fellowships annually, one in each of the following fields: electrical engineering, mechanical engineering, and physics. The recipients are designated as Cole Fellows.

Drake Scholarships: The income from the Drake Fund, provided by the late Mr. and Mrs. Alexander M. Drake, is used to maintain scholarships in such numbers and amounts as the Board of Trustees determines. Graduate students who are recipients from this fund are designated as Drake Scholars.

Blacker Scholarships: The Robert Roe Blacker and Nellie Canfield Blacker Scholarship Endowment Fund, established by the late Mr. R. R. Blacker and Mrs. Blacker, provides in part for the support of graduate men engaged in research work. The recipients are designated as Blacker Scholars.

Henry Laws Scholarships: The income from a fund given by the late Mr. Henry Laws is used to provide scholarships for research in pure science, preferably in physics, chemistry, and mathematics. The recipients are designated as Henry Laws Scholars.

Caroline W. Dobbins Scholarships. The income from the Caroline W. Dobbins Scholarship Fund, provided by the late Mrs. Caroline W. Dobbins, is used to maintain scholarships at the Institute. Graduate student recipients are designated as Caroline W. Dobbins Scholars.

Meridan Hunt Bennett Scholarships: The scholarships for graduate students are granted from the Meridan Hunt Bennett Fund as stated on page 166.

Bridge Fellowship: The late Dr. Norman Bridge provided a fund, the income of which is used to support a research fellowship in physics. The recipient is designated as the Bridge Fellow.

Frederick Roeser Scholarship: This scholarship is granted from the Frederick Roeser Loan, Scholarship, and Research Fund. The recipient is designated as the Roeser Scholar.

David Lindley Murray Scholarships: The income from the David Lindley Murray Educational Fund is used in part to provide scholarships for graduate students. The recipients are designated as Murray Scholars.

Edith Newell Brown Scholarships: The income from the Edith Newell Brown Fund is used to maintain scholarships for graduate students. The recipients are designated as Edith Newell Brown Scholars.

*Fellows receiving grants equivalent to tuition and $1000 or more per academic year are permitted to accept employment or other appointment from the Institute during the academic year only with special approval of the Dean of Graduate Studies.

Theodore S. Brown Scholarships: The income from the Theodore S. Brown Fund is used to maintain scholarships for graduate students. The recipients are designated as Theodore S. Brown Scholars.

Clarence J. Hicks Memorial Fellowship in Industrial Relations: This fellowship is supported by a fund made available by Industrial Relations Counselors, Inc., and other contributors. The fellowship is granted to a graduate student who undertakes some studies in industrial relations, as approved by the Director of the Industrial Relations Section.

Lucy Mason Clark Fellowship: This fellowship, in the field of plant physiology, is supported by a fund contributed by Miss Lucy Mason Clark.

Van Maanen Fellowship: One or more pre-doctoral or post-doctoral fellowships are provided in the department of astronomy from the Van Maanen Fund. The recipients are known as Van Maanen Fellows.

Royal W. Sorensen Fellowship: The income from a fund created in honor of Royal W. Sorensen is used to provide a fellowship or a scholarship for a student in electrical engineering.

Von Kármán Scholarship Fund: Given by Dr. William Bollay for scholarships for sons or daughters of Aerophysics Development Corporation employees. The recipients are designated as von Kármán Scholars.

Ray G. Coates Scholarship: Provided by the income from a bequest made by the late Mrs. Alice Raymond Scudder Coates, to maintain a scholarship for a student of physics. The graduate student recipient is designated as Ray G. Coates Scholar.

ARCS Foundation (Achievement Rewards for College Scientists) of Los Angeles. The ARCS Foundation has established a fund for the award of several graduate and undergraduate scholarships.

Earle C. Anthony Scholarship: A fund has been established by Mr. Earle C. Anthony for scholarships for graduate students.

SPECIAL FELLOWSHIP AND RESEARCH FUNDS

In addition to the National Science Foundation, the Department of Health, Education and Welfare, the Institute for Defense Analyses, the National Aeronautics and Space Administration, the Woodrow Wilson Foundation, and the Ford Foundation, the following corporations, foundations, and individuals contribute funds for the support of Graduate Fellowships which are administered by the Institute: Allied Chemical and Dye Corporation, American Society for Testing Materials, Bell Telephone Laboratories, Bendix Aviation Corporation, Boeing Airplane Company, California Research Corporation, Consolidated Electrodynamics Corporation, Convair, Corning Glass Works Foundation, Curtiss-Wright Corporation, Del Mar Science Foundation, Douglas Aircraft Company, Dow Chemical Company, E. I. duPont de Nemours and Company, Eastman Kodak Company, Electro-Optical Systems, Inc., Firestone Tire and Rubber Company, Fluor Foundation, Garrett Corporation, General Atomic, General Electric Educational and Charitable Fund, General Precision, Inc., Gillette-Paper Mate Manufacturing Company, Hughes Aircraft Company, International Business Machines Corporation, International Nickel Company, Inc., Kaiser Aluminum & Chemical Corporation, Kennecott Copper Corporation, H. E. Linden, Paul E. Lloyd, Lockheed Leadership Fund, Arthur McCallum Fund, Mobil Oil Company, Pacific Scientific Company, Pan American Petroleum Foundation, Inc., Radio Corporation of America, Rand Corporation, Richfield Oil Corporation, Schlumberger Foundation, Shell Companies Foundation, Alfred P. Sloan Foundation, Space Technology Laboratories, Standard Oil Company of California, Stauffer Chemical Company, Stauffer Foundation, John Stauffer, Union Carbide Corporation, United States Rubber Company, United States Steel Foundation, Westinghouse Educational Foundation.

A number of governmental units, industrial organizations, educational foundations, and private individuals have contributed funds for the support of fundamental researches related to their interests and activities. These funds offer financial assistance to selected graduate students in the form of graduate research assistantships.

Daniel and Florence Guggenheim Fellowships in Jet Propulsion: These are fellowships established with the Guggenheim Jet Propulsion Center by the Daniel and Florence Guggenheim Foundation for graduate study in jet propulsion.

AEC Special Fellowships in Nuclear Science and Engineering: These fellowships are made available and are administered by the Atomic Energy Commission to support study in the general field of nuclear energy technology. The California Institute is a participating school at which AEC Fellows may pursue graduate study. See Nuclear Energy Option in Mechanical Engineering, page 228, and note under Engineering Science, page 125.

II. POST-DOCTORAL FELLOWSHIPS

A number of government agencies, foundations, societies, and companies support fellowships for the encouragement of further research by men who hold the doctor's degree. These grants usually permit choice of the institution at which the work will be done, and include, among others, those administered by the National Research Council, Rockefeller Foundation, John Simon Guggenheim Memorial Foundation, Commonwealth Fund, American Chemical Society, Bell Telephone Laboratories, E. I. du Pont de Nemours and Company, Merck and Company, Inc., American Cancer Society, the Atomic Energy Commission, the U. S. Public Health Service, the National Science Foundation, the National Foundation, and other government agencies, as well as various foreign governments. Applications for such fellowships should in general be directed to the agency concerned.

Institute Research Fellowships: The Institute each year appoints as Research Fellows a number of men holding the degree of Doctor of Philosophy who desire to pursue further research work. Applications for these appointments, as well as for the other special fellowships listed below, should be made on forms provided by the Institute. These forms, which should be filed with the Dean of the Faculty, may be obtained either from his office or from the Chairman of the Division in which the applicant wishes to work.

Gosney Fellowships: In 1929, Mr. E. S. Gosney established and endowed the Human Betterment Foundation. Following the death of Mr. Gosney in 1942, the Trustees of this Foundation transmitted the fund to the California Institute for the study of biological bases of human characteristics. The Trustees of the Institute have, for the present, set the income aside for the establishment of Gosney Fellowships. These are post-doctoral research fellowships, the conditions being similar to those of Guggenheim Fellowships. The stipend varies with the experience of the Fellow.

Harry Bateman Research Fellowship: In honor of the late Professor Harry Bateman, the Institute offers a research fellowship in pure mathematics to a candidate holding the doctorate. The recipient will devote the major part of his time to research, but will be expected to teach one course in mathematics. The appointment is normally made for one year, but may be renewed for a second year.

Noyes Fellowships: Dr. Noyes further left his entire estate, after providing for certain specific bequests and annuities, to the Institute to constitute a fund to be known as the "Noyes Chemical Research Fund." The purpose of this fund, as stated in his will, is to provide for the payment of salaries or grants to competent persons to enable them to carry on scientific investigations in the field of chemistry at the Institute. Such persons shall have the status of members of the staff of the Institute, and shall devote their time and attention mainly to the execution at the Institute of experimental and theoretical researches upon the problems of pure science (as distinct from those of applied science) in the field of chemistry. Dr. Noyes further provided that "no portion of the income of said fund shall be used for the payment of tuition fees, nor for scholarships or fellowship grants to persons still registered as students, or in general for the education of persons as to existing knowledge; but on the contrary the whole thereof shall be used for promoting, in the manner aforesaid in the field aforesaid, the search for new or more exact knowledge by persons who have completed their period of formal study and are devoting at least one-half of their working time to scientific investigations."

Millikan Fellowship: Established by the late Dr. Robert A. and Greta B. Millikan. Post-doctoral fellowship in the field of physical sciences, the recipients to be known as Millikan Fellows.

Richard Chace Tolman Fellowship: A fellowship in theoretical physics established in honor of Dr. Tolman, late Professor of Physical Chemistry and Mathematical Physics.

III. INSTITUTE GUESTS

Members of the faculties of other educational institutions and Research Fellows already holding the doctor's degree, who desire to carry on special investigations, may be invited to make use of the facilities of the Institute provided the work they wish to do can be integrated with the overall research program of the Institute and does not overcrowd its facilities. Arrangement should be made in advance with the chairman of the division of the Institute concerned. Such guests are given official appointment as Research Fellows, Senior Research Fellows, Research Associates, Visiting Associates, or Visiting Professors and thus have faculty status during their stay at the Institute.

Section V

SCHEDULES OF THE COURSES

The school year is divided into three terms. The number of units assigned in any term to any subject represents the number of hours spent in class, laboratory, and preparation. In the following schedules, figures in parentheses denote hours in class (first figure), hours in laboratory (second figure), and hours of outside preparation (third figure).[1]

Besides the subjects shown in the course schedules, students are required to take either military or physical education[2] in each term of the four school years. Students who continue their undergraduate work beyond four years continue to take physical education throughout their undergraduate course.

KEY TO ABBREVIATIONS

Aeronautics	Ae	Engineering Science	ES
Air Science	AS	English	En
Applied Chemistry	ACh	Geology	Ge
Applied Mechanics and Applied Mathematics	AM	History and Government	H
Astronomy	Ay	Hydraulics	Hy
Biology	Bi	Jet Propulsion	JP
Chemical Engineering	ChE	Languages	L
Chemistry	Ch	Mathematics	Ma
Civil Engineering	CE	Mechanical Engineering	ME
Graphics	Gr	Philosophy	Pl
Economics	Ec	Physical Education	PE
Electrical Engineering	EE	Physical Metallurgy	PM
		Physics	Ph

[1]The units used at the California Institute may be reduced to semester hours by multiplying the Institute units by the fraction of 2/9. Thus a twelve-unit course taken throughout the three terms of an academic year would total thirty-six Institute units or eight semester hours. If the course were taken for only one term, it would be the equivalent of 2.6 semester hours.

Note to Veteran Students: Inasmuch as subsistence allowances for Veterans are based on total "standard semester hours of credit *for a semester*, or their equivalent," it must be borne in mind that 1½ Institute terms are equivalent to one semester. Therefore, for purposes of determining your subsistence entitlement each term, multiply total Institute units by 2/9 (to reduce to semester hours per term) and then by 1½ (to evaluate your course in terms of semester hours per semester). This is more simply accomplished by multiplying total units for the term by ⅓.

[2]See page 157 for rule regarding excuses from physical education.

SENIOR HUMANITIES ELECTIVES

Pl 1	Philosophy
Pl 2	Logic
Pl 3	Contemporary European Philosophies
Pl 4	Ethics
Pl 6	Psychology
En 8	Contemporary English and European Literature
En 9	American Literature
En 10	Modern Drama
En 11	Literature of the Bible
En 17	Technical Report Writing
En 18	Modern Poetry
En 19	Seminar in Literature
L 5	French Literature
L 40	German Literature
Ec 48	Introduction to Industrial Relations
Ec 124	Economics of Underdeveloped Areas
H 4	The British Empire
H 7	Modern and Contemporary Germany
H 8	The History of Russia
H 15	The World Since 1914
H 16	American Foreign Relations
H 17	The Far West and the Great Plains
H 19	Modern America
H 21	Medieval England
H 22	Modern England
H 23	Modern War
H 25	Political Parties and Pressure Groups
H 26	The Political Novel
H 35	Modern India and Pakistan
H 124	Foreign Area Problems
H 125	International Law and Organization

FIRST YEAR, ALL OPTIONS

The subjects listed below are taken by all students during their first year. Differentiation into the various options begins in the second year.[1]

		Units per Term 1st	2nd	3rd
Ma 1 abc	Calculus, Vector Algebra, Analytic Geometry, Infinite series (4-0-8)	12	12	12
Ph 1 abc	Mechanics, Molecular Physics, Heat, Sound (3-3-6)	12	12	12
Ch 1 abc	General Chemistry (3-6-3)	12	12	12
En 1 abc	English: Reading, Writing, and Speaking (3-0-3)	6	6	6
H 1 abc	History of European Civilization (2-0-3)	5	5	5
Gr 1	Basic and Applied Graphics (0-3-0)	3	.	.
PE 1 abc[2]	Physical Education (0-3-0)	3	3	3
		53	50	50

[1]Honor electives (3 units) to be given second and third terms. See page 156.

[2]AFROTC students substitute 4 units of Air Science (AS 1 abc, 2-1-1) for Physical Education (PE 1 abc, 0-3-0).

ASTRONOMY OPTION

(For First Year see page 206)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 154.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ph 2 abc	Electricity, Optics and Modern Physics (3-3-6)	12	12	12
Ma 2 abc	Calculus, Vectors and Differential Equations (4-0-8)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ay 1	Introduction to Astronomy (3-1-5)	.	.	9
	Electives (see below)	15-19	15-19	6-10
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		48-52	48-52	48-52

Sophomore electives should include at least 27 units of science and engineering courses. At least 18 units of science and engineering electives shall be in subjects other than mathematics or physics. It is desirable for a student to acquire as broad as possible a background in other related fields of science or engineering.

THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 111 abc	Structure of Matter (3-0-6)	9	9	9
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Electives (see below)	9-15	9-15	9-15
		47-53	47-53	47-53

FOURTH YEAR

	Humanities Electives[3] (3-0-6)	9	9	9
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
Ph 112 abc	Atomic and Nuclear Physics (4-0-8)	12	12	12
PE 4 abc[4]	Physical Education (0-3-0)	3	3	3
	Electives (see below)	11-18	9-11	9-11
		46-53	50-52	50-52

Suggested Electives

The student may elect any course that is offered in any division in a given term, provided that he has the necessary prerequisites for that course. The following list contains some of the courses that are useful to work in various fields of astronomy.

Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
EE 5	Introductory Electronics (3-0-6)	.	.	9
Ma 5 abc	Introduction to Abstract Algebra (3-0-6)	9	9	9
AM 8 abc	Mechanics of Solids I. (3-0-6)	9	9	9
ME 17 ab	Thermodynamics (3-0-6)	9	9	.
L 32 abc	Elementary German (4-0-6)	10	10	10
L 35	Scientific German (4-0-6)	10	.	.
L 50 abc	Elementary Russian (4-0-6)	10	10	10
L 1 ab	Elementary French	.	10	10
AM 115 ab[5]	Engineering Mathematics	12	12	.
	or	.	12	12

AM 116	Complex Variables and Applications	12	or	12
Ma 108 abc[5]	Advanced Calculus (4-0-8)	12	12	12
Ma 112	Elementary Statistics (3-0-6)	9 or	9	.
Ge 2	Geophysics	.	.	9
EE 1 abc	Basic Electrical Engineering (3-0-6)	9	9	9
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0)	.	3	3
EE 101 abc	Electric Circuit Theory (3-0-6)	9	9	9
EE 106 ab	Electronics (3-0-6)	9	9	.
Ph 115 ab[5]	Geometrical and Physical Optics (3-0-6)	9	9	.
Ma 105 ab	Introduction to Numerical Analysis (3-2-6)	.	11	11
Ph 217[5]	Spectroscopy (3-0-6)	.	.	9
Ay 108 ab[5]	Astronomical Instruments and Radiation Measurements (3-1-5), (3-2-4)	9	9	.
Ay 133[5]	Radio Astronomy (3-0-6)	.	.	9
Ay 131 abc[5]	Astrophysics I (3-0-6)	9	9	9
Ay 132 ab[5]	Astrophysics II (3-0-6)	9	9	.
Ay 141 abc[5]	Astronomy Research Conference (1-0-1)	2	2	2

1AFROTC students will substitute AS 2 abc for PE 2 abc.

2AFROTC students will substitute AS 3 abc for PE 3 abc and take 6-10 units electives per term.

3For senior Humanities electives see p. 206.

4AFROTC students will substitute AS 4 abc for PE 4 abc and take 6-10 units of electives each term. H 23 will substitute for Humanities elective in one term.

5Students who plan to do graduate work in astronomy or radio astronomy should elect some of these courses during their 3rd and 4th years, on consultation with their advisors.

BIOLOGY OPTION

(For First Year see page 206)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 154.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
	Electives	19	19	19
		52	52	52

Electives

27 units of the electives must be in Science or Engineering.
The following Sophomore electives are recommended* for Biology majors:

Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
Bi 1	Elementary Biology (3-3-3)	.	9	.
Bi 9	Cell Biology (3-3-3)	.	.	9
	Non-Biology elective	9	.	.

*Biology majors not electing Ch 41 abc and Ch 46 abc in the second year are required to take these courses in the third year and postpone Bi 107 to the fourth year. Biology majors who have not elected Bi 1 and Bi 9 in the second year are expected to elect them or approved alternatives in the third or fourth year.

THIRD YEAR (1960-61)

Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
En 77 abc	Introduction to Literature (3-0-5)	8	8	8
Bi 107 abc	Biochemistry (3-0-7; 3-3-4; 3-5-2)	10	10	10
Bi 3	Plant Biology (4-6-2)	12	.	.
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Electives	10	22	22
		52	52	52

THIRD YEAR (1961-62 and after)

Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Bi 107 abc	Biochemistry (3-0-7; 3-3-4; 3-5-2)	10	10	10
Bi 3	Plant Biology (4-6-2)	12	.	.
Bi 10	Animal Biology (4-6-2)	.	12	.
PE abc[2]	Physical Education (0-3-0)	3	3	3
	Electives	10	10	22
		52	52	52

Electives

Electives, additional to those available in the sophomore year, may, with the approval of the student's advisor, be selected from the following:

Bi 114	Immunology (2-4-3)	9	9	9
Bi 122	Genetics (3-3-4) (Not offered in 1960-61)	10	.	.
Bi 106	Embryology (2-6-4)	.	12	.
Bi 126	Genetics of Microorganisms (2-4-4)	.	10	.
Bi 20	Mammalian Anatomy and Histology (2-6-4)	.	.	12
Bi 110	General Microbiology (3-4-5)	.	.	12
Bi 127	Biochemical Genetics (3-4-3)	.	.	10
L 32 abc	Elementary German (4-0-6)	10	10	10
L 50 abc	Elementary Russian (4-0-6)	10	10	10

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1), for Physical Education (PE 2 abc 0-3-0).

[2]AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1), for Physical Education (PE 3 abc, 0-3-0).

FOURTH YEAR (1960-61)

		Units per Term 1st	2nd	3rd
	Humanities Electives[4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	.
Bi 118	General Physiology (3-3-4)	10	.	.
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Electives	22	32	38
		52	52	52

FOURTH YEAR (1961-62 and after)

		1st	2nd	3rd
	Humanities Electives[4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	.
Bi 118	General Physiology (3-3-4)	10	.	.
Bi 122*	Genetics (3-3-4)	10	.	.
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Electives	12	32	38
		52	52	52

Electives

In addition to those listed for the third year:

		1st		2nd		3rd
Bi 117	Psychobiology 1 (3-3-3)	.		.		9
Bi 129 ab	Biophysics (2-0-4)	6		6		.
Ch 132	Biophysical Chemistry (2-0-4)	.		.		6
Bi 214 abc	Chemistry of Bioorganic Substances (1-0-2)	3		3		3
Bi 218	Virology (2-3-4)	.		9		.
Bi 220 abc	Experimental Embryology (2-0-4)	6		6		6
Bi 230	Psychobiology 2 (units to be arranged)	x	or	x	or	x
Bi 125	Topics in Plant Biology (3-3-6)	12		.		.
Bi 240 abc	Plant Physiology (2-0-4)	6		6		6
Bi 241 abc	Advanced Biochemistry (2-0-4)	6		6		6
Bi 260	Advanced Physiology (units to be arranged)	.		x		.
Bi 109	Advanced Genetics Laboratory (units to be arranged)	.		x		.
Bi 22	Special Problems (units to be arranged)	x	or	x	or	x
	Any advanced course offered by other Divisions subject to approval by the student's advisor.					

*Required of Biology majors unless Bi 2 or Bi 122 have been taken earlier.

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

[4]For list of Humanities electives, see page 206.

CHEMICAL ENGINEERING OPTION

(For First Year see page 206)

Any student of the Chemical Engineering Option whose grade-point average in the required chemistry and chemical engineering subjects of any year is less than 1.9 will be admitted to the required chemistry and chemical engineering subjects of the following year only with the special permission of the Division of Chemistry and Chemical Engineering.

SECOND YEAR

(Identical with the Chemistry Option)

		Units per Term 1st	2nd	3rd
H 2 abc	History and Government of the United States (2-0-4)	6	6	6
Ma 2 abc	Calculus, Vectors, and Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Electricity, Optics, and Modern Physics (3-3-6)	12	12	12
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
	Electives in Science and/or Engineering[1]	9	9	9
PE 2 abc	Physical Education (0-3-0)[2]	3	3	3
		52	52	52

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	.	6
Ch 14	Quantitative Analysis (2-6-2)	10	.	.
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
ChE 63 ab	Chemical Engineering Thermodynamics (3-0-6)	.	9	9
AM 115 ab	Engineering Mathematics (4-0-8)	12	12	.
EE 5	Introductory Electronics (3-0-6)	.	.	9
PE 3 abc	Physical Education (0-3-0)[3]	3	3	3
		48	49	52

FOURTH YEAR

		1st	2nd	3rd
	Humanities electives (3-0-6)[4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
ChE 61 ab	Industrial Chemistry (3-0-6)	.	9	9
ChE 63 c	Chemical Engineering Thermodynamics (3-0-6)	9	.	.
AM 8 ac	Mechanics of Solids I (3-0-6)	9	.	9
ChE 66 abc	Chemical Engineering Operations (3-0-9; 2-0-7)	12	9	12
ChE 67	Chemical Engineering Laboratory (0-9-3)	.	12	.
	Electives[5]	6-10	6-10	6-10
PE 4 abc	Physical Education (0-3-0)[6]	3	3	3
		50-54	50-54	50-54

[1]No more than 9 units in chemical engineering and no units in chemistry courses may be elected.

[2]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Phyhical Education (PE 2 abc, 0-3-0).

[3]AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-1-3) for Physical Education (PE 3 abc, 0-3-0).

[4]For list of Humanities electives, see page 206.

[5]These elective units must be approved by the advisor. If Ch 41 abc and Ch 46 abc have not been taken, they must be substituted in place of these electives.

[6]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

CHEMISTRY OPTION

(For First Year see page 206)

Any student of the Chemistry Option whose grade-point average in the required chemistry subjects of any year is less than 1.9 will be admitted to the required chemistry subjects of the following year only with the special permission of the Division of Chemistry and Chemical Engineering.

SECOND YEAR

(Identical with the Chemical Engineering Option)

		Units per Term 1st	2nd	3rd
H 2 abc	History and Government of the United States (2-0-4)	6	6	6
Ma 2 abc	Calculus, Vectors, and Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Electricity, Optics, and Modern Physics (3-3-6)	12	12	12
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
	Electives in Science and/or Engineering[1]	9	9	9
PE 2 abc	Physical Education (0-3-0)[2]	3	3	3
		52	52	52

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
L 32 abc	Elementary German[3] (4-0-6)	10	10	10
Ch 14	Quantitative Analysis (2-6-2)	10	.	.
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
Ch 90	Oral Presentation (1-0-1)	2	.	.
	Electives[4]	8-12	6-10	6-10
PE 3 abc	Physical Education (0-3-0)[5]	3	3	3
		50-54	50-54	50-54

FOURTH YEAR

		1st	2nd	3rd
	Humanities electives (3-0-6)[6]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
	Electives[7]	36-40	36-40	36-40
PE 4 abc	Physical Education (0-3-0)[8]	3	3	3
		50-54	50-54	50-54

[1] No more than 9 units in chemical engineering and no units in chemistry courses may be elected.

[2] AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

[3] May be taken in either third or fourth year.

[4] In addition to approved elective courses listed on page 213 any science and engineering course and L 35 will be accepted if approved by the advisor. If Ch 41 abc and Ch 46 abc have not been taken, they must be substituted in place of these electives.

[5] AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-1-3) for Physical Education (PE 3 abc, 0-3-0).

[6] For list of Humanities electives see page 206.

[7] Approved elective courses listed on page 213.

[8] AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

APPROVED ELECTIVE COURSES IN THE CHEMISTRY OPTION

The choice of electives must include courses which require a total of 18 units of laboratory work (for example, Ch. 16, Instrumental Analysis (0-6-2) requires 6 units of laboratory) or a total of 36 units of research (Ch 80). These elective laboratory units can be accumulated throughout the undergraduate years. Other courses may be taken as electives provided they are in science or engineering subjects and are approved by the advisor. Students must meet any prerequisites required by a course.

		Units per Term 1st	2nd	3rd
Ch 13 abc	Inorganic Chemistry (2-0-4)	6	6	6
Ch 16	Instrumental Analysis (0-6-2)	8	.	.
Ch 117	Electroanalytical Chemistry (2-0-2)	.	4	.
Ch 118 ab	Electroanalytical Chemistry Laboratory (0-6-0)	.	.	6
Ch 125 abc	Advanced Physical Chemistry (3-0-6)	9	9	9
Ch 127 abc	Radioactivity and Isotopes (2-0-4)	6	6	6
Ch 129	Surface and Colloid Chemistry (3-0-5)	.	.	8
Ch 130	Photochemistry (2-0-4)	.	6	.
Ch 144 abc	Advanced Organic Chemistry (3-0-6)	9	9	9
Ch 148 abc	Characterization of Organic Compounds (2-0-2)	4	4	4
Ch 149 abc	Laboratory in Characterization of Organic Compounds (0-6-0)	6	6	6
Ch 80	Chemical Research (units to be arranged)	.	.	.
ChE 61 ab	Industrial Chemistry (3-0-6)	.	9	9
ChE 63 abc	Chemical Engineering Thermodynamics (3-0-6)[1]	9	9	9
ChE 66 abc	Chemical Engineering Operations (3-0-9; 2-0-7)	12	9	12
ChE 80	Undergraduate Research (units to be arranged)			
Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
Ph 111 abc	Structure of Matter (3-0-6)	9	9	9
Ph 112 abc	Atomic and Nuclear Physics (4-0-8)	12	12	12
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8)	12	12	12
AM 115 ab	Engineering Mathematics (4-0-8)[2]	.	.	.
AM 102 abc	Applied Nuclear Physics (2-0-4)	6	6	6
Bi 107 abc	Biochemistry-Biophysics (3-0-7; 3-3-4; 3-5-2)	10	10	10
Bi 110	General Microbiology (3-4-5)	.	.	12
Bi 127	Biochemical Genetics (3-4-3)	.	.	10
Ge 3	Mineralogy (3-3-3)	.	9	.
Ge 30	Introduction to Geochemistry (3-0-7)	.	.	10
Ge 151	Laboratory Techniques in the Earth Sciences (0-5-0)	.	5	.
L 35	Scientific German (4-0-6)	10	.	.

[1]Given in the sequence second, third, first terms.

[2]May be taken first and second or second and third terms.

ENGINEERING OPTION

(For First Year see page 206)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of the faculty in Engineering, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 154.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, & Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
	Science or Engineering Electives	9	9	9
	Electives*	6-12	6-12	6-12
		48-54	48-54	48-54

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
AM 115 ab	Engineering Mathematics			
AM 116	Complex Variables and Applications			
	or			
Ma 108 abc	Introduction to Real & Complex Analysis (4-0-8)	12	12	12
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Electives*	25-31	25-31	25-31
		48-54	48-54	48-54

FOURTH YEAR

		1st	2nd	3rd
	Humanities Elective[3] (3-0-6)	9	9	9
H 5 abc	Current History (1-0-1)	2	2	2
E 10 ab or E 11 ab	Technical Presentations (1-0-1)	2	2	2
PE 4 abc[4]	Physical Education (0-3-0)	3	3	3
	Electives*	32-38	32-38	34-40
		48-54	48-54	50-56

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

[2]AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1) for Physical Education (PE 3 abc, 0-3-0).

[3]For list of Humanities electives, see page 206.

[4]AFROTC students substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0).

*With approval of advisor. Ec 4 ab, 6 units each term must be included in the electives for graduation. All courses for B.S. in Engineering must total 580 units.

NOTE: A student who plans to apply for graduate study at the Institute in some field of Engineering should, before choosing his electives, consult Sections IV and V of this catalog for specific requirements for admission to graduate study in this field.

GEOLOGICAL SCIENCES OPTION

(For First Year see page 206)

Attention is called to the fact that any student whose grade-point average in freshman physics, chemistry, and mathematics is less than 1.9, may at the discretion of the Division of the Geological Sciences, be refused permission to register in the Geological Sciences Option. Furthermore, any student whose grade-point average is less than 1.9 in the subjects in the Division of Geological Sciences during any term may, at the discretion of the Division, be refused permission to continue in the Geological Sciences Option.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, and Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6) .	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	.	.
Ge 3	Mineralogy (3-3-3)	.	9	.
PE 2 abc	Physical Education (0-3-0)	3	3	3
	(AFROTC students substitute 4 units or Air Science AS 2 abc, 2-1-1)			
	Electives (see suggested Electives listed below)	10	9	18
		52	51	51

Suggested Electives—Second Year

The following courses are suggested as being especially suitable for a balanced program of study. Different courses may be elected with the advice and consent of the student's advisor, but at least 18 units of electives must be taken outside of the Division.

CH 14	Quantitative Analysis (2-6-2)	10	.	.
B 1	Elementary Biology (3-3-3)	.	9	.
Ge 2	Geophysics (3-0-6)	.	.	9
Ge 5	Geobiology (3-0-6)	.	.	9

Bi 10 Animal Biology is strongly recommended for those interested in paleontology.

THIRD YEAR

Common to All Options in the Division

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ge 120 abc	Field Geology (4-5-1; 0-8-2; 0-6-4)	10	10	10
PE 3 abc	Physical Education (0-3-0) (AFROTC students substitute 8 units of Air Science AS 3 abc, 4-3-1)	3	3	3

Geology and Geochemistry Options

Ge 104 a	Petrology, Igneous (3-3-2)	8	.	.
Ge 104 b	Petrology, Sedimentary (3-4-3)	.	10	.
Ge 104 c	Petrology, Metamorphic (2-3-2)	.	.	7
Ch 24 ab	Physical Chemistry for Geologists (4-0-6)	10	10	.
Ge 30	Introduction to Geochemistry (3-0-7)	.	.	10
	Electives (select from Electives listed below)	11	9	12
		50	50	50

Add electives with advice and consent of advisor to bring load up to a minimum of 45 units but not to exceed the allowable limit. Ec 4 a, b must be included in the electives by or before the 4th year as it is an Institute requirement for graduation. Special attention is called to the opportunity to take L 32 abc. Other desirable elective subjects include Ay 1, Bi 2 (for paleontologists), Ma 112, Ch 14, ChE 50, Hy 134, Hy 210 a, b, AM 4 ab, AM 110 a, CE 155 among others, provided student has proper prerequisites. Geochemists are urged to take Ch 21 abc instead of Ch 24 ab and Ge 30. Ge 30 can be elected at a later date. A geochemist can also substitute other courses for Ge 104 c with the advice and consent of his advisor.

Summer Field Geology, Ge 123, 30 units, required after third year in Geology and Geochemistry Options.

Geophysics Option

Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
	Electives (select from Electives listed below)	20	20	20
		50	50	50

Add electives to bring unit load up to a minimum of 45 units but not to exceed the allowable limit, selected with the advice and consent of the advisor from the following courses for which prerequisites have been completed. Any Ge course, Ay 1, AM 15 abc, Ch 21 abc, EE 19 a, EE 40, Ma 108 abc, Ph 108 abc. Special attention is called to the opportunity to take L 32 abc. Ec 4 ab must be elected by or before the 4th year as it is an Institute requirement for graduation.

FOURTH YEAR

Common to All Options in the Division

L 32 abc	Elementary German (4-0-6)	10	10	10
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ge 100	Geology Club (1-0-0)	1	1	1
PE 4 abc	Physical Education (0-3-0)	3	3	3
	(AFROTC students substitute 8 units of Air Science, AS 4 abc, 4-1-3. AFROTC students must take H 23, Modern War, as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.)			
	Humanities Elective (3-0-6)	9	9	9
	(Elect from selection listed on page 206)			

Geology Option

Ge 121 abc	Advanced Field Geology (4-8-2; 0-8-2; 0-5-6)	14	10	11
	Electives	9-11	12-15	11-14
	Electives to be selected from any advanced courses in the Division of Geological Sciences or courses in other Science or Engineering Division. (See list under third year.) The elective courses must be approved by the student's advisor.			
		48-50	47-50	47-50

Geochemistry Option

	Electives (see statement immediately below)	25	25	25
	A suitable program will be worked out by the student and his advisor. This program will include courses from the Chemistry and Geology options. For example: Ch 13 abc, Ch 127 ab, Ch 129, Ge 105, Ge 106 ab, and Ge 151.			
		50	50	50

Geophysics Option

Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
	Geology Electives	7-10	7-10	7-10
	General Electives	.	.	.
	Add other electives in Physics, Mathematics, Chemistry, Astronomy, or Engineering to bring unit load to a minimum of 45 units, but not to exceed the allowable limit. Elective courses must be approved by the student's advisor.			
		45-50	45-50	45-50

MATHEMATICS OPTION

(For First Year see page 206)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under the division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 154.

	SECOND YEAR	Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
H 2abc	History of the United States (2-0-4)	6	6	6
Ma 5 abc	Introduction to Abstract Algebra (3-0-6)	9	9	9
	Electives in Science or Engineering	9	9	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		51	51	51

	THIRD YEAR	1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (or a selected course in the Humanities[5]) (can be taken in senior year) . . . Minimum	6	6	.
Ma 108 abc	Advanced Calculus (4-0-8)	12	12	12
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Selected courses in Mathematics . . . Minimum	9	9	9
	Electives[4] . . . Minimum	9	9	9
	The total number of units must fall within the range	47-52	47-52	47-52

	FOURTH YEAR	1st	2nd	3rd
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (or a selected course in the Humanities[5]) (if not taken in junior year) . . . Minimum	6	6	.
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Selected courses in Mathematics . . . Minimum	9	9	9
	Selected courses in the Humanities[5]	9	9	9
	Electives[4] . . . Minimum	8	8	8
	The total number of units must fall within the range	41-51	41-51	41-51

Normally a junior will select 9 units each term and a senior 18 units each term in Mathematics. Sophomores who have not taken Ma 5 must take this course as juniors, postponing the selected course in Mathematics to the senior year. They are strongly advised to take one or preferably two full-year courses in languages.

[1]AFROTC students take AS 2 abc (2-1-1) instead of PE 3 abc (0-3-0).

[2]AFROTC students take AS 3 abc (4-3-1) instead of PE 3 abc (0-3-0).

[3]AFROTC students take AS 4 abc (4-1-3) instead of PE 4 abc (0-3-0).

[4]An elective is any course in any subject other than Mathematics.

[5]For list of Electives in the Humanities, see page 206. AFROTC students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

PHYSICS OPTION

(For First Year see page 206)

Attention is called to the fact that any student whose grade-point average for any three consecutive terms is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A more complete statement of this regulation will be found on page 154.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ph 2 abc	Electricity, Optics, and Modern Physics (3-3-6)	12	12	12
Ma 2 abc	Calculus, Vectors, and Differential Equations (4-0-8)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
	Electives[1]	15-19	15-19	15-19
PE 2 abc[2]	Physical Education (0-3-0)	3	3	3
		48-52	48-52	48-52

Suggested Electives

The student may elect any course that is offered in any term, provided only that he has the necessary prerequisites for that course. The following subjects are suggested as being especially suitable for a well-rounded course of study.

		1st	2nd	3rd
Ma 5 abc	Introduction to Abstract Algebra (3-0-6)	9	9	9
Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
Ay 1	Introduction to Astronomy (3-1-5)	.	.	9
ME 1	Introduction to Design (0-9-0)	9 or	9 or	9
ME 3	Materials and Processes (3-3-3)	9 or	9 or	9
ME 17 ab	Thermodynamics (3-0-6)	9	9	.
EE 5	Introductory Electronics (3-0-6)	.	.	9
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
ChE 50	Applications of Chemistry (3-0-6)	.	9	.
L 32 abc	Elementary German (4-0-6)	10	10	10

THIRD YEAR

		1st	2nd	3rd
Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 111 abc	Structure of Matter (3-0-6)	9	9	9
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
	Electives[3]	18-22	18-22	18-22
PE 3 abc[4]	Physical Education (0-3-0)	3	3	3
		47-51	47-51	47-51

Suggested Electives

		1st	2nd	3rd
Ma 108 abc	Advanced Calculus (4-0-8)	12	12	12
Ge 165	General Geophysics (3-0-3)	.	.	6
Ge 171	Applied Geophysics (4-2-4)	.	.	10
Bi 9	Cell Biology (3-3-3)	.	.	9
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
EE 1 abc	Basic Electrical Engineering (3-0-6)	9	9	9
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0)	.	3	3
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
Ph 115 ab	Geometrical and Physical Optics (3-0-6)	9	9	.
Ph 108 abc[5]	Theoretical Mechanics (3-0-6)	9	9	9

[1]At least 27 units of sophomore electives shall be chosen from science and engineering courses. At least 18 units shall be in science and engineering courses other than mathematics or physics.

[2]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

[3]Students should note that EE 1 abc is prerequisite to most advanced electrical engineering courses, and that Ma 108 abc is prerequisite to most advanced mathematical courses.

[4]AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1) for Physical Education (PE 3 abc, 0-3-0).

[5]A student may register for Ph 108 abc as a third-year elective only if he has attained an average grade of B+ or better in both Ph 2 abc and Ma 2 abc.

L 35	Scientific German (4-0-6)	10	.	.
L 50 abc	Elementary Russian (4-0-6)	10	10	10
L 1 ab	Elementary French (4-0-6)	.	10	10

FOURTH YEAR

Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
Ph 112 abc	Atomic and Nuclear Physics (4-0-8)	12	12	12
	Laboratory Course .... Minimum	6	.	.
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
H 5 abc	Public Affairs (1-0-1)	2	2	2
	Humanities elective[1]	9	9	9
	Electives	9-11	9-11	9-11
PE 4 abc[2]	Physical Education (0-3-0)	3	3	3
		50-52	50-52	50-52

Laboratory Courses

Ph 77	Experimental Physics Laboratory	6-9 or	6-9	.
EE 7 abc	Experimental Techniques in Electrical Engineering (0-3-2)	5	5	5
Ph 172	Experimental Research in Physics (units as arranged with instructor)	.	.	.

Suggested Electives

Ma 112	Elementary Statistics (3-0-6)	9 or	9	.
Ma 105 ab	Introduction to Numerical Analysis (3-2-6)	.	11	11
Ma 137	Introduction to Lebesgue Integrals (3-0-6)	9	.	.
EE 101 abc	Electric Circuit Theory (3-0-6)	9	9	9
EE 106 ab	Electronics (3-0-6)	9	9	.
EE 107	Principles of Feedback (3-0-6)	.	.	9
EE 40	Introduction to Information Theory (2-0-4)	.	.	6
Ph 129 abc	Methods of Mathematical Physics (3-0-6)	9	9	9
Ph 172	Experimental Research in Physics (units arranged)	.	.	.
L 51 abc	Intermediate Russian (4-0-6)	10	10	10

1For list of Humanities electives, see page 206.

2AFROTC students substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0) and take H 23 (Modern War) as their Humanities elective in the second term. For this they receive 8 units of Air Science credit and also satisfy the Humanities elective requirement for this term.

SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

GRADUATE HUMANITIES ELECTIVES

H 100 abc	Seminar in History and Government
En 100 abc	Seminar in Literature
Pl 100 abc	Seminar in Philosophy
Pl 101 abc	History of Thought
Pl 102 abc	Philosophy and Literature
Ec 100 abc	Business Economics
Ec 110	Industrial Relations
Ec 111	Business Cycles and Fiscal Policy
Ec 112	Modern Schools of Economic Thought
Ec 126 abc	Economics Analysis and Policy (Seminar)
H 123	Growth of Industrial Civilization
H 124	Foreign Area Problems
Ec 124	Economics of Underdeveloped Areas
H 125	International Law and Organization

AERONAUTICS

FIFTH YEAR

(Leading to the degree of Master of Science in Aeronautics)

		Units per Term 1st	2nd	3rd
	Humanities electives	9 or 10	9 or 10	9 or 10
Ae 101 abc	Mechanics and Thermodynamics of Fluids (3-0-6)	9	9	9
Ae 102 abc	Engineering Elasticity and Design (3-0-6)	9	9	9
Ae 103 abc	Aerodynamics of Aircraft (3-0-6)	9	9	9
AM 116	Complex Variables and Applications (4-0-8)	12	.	.
AM 115 ab	Engineering Mathematics	.	9	9
	Electives[1]	6	6	6
Ae 150 abc	Aeronautics Seminar (1-0-0)	1	1	1
		55-56	52-53	52-53

[1]Students who have had no laboratory work in fluid and solid mechanics should take at least one term of laboratory in each of these subjects, equivalent to Ae 106 a,b.

Note: The above program represents the minimum level of work for the M.S. degree in Aeronautics. If any of the subjects listed have been taken as an undergraduate, more advanced subjects may be substituted for them.

AERONAUTICS

SIXTH YEAR

(Leading to the degree of Aeronautical Engineer)

		Units per Term 1st	2nd	3rd
Ae 200 abc	Research in Aeronautics	20	20	20
AM 125 abc	*Engineering Mathematical Principles (3-0-6)	9	9	9
Ae 107 abc	Elasticity Applied to Aeronautics (3-0-6)	9	9	9
	Seminar[1]	1-3	1-3	1-3
	Electives (not less than)	6	6	6
		45-47	45-47	45-47

[1]Seminar elective should be chosen between Ae 208 abc, Ae 209 abc, or JP 280 abc.

*Possible alternatives for AM 125 abc are AM 126 abc, Ph 108 abc, or Ph 129 abc with the approval of the departmental advisor.

AERONAUTICS (JET PROPULSION OPTION)

SIXTH YEAR

JP 208	Research in Jet Propulsion	20	20	20
Ae 201 abc	Inviscid Fluid Mechanics (3-0-6)	9	9	9
or				
Ae 204 abc	Mechanics of Real Gases (3-0-6)	9	9	9
	Seminar elective (see Note 1 above)	1-3	1-3	1-3
	Elective (not less than)[3]	15-13	15-13	15-13
		45	45	45

[3]The electives are to be chosen from the Jet Propulsion subjects on pages 277-278 with the approval of the Goddard Professor of Jet Propulsion.

ASTRONOMY

FIFTH YEAR

(Leading to the degree of Master of Science in Astronomy)

Ay 131 abc, or Ay 132 ab, Astrophysics (3-0-6)

	Units per Term 1st	2nd	3rd
Humanities elective (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
Ay 131 abc, or Ay 132 ab, Astrophysics (3-0-6) and Ay 210 or Ay 211	9	9	9
Electives to total	48 to 50	48 to 50	48 to 50

Elective subjects program, to be approved by the department, from advanced subjects in astronomy and physics. Placement examination will be required. (See page 193, section 2(a). Ay 108, Ay 112, Ph 107, Ph 108, Ph 112 may be required of those students whose previous training in some of these subjects proves to be insufficient.

[1]For list of Humanities electives, see page 221.

BIOLOGY

As nearly all biology majors are working for the doctor's degree and following programs arranged by the students in consultation with members of the Division, no specific graduate curricula can be outlined.

CHEMICAL ENGINEERING

FIFTH YEAR

(Leading to the degree of Master of Science in Chemical Engineering)

		Units per Term 1st	2nd	3rd
	Humanities Elective (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
ChE 167 abc	Chemical Engineering Laboratory (0-15-0)	15	15	15
	Electives[2] at least	23	23	23
		47-48	47-48	47-48

[1]For list of Humanities electives, see page 221.

[2]Elective subjects are to be approved by a member of the Division and must include AM 115 ab if equivalent has not been taken. A minimum of 27 units of these electives must be in advanced chemical engineering subjects, the remainder are to be chosen from other advanced subjects.

A minimum of 141 units of approved graduate subjects, with three terms of residence (at least 45 units per term) is required for the Master's degree.

Students admitted for work toward the M.S. in Chemical Engineering will be required to take the placement examinations in engineering thermodynamics, and in the unit operations of chemical engineering.

SIXTH YEAR

(Leading to the degree of Chemical Engineer)

Programs are selected from a comprehensive list of available subjects and are arranged by the student in consultation with members of the Division. At least half of the student's time will be spent on research.

CHEMISTRY
FIFTH YEAR
(Leading to the degree of Master of Science in Chemistry)

On the Monday and Tuesday preceding General Registration for the first term of graduate study, graduate students admitted to work for the M.S. degree will be required to take written placement examinations in the fields of inorganic chemistry, physical chemistry, and organic chemistry. These examinations will cover their respective subjects to the extent that these subjects are treated in the undergraduate chemistry option offered at this Institute and in general will be designed to test whether the student possesses an understanding of general principles and a power to apply these to concrete problems, rather than a detailed informational knowledge. It is expected of graduate students that they demonstrate a proficiency in the above subjects not less than that acquired by abler undergraduates. Students who have demonstrated this proficiency in earlier residence at this Institute may be excused from these examinations.

In the event that a student fails to show satisfactory performance in any of the placement examinations he will be required to register for a prescribed course, or courses, in order to correct the deficiency at an early date. In general no graduate credit will be allowed for prescribed undergraduate courses. If the student's performance in the required course or courses is not satisfactory he will not be allowed to continue his graduate studies except by special action of the Division of Chemistry and Chemical Engineering on receipt of his petition to be allowed to continue.

The needs of Chemistry majors vary so widely in specialized fields of this subject that no specific curricula can be outlined. Before registering for the first time, a candidate for the master's degree should consult a member of the Committee on Graduate Study of the Division.

A total of at least 27 units in the Humanities is required for a master's degree. Not fewer than 30 units of courses of science subjects chosen from advanced courses and not fewer than 40 units of Chemical Research must be offered for the master's degree. Two copies of a satisfactory thesis describing this research, including a one-page digest or summary of the main results obtained, must be submitted to the Chairman of the Division at least ten days before the degree is to be conferred. The copies of the thesis should be prepared according to the directions formulated by the Dean of Graduate Studies and should be accompanied by a statement approving the thesis, signed by the staff member directing the research and by the Chairman of the Committee on Graduate Study of the Division.

CIVIL ENGINEERING
FIFTH YEAR
(Leading to the degree of Master of Science in Civil Engineering)

	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
CE 129	Spring Field Trip (0-1-0)	.	.	1
CE 130 abc	Civil Engineering Seminar (1-0-0; 0-4-0)	1	1	4
	Electives (minimum total for year 108)[2,3]	36-39	36-39	33-36
		46-50	46-50	47-51

Suggested Electives

(Courses are grouped into general areas for ready reference; however, the student is encouraged to select electives from several areas in order to avoid overspecialization).

STRUCTURES

AM 105	Advanced Strength of Materials (2-0-4)	.	6	.
AM 106	Problems in Buckling (2-0-4)	.	.	6
AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 111	Experimental Stress Analysis (1-6-2)	.	9	.
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
CE 120 ab	Advanced Structural Analysis (3-0-6)	9	9	0
CE 121	Analysis and Design of Structural Systems (0-9-0)	.	.	9
CE 123	Dynamics of Structures (3-0-6)	.	.	9
CE 124	Special Problems in Structures (3-0-6)	9	9	9

SOIL MECHANICS

CE 105	Introduction to Soil Mechanics (2-3-4)	9	.	.
CE 115 ab	Soil Mechanics (3-0-6; 2 3-4)	9	9	.
CE 150	Foundation Engineering (3-0-6)	.	.	9

HYDRAULICS AND WATER RESOURCES

CE 155	Hydrology (3-0-6)	9	.	.
CE 160	Advanced Hydrology[4]	.	.	.
CE 132	Water Power Engineering (2-3-4)	.	.	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9
Hy 103 a	Advanced Hydraulics (3-0-6)	9	.	.
Hy 101 b	Hydraulic Structures (3-0-6)	.	9	.
Hy 104	Advanced Hydraulics Laboratory[4]	.	.	.
Hy 134	Flow in Porous Media (3-0-6)	.	.	9

ENVIRONMENTAL HEALTH ENGINEERING

CE 137 abc	Water Supply & Waste-Water Disposal (3-3-6; 1-6-2)	12	12	9
CE 138 abc	Sanitary Sciences (2-3-4)	9	9	9
CE 139 ab	Engineering Principles in Environmental Health (2-3-4)	9	9	.
CE 156	Industrial Wastes (3-0-6)	.	.	9

APPLIED MATHEMATICS

AM 115 ab	Engineering Mathematics (4-0-8)	.	12	12
AM 116	Complex Variables & Applications (4-0-8)	12	.	.
AM 180	Matrix Algebra (3-0-6)	9	.	.
Ma 105 ab	Intro. to Numerical Analysis (3-2-6)	.	11	11
Ma 112	Elementary Statistics (3-0-6)	9	or 9	.

[1]For list of Humanities electives, see page 221.
[2]Students who have not had AM 115 ab or its equivalent will be required to include it as part of their elective units.
[3]Electives must be approved by Civil Engineering faculty.
[4]Six or more units as arranged.

ELECTRICAL ENGINEERING

FIFTH YEAR

(Leading to the degree of Master of Science in Electrical Engineering)

	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
EE 220 abc	Research Seminar in Electrical Engineering	2	2	2
	Three or more of the following electives:			
EE 132 abc	Circuit Analysis (3-0-6)[2]	9	9	9
EE 140 abc	Electric Communication (3-0-6)	9	9	9
EE 150 abc	Electromagnetic Fields (3-0-6)	9	9	9
EE 164 abc	Microwave Electronics and Circuits (3-0-6)	9	9	9
EE 170 abc	Feedback Control Systems (3-0-6; 3-3-6)	9	12	12
EE 180	Digital Computer Design (3-3-3)	9	.	.
EE 181 ab	Principles of Analog Computation (3-3-6)	.	12	12
EE 190 abc	Advanced Electronics (3-0-6)	9	9	9
Ph 112 abc	Atomic & Nuclear Physics (4-0-8)	12	12	12
	Other electives as approved by Electrical Engineering Faculty			

SIXTH YEAR

(Leading to the degree of Electrical Engineer)

Special Requirements for the Degree of Electrical Engineer. To be recommended for the degree of Electrical Engineer the applicant must pass the same subject requirements as listed for the doctor's degree on page 191, except that a grade of D in Ph 131 is acceptable.

[1]For list of Humanities electives, see page 221.
[2]Required unless comparable work done elsewhere.

ENGINEERING SCIENCE

(Leading to the degree of Master of Science in Engineering Science)

Most engineering science majors work for the doctor's degree and follow programs arranged by the student in consultation with members of the Division. Under special circumstances a master's degree may be awarded upon satisfactory completion of a program of study approved by the student's advisor. General requirements for this degree should include the following:

		Units per Term 1st	2nd	3rd
	Humanities electives	9 or 10	9 or 10	9 or 10
AM 125 abc	Engineering Mathematical Principles	9	9	9
AM 130 abc	Classical Theoretical Physics	9	9	9

GEOLOGICAL SCIENCES

FIFTH YEAR

Option leading to degree of Master of Science in Geology

		Units per Term 1st	2nd	3rd
	Humanities elective (3-0-6; 4-0-6) (select from Electives listed on page 221	9	9	9
Ge 100	Geology Club	1	1	1
Ge 121 abc	Advanced Field Geology	14	10	11
Ge 123	Summer Field Geology (30 units)	.	.	.
Ch 124 ab	Physical Chemistry for Geologists	6	6	.
	Add Electives to bring total to 140 units. Electives must be approved by advisor.			

Option leading to degree of Master of Science in Geophysics

		1st	2nd	3rd
	Humanities elective (3-0-6; 4-0-6) (select from Electives listed on page 221	9	9	9
Ge 100	Geology Club	1	1	1
Ge 120 abc	Elementary Field Geology	10	10	10
Ge 282 abc	Geophysics-Geochemistry Seminar	1	1	1
Ph 107 abc	Electricity and Magnetism	9	9	9
Ph 108 abc	Theoretical Mechanics	9	9	9
	Add Electives to bring total to 140 units. Electives must be approved by advisor.			

Option leading to degree of Master of Science in Geochemistry

		1st	2nd	3rd
	Humanities elective (3-0-6; 4-0-6) (select from Electives listed on page 221	9	9	9
Ge 100	Geology Club	1	1	1
Ge 104 abc	Petrology	8	10	7
Ge 120 abc	Elementary Field Geology	10	10	10
Ge 130	Introduction to Geochemistry	.	.	9
Ch 124 ab	Physical Chemistry for Geologists	6	6	.

Add Electives to bring total to 140 units, including at least 30 additional units of advanced courses in Chemistry and Geochemistry, and at least 30 units of research in Geochemistry. Equivalent or previous courses may be substituted for Ge 104, Ge 120, Ge 130, and Ch 124. Substitutions and Electives must be approved by advisor.

Only in exceptional cases will the Division permit a student to undertake work leading to an Engineer's Degree in the Geological Sciences. If such instances arise, a program of prescribed study will be worked out with each student on an individual basis.

Students with limited experience in geological field work may be required to take all or a portion of Ge 120 abc as a prerequisite to Ge 121 abc or Ge 123. By approval of the Committee on Field Geology the field geology requirements may be satisfied by evidence of equivalent training obtained elsewhere.

MATHEMATICS

As nearly all mathematics majors are working for the doctor's degree and follow programs arranged by the student in consultation with members of the Division, no specific fifth year curriculum is outlined.

MECHANICAL ENGINEERING OPTION

FIFTH YEAR

(Leading to the degree of Master of Science in Mechanical Engineering)

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 page 228)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
	Electives as below, See notes 1, 2, 3, page 228 (minimum total for year 81)	27	27	27
		47 or 48	47 or 48	47 or 48

Electives (See Note 3, page 228, for other electives)

AM 101 abc	Nuclear Reactor Theory (3-0-6)	9	9	9
AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 101 abc	Advanced Design (1-6-2)	9	9	9
ME 118 abc	Advanced Thermodynamics and Energy Transfer (3-0-6)	9	9	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9

MECHANICAL ENGINEERING (JET PROPULSION OPTION)

FIFTH YEAR

(Leading to the degree of Master of Science in Mechanical Engineering)

		1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 page 228)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
JP 121 abc	Rocket (3-0-6)	9	9	9
JP 130 abc	Thermal Jets (2-0-4)	6	6	6
JP 200 abc	Chemistry Problems in Jet Propulsion (3-0-6)	9	9	9
	Electives as below, See notes 1, 2, 3, page 228 (minimum total for year 18)	6	6	6
		50 or 51	50 or 51	50 or 51

Electives (See Note 3, page 228, for other electives)

AM 101 abc	Nuclear Reactor Theory (3-0-6)	9	9	9
AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 101 abc	Advanced Design (1-6-2)	9	9	9
ME 118 abc	Advanced Thermodynamics and Energy Transfer (3-0-6)	9	9	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9

[1]For list of Humanities electives, see page 221.

MECHANICAL ENGINEERING (NUCLEAR ENERGY OPTION)
FIFTH YEAR
(Leading to the degree of Master of Science in Mechanical Engineering)

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 page 228)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
AM 101 abc	Nuclear Reactor Theory (3-0-6)	9	9	9
AM 102 abc	Applied Nuclear Physics (2-0-4)	6	6	6
	Electives as below. See notes 1, 2, 3 page 228 (minimum)	12	12	12
		47 or 48	47 or 48	47 or 48

Electives (See Note 3, page 228, for other electives)

		1st	2nd	3rd
Ch 127 bc	Radioactivity and Isotopes (2-0-4)	.	6	6
ME 115 abc	Thermodynamics and Heat Transfer (3-0-6)	9	9	9
Hy 101 abc	Fluid Mechanics (3-0-6)	9	9	9
AM 110 abc	Elasticity (2-0-4)	6	6	6
PM 101	Physical Metallurgy (3-3-3)	9	.	.
PM 115 ab	Crystal Structure and Properties of Metals and Alloys (3-0-6)	.	9	9
PM 116	X-Ray Metallography I (0-6-3)	.	.	9

Note: Students holding AEC Fellowships may substitute electives for certain of the above required courses by special approval of the faculty in Mechanical Engineering.

MECHANICAL ENGINEERING (PHYSICAL METALLURGY OPTION)
FIFTH YEAR
(Leading to the degree of Master of Science in Mechanical Engineering)

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 page 228)	9	9	9
AM 110 a	Elasticity (2-0-4)	6	.	.
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
PM 103 ab	Physical Metallurgy Laboratory (0-9-0; 0-6-0)	9	6	.
PM 112 ab	Advanced Physical Metallurgy (3-0-6)	.	9	9
PM 116	X-Ray Metallography I (0-6-3)[2]	.	.	9
	Electives as below. See notes 1, 2, 3 page 228 (minimum total for year 36)	12	12	12
		47 or 48	47 or 48	50 or 51

Electives (See Note 3, page 228, for other electives)

		1st	2nd	3rd
AM 101 abc	Nuclear Reactor Theory (3-0-6)	9	9	9
AM 110 abc	Theory of Plates and Shells, Mechanics of Materials (2-0-4)	.	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
Ch 226 abc	Introduction to Quantum Mechanics, with Chemical Applications (3-0-6)	9	9	9
ME 101 abc	Advanced Design (1-6-2)	9	9	9
ME 118 abc	Advanced Thermodynamics and Energy Transfer	9	9	9
Ph 205 abc	Principles of Quantum Mechanics (3-0-6)	9	9	9

[1]For list of Humanities electives, see page 221.
[2]Students who have not had PM 115 ab or the equivalent will take this course as elective.

Notes applying to all options in Mechanical Engineering:

Note 1: Students who have not had a course in Engineering Mathematics, Advanced Calculus, or the equivalent in their undergraduate work are required to include AM 115 ab and AM 116 among the elective units.

Note 2: Students who plan advanced study past the fifth year, and who have had AM 115 ab and AM 116 or an equivalent course in their undergraduate work may substitute one of the following courses for one of the professional courses listed above, subject to the approval of the faculty in Mechanical Engineering.

AM 125 abc	Engineering and Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ph 107 abc	Electricity and Magnetism

Note 3: Substitutions for the scheduled electives may be made upon specific approval of the faculty in Mechanical Engineering. The following are examples of substitutions that have been made in some instances and may be used as a guide by those desiring to make substitutions:

AM 105	Advanced Strength of Materials, 6 units second term
AM 106	Problems in Buckling, 6 units third term
Ae 101 abc	Introductory Mechanics and Thermodynamics of Fluids, 9 units each term
EE 101 abc	Electric Circuit Theory, 9 units each term
EE 106 ab	Electronic Circuits, 9 units first and second terms
EE 170 abc	Feedback Control Systems, 9 units each term
JP 121 abc	Rocket, 9 units each term
JP 130 abc	Thermal Jets, 6 units each term
PM 105	Mechanical Behavior of Metals, 6 units first term

Note 4: Laboratory electives

First Term:	AM 103, AM 155, PM 104
Second Term:	AM 111, Ma 112, ME 127
Third Term:	ME 126, PM 102, JP 170

MECHANICAL ENGINEERING

SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

Specific requirements for the degree of Mechanical Engineer are given on page 182. The following list will suggest possible subjects from which a program of study may be organized:

ME 200	Advanced Work in Mechanical Engineering
ME 217 abc	Turbomachines
ME 300	Thesis—Research
Hy 200	Advanced Work in Hydraulic Engineering
Hy 201 abc	Hydraulic Machinery
Hy 203	Cavitation Phenomena
Hy 210 ab	Hydrodynamics of Sediment Transportation
Hy 300	Thesis
Ae 201 abc	Hydrodynamics of Compressible Fluids
Ae 204 abc	Theoretical Aerodynamics of Real and Perfect Fluids
Ae 205 abc	Statistical Problems in Gas Dynamics
Ae 107 abc	Elasticity Applied to Aeronautics
AM 201 abc	Advanced Reactor Theory
Ch 163 ab	Chemical Engineering Thermodynamics
Ch 226 abc	Introduction to Quantum Mechanics
Ch 227 abc	The Structure of Crystals
Ch 229	Diffraction Methods of Determining the Structure of Molecules
Ch 262 abc	Thermodynamics of Multi-Component Systems
Ph 112 abc	Atomic and Nuclear Physics
Ph 205 abc	Principles of Quantum Mechanics
Ph 227 ab	Thermodynamics, Statistical Mechanics, and Kinetic Theory
PM 103 ab	Physical Metallurgy Laboratory
PM 112 ab	Advanced Physical Metallurgy
PM 205	Theory of Mechanical Behavior of Metals
PM 217	X-Ray Metallography II
PM 250 abc	Advanced Topics in Physical Metallurgy
JP 220 abc	Theory of Stability and Control

MECHANICAL ENGINEERING (JET PROPULSION OPTION)

SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

		Units per Term 1st	2nd	3rd
JP 280 abc	Jet Propulsion Research (Thesis)	18	18	18
	Electives (not less than)	30	30	30
		48	48	48

The list of subjects which could be chosen as electives for the sixth-year work is given above.

PHYSICS

FIFTH YEAR

(Leading to the degree of Master of Science in Physics)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)[2]	9 or 10	9 or 10	9 or 10
	Electives as below (At least 54 of these units must be from courses in Groups I and II as listed on page 197)	39	39	39
		48 or 49	48 or 49	48 or 49
Ph 107 abc	Electricity and Magnetism (3-0-6)[1]	6	6	6
Ph 108 abc	Theoretical Mechanics (3-0-6)[1]	6	6	6
Ph 110 ab	Kinetic Theory of Matter (3-0-6)	.	9	9
Ph 112 abc	Atomic and Nuclear Physics[1]	12	12	12
Ph 115 ab	Geometrical and Physical Optics (3-0-6)	.	9	9
Ph 129 abc	Methods of Mathematical Physics (3-0-6)	9	9	9
Ph 131 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 203 abc	Nuclear Physics (3-0-6)	9	9	9
Ph 205 abc	Principles of Quantum Mechanics (3-0-6)	9	9	9
Ph 207 abc	X- and Gamma-Rays (3-0-6)	9	9	9
Ph 217	Spectroscopy (3-0-6)	.	.	9
Ma 108 abc	Introduction to Real & Complex Analysis (4-0-8)[3]	12	12	12
Ma 118 abc	Functions of Complex Variable (3-0-6)	9	9	9

[1]Prerequisite for most other fifth-year courses.

[2]For list of Humanities electives, see page 221.

[3]Prerequisite for Ma 118.

NOTE: With the department's approval, students who have the proper preparation may substitute other graduate courses in Electrical Engineering, Mathematics, or Physics for some of those listed above. Students who have received credit for Ph 131 abc, Ph 129 abc, or Ph 205 abc as undergraduates may use these credits towards a master of science degree provided they replace them with undergraduate credits in L 32 abc (4-0-6), or L 50 abc (4-0-6) earned during the fifth year.

Section VI

SUBJECTS OF INSTRUCTION

Aeronautics

ADVANCED SUBJECTS

Ae 101 abc. Thermodynamics and Dynamics of Continua. *9 units (3-0-6); each term. Prerequisites: AM 115, AM 116* (may be taken concurrently with approval of instructor). Thermodynamics of solids, liquids, and gas mixtures. Equilibrium relations, dissociation and ionization. Black body radiation. General irreversible processes. Elements of kinetic theory and statistical mechanics. Stress-strain relations. Discussion of typical problems in subsonic flow and supersonic flow such as simple air foil theory, steady one-dimensional flows, nozzle flow, shock waves, laminar and turbulent skin friction and heat transfer. Texts: *Thermodynamics,* Fermi; *Elements of Gasdynamics,* Liepmann and Roshko. Instructors: Liepmann and Roshko.

Ae 102 abc. Engineering Elasticity and Design. *9 units (3-0-6); each term. Prerequisites: Applied Mechanics and Strength of Materials.* A study of the fundamental equations of applied elasticity and their application to aircraft, missile and spacecraft structural analysis. Basic stress-strain relationship, exact and approximate methods of beam and truss analysis, and other two- and three-dimensional problems are treated. Buckling phenomena of columns and plates and shells are discussed and an introduction is given to analog methods of static and dynamic structural analysis. Text: *Elasticity in Engineering,* Sechler. Instructor: Sechler.

Ae 103 abc. Aerodynamics of Aircraft. *9 units (3-0-6); each term. Prerequisite: AM 15, Hydraulics.* Airfoil lift, drag and moment characteristics. Boundary layers. Effects of compressibility. Calculation of spanwise lift distribution on finite wings. Performance of complete airplane. Static and dynamic stability and control. Determination of response characteristics. Texts: *Aerodynamics of the Airplane,* Millikan; *Airplane Performance, Stability, and Control,* Perkins and Hage. Instructor: Royce.

Ae 106 ab. Experimental Methods in Aeronautics. *6 units (2-2-2); second and third terms. Prerequisites: Ae 101 a, Ae 102 a, Applied Mechanics.* One term is devoted to a study of experimental techniques in the field of aircraft structures and applied elasticity; methods of reducing and correlating experimentally obtained data; and a study of sources of error in experimentation. The second term is devoted to experimental techniques in the field of fluid mechanics and aerodynamics. Statistical methods; analogs; hot-wire measurements; and boundary layers are among the problems discussed from an experimental standpoint. Texts: Numerous reference works on experimental methods. Instructors: Staff.

Ae 107 abc. Elasticity Applied to Aeronautics. *9 units (3-0-6); each term. Prerequisites: Ae 102 abc, AM 115 ab, AM 116.* Stress, strain and displacement relations in anisotropic elastic media. Classical problems of thermal stress, bending, torsion, and plane strain. Formulation of the non-linear large deflection problem of combined stretching and bending of thin plates; examination of the classical limit cases. Shell theory. Considerable emphasis on the development of approximate analysis methods for the above problems based on minimum potential and complementary energy theorems. Brief treatment of elastic stability and wave propagation in elastic media. Instructor: Williams.

Ae 109. Instrumentation Design. *4 units (2-0-2); one term.* The problem of design and use of instrumentation and the fundamental principles involved in making precision measurements. Instructor: Klein.

Ae 110 abc. Systems Concepts in Aeronautics. *6 units (2-0-4); each term.* An integrated study of various related subjects in the field with emphasis upon synthesizing the interactions which affect aeronautical vehicles. The interplay between performance requirements, strength-weight analysis, propulsion characteristics, air loads analysis, and economic factors is evaluated in conjunction with familiarizing the student with some of the more elementary features of the mathematical tools at his disposal, such as operations analysis, digital computation and the variational calculus. Instructor: Williams.

Ae 150 abc. Aeronautical Seminar. *1 unit (1-0-0); each term.* Speakers from campus and outside research and manufacturing organizations who will discuss current problems and advances in aeronautics.

Ae 200 abc. Research in Aeronautics. *Units to be arranged.* Theoretical and experimental investigations in the following fields: aerodynamics, compressibility, fluid and solid mechanics, supersonic and hypersonic flow, aeroelasticity, structures, thermoelasticity, fatigue, photoelasticity. Instructors: Staff.

Ae 201 abc. Inviscid Fluid Mechanics. *9 units (3-0-6); each term. Prerequisites: Ae 101, Ae 103.* A course covering the general theory of compressible and incompressible fluid mechanics of a non-viscous fluid. Among the topics studied are: General equations of motion, general energy and vorticity theorems, incompressible flow and potential theory, lifting surfaces and lifting lines, shock waves and expansion waves characteristics, linearized theory for subsonic and supersonic flow applied to drag and lift, minimum theorems of linearized theory, transonic and hypersonic approximations. Text: Class notes and reference material. Instructors: J. Cole, Millikan.

Ae 202 abc. *9 units (3-0-6); each term as described below. To be offered as student demand and staff facilities permit. Prerequisite for all courses, Ae 107 abc.*

Ae 202 a. Thermal Stress Problems. General survey of thermal problems in the design of high speed aircraft. Heat generation in the boundary layer. Temperature distribution in structures. Stress-strain relationship. Thermodynamics of strained elastic solids. Fundamental differential equations of equilibrium, compatibility, and motion. Variational principles. Energy theorems. Thermal stresses in beams, trusses, plates and shells. Buckling due to thermal stresses. Stiffness of structures. Effect on the aeroelastic properties of aircraft. Instructor: Staff.

Ae 202 b. Mechanics of Inelastic Materials. Ultimate strength of structures. Mechanical properties of structural materials at high temperature. Modes of failure of structures. Theory of anelasticity. Theory of perfectly plastic solids. Thermodynamics of irreversible process and the basic laws of viscoelastic materials. Rate process and the theory of dislocations. Creep analysis. Elastic analogies for linear viscoelastic materials and nonlinear secondary creep. Repeated loads. Fatigue. Limit design. Instructor: Staff.

Ae 202 c. Nonlinear Problems in Structures and Aeroelasticity. Large deflection of beams, columns, and plates. Edge layer theories. Post-buckling behavior of circular and rectangular plates. Slightly curved plates. Nonlinear vibrations of plates and shells. Buckling of arches and shells. Critical examination of the criteria of buckling. Nonlinear static aeroelastic problems. Flutter of buckled plates. Flutter of airfoils with nonlinear stiffness and damping characteristics. Stall flutter. Instructor: Staff.

Ae 202 d. Finite Elastic Theory. Stress-strain relationships in highly deformable media such as rubber. Application of variational principles. Solutions to crack and wave problems involving large deformations. Discussion of elastic stability of hollow cylinders and spheres under plane strain and plane stress. Form of the strain energy function appropriate to compressible rubbers. Finite elastic analog of Poisson's ratio. Instructor: Blatz.

Ae 202 e. Viscoelastic Theory. Topology of networks involving springs and dashpots. Mechanical behavior of the generalized model. Boltzmann super-position principle and principle of temperature-time equivalence. Mathematical operations used to interconnect stress relaxation, creep, simple tensile, and dynamic data. Phenomenological descriptions of viscoelastic materials. Instructor: Blatz.

Ae 202 f. Polymer Mechanics. *Prerequisite: Ae 202 d, e.* Microscopic description of a filled rubber or resin. Mechanical behavior of unfilled rubber based on finite elastic theory. Viscoelastic behavior of unfilled rubber. Stress distribution around filler particles. Fall-off of Poisson's ratio with tensile strain. Relation between void distribution and stress-strain behavior. Solution of plane strain problems based on properties of filled rubbers. Instructor: Blatz.

Ae 203 abc. Advanced Problems in Aerodynamics. *6 units (2-0-4); each term. Prerequisites: Ae 101, AM 125, Ae 103.* Introduction to theory of servo-mechanisms and application to stability and control. Helicopter aerodynamics, propeller theory, boundary layer theory, and internal aerodynamics. Aerodynamics of high speed flight including the effects of compressibility on stability and control. Fundamentals of aeronautical electronics. Instructor: Staff.

Ae 204 abc. Mechanics of Real Gases. *9 units (3-0-6); each term. Prerequisites: Ae 101, Am 125, Ae 103.* Motion of real gases as determined by state and transport properties. Navier-Stokes equations and boundary conditions. Some exact solutions for incompressible flow. Stokes and Oseen approximations for low Reynolds numbers. Prandtl boundary-layer approximation for high Reynolds numbers. Boundary layer equations for chemically reacting mixtures of perfect gases. Integral methods; discussion of laminar skin-friction, heat transfer, and mass transfer. Turbulent shear flow. Dimensional arguments and similarity laws. Integral methods; semi-empirical formulas for turbulent skin friction and heat and mass transfer. Separation and other unsolved problems of laminar and turbulent flow, including discussions of experimental observations of these phenomena. Instructors: Lees and Coles, D.

Ae 205 abc. Problems in Gas Dynamics. *9 units (3-0-6); each term. Offered in alternate years beginning in 1955-56. Prerequisites: Ae 101, Ae 201, AM 125, Ma 114, or equivalent.* Selected topics in gas dynamics; the subject matter may vary from year to year. For example, magneto-hydrodynamics, kinetic approach to gas flow, turbulence, laminar instability theory, etc. Instructors: Cole, Lagerstrom, Leipmann.

Ae 206 abc. Advanced Problems in Fluid Mechanics. *9 units (3-0-6); each term. Offered in alternate years beginning in 1956-57. Prerequisites: Ae 101, Ae 201, Ae 204, or* consent of instructor. Selected topics in fluid mechanics: for example, advanced problems in linearized theory of inviscid fluids; non-linear theory of transonic, supersonic and hypersonic flow; theory of viscous incompressible flow and of viscous heat-conducting compressible flow; related topics from physics and mathematics. Instructors: Lagerstrom, Kaplun.

Ae 207 abc. Aeroelasticity. *9 units (3-0-6); each term. To be offered in alternate years beginning in 1957-58. Prerequisites: Ae 103 abc, Ae 107 abc.* Aeroelastic oscillations of cylinders, transmission lines, and suspension bridges. Steady-state problems: divergence, loss of control, and lift-distribution. Flutter. Dynamic stresses: landing and gust loads. Buffeting. Stall flutter. General formulation of aeroelastic problems. Linearized theory of oscillating airfoils. Comparison of the unsteady airfoil theory with experimental results. Texts: *An Introduction to the Theory of Aeroelasticity*, Fung; *Aeroelasticity*, Bisplinghoff, Ashley and Halfman. Instructor: Fung.

Ae 208 abc. Seminar in Fluid Mechanics. *1 unit (1-0-0); each term.* A seminar course in modern fluid dynamics. Instructor: Liepmann.

Ae 209 abc. Seminar in Solid Mechanics. *1 unit (1-0-0); each term.* A seminar course for students whose interests lie in the general field of advanced elasticity. Recent (theoretical and experimental) developments and original research in the field as reviewed for possible application to the current problems in the aircraft and related industries. Instructor: Sechler.

Jet Propulsion

(For Jet Propulsion see pages 277-278)

Air Science

As 1 abc. Air Science 1. *One unit first and second terms, four units third term (2-1-1). Foundations of Aerospace Power—1.* AS 1 a and 1 b are devoted entirely to leadership laboratory, one hour each week. AS 1 c is a four unit course (2-1-1) which provides a general survey of aerospace power designed to provide the student with an understanding of the elements and potentials of aerospace power, evolution of aerial warfare, and the military as an instrument of national security. Also, one hour each week is devoted to leadership laboratory. Texts: Foundations of Airpower and other Air Force Manuals will be issued to students. Instructor: Air Force ROTC Staff.

AS 2 abc. Air Science 2. *Four units first and second terms (2-1-1), one unit third term. Foundations of Aerospace Power–2.* AS 2 a and 2 b, a two term survey of the elements of aerial warfare, concepts of employment of air forces, and space operations. The elements of aerial warfare phase includes a specialized study of targets, weapon systems, delivery vehicles, bases, materiel, and personnel. During the first and second terms one hour each week is devoted to leadership laboratory. The third term, AS 2 c, consists only of the leadership laboratory. Texts: Air Force Manuals will be issued to the students. Instructor: Air Force ROTC Staff.

AS 3 abc. Air Science 3. *8 units (4-1-3); each term. Air Force Officer Development.* A year-long treatment of the knowledge and skills required of a junior officer in the Air Force, with special emphasis on staff duties and leadership. Includes Air Force leadership doctrine, staff organization and functions, communicating, instructing, problem solving techniques, and military justice system. One hour each week is devoted to Leadership Laboratory. Text: Furnished by the Air Force. Instructor: Air Force ROTC Staff and Institute faculty.

AS 4 abc. Air Science 4. *8 units (4-1-3); each term.* Air Force Officer Development. A study of a series of short courses including the following: Weather and Navigation, International Relations, and Military Aspects of World Political Geography. One hour each week is devoted to Leadership Laboratory. Text: Furnished by the Air Force. Instructor: Air Force ROTC Staff and Institute faculty.

APPLIED MECHANICS

UNDERGRADUATE SUBJECTS

AM 5 ab. Applied Mechanics—Dynamics. *9 units (3-0-6); first and second terms.* Principles of dynamics; dynamics of a particle; dynamics of rigid bodies; Lagrange's equations; applications to engineering problems involving dynamic characteristics of machine parts, mechanical and structural vibrations, impact, momentum transport, etc. Text: *Applied Mechanics-Dynamics,* Housner and Hudson. Instructors: Hudson and Staff.

AM 8 abc. Mechanics of Solids I. *9 units (3-0-6); first, second and third terms. Prerequisites: Ph 1 abc, Ma 1 abc.* Dynamics of particles, groups of particles and rigid bodies; general principles of statics including energy, stability and an introduction to statically indeterminant structures; kinematics of relative motion; vibrating systems; planetary motion; gyroscopes; momentum relations in flow of matter, Lagrange's equations and generalized coordinates. Concept of stress and strain in continuous solids; stress states; deformation of continuous solids, displacement-strain and stress-strain-temperature relations; strain energy and energy methods; equilibrium and compatibility equations for stresses; uniqueness theorem, St. Venant's principle. Emphasis is on development of fundamental principles with application to selected problems. Instructors: Crede, Vreeland.

AM 9 abc. Mechanics of Solids II. *9 units (3-0-6); first, second and third terms. Prerequisite: AM 8 abc.* Analysis of stress, strain and deflection in torsion, bending, columns, beams, plates and shells, pressure vessels and rotating discs. Hamilton's principle and Euler's equations of motion; non-periodic and transient vibration, super-position integral and transform methods; random vibration; vibration of non-linear systems; vibration of systems with distributed mass and stiffness, longi-

[1]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

tudinal and flexural vibrations of bars; wave propagation; Rayleigh's principle; representation of continuous vibrating systems by lumped parameters, analog and numerical methods of analysis. Emphasis is on more advanced methods of analysis and application to physical problems. Instructors: Crede, Vreeland.

ADVANCED SUBJECTS

Note: Other subjects in the general field of Applied Mechanics will be found listed under the departments of Aeronautics, Electrical Engineering, Mechanical Engineering, and Physics.

AM 101 abc. Nuclear Reactor Theory. *9 units (3-0-6); each term. Prerequisite: AM 115 ab or equivalent (may be taken concurrently).* Neutron chain reactions and the criticality condition; the slowing down of neutrons in an infinite medium; one-speed diffusion of neutrons in multiplying and non-multiplying systems; combined slowing down and diffusion; bare and reflected homogeneous reactors; effects of heterogeneity; time dependent behavior of reactors; control rod theory; elements of transport theory. Instructor: Lurie.

AM 102 abc. Applied Nuclear Physics. *6 units (2-0-4); each term. Prerequisites: Ph 2 abc; AM 115 ab or equivalent.* An introductory course covering those aspects of nuclear physics which are encountered in nuclear engineering. Topics covered will include radioactivity, the interactions of charged particles and gamma rays with matter, nuclear reactions, neutron physics and nuclear fission. Part of the third term will be devoted to such specialized topics as radiation shielding including bulk and thermal shields. Instructors: Plesset, Hsieh.

AM 103. Nuclear Engineering Laboratory. *9 units (1-6-2); first term. Prerequisite: Ph 2 abc.* A one-term laboratory course designed to familiarize students with the basic nuclear detecting and measuring devices which are used in reactor technology. Consideration will be given to some of the basic measurement problems involved in counting techniques. The instruments are first used to determine the properties of particles and radiations, and their interaction with matter. A subcritical assemby then allows the student to gain familiarity with some of the methods used for determining macroscopic reactor properties. Instructor: Lurie.

AM 105. Advanced Strength of Materials. *6 units (2-0-4); second term. Prerequisites: AM 8, AM 9.* Analysis of problems of stress and strain that are described by ordinary differential equations, such as beams on elastic foundation, curved bars, combined bending and axial loading of beams, combined bending and torsion of beams. Energy methods of solution. Instructor: Housner.

AM 106. Problems in Buckling. *6 units (2-0-4); third term. Prerequisites: AM 8, AM 9.* Analysis of problems dealing with the elastic instability of columns, beams, arches and rings, and the inelastic buckling of columns. Instructor: Housner.

AM 110 a. Introduction to the Theory of Elasticity. *6 units (2-0-4); first term. Prerequisites: AM 8, AM 9.* Fundamental concepts of elasticity theory. Equations of stress equilibrium and strain compatibility. Solution of two-dimensional problems. Photoelastic method of stress measurements. Analysis of stress and strain in three dimensions. Solution of torsion problems. Wave propagation in elastic solids. Instructors: Housner, Miklowitz.

AM 110 b. Theory of Plates and Shells. *6 units (2-0-4); second term. Prerequisites: AM 8, AM 9.* Simplifications introduced in elasticity theory. Laterally loaded plates with various boundary conditions. Elastic stability of plates. Membrane theory of shells. General theory of shells. Instructors: Housner, Miklowitz.

AM 110 c. Mechanics of Materials. *6 units (2-0-4); third term. Prerequisites: AB 8, AM 9, AM 110 a.* Use of tensors in elasticity theory. Non-linear stress-strain relations. Theory of plasticity. Theories of failures of stressed materials. Instructors: Housner, Miklowitz.

AM 111. Experimental Stress Analysis. *9 units (1-6-2); second term. Prerequisite: AM 8 abc or equivalent.* Static and dynamic stress and strain measurements, including the use of piezoelectric materials; wire resistance strain gages; mechanical, optical, inductance, and capacitance displacement gages; photoelastic materials; brittle lacquer coatings; x-rays, and associated instrumentation and recording systems. Instructor: Staff.

AM 115 ab. Engineering Mathematics. *12 units (4-0-8); first and second and second and third terms. 9 units credit for graduate students. Prerequisites: Ma 1 abc, Ma 2 abc or equivalent.* A course in the mathematical treatment of problems in engineering and physics. Emphasis is placed on the setting up of problems as well as their mathematical solution. The topics studied include: vector analysis as applied to formulation of the partial differential equation of classical field theory; power series solutions of ordinary differential equations; special functions such as the Bessel functions and Legendre functions; partial differential equations and boundary value problems, with emphasis on application of series of orthogonal functions; and an introduction to transform methods. Text: *Differential Equations Applied in Science and Engineering,* Wayland. Instructors: Knowles, Wayland, and Staff.

AM 116. Complex Variables and Applications. *12 units (4-0-8); first term and third term. 9 units credit for graduate students. Prerequisites: Ma 1 abc, Ma 2 abc or equivalent.* A basic introduction to analytic functions of a complex variable. Emphasis is placed on application of conformal mapping to boundary value problems and on techniques and applications of contour integration. Text: Churchill, *Introduction to Complex Variables and Applications.* Instructors: Miklowitz, Wayland, and Staff.

AM 125 abc. Engineering Mathematical Principles. *9 units (3-0-6); each term. Prerequisites: AM 115 ab and AM 116, Ma 108, or equivalent.* Topics from ordinary and partial differential equations with applications to vibrations, elasticity, theory of sound, fluid mechanics, and diffusion. Instructor: De Prima.

AM 126 abc. Applied Engineering Mathematics. *12 units (3-0-9); each term. Prerequisites: AM 115 ab and AM 116, Ma 108, or equivalent.* A problem and lecture course in engineering mathematics. Preparation of approximately six reports per term on problems taken from all branches of engineering. First term lectures cover topics in ordinary differential equations including: Lagrange's equations, normal modes of vibration, and nonlinear systems. Second and third term lectures cover topics in partial differential equations including: characteristics, vibration theory, Rayleigh-Ritz method, conformal mapping, Laplace transform, difference equations, relaxation methods. Instructor: Lindvall.

AM 130 abc. Applications of Classical Theoretical Physics I. *9 units (3-0-6); first, second, and third terms. Prerequisites: AM 115 abc, or equivalent.* Analytical mechanics of systems of particles, heat conduction, thermodynamics, mechanics of continuous media. Instructors: Plesset and Wu. Not given in 1960-61.

AM 131 abc. Applications of Classical Theoretical Physics II. *9 units (3-0-6); first, second, and third terms. Prerequisites: AM 115 abc, or equivalent.* Kinetic theory, classical and quantum statistical mechanics, electrodynamics, and special relativity. Instructors: Plesset and Wu.

AM 140. Plasticity. *6 units (2-0-4); first term. Prerequisites: AM 110 ac, AM 115 ab.* Further study in theory of plasticity and applications. Yield criteria and strain hardening in metals. Rules of flow and the general stress-strain laws. Application to problems of combined stress. Creep and relaxation in metals and polymers. Plastico-viscous solid. Introduction to theory of viscoelasticity. Instructor: Miklowitz.

AM 141 ab. Wave Propagation in Solids. *6 units (2-0-4); second and third terms. Prerequisites: AM 5 ab, AM 110 a, AM 115 ab, AM 116.* Theory of wave propagation in solids with application to problems. Waves in elastic media. Dispersion of waves in bounded solids. Approximate elasticity theories governing waves in rods, beams, plates and shells. Use of Laplace transform techniques, asymptotic expansion of integrals in deriving wave solutions for these theories. Related experiments. Waves in plastic and visco-elastic media. Damage due to wave action. Instructor: Miklowitz.

AM 150 abc. Mechanical Vibrations. *6 units (2-0-4); first, second, and third terms. Prerequisites: AM 5, AM 15 or equivalents.* A study of the theory of vibrating systems, and the application of such theory to problems of mechanical design. Subjects considered include theory of resonant systems; elimination of undesirable vibrations; design of vibration instruments; periodic disturbing forces such as engine vibration problems; critical speed phenomena; transient excitations; general normal mode theory. The third term is an introduction to non-linear vibration theory. Instructors: Caughey, Crede, Hudson.

AM 155. Dynamic Measurements Laboratory. *9 units (1-6-2); first term.* Theory and technique of making measurements encountered in engineering practice and research, with special reference to dynamic measurements. Experiments in vibrations and stability using the latest electro-mechanical and electronic instruments are performed. Instructors: Caughey, Crede, Hudson.

AM 160. Vibrations Laboratory. *6 units (0-3-3). Prerequisite: AM 150.* The experimental analysis of typical problems involving vibrations in mechanical systems, such as a study of the characteristics of a vibration isolation system, or a determination of the transient strains in a machine member subjected to impact loads. The measurements of strains, accelerations, frequencies, etc., in vibrating systems, and the interpretation of the results of such measurements. Consideration is given to the design, calibration and operation of the various types of instruments used for the experimental study of dynamics problems. Instructors, Caughey, Crede.

AM 174 abc. Advanced Dynamics I. *6 units (3-0-3). Prerequisites: AM 125 abc and AM 150 abc or equivalents.* The first two terms will cover topics in advanced linear vibration theory with special emphasis on approximate methods of analysis of complex systems and topics in non-linear vibration theory with special emphasis on systems with strong non-linearities. The third term will be devoted to noise and stochastic processes applied to vibration problems. This course will be given every other year to alternate with AM 176. Given 1960-61. Instructor: Caughey.

AM 176 abc. Advanced Dynamics II. *6 units (3-0-3). Prerequisites: AM 125 abc and AM 150 abc or equivalents.* The first term will be devoted to topics in engineering applications of acoustics. The second and third terms will cover topics in stability of dynamic mechanical systems and in control of mechanical-electrical systems. This course will be given every other year to alternate with AM 174. Instructor: Caughey.

AM 180. Matrix Algebra. *9 units (3-0-6); first term. Prerequisite: AM 115 ab or equivalent.* Theory of matrices from the standpoint of mathematical physics and as used in the formulation of problems on high speed analog and digital computers. Canonical forms are developed for self adjoint and for general matrices. Text: *Principles of Numerical Analysis,* Householder. Instructor: Franklin.

AM 200. Special Problems in Advanced Mechanics. Dynamics of solid and deformable bodies, fluids, and gases; mathematical and applied elasticity. By arrangement with members of the staff, properly qualified graduate students are directed in independent studies. Hours and units by arrangement.

AM 201 abc. Advanced Reactor Theory. *9 units (3-0-6); first, second, and third terms. Prerequisites: AM 101 abc, AM 102 abc, or equivalent.* Neutron scattering and absorption cross-sections; the fission process. The neutron transport equation. Stationary and time-dependent problems. The monoenergetic case; the Milne problem; the diffusion approximation. Energy dependent problems; slowing-down problems. Instructor: Plesset.

AM 204 abc. Hydrodynamics of Free Surface Flows. *9 units (3-0-6); each term. Prerequisites: Hy 101 abc, AM 125 ab and AM 116, or equivalent.* Theory of surface waves in a liquid; initial value problems and boundary value problems. Wave pattern due to moving disturbances. Wave resistance of a floating or submerged body. Theory of thin ships. Lifting surfaces in flows having a free surface: planing surfaces, hydrofoils. Theory of tidal waves. The mathematical method of characteristics will be applied to the problems of the flow in open channels, river waves and flood waves. Free boundary theory; theories of physical cavity flows. Dynamics and stability of vapor bubbles in a liquid. Water entry problems. Given in alternate years. Not given in 1960-61. Instructor: Wu.

AM 205 abc. Theory of Solids. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 112 abc or equivalent.* Theory of specific heats. Free electron theory of metals and semiconductors, Thomas-Fermi and Hartee-Fock approximations. Theory of cohesion, conductivity, and optical properties Instructor: Plesset.

AM 225. Advanced Topics in Applied Mathematics. *Prerequisites: AM 125 or equivalent.* Advanced mathematical techniques used in Engineering and Physics. Special emphasis on a systematic theory of partial differential equations. This will include theory of characteristics, Green's functions, tensor analysis, perturbation methods, similarity, Wiener-Hopf method. Selected advanced topics, such as Calculus of Variation, Integral Equations, will be included. The connections between physical and mathematical problems will be emphasized. Instructors: Cole, Lagerstrom.

AM 250 abc. Research in Applied Mechanics. Research in the field of Applied Mechanics. By arrangement with members of the staff, properly qualified graduate students are directed in research. Hours and units by arrangement.

ASTRONOMY

UNDERGRADUATE SUBJECTS

Ay 1. Introduction to Astronomy. *9 units (3-1-5); third term.* This course is intended to give the student sufficient familiarity with general astronomy to enable him to read with profit all but the more technical books and articles dealing with this subject. Instructor: Schmidt.

Ay 2 abc. General Astronomy. *9 units (3-3-3); first, second, and third terms. Prerequisites: Ph 2 abc, Ma 2 abc.* The planets, the sun and solar-terrestrial relations. Physical properties of the stars and the spectral sequence. Binary and variable stars. Dynamics of the galaxy, extragalactic nebulae. Instructors: Munch, Schmidt, Oke.

ADVANCED SUBJECTS

Ay 108 ab. Astronomical Instruments and Radiation Measurement. *9 units (3-1-5), (3-2-4); first and second terms.* The use of the photographic plate as a scientific instrument; quantitative techniques in laboratory photography. Astronomical optics. Theory of reflectors, schmidts and spectrographs. Photoelectric detectors, amplifiers. Photometric systems and their applications. Open to qualified undergraduates. Instructor: Oke.

Ay 112 abc. General Astronomy. *6 units; first, second, and third terms.* This subject is the same is Ay 2, but with reduced credit for graduate students. Instructors: Munch, Schmidt, Oke.

Ay 131 abc. Astrophysics I. *9 units (3-0-6); first, second, third terms. Prerequisites: Ay 2 abc, Ph 112 abc.* The masses, luminosities and radii of the stars. The sun. Atomic spectroscopy. Stellar spectra. The theory of radiative equilibrium in stellar atmospheres. The continuous absorption by atoms and the production of the continuous spectrum of the stars; the line absorption coefficient and the formation of spectral lines. The solar atmosphere. Analysis of stellar spectra. Abundances of the elements. Instructors: Greenstein, Munch.

Ay 132 ab. Astrophysics II. *9 units (3-0-6); first and second terms. Prerequisites: Ay 2 abc, Ph 112 abc, or their equivalents.* Introduction to the study of stellar interiors; polytropes; opacity and energy generation. Stellar models. Red giants and white dwarfs. Stellar evolution. Pulsating stars. Given in alternate years. Not given in 1960-61.

Ay 133. Radio Astronomy. *9 units (3-0-6); third term.* Radio measurements of the flux and brightness of celestial noise sources. Outline of receiver principles; antennae and interferometers. Solar noise, normal and disturbed; theory of thermal emission. Galactic noise. Discrete sources and their identification; theory of nonthermal emission. The 21-cm hydrogen line and galactic structure. Given in alternate year. Not given in 1960-61.

Ay 134. Seminar in Radio Astronomy. *8 units (2-0-6); second term. Prerequisite: Ay 133.* Recent developments in radio astronomy for the advanced student. Current publications and research in progress will be discussed by students and staff. Instructor: Schmidt.

Ay 140 abc. Seminar in Astrophysics. *4-12 units; first, second, third terms.* Discussions on the large scale distribution of matter in the Universe, statistics of the distribution of nebulae and clusters of nebulae. Hydrodynamic and statistical mechanical analysis of the morphology of nebulae. Theory and discussion of observational data obtained from observations on stars of special interest, such as supernovae, novae, white dwarfs, variable stars, and emission line stars. Theory and practice of new types of telescopes and other observational devices. Practical work of reduction of data obtained with the Schmidt telescopes on Palomar Mountain. Only students, assistants, faculty members, and visiting research personnel are admitted to the seminar who have the time, inclination and ability to engage in active, constructive work on problems which will be formulated in this seminar. Meetings throughout the year according to agreement. Instructor: Zwicky.

Ay 141 abc. Research Conference in Astronomy. *2 units; first, second and third terms.* Meets weekly to discuss work in progress in connection with the staff of the Mount Wilson and Palomar Observatories.

Ay 142. Research in Astronomy, Radio Astronomy, and Astrophysics. *Units in accordance with the work accomplished.* The student should consult a member of the department and have a definite program of research outlined before registering. Eighteen units required for candidacy.

Ay 206. Variable Stars. *6 units (2-0-4); third term.* The physical properties of various types of intrinsic variables. Their role in stellar evolution. The use of variables in galactic structure and the extragalactic distance scale. Instructor: Kraft.

Ay 210. Interstellar Matter. *9 units (3-0-6); second term.* The interstellar gas and dust. Reddening, absorption and polarization of light. Interstellar absorption lines. Ionized and neutral regions. Excitation of emission lines. The dynamics of gas clouds. Star formation. Given in alternate years. Not given in 1960-61.

Ay 211. Stellar Dynamics and Galactic Structure. *9 units (3-0-6); first term.* Dynamical and kinematical description of stellar motions. Galactic rotation and the density distribution. Dynamics of clusters; relaxation times. Structure and mass of the galaxy and external systems. Given in alternate years. Not given in 1960-61.

Ay 212. Extragalactic Nebulae. *9 units (3-0-6); second term.* Nature and contents of extragalactic nebulae. Instructor: Baade.

Ay 215. Seminar in Theoretical Astrophysics. *6 units (2-0-4); third term. Prerequisites: Ay 131 and/or Ay 132.* Recent developments in astrophysics for advanced students. The current theoretical literature will be discussed with special reference to possible observational applications. Subject matter will vary from year to year. Given in alternate years. Not given in 1960-61.

Ay 216. Advanced Stellar Interiors and Evolution. *9 units (3-0-6); first term.* Physical problems of stellar interiors. Methods of machine computation. Stellar evolution. Instructor: Hoyle.

The following courses will be offered from time time to time by members of the Mount Wilson Observatory and Institute staffs:

Ay 201. The Sun and the Planetary System.

Ay 202. The Solar Atmosphere.

Ay 203. Stellar Electromagnetism.

Ay 204. Advanced Stellar Spectroscopy.

Ay 207. Stellar Luminosities and Colors.

Ay 208. Photometry.

Ay 209. Planetary and Diffuse Nebulae.

Ay 213. Selected Topics in Observational Cosmology.

Ay 214. Theoretical Cosmology.

BIOLOGY

UNDERGRADUATE SUBJECTS

Bi 1. Elementary Biology. *9 units (3-3-3); second term.* A study of the organisms as a structural and functional entity, and of the relation of biological problems to human affairs. Instructors, Bonner, Staff.

Bi 3. Plant Biology. *12 units (4-6-2); first term. Prerequisite: Bi 1, Bi 9, or consent of instructor.* Principles of plant structure, plant diversity, and plant function. Instructors: Lang, Bonner, Staff.

Bi 9. Cell Biology. *9 units (3-3-3); third term.* Studies of life at the cellular level: nature, functions, and integration of ultrastructural components; physical and chemical parameters; influences of external agents and internal regulation. Instructors: Owen, Staff.

Bi 10. Animal Biology. *12 units (4-6-2); second term.* (Not offered in 1960-61.) A course in comparative anatomy taught in terms of function.

Bi 20. Mammalian Anatomy and Histology. *12 units (2-6-4); third term.* Macroscopic and microscopic structure of a mammal, including elementary instruction in preparation of tissue for microscopic inspection. Instructors: Van Harreveld, Keighley.

Bi 22. Special Problems. *Units to be arranged; first, second, and third terms.* Special problems in one of the fields represented in the undergraduate biology curriculum; to be arranged with instructors before registration. Instructors: The Biology teaching staff.

ADVANCED SUBJECTS

A. Subjects open to graduate students, but not to be counted toward a major for the degree of Doctor of Philosophy.

Bi 106. Embryology. *12 units (2-6-4); second term. Prerequisite: Bi 10.* The subject deals mainly with vertebrate embryology and includes some invertebrate, experimental and cytological material. Instructor: Tyler.

Bi 107 abc. Biochemistry. *10 units (3-0-7; 3-3-4; 3-5-2); first, second, and third terms. Prerequisite: Ch 41.* A lecture course on the chemical constitution of living matter and the chemical changes in animals, with laboratory work illustrating principles and methods in current use. In the third quarter emphasis is placed upon the application of physical methods to biochemical problems. Instructors: Borsook, Sinsheimer.

Bi 109. Advanced Genetics Laboratory. *Units to be arranged; second term.* An advanced laboratory course in the genetics of Drosophila. Instructor: Lewis.

Bi 110. General Microbiology. *12 units (3-4-5); third term. Prerequisites: Bi 122, Bi 107 a.* A course dealing with the various aspects of microorganisms, including cytology, antigenic properties of bacteria; nutritional requirements, with particular emphasis on autotrophic bacteria; the influence of environment; growth; spontaneous death and artificial killing; microbial variation; sexuality in microorganisms; taxonomical problems. Instructor: Dulbecco.

Bi 114. Immunology. *9 units (2-4-3); first term. Prerequisite: Ch 41 abc.* A course on the principles and methods of immunology and their application to various biological problems. Instructor: Owen.

Bi 117. Psychobiology I. *9 units (3-3-3); third term. Prerequisite: Bi 1.* An introduction to the biology of behavior with correlated laboratory study of the vertebrate nervous system. Instructor: Sperry.

Bi 118. General Physiology. *10 units (3-3-4); first term.* A lecture and laboratory course on selected topics like nervous excitation and conduction, synaptic transmission, inhibition, muscle contraction, sense organ physiology, etc. Instructors: Van Harreveld, Wiersma.

Bi 120. Mammalian Anatomy and Histology. *9 units; third term.* This subject is the same as Bi 20 but with reduced credit for graduate students. Graduate students majoring in Biology receive no credit for this subject. Instructors: Keighley, Van Harreveld.

Bi 122. Genetics. *10 units (3-3-4); first term. Prerequisite: Bi 1 or Bi 9.* (Not offered in 1960-61.) A course presenting the fundamentals of genetics in relation to general biological problems. (This course was previously listed as Bi 2.) Instructor: Lewis.

Bi 126. Genetics of Microorganisms. *10 units (2-4-4); second term. Prerequisite: Bi 122.* The genetics of algae, fungi, protozoa, and bacteriophage with laboratory work to illustrate the suitability of different microorganisms to particular kinds of genetic analysis. Instructors: Emerson, Edgar, Staff.

Bi 127. Biochemical Genetics. *10 units (3-4-3); third term. Prerequisite: Bi 122.* A course dealing with gene action at the molecular and cellular levels. Topics to be reviewed include genetic determination of protein structure, gene-enzyme relationships, genetic control of metabolism and biosynthetic pathways, and genes and development. Instructor: Horowitz.

Bi 128. Advanced Microtechnique. *6 units (1-4-1); third term.* Theory and practice of preparing biological material for microscopic examination; histochemical methods; phase contrast microscopy; methods in electron microscopy. Instructor: Tyler.

Bi 129 ab. Biophysics. *6 units (2-0-4); first and second terms.* The subject matter to be covered will be repeated approximately in a three-year cycle. During the first term the subject matter will be organized according to various biological functions, such as replication, contractility, sensory processes, endogenous rhythms, etc. Each function will be discussed in its various biophysical aspects. During the second term the subject matter will be organized according to methods of research. This course together with Ch 132 constitutes an integrated program covering the physical and physico-chemical approaches to biology. Instructors: Delbrück, Sinsheimer.

B. Subjects primarily for graduate students.

Bi 201. General Biology Seminar. *1 unit; all terms.* Meets weekly for reports on current research of general biological interest by members of the Institute staff and visiting scientists. In charge: Horowitz, Lewis, Van Harreveld.

Bi 202. Biochemistry Seminar. *1 unit; all terms.* A seminar on selected topics and on recent advances in the field. In charge: Staff.

Bi 204. Genetics Seminar. *1 unit; all terms.* Reports and discussion on special topics. In charge: Beadle.

Bi 205. Experimental Embryology Seminar. *1 unit; all terms.* Reports on special topics in the field; meets twice monthly. In charge: Tyler.

Bi 206. Immunology Seminar. *1 unit; all terms.* Reports and discussions; meets twice monthly. In charge: Owen, Tyler.

Bi 207. Biophysics Seminar. *1 unit; all terms.* A seminar on the application of physical concepts to selected biological problems. Reports and discussions. Open also to graduate students in physics who contemplate minoring in Biology. Instructor: Delbrück.

Bi 214 abc. Chemistry of Bio-Organic Substances. *3 units (1-0-2); first, second, and third terms. Prerequisite: Ch 41 ab.* A series of lectures on selected topics of organic chemistry that have special interest from a biological viewpoint. Instructor: Haagen-Smit.

Bi 217. Quantitative Organic Microanalysis. *Units to be arranged; second term.* Laboratory practice in the methods of quantitative organic microanalysis required for structure determination of organic compounds. Students must obtain permission from the instructor before registering for this subject as the enrollment is necessarily limited. Instructor: Haagen-Smit.

Bi 218. Virology. *9 units (2-3-4); second term. Prerequisites: Bi 1 or Bi 9, and permission of instructor.* The multiplication of viruses, the origin of their chemical constituents, and the determination and transmission of their genetic properties. Instructor: Dulbecco.

Bi 220 abc. Experimental Embryology. *6 units (2-0-4); first, second and third terms.* Lectures and discussion of the problems of embryonic development, including such topics as growth of the ovary, breeding habits of animals, fertilization, cleavage, organ formation, metamorphosis, regeneration, tissue culture, embryonic metabolism, etc. The subject may be taken for two consecutive years since the subject matter will be duplicated only in alternate years. Instructor: Tyler.

Bi 221. Experimental Embryology Laboratory. *Units to be arranged; all terms.* The work will include certain classical experiments and instruction in the methods of studying embryonic metabolism, transplantation, vital staining, cytochemistry, etc. Instructor: Tyler.

Bi 230. Psychobiology 2. *Units to be arranged. First, second and third terms. Prerequisite: consent of instructor.* An advanced course on the neural organization of behavior. Instructor: Sperry.

Bi 240 abc. Plant Physiology. *6 units (2-0-4); first, second, and third terms.* Reading and discussion of the problems of plant physiology. Instructors: Bonner, Lang.

Bi 241 abc. Advanced Biochemistry. *6 units (2-0-4); first, second, and third terms.* Detailed discussions of biochemical topics on an advanced level. Instructor: Bonner.

Bi 260. Advanced Physiology. *Units to be arranged. Second term.* A course in the methods of physiology, with special reference to nerve and muscle, with opportunity for research. Instructors: Van Harreveld, Wiersma.

Bi 270. Special Topics in Biology. *Units to be arranged. First, second, and third terms.* Students may register with permission of the responsible faculty member.

Bi 280-290. Biological Research. *Units to be arranged. First, second, and third terms.* Students may register for research in the following fields after consultation with those in charge: Animal physiology (280), biochemistry (281), bio-organic chemistry (282), embryology (283), genetics (284), immunology (285), marine zoology (286), plant physiology (287), biophysics (288), psychobiology (289), virology (290).

CHEMICAL ENGINEERING

UNDERGRADUATE SUBJECTS

ChE 50. Applications of Chemistry. *9 units (3-0-6); second term.* Consideration of the most recent developments in the field of chemical engineering viewed from the quantitative backgrounds of physics, mathematics, chemistry, and economics. Instructor: Corcoran.

ChE 61 ab. Industrial Chemistry. *9 units (3-0-6); second, third terms. Prerequisite: Ch 21 abc.* A study of the more important industrial chemical processes, from the point of view not only of the chemical reactions, but of the conditions and equipment necessary to carry on these reactions. Instructor: Manning.

ChE 63 abc. Chemical Engineering Thermodynamics. *9 units (3-0-6); second, third, first terms. Prerequisite: Ch 21 a.* Class exercises and problems in engineering, thermodynamics studied from the point of view of the chemical engineer. Text: *Thermodynamics of One-Component Systems,* Lacey and Sage. Instructors: Lacey, 63 c; Pings, 63 ab.

ChE 65. Economics of Chemical Technology. *9 units (1-0-8); second term.* Detailed studies of the technology and its relation to the economic feasibility of exemplary chemical processes. Offered to seniors in the chemical engineering option as an elective. Instructor: Manning.

ChE 66 abc. Chemical Engineering Operations. *12 units (3-0-9); first, third terms; 9 units (2-0-7); second term. Prerequisite: ChE 63 ab.* Calculations and discussions on the quantitative problems encountered in carrying out chemical processes efficiently on a commercial scale. The unit operations of chemical engineering are studied both as to principle and practice. Instructor: Pings.

ChE 67. Chemical Engineering Laboratory. *12 units (0-9-3); second term. Prerequisite: Ch 21 abc, ChE 61 a, ChE 63 abc.* Instruction and practice in making engineering measurements, and illustration of some of the principles encountered in engineering courses. Instructor: Richter.

ChE 68. Introductory Chemical Engineering Kinetics. *9 units (3-0-6); first term. Prerequisite: Ch 21 abc.* A quantitative treatment of the engineering design of chemical reactors. Instructor: Rinker.

ChE 80. Undergraduate Research. Research in chemical engineering and industrial chemistry offered as an elective in each of three terms.

ADVANCED SUBJECTS

ChE 163 abc. Chemical Engineering Thermodynamics. *6 units (3-0-3); second, third, first terms. Prerequisite: Ch 21 a.* This subject is the same as ChE 63 abc for third- and fourth-year students, but with reduced credit for graduate students. No graduate credit is given for this subject to students in chemical engineering.

ChE 166 abc. Chemical Engineering Operations. *8 units (3-0-5); first, third terms. 6 units (3-0-3); second term. Prerequisite: ChE 63 ab.* This subject is the same as ChE 66 abc, but with reduced credit for graduate students. No graduate credit is given for this subject to students in chemical engineering.

ChE 167 abc. Chemical Engineering Laboratory. *15 units (0-15-0); first, second, third terms. Prerequisites: Ch 21 abc, ChE 61 ab, ChE 63 abc.* A laboratory course providing fundamental training in the methods and techniques of engineering measurements and in research encountered by the chemical engineer. Instructors: Sage, Richter.

ChE 168 ab. Mechanics of Fluid Flow. *9 units (2-0-7); first, second terms. Prerequisites: ChE 66 a, AM 15 abc (or taking AM 115 ab).* A study of the flow of fluids in situations of interest to chemical engineers, with emphasis on estimation of velocity and pressure distribution. Subjects include the conservation of momentum and the Navier-Stokes equations, boundary-layer theory, turbulence, non-Newtonian fluids, and flow in porous media. Instructor: Longwell.

ChE 169. Advanced Industrial Chemistry. *9 units (3-0-6); third term. Prerequisites: ChE 61 ab, ChE 63 abc.* An extension of ChE 61 with emphasis on quantitative approaches to industrial chemical problems. Consideration is given to the more important chemical reactions of industrial interest. Chemical kinetics and material and energy balances are treated. Instructor: Corcoran.

ChE 170. Chemical Process Dynamics. *9 units (2-0-7); third term. Prerequisite: Ma 2 abc.* A treatment of automatic control of chemical processes with emphasis on theory and dynamic response. Instructor: Richter.

ChE 171 abc. Chemical Engineering Applied Mathematics. *6 units (2-0-4); first, second terms. Prerequisite: AM 115 ab.* Handling and interpretation of data including elementary statistical treatment, Laplace transforms and other methods of solution of linear partial differential equations, numerical solution of ordinary and partial differential equations, calculus or finite differences Text: *Applied Mathematics in Chemical Engineering,* Mickley, Sherwood and Reed; course notes. Instructor: Longwell.

ChE 172. Heat Transfer. *9 units (2-0-7); first term. Prerequisite: ChE 66 abc.* Detailed consideration of problems in thermal transfer. Instructor: Sage or Corcoran.

ChE 175 ab. Chemical Process Development. *9 units (0-0-9); two terms, by arrangement with instructor. Prerequisites: ChE 61 ab, ChE 66 abc.* Application of chemical engineering and related economic principles involved in process development, equipment selection and plant design. Through regular consultation with the instructor, the student will select a chemical compound or product and carry out a comprehensive investigation leading to a detailed report which will include the elements of a technical business problem in the chemical industry. Instructor: Manning.

ChE 262 abc. Thermodynamics of Multi-Component Systems. *9 units (2-0-7); first, second, third terms. Prerequisites: ChE 61 ab, ChE 63 abc, AM 115 ab or taking AM 115 ab concurrently.* A presentation of the background necessary for a working knowledge of multicomponent open systems from the engineering viewpoint. A discussion of the volumetric and phase behavior of pure substances, and of binary, ternary, and multicomponent fluid systems at physical and chemical equilibrium is included as a part of this thermodynamic treatment. The solution of numerous problems relating to the application of these principles to industrial practice constitutes a part of this course. Texts: *Volumetric and Phase Behavior of Hydrocarbons,* Sage and Lacey; *Thermodynamics of Multi-Component Systems,* Sage. Instructor: Sage.

ChE 263 abc. Transfers in Fluid Systems. *12 units (2-0-10); first, second, third terms. Prerequisites: ChE 66 abc, ChE 168 ab, AM 115 ab.* A consideration of thermal and material transfers in fluid systems under conditions encountered in practice. Emphasis is placed upon point conditions and upon the analogies between momentum, thermal, and material transfers in turbulent flow. The greater part of the effort in the course is devoted to the solution of transfer problems, many of which require the use of graphical or numerical methods for solution of the differential equations involved. Given in alternate years. Offered in 1961-62. Instructor: Sage.

ChE 264 abc. Molecular Theory of Fluids. *9 units (3-0-6); first, second, third terms.* A study of the models and mathematical theories of the gaseous and liquid states. The rigorous kinetic theory of equilibrium and transport properties of dilute gases is presented. Models of the liquid state are discussed and their limitations noted. An introduction is given to the use of high speed computers for the random walk estimation of transport coefficients and for Monte Carlo analysis of the many-body problem. Some emphasis is placed on the prediction of macroscopic properties from molecular parameters. Discussion is included of the study of molecular phenomena by resonance experiments, X-ray diffraction, and molecular beams. Given in alternate years. Offered in 1960-61. Instructor: Pings.

ChE 266 abc. Applied Chemical Kinetics. *9 units (2-0-7); first, second, third terms. Prerequisite: ChE 66 abc.* Kinetics of various reactions. Primary emphasis is placed upon predicting the course of chemical reaction under the conditions encountered in processing operations. The third term is concerned with the application of high-speed digital computation to reaction-rate problems. Given in alternate years. Offered in 1960-61. Instructor: Corcoran.

ChE 280. Chemical Engineering Research. Offered to Ch.E. and Ph.D. candidates in Chemical Engineering. The main lines of research now in progress are:

- Influence of turbulence upon heat transfer in fluids.
- Influence of turbulence on the transfer of material through fluids.
- Phase and thermodynamic behavior of hydrocarbons and other fluids.
- Studies of non-equilibrium behavior of fluid systems at elevated pressure.
- Reaction kinetics in flow and non-flow systems.
- Application of mathematics to complex chemical engineering problems.
- Structure and relaxation phenomena of liquids.
- Thermodynamics of irreversible processes.

ChE 291 abc. Chemical Engineering Conference. *2 units (1-0-1); first, second, third terms.* Oral presentations of industrial chemistry and chemical engineering problems of current interest. Instructor: Corcoran.

CHEMISTRY

UNDERGRADUATE SUBJECTS

Ch 1 abc. General and Quantitative Chemistry. *12 units (3-6-3); first, second, third terms.* Lectures, recitations, and laboratory exercises dealing with the general principles of chemistry. Fundamental laws and theories of chemistry are discussed and illustrated by factual material. In the first and second terms of the laboratory analytical experiments involving quantitative gravimetric, volumetric, optical, and electrical measurements are provided; in the third term use is made of a system of qualitative and semiquantitative analysis for selected elements representative of the periodic system. The stress in the course is on quantitative reasoning and on accurate and intelligent work in the laboratory. Texts: *General Chemistry,* Pauling; *A System of Qualitative Analysis for a Representative Group of the Chemical Elements,* Swift. Instructors: Waser, other staff members, and assistants.

Ch 13 abc. Inorganic Chemistry. *6 units (2-0-4); first, second, third terms. Prerequisites: Ch 1 abc, Ch 21 ab.* The chemical and physical properties of the elements are discussed with reference to the periodic system and from the viewpoints of atomic structure and radiation effects. Such topics as coordination compounds, the liquid ammonia system, the compounds of nitrogen, the halides, and selected groups of metals are taken up in some detail. The class work is supplemented by problems which require a study of current literature. Instructor: Yost.

Ch 14. Quantitative Analysis. *10 units (2-6-2); first term. Prerequisite: Ch 1 abc or equivalent.* Laboratory instruction in advanced gravimetric and volumetric chemical measurements, supplemented by lectures in which the principles involved in the laboratory work are emphasized. Text: *Chemical Analysis,* Laitinen. Instructors: Anson, Swift.

Ch 16. Instrumental Analysis. *8 units (0-6-2); first term. Prerequisite: Ch 1 abc.* Laboratory practice designed to familiarize the student with special analytical apparatus and methods, used both for process and control and for research. Instructor: Sturdivant.

Ch 21 abc. Physical Chemistry. *9 units (3-0-6); first, second, third terms. Prerequisites: Ch 1 abc; Ph 2 abc; Ma 2 abc.* A lecture and recitation course. The main emphasis is on the principles of thermodynamics, statistical mechanics, and atomic theory, and their application to the quantitative interpretation of the properties of matter. Instructors: Davidson, Hanna.

Ch 24 ab. Physical Chemistry for Geologists. *10 units (4-0-6); first, second terms. Prerequisites: Ch 1 abc; Ma 2 abc; Ph 2 abc.* A discussion of selected topics in physical chemistry, adapted to the needs of Science Course students in the Geology Option. Instructor: Hughes.

Ch 26 ab. Physical Chemistry Laboratory. *8 units (0-6-2); second, third terms. Prerequisites: Ch 1 abc; Ch 21 a.* Text: Mimeographed notes. Instructors: Stanford and other staff members.

Ch 41 abc. Basic Organic Chemistry. *4 units (2-0-2); first, second, third terms. Prerequisite: Ch 1 abc.* Lectures and recitations relating to the classification of carbon compounds, development of fundamental theories, and preparation and characteristic properties of the principal classes of carbon compounds. Text: *Basic Organic Chemistry,* Roberts. Instructor: Roberts.

Ch 46 abc. Basic Organic Chemistry Laboratory. *6 units (1-5-0); first, second, third terms. Prerequisite: Ch 1 abc.* Laboratory exercises to accompany Ch 41 abc. The preparation and purification of carbon compounds and the study of their characteristic properties. Qualified students may pursue research work. Text: *Principles and Practice in Organic Chemistry,* Lucas and Pressman. Instructors: Richards and assistants.

Ch 80. Chemical Research. *Offered to B.S. candidates in Chemistry.*

Ch 90. Oral Presentation. *2 units (1-0-1); first term.* Training in the technique of oral presentation of chemical topics. Practice in the effective organization and delivery of reports before groups. Instructors: Corey, Thomas.

ADVANCED SUBJECTS

Ch 113 abc. Inorganic Chemistry. *4 units (2-0-2); first, second, third terms.* Selected groups of inorganic compounds will be considered from modern physicochemical viewpoints; thus with reference to their physical properties, their thermodynamic constants (their heat-contents, free-energies, and entropies), their rates of conversion into one another (including effects of catalysis and energy radiations), and their molecular structure and valence relations. Instructor: Yost.

Ch 117. Electroanalytical Chemistry. *4 units (2-0-2); second term.* The theory and practice of selected electroanalytical techniques are presented. Topics covered include potentiometry, diffusion currents, polarography, amperometry, coulometry, chronopotentiometry, and other electrochemical methods. Text: *Electroanalytical Chemistry,* Lingane. Instructor: Anson.

Ch 118 ab. Electroanalytical Chemistry Laboratory. *6 units (0-6-0); second, third terms.* Laboratory experiments involving the use of electroanalytical instruments. Instructor: Anson.

Ch 120. Electric and Magnetic Properties of Molecules. *6 units (2-0-4); second term.* The course begins with an introduction to atomic and molecular structure and to the quantum theory of matter. Other topics discussed are index of refraction and birefringence of substances, electronic polarizability of molecules, dielectric constant, diamagnetism, paramagnetism, ferromagnetism, ferrimagnetism, Kerr effect, electric dipole moments, magnetic moments, and other molecular properties. This course is recommended as preparation for Ch 121, The Nature of the Chemical Bond. Given in alternate years. Offered in 1960-61. Instructor: Pauling.

Ch 121 ab. The Nature of the Chemical Bond. *6 units (2-0-4); second, third terms.* This subject comprises the detailed non-mathematical discussion of the electronic structure of molecules and its correlation with the chemical and physical properties of substances. Text: *The Nature of the Chemical Bond,* Pauling. Not offered in 1960-61. Instructors: Pauling and others.

Ch 124 ab. Physical Chemistry for Geologists. *6 units (4-0-2); first, second terms.* This course is the same as Ch 24. Instructor: Hughes.

Ch 125 abc. Advanced Physical Chemistry. *9 units (3-0-6); first, second, third terms. Prerequisite: Ch 21 abc or the equivalent.* This course provides a brief but quantitative introduction to quantum mechanics, and is otherwise devoted primarily to both theoretical and experimental aspects of the electronic wave functions of molecules and solids. Illustrative topics are: molecular orbital and valence bond theories of molecules, Bloch states in solids, and applications of electron and nuclear magnetic resonance to electronic structure problems. Instructor: McConnell.

Ch 127 abc. Radioactivity and Isotopes. *6 units (2-0-4); first, second, third terms.* The fundamental particles and isotopes. Nuclear structure. Natural and artificial radioactivity. Instrumentation in nuclear studies. Techniques of radiochemistry. The applications of stable and radioactive isotopes to various chemical studies. Instructor: Yost.

Ch 128. Electronic Structure of Molecules. *6 units (2-0-4); second, third terms. Prerequisite: Ch 21 abc.* Molecular electronic structure is treated with particular reference to chemical and geometric properties of molecules and the variation of these properties with electronic excitation. An elementary introduction to group theoretical methods in molecular problems is presented. A generally descriptive treatment follows of the electronic structure of organic and inorganic prototype molecules, free radicals, and ions, starting from the molecular orbital and valence bond approximations. The nature and chemical importance of the coupling of electronic motions with other kinds of molecular motions are stressed, and a discussion of inter-molecular interactions is given. Instructor: Robinson.

Ch 129. Surface and Colloid Chemistry. *8 units (3-0-5); third term. Prerequisite: Ch 21 abc or equivalent.* Classroom exercises with outside reading and problems, devoted to the properties of surfaces and interfaces, and the general principles relating to disperse systems with particular reference to the colloidal state. Not offered in 1960-61. Instructor: Badger.

Ch. 130. Photochemistry. *6 units (2-0-4); second term. Prerequisite: Ch. 21 abc.* Lectures and discussions on photochemical processes, especially in their relation to quantum phenomena. The following topics are included: the photochemical absorption law; the processes—excitation, dissociation, ionization—accompanying the absorption of radiation; subsequent processes including fluorescence and collisions of the second kind; photosensitization; quantum yield and its relation to photochemical mechanism; kinetics of homogeneous thermal and photochemical reactions; catalysis and inhibition; temperature coefficients of photochemical reactions. Instructor: Wulf.

Ch 132 b. Biophysical Chemistry. *6 units (2-0-4); third term.* This course considers the physical chemistry of macromolecules of biological interest. Together with Bi 129 ab it constitutes an integrated program covering the physical and physico-chemical approaches to biology. The subject matter to be repeated, approximately in a three-year cycle, will consist of a discussion of the principles and methods employed in the determination of size, shape, charge, and thermodynamic properties of biological macromolecules. The methods to be considered in 1960-61 are sedimentation, diffusion, and viscometry. Instructor: Vinograd.

Ch 135. Chemical Kinetics. *6 units (2-0-4); third term.* The mechanisms of chemical reactions as revealed by various methods, especially rate measurements and photochemical experiments, are discussed. Both theoretical and experimental aspects of the subject are studied. Topics include the transition state theory and the collision theory, unimolecular reactions, ionic reactions, modern experimental approaches to the nature of transient intermediates and elementary reactions, molecular structure and reactivity, catalysis, tracer studies, hydrodynamics and kinetics, combustion and detonation. Not offered in 1960-61. Instructor: Davidson.

Ch 144 abc. Advanced Organic Chemistry. *9 units (3-0-6); first, second, third terms.* A survey of synthetic and theoretical organic chemistry at an advanced level with emphasis on stereochemistry. Applications of fundamental principles to the chemistry of naturally occurring substances. Instructor: Hammond.

Ch 148 abc. Characterization of Organic Compounds. *4 units (2-0-2); first, second, third terms. Prerequisites: Ch 41 abc, Ch 46 abc.* Lectures and recitations emphasizing the analytical methods of organic chemistry. Consideration of the general problem of the characterization of organic compounds by qualitative and quantitative procedures. Instructor: Niemann.

Ch 149 abc. Laboratory in Characterization of Organic Compounds. *6 units (0-6-0); first, second, third terms. Prerequisites: Ch 41 abc, Ch 46 abc, and consent of instructor.* Laboratory exercises to accompany Ch 148. The isolation, purification, and identification of organic compounds with special reference to the manipulation of milligram and decigram quantities. Qualified students may pursue research work. Instructors: Niemann and assistant.

Ch 180. Chemical Research. *Offered to M.S. candidates in Chemistry.*

Ch 190. Oral Presentation. *2 units (1-0-1); first term.* Training in the technique of oral presentation of chemical topics; graduate teaching assistants in chemistry are required to take this course, unless excused for demonstrated proficiency. Instructors: Thomas, Waser.

Ch 223 abc. Statistical Mechanics. *9 units (3-0-6); first, second, third terms.* After a survey of the principles of classical and quantum mechanics and of the theory of probability, the equilibrium theory of statistical mechanics is developed and used to interpret the laws of thermodynamics from the molecular standpoint. A detailed study of the relationships between the thermodynamic functions of gases, liquids, and solids and their structure on the molecular scale follows. Given in alternate years. Not offered in 1960-61. Instructor: Davidson.

Ch 225 abc. Advanced Chemical Thermodynamics. *9 units (3-0-6); first, second, third terms. Prerequisite: Ch 21 abc or the equivalent.* Basic concepts and the laws of thermodynamics are reviewed. The theories of heterogeneous and chemical equilibrium are developed according to the methods of J. Willard Gibbs. A systematic treatment is presented of the thermodynamic properties of pure systems, mixtures, chemical reactions, electrochemical systems, surface phases, and systems under the influence of external fields. The theory of heterogeneous equilibrium and phase diagrams is developed analytically. The third term is largely devoted to the thermodynamics of irreversible processes. Offered in 1960-61. Instructor: Mazo.

Ch 226 abc. Introduction to Quantum Mechanics, with Chemical Applications. *9 units (3-0-6); first, second, third terms.* A review of the Lagrangian and Hamiltonian mechanics and of the old quantum theory is first given, followed by the discussion of the development and significance of the new quantum mechanics and the thorough treatment of the Schrödinger wave equation, including its solution for many simple systems such as the rotator, the harmonic oscillator, the hydrogen atom, etc. During the second and third terms various approximate methods of solution (perturbation theory, the variation method, etc.) are discussed and applied in the consideration of the resonance phenomenon, the structure of many-electron atoms and of simple molecules, the nature of the covalent chemical bond, the structure of aromatic molecules, and other recent chemical applications. Given in alternate years. Not offered in 1960-61. Instructor: Mazo.

Ch 227 abc. The Structure of Crystals. *9 units (3-0-6); first, second, third terms.* The nature of crystals and x-rays and their interaction. The various diffraction techniques. The theory of space groups and the use of symmetry in the determination of the structures of crystals. The detailed study of representative structure investigations. The quantitative treatment of x-ray diffraction. Fourier-series methods of structure investigation. Given in alternate years. Not offered in 1960-61. Instructor: Sturdivant.

Ch 229 ab. X-Ray Diffraction Methods. *6 units (2-0-4); second, third terms. Prerequisite: Ch 227 abc or equivalent.* An advanced discussion of the techniques of structure analysis by x-ray diffraction. Offered in 1960-61. Instructors: Hughes, Sturdivant.

Ch 233 ab. The Metallic State. *6 units (2-0-4); first, second terms.* The physical, electrical, and magnetic as well as the structural, chemical, and thermodynamic properties of metals and alloys considered from modern viewpoints. Instructor: Yost.

Ch 234. Introduction to the Spectra of Molecules. *6 units (2-0-4); first term.* The theory of the structure of the spectra of both the diatomic and simpler polyatomic molecules is presented, and the transition rules and their relation to the symmetry elements of molecules are discussed. Emphasis is laid on the methods of interpreting and analyzing molecular spectra, and it is shown how from an analysis one obtains information regarding the structure and other properties of a molecule of interest to the chemist. Problems are given in the interpretation of actual data. Given every third year. Not offered in 1960-61. Instructor: Badger.

Ch 242 ab. Chemistry of Natural Products. *4 units (2-0-2); first, second terms. Prerequisite: Ch 41 abc.* The chemistry of antibiotics, alkaloids, pigments, steroids, terpenes, etc. is used as a vehicle for a discussion of the general principles of structural elucidation, total synthesis, and biogenesis of natural products. The course is given as a continuing cycle such that each of the major areas is presented once every three years. Instructor: Richards.

Ch 246 ab. Structures and Reactions of Organic Compounds. *4 units (2-0-2); first, second, third terms. Prerequisites: Ch 41 abc, Ch 21 abc.* Special methods for study of organic compounds and reactions. Topics discussed vary from year to year but usually include applications of the molecular orbital approach and nuclear magnetic resonance spectroscopy to problems of structure and reactivity. Given in alternate years. Offered in 1960-61. Instructor: Roberts.

Ch 247 ab. Organic Reaction Mechanisms. *6 units (2-0-4); two consecutive terms at the discretion of the instructor. Prerequisite: Ch 144 or equivalent.* Various tools for the study of organic reaction mechanisms will be discussed with major emphasis on kinetic methods. Given in alternate years. Offered in 1960-61. Instructor: Hammond.

Ch 253 ab. Chemistry of the Enzymes. *6 units (2-0-4); first, second terms.* Consideration of the nature and mechanism of enzyme action. Instructor: Niemann.

Ch 254 abc. The Chemistry of Amino Acids and Proteins. *3 units (1-0-2); first, second, third terms. Prerequisites: Ch 41 abc, Ch 46 abc.* A consideration of the physical and chemical properties of the amino acids, peptides, and proteins. Given every third year. Offered in 1958-59. Instructor: Niemann.

Ch 255 abc. Chemistry of Bio-organic Substances. *3 units (1-0-2); first, second, third terms.* Lectures on selected subjects of organic chemistry such as alkaloids, essential oils, and other major groups of natural products. Instructor: Haagen-Smit.

Ch 258. Immunochemistry. *8 units (2-3-3); second term. Prerequisite: Ch 129 and Bi 114, or consent of instructor.* Lectures cover the following material: fundamental physical and biochemical factors of importance in immunochemistry; nature of antigens and antibodies; physical and biological manifestations of antigen-antibody reactions; basis of immunological specificity; and practical aspects of immunology. The laboratory consists of a variety of experiments designed essentially to familiarize the student with the preparation of antigens and antibodies and the nature of antigen-antibody interactions. Particular emphasis is given to quantitative aspects of the precipitin reaction and its significance. Texts: *Principles of Immunology*, Cushing and Campbell; *Experimental Immunochemistry*, Kabat and Mayer; *Fundamentals of Immunology*, Boyd. Given in alternate years. Offered in 1961-62. Instructors: Campbell and associates.

Ch 280. Chemical Research. *Offered to Ph.D. candidates in Chemistry.* The main lines of research now in progress are:

In physical and inorganic chemistry—

- Free energies, equilibria, and electrode potentials of reactions.
- Distribution of chemical compounds between immiscible phases.
- Studies of inorganic analytical methods.
- Kinetics of chemical reactions including photochemical reactions.
- Determination of the structure of crystals by the diffraction of X-rays.
- Application of quantum mechanics to chemical problems.
- Study of molecular structure and of chemical problems by spectroscopic methods.
- Nature of the metallic bond and the structure of metals and intermetallic compounds.
- Microwaves and nuclear resonance.
- Electronic structures of simple molecules and molecular fragments.
- Spectroscopic studies of the chemistry of free radicals trapped at low temperatures.

In organic chemistry—

- Studies of the mechanism of organic reactions in relation to electronic theory.
- Isolation of alkaloids and determination of their structure.
- Synthesis of substances related to cyclobutadiene.
- Chemistry of amino acids and peptides.
- Chemistry of small-ring carbon compounds.
- Application of isotopic tracer and nuclear magnetic resonance techniques to problems in organic chemistry.
- Relation of structure to reactivity of organic compounds.
- Organic chemistry of metal chelates.
- Solution photochemistry.
- Reactions of free radicals in solutions.

In fields of application of chemistry to biological and medical problems—

- Study of the mechanism of antigen-antibody reactions and the structure of antibodies.
- Functional significance of antibodies.
- Chemical and physical properties of blood.
- Investigation of plasma substitutes.
- Isolation and characterization of cellular antigens.
- Studies on the enzymatic cleavage and formation of amide bonds.
- Chemical analysis of proteins and determination of the order of amino-acid residues in polypeptide chains.
- Crystal structures of amino acids, peptides, and proteins.
- Investigation of fluorescent compounds in plants and animals, including microorganisms.
- Study of plant hormones and related substances of physiological importance.
- Investigation of mammalian and bacterial polysaccharides including the blood-group specific substances.
- Nature of sickle cell anemia and other hemolytic diseases.
- Chemistry in relation to mental disease.

Ch 290 abc. Chemical Research Conference. *First, second, third terms.* These conferences consist of reports on investigations in progress in the chemical laboratories and on other researches which are of current interest. Every graduate student in chemistry is expected to attend these conferences. Seminars in special fields (immunochemistry, analytical chemistry, crystal structure, physical chemistry, organic chemistry) are also held.

Civil Engineering

UNDERGRADUATE SUBJECTS

CE 1. Surveying. *12 units (2-6-4); third term.* A study of the elementary operations employed in making surveys for engineering work, including the use, care, and adjustment of instruments, linear measurements, angle measurements, note keeping, stadia and plane table surveys, calculation and balancing of traverses, topographic mapping and field methods. Triangulation, base line measurements, determination of latitude and a true meridian by sun and circumpolar star observations, stream gauging. Route location of highways.

CE 10 abc. Structural Analysis and Design. *9 units (3-0-6); first, second and third terms. Prerequisites: AM 8 and AM 9, may be taken concurrently.* Analysis of lumped-parameter structural systems, including the basic concepts of relaxation. The design of structural components using such materials as steel and reinforced concrete. Instructor: McCormick.

CE 17. Civil Engineering. *9 units (3-0-6); third term. Prerequisite: Senior standing.* Selected comprehensive problems of civil engineering systems involving a wide variety of interrelated factors. Instructor: Staff.

ADVANCED SUBJECTS

CE 105. Introduction to Soil Mechanics. *9 units (2-3-4); first term. Prerequisites: AM 8, AM 9.* A general introduction to the physical and engineering properties of soil, including origin, classification and identification methods, permeability, seepage, consolidation, settlement, slope stability, lateral pressures and bearing capacity of footings. Standard laboratory soil tests will be performed. Text: *Basic Soil Engineering,* Hough. Instructor: Scott.

CE 115 ab. Soil Mechanics. *9 units (3-0-6); first term. 9 units (2-3-4); second term. Prerequisite: CE 105 or equivalent, may be taken concurrently.* A detailed study of the physical and engineering properties and characteristics of soil including classification methods, permeability, flow nets and seepage, leading to the consolidation process and analyses of settlement problems. In the second term the shear strength of soils and the mechanics of soil masses under load will be studied, including stress distribution, active and passive pressures, stability of slopes and earth dams, and bearing capacity of footings and piles. Laboratory tests of the shear strength of soils will be performed. Text: *Fundamentals of Soil Mechanics,* Taylor. Instructor: Scott

CE 120 ab. Advanced Structural Analysis. *9 units (3-0-6); first and second terms. Prerequisite: CE 10 or equivalent.* Advanced methods of structural analysis, including the solution of differential equations, energy methods, moment distribution and relaxation methods, finite difference and numerical methods, applied to special structures such as elastic and plastic frames, unstable columns and frames, suspension bridges, arches, prismatic shells. Instructors: Housner, McCormick.

CE 121. Analysis and Design of Structural Systems. *9 units (0-9-0); third term. Prerequisite: CE 120 ab.* The analysis and design of complete structural systems. In general, students will work on a single problem for the entire term. The problem may be primarily one of analysis or one of design. Instructors: Housner, McCormick.

CE 123. Dynamics of Structures. *9 units (3-0-6); third term. Prerequisites: AM 150 ab, CE 120.* Analysis of structures and their response to dynamic loads such as blast and earthquakes. Consideration will be given to both elastic and plastic deformations. Instructor: Housner.

CE 124. Special Problems in Structures. *9 units (3-0-6); any term.* Selected topics in the field of structures to meet the needs of first-year graduate students. Instructors: Housner, McCormick.

CE 129. Spring Field Trip. *1 unit (0-1-0); week between second and third terms. Prerequisite: Graduate standing.* An inspection tour of the waterworks structures of the lower Colorado River basin, including the Regional Salinity Laboratory of the Department of Agriculture, Imperial Irrigation District and Dam, Parker Dam and pumping facilities of the Metropolitan Water District, Davis Dam, Hoover Dam, and the work of the USBR River Control Section. Required of all graduate students in Civil Engineering.

CE 130 ab. Civil Engineering Seminar. *1 unit (1-0-0); first, second terms; 4 units (0-4-0); third term.* Conferences participated in by faculty and graduate students of the Civil Engineering department. The discussions cover current developments and advancements within the fields of civil engineering and related sciences, with special consideration given to the progress of research being conducted at the Institute. Inspection trips.

CE 132. Water Power Engineering. *9 units (2-3-4); third term. Prerequisite: CE 155.* The application of hydraulics and hydrology to the development of hydroelectic power. Estimates of water power available from streamflow records. Impulse and reaction turbines, penstocks, draft tubes, governors and surge tanks. Water hammer and cavitation problems. Design of power plant at a particular site.

CE 137 abc. Water Supply and Waste Water Disposal. *12 units (3-3-6), first term; 9 units (3-0-6), second term; 9 units (1-6-2), third term. Prerequisites: ME 17 ab, ME 19 ab or equivalent, CE 155 (may be taken concurrently).* A study of the principles involved in the collection, storage, treatment, and distribution of water for municipal, industrial, and irrigation use, and the removal of storm waters, municipal sewage, and excess irrigation waters; water rights and stream administration; water quality criteria; the economic aspects of projects; the theory of unit operations as applied to the treatment of water and waste water; and the design of works for the collection, treatment, and disposal of water and liquid wastes. Instructors: McKee, Samples.

CE 138 abc. Sanitary Sciences. *9 units (2-3-4); first, second and third terms. Prerequisites: Ch 1 abc, Ph 2 abc.* A review of chemical, physical, and biological phenomena and their application to the analysis and treatment of water, waste waters, and polluted atmospheres; laboratory exercises and problems in water and air analysis. Instructors: Samples, McKee.

CE 139 ab. Engineering Principles of Environmental Health. *9 units (2-3-4); first and second terms. Prerequisites: Ch 1 abc, ME 17 ab, ME 19 ab, Ph 2 abc.* The application of engineering analysis and scientific phenomena to problems of atmospheric pollution; evaluation of source emissions, meteorologic and climatologic factors, air quality measurements, aerosol properties and behavior, photochemical reactions, effects on animate and inanimate receptors and principles of control. Detection and control of health hazards from radioactive materials in air, water, food and wastes, and from ionizing radiations. Study of hazardous conditions in work places; evaluation of dust, fumes, gases, excessive temperature humidity and noise, inadequate ventilation and illumination. Discussions of engineering control of insects, rodents, and vermin; sanitation of swimming pools, housing, and hospitals; and engineering analysis in problems of epidemiology. Instructors: Rossano, Samples.

CE 150. Foundation Engineering. *9 units (3-0-6); third term. Prerequisite: CE 115 ab.* Methods of subsoil exploration. Study of types and methods of design and construction of foundations for structures, including spread and combined footings, mats, piles, caissons, retaining walls, cofferdams, and methods of underpinning. Instructor: Scott.

CE 155. Hydrology. *9 units (3-0-6); first term. Prerequisite: Ma 2 abc, Ph 2 abc.* An introductory study of the occurrence and movement of water on the earth's surface, including such topics as precipitation, evaporation, transpiration, infiltration, ground water, runoff, and flood flows; applications to various phases of hydraulic engineering such as water supply, irrigation, water power, and flood control; the use of statistical methods in analyzing hydrologic data. Instructor: Brooks.

CE 156. Industrial Wastes. *9 units (3-0-6); third term. Prerequisite: CE 137 ab, CE 138 ab.* A study of the industrial processes resulting in the production of liquid wastes; the characteristics of such wastes and their effects upon municipal sewage-treatment plants, receiving streams, and ground waters; and the theory and methods of treating, eliminating, or reducing the wastes. Instructor: McKee.

CE 160. Advanced Hydrology. *6 or more units as arranged; any term. Prerequisite: CE 155.* Advanced studies of various phases of hydrology. The course content will vary depending on needs and interests of students enrolling in the course. Instructor: Brooks.

CE 200. Advanced Work in Civil Engineering. *6 or more units as arranged; any term.* Members of the staff will arrange special courses on advanced topics in civil engineering for properly qualified graduate students. The following numbers may be used to indicate a particular area of study.

CE 201. Advanced Work in Structural Engineering.

CE 202. Advanced Work in Soil Mechanics.

CE 203. Advanced Work in Environmental Health Engineering.

CE 204. Advanced Work in Water Resources.

Hy 200. Advanced Work in Hydrodynamics or Hydraulic Engineering.

CE 300. Civil Engineering Research.

Computers and Machine Methods of Computation

The following courses in computers and their application to applied mathematics and engineering analysis are offered under the various options indicated.

EE 180. Digital Computer Design. *9 units (3-3-3); first term.* This course is concerned with the basic principles of logical design and instrumentation of digital computers. Modern switching theory including Boolean algebra and other forms of symbolic logic; pulse circuitry; magnetic drum, electrostatic, magnetic core and ferroelectric principles as applied to switching and data storage. The basic design philosophies of stored and externally programmed matrices will be given. The design and operating characteristics of a magnetic drum, serial-stored program binary computer will be treated in detail. Text: Course notes. Instructor: McCann.

EE 181 ab. Principles of Analog Computation. *12 units (3-3-6); second, third terms. Prerequisite: AM 180.* General survey of the basic principles of electric analog computing techniques. Development and application of electronic differential analyzer and direct analogy principles. Synthesis of passive analogies—lumped parameter systems. Synthesis of passive analogies—distributed systems. Synthesis of active circuit analogies. Applications to solid mechanics, aeroelasticity, heat transfer, fluid mechanics, servomechanisms. Text: Course notes. Instructor: McCann.

EE 280 abc. Advanced Course in Machine Computing Methods for Engineering Analysis. *9 units (2-3-4); first, second, third terms.* The application of analog and digital methods to problems in engineering analysis. Specific system and design analysis problems in such fields as electricity and magnetism, solid mechanics, fluid mechanics, aeroelasticity and thermal conductivity will be solved by machine computing techniques. Course open only to advanced graduate students and by permission of instructor. Instructors: Franklin, McCann.

AM 180. Matrix Algebra. *9 units (3-0-6); first term.* Theory of matrices from the standpoint of mathematical physics and as used in the formulation of problems on high speed analog and digital computers. Canonical forms are developed for self-adjoint and for general matrices. Text: *Theory of Matrices,* Perlis. Instructor: Franklin.

Ma 105 ab. Introduction to Numerical Analysis. *11 units (3-2-6); second, third terms. Prerequisites: Ma 108 or AM 115, and Ma 5 or AM 180, or equivalent, and familiarity with coding procedures by the middle of the first quarter of the course.* Topics will include: interpolation and quadrature; numerical solution of algebraic and transcendental equations; matrix inversion and determination of eigenvalues; numerical solution of ordinary differential equations; numerical solution of elliptic, parabolic, and hyperbolic partial differential equations. Instructor: Franklin.

Ma 107. Advanced Topics in Numerical Analysis. *9 units (3-0-6); first, second, third terms. Prerequisites: Ma 105 or equivalent.* Discussion at an advanced level of areas of current interest in numerical analysis, and in related mathematics, such as matrix inversion and decomposition, ordinary differential equations, partial differential equations and integral equations, discrete problems, linear programming and game theory, approximation theory, applications of functional analysis, theory of machines, estimates of eigenvalues of matrices. Each quarter will be treated as a separate unit. Where appropriate, accompanying laboratory periods will be arranged as a separate reading course. Instructor: Todd (in charge) and other members of staff.

ECONOMICS

Ec 2 ab. General Economics and Economic Problems. *9 units (3-0-6).* A course in economic life and institutions, the principles underlying them, and the major problem they present. Subjects studied include production, exchange, distribution, money and banking, the economic activities and policies of government, and international trade. Instructors: Brockie, Oliver, Untereiner.

Ec 4 ab. Economic Principles and Problems. *6 units (3-0-3); first term, and either second or third term.* A course in economic life, institutions, and problems, stressing the national income approach. Subjects studied parallel those of Ec 2 ab, with such difference in emphasis as is necessary to make this shorter course complete in itself. Instructor: Sweezy.

Ec 13. Reading in Economics. *Units to be determined for the individual by the department.*

Ec 18. Industrial Organization. *7 units (3-0-4); third term.* After outlining the historical background of industry with the economic changes involved, this subject surveys the major problems facing management, especially in factory operations. The principal topics included are organization, plant layout, costs and budgets, methods, time and motion study, production control, labor relations, and wage scales. Instructor: Gray.

Ec 25. Engineering Law. *7 units (3-0-4); third term.* The law of business, with particular emphasis on the legal rights and obligations pertaining most directly to the engineering profession. Contracts and specifications, agency, property, mechanics' liens, workmen's compensation, and the principles of legal liability are studied. Instructor: Untereiner.

Ec 48. Introduction to Industrial Relations.* *9 units (3-0-6). Senior Elective.* This course stresses the personnel and industrial relations functions and responsibilities of supervisors and executives. The history, organization, and activities of unions and the provisions of current labor legislation are included. The relationships of a supervisor or executive with his employees, his associates, and his superiors are analyzed, and the services which he may receive from the personnel department are examined. The course also discusses the use of basic tools of supervision. Instructor: Gray.

ADVANCED SUBJECTS

Ec 100 abc. Business Economics. *10 units (4-0-6); first, second, third terms. Open to graduate students.* This course endeavors to bridge the gap between engineering and business, especially industry. It is intended for two groups of technically trained students: 1) those who wish sooner or later, to take advantage of opportunities in industry beyond their strict technical fields, and 2) those who will be engaged in teaching and in scientific research, but who wish to get an understanding of industry in both its technical and philosophical aspects. The broad assumptions in the course are that technical training is an excellent approach to positions of general responsibility in business and industry, and that technically trained men going into industry can make significant contributions to the improved functioning of the economy. The principal divisions of the subject matter of

*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

the courses are: 1) business organization, 2) industrial promotion and finance, 3) factory management, 4) industrial sales, and 5) business economic topics, especially the business cycle. This treatment provides a description of the industrial economy about us and of the latest management techniques. The points of most frequent difficulty are given special study. The case method of instruction is used extensively in the course. Instructor: Gilbert.

Ec 106 abc. Business Economics (Seminar). *Units by arrangement; first, second, third terms. Open to graduate students.* This seminar is intended to assist the occasional graduate student who wishes to do special work in some part of the field of business economics or industrial relations. Special permission to register for this course must be secured from the instructors. Instructors: Gilbert, Gray.

Ec 110. Industrial Relations. *9 units (3-0-6); first term. Not open to students who have taken Ec 48, Introduction to Industrial Relations.* An introductory course dealing with basic problems of employer-employee relationships and covering the internal organization of an enterprise, the organization and functions of unions, and the techniques of personnel administration with emphasis on the problems of setting wage rates. Instructor: Gray.

Ec 111. Business Cycles and Governmental Policy. *9 units (3-0-6); second term.* A study of the nature, causes, and possible control of economic fluctuations with special emphasis on the interrelationship of business cycles and such fiscal matters as national debt control, national budgetary control, and the maintenance of high levels of employment, production, and purchasing power. The course also integrates the international problems of war, reconstruction, trade, and investment with the analysis of business cycles and internal fiscal policies in order to provide a unified theory of national and international equilibrium. May be taken as a senior elective. Instructor: Brockie.

Ec 112. Modern Schools of Economic Thought. *9 units (3-0-6); third term.* A study of economic doctrine in transition, with particular emphasis on the American contribution. Against a background of Marshall and Keynes, a critical examination will be made of the institutional, collective, quantitative, social, experimental, and administrative schools of economics. Instructor: Brockie.

Ec 113. Reading in Economics. *Same as Ec 13 but for graduate credit.*

Ec 124. Economic Problems of Underdeveloped Areas.* *9 units (3-0-6); third term. Senior elective.* An examination of economic conditions in low income countries. Modern techniques of promoting development are studied, including international assistance programs and national economic planning. Instructor: Sweezy.

Ec 126 abc. Economics Analysis and Policy* (Seminar). *9 units (3-0-6); first, second, third term. Senior elective.* Open to students who have taken Ec 2 ab or Ec 4 ab and to other qualified students with the consent of the instructor. Instructor: Sweezy.

*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

Electrical Engineering

UNDERGRADUATE SUBJECTS

EE 1 abc. Basic Electrical Engineering. *9 units (3-0-6); first, second, third terms. Prerequisites: Ma 2 abc; Ph 2 abc.* An introductory course in circuit analysis, energy conversion, electromechanical devices, vacuum and solid state devices and circuits. Instructors: Martel, McCann, Middlebrook.

EE 2 ab. Basic Electrical Engineering Laboratory.

EE 2 a. Laboratory in Electrical Circuits. 3 units (0-3-0); second term. Prerequisite: *EE 1 a.* This course is the laboratory for EE 1 a. The experiments are designed to acquaint the student with techniques of electrical measurements and to provide experimental verification of the behavior of passive electrical circuits. Instructors: Gould and Wilts.

EE 2 b. Laboratory in Electronics. *3 units (0-3-0); third term. Prerequisites: EE 1 ab, EE 2 a.* This course is the laboratory for EE 1 b. The experiments are designed to acquaint the student with techniques of electrical measurements and to provide experimental verification of the properties of electron devices and simple electronic circuits. Instructor: Nicolet.

EE 3. Introduction to Electric Circuits and Power. *12 units (4-0-8); first term. Prerequisites: Ma 2 abc, Ph 2 abc.* A course in direct and alternating current circuits, rotating machinery, and equipment, with primary emphasis on the characteristics and application of such equipment. Electric power distribution. Instructor: Maxstadt.

EE 4. Laboratory in Energy Conversion. *3 units (0-3-0); third term. Prerequisites: EE 1 a or EE 3.* A laboratory program to illustrate the basic principles and properties of electrical-mechanical energy conversion. Chief emphasis is on transducers, transformers and rotating machines. Instructor: Maxstadt.

EE 5. Introductory Electronics. *9 units (3-0-6); third term. Prerequisite: Ph 2 ab.* This is an introductory course to provide a background in electronics for students both in engineering and in other fields. The subjects covered will be simple a.c. circuit theory, properties of vacuum tubes and transistors, simple amplifiers and switching circuits. Instructors: Dow and Langmuir.

EE 7 abc. Experimental Techniques in Electrical Engineering. *5 units (0-3-2); first, second, third terms.* A general laboratory program devoloping experimental techniques and verifying the theory of the five senior engineering courses (EE 101, EE 106, EE 107, EE 115 and EE 162). Text: Laboratory notes. Instructors: Electrical Engineering Faculty.

ADVANCED SUBJECTS

EE 101 abc. Electric Circuit Theory. *9 units (3-0-6); first, second and third terms. Prerequisites: EE 1 abc; AM 116.* A course of study relating to general methods of steady state and transient analysis of linear electric circuits. Application of transform methods. Elementary principles of circuit synthesis, maximally flat and Chebyshev approximations. Filter theory, low-pass, band-pass. Classical transmission-line theory. Instructors: Mason, Wilts.

EE 106 ab. Electronic Circuits. *9 units (3-0-6); first and second terms.* Resistive diode circuits; rectifiers. Piecewise linear and incremental analysis of vacuum tubes and transistors. Power amplifiers: Class A and B. Electromechanical analogs: loudspeakers. Regulators. Waveshaping; multivibrators. Negative resistance and sinusoidal oscillators. Modulation and demodulation; AM and FM. Prerequisite: EE 1 ab. Instructor: Mead.

EE 107. Principles of Feedback. *9 units (3-0-6); third term. Prerequisite: EE 101 ab.* Basic principles of linear feedback theory. Automatic control systems, feedback amplifiers, oscillators. Instructors: Mullin, Wilts.

EE 115 abc. Electromagnetism. *9 units (3-0-6); first, second terms; 6 units (2-0-4); third term. Prerequisites: Ph 2 abc; Ma 2 abc; AM 115.* A course in theoretical electricity and magnetism, primarily for electrical engineering students. Topics covered include electrostatics, magnetostatics, Maxwell's equations, wave-guides, cavity resonators, and antennas. EE 115 c will include topics on propagation in the ionosphere, propagation over the earth's surface, and modern microwave tubes. Text: Course notes. Instructor: Langmuir.

EE 132 abc. Network Synthesis. *9 units (3-0-6); first, second, third terms. Prerequisite: EE 101 ab.* The analysis and synthesis of lumped and distributed parameter circuits. Mathematical properties of network functions. Realization theory for driving-point and transfer functions, including the synthesis techniques of Bode, Brune, Cauer, Darlington, Foster, Guillemin and others. The approximation problem, the scattering matrix, the Deschamps chart, and selected topics of research importance. Text: *Synthesis of Passive Networks,* Guillemin; *Principles of Microwave Circuits,* Montgomery et al. Instructor: George.

EE 140 abc. Communication Theory. *9 units (3-0-6); first, second, third terms. Prerequisites: EE 101 ab; EE 106 ab.* Modern basis of the theory of communication of information. Review of probability and statistical methods. Noise, its description, properties and effects; random time series; autocorrelation and cross-correlation functions; spectral density; physical origins and mathematical models of noise; effects of linear and non-linear circuits. Information theory; entropy of a source and channel capacity; equivocation and redundancy; coding theorems; error detecting and correcting codes; continuous information; modulation methods—AM, FM, PM, PCM. Optimum linear circuits (Wiener filters) for smoothing or prediction of statistical signals in noise. Text: Course notes. Instructor: H. Martel.

EE 150 abc. Electromagnetic Fields. *9 units (3-0-6); first, second, third terms. Prerequisites: EE 115 ab or Ph 107.* An advanced course in classical electromagnetic theory and its application to guided waves, cavity resonators, antennas, artificial dielectrics, propagation in ionized media, propagation in anisotropic media, magnetohydrodynamics, and to other selected topics of research importance. Text: Course notes. Instructor: Papas.

EE 162 abc. Physical Electronics. *6 units (2-0-4); first, second, third terms. Prerequisites: EE 1 ab.* A course in the physical principles of electron devices and an introduction to atomic and molecular physics. Motion of charged particles in electric and magnetic fields and applications. Electronic phenomena in metals; conduction, emission, contact potential. Electrical conduction in gases; breakdown, plasmas, gas tubes. Electronic phenomena in semiconductors; transistors. Instructor: Dow.

EE 164 abc. Microwave Electronics and Circuits. *9 units (3-0-6); first, second, third terms. Prerequisites: EE 115 ab or Ph 107 and EE 162 abc.* Principles of the interaction of electron beams and microwave electromagnetic fields. Generation and focusing of high current electron beams with electric and magnetic fields, electron optics. The Llewellyn Peterson equations and transit time effects in diodes and triodes. Velocity modulation, space charge wave propagation, and traveling wave interaction with electron beams with application to microwave amplifiers and oscillators. The electromagnetic theory of slow wave circuits. Noise in electron beams and microwave amplifiers. Instructor: Field.

EE 165. Ultra-High Frequency Laboratory. *6 units (1-3-2); third term. Prerequisites: EE 150 and EE 164 or may be taken concurrently.* Covering experiments on microwave generation, bridges, precise impedance measurement, nodal shift methods, and the properties of microwave circuit elements such as matched T's, directional couplers and antennas. Instructor: Gould.

EE 170 abc. Feedback Control Systems. *9 units (3-0-6); first term; 12 units (3-3-6); second and third terms. Prerequisites: EE 101 ab, EE 107.* A study of automatic feedback control systems. Basic theory and methods of analysis and synthesis; root locus methods, the Nyquist criterion, and analog computer techniques. Multiple loop systems. Non-linear systems with emphasis on phase plane and describing function techniques. Sampled-data systems. The laboratory experiments are designed to acquaint the student with characteristics of practical components, but emphasis is placed on a correlation of observed response with predictions based on the various theoretical methods. Instructors: Mullin, Wilts.

EE 171 abc. Sampled-Data Systems. *6 units (2-0-4). Prerequisites: EE 170, AM 116.* A study of feedback systems which operate on pulsed-data. The analysis of sampled-data systems using the z-transform and the modified z-transform; root locus techniques and frequency response of sampled-data systems; difference equations applied to sampled-data systems. Compensation by discrete and continuous networks. The synthesis of optimum discrete systems using statistical techniques. Selected topics on nonlinear sampled-data systems. Text: *Sampled-Data Control Systems,* Jury. To be offered in alternate years. Instructor: Mullin.

EE 180. Digital Computer Design. *9 units (3-3-3); first term. Prerequisites: EE 1 a, AM 115 or Ma 108.* This course is concerned with the basic principles of logical design and instrumentation of digital computers. Modern switching theory including Boolean algebra and other forms of symbolic logic; pulse circuitry; magnetic drum, electrostatic, magnetic core and ferroelectric principles as applied to switching and data storage. The basic design philosophies of stored and externally programmed matrices will be given. The design and operating characteristics of a magnetic drum, serial-stored program binary computer will be treated in detail. Text: Course notes. Instructor: McCann.

EE 181 ab. Principles of Analog Computation. *12 units (3-3-6); second, third terms. Prerequisite: AM 180.* General survey of the basic principles of electric analog computing techniques. Development and application of electronic differential analyzer and direct analogy principles. Synthesis of passive analogies–lumped parameter systems. Synthesis of passive analogies–distributed systems. Synthesis of active circuit analogies. Applications to solid mechanics, aeroelasticity, heat transfer, fluid mechanics, servomechanisms. Text: Course notes. Instructor: McCann.

EE 190 abc. Advanced Electronics. *9 units (3-0-6); first, second, third terms.* An integrated treatment of the theory and application of vacuum and solid-state electron devices.

EE 190 a. Solid State Physics. Simple solutions of the wave equation; application to crystals. Insulators, semiconductors, and conductors. Basic equations of current flow, and application to various media. Principle of charge-controlled devices.

EE 190 b. Electronic Devices. Junctions between media, and application to vacuum and solid-state diodes. Detailed treatment of p-n junction. Ideal and real vacuum and semiconductor triodes; static characteristics and incremental models.

EE 190 c. Circuit Applications. Design of bias networks for required stability. Practical design of feedback amplifiers, power amplifiers, DC amplifiers and regulators, high-frequency amplifiers. Piecewise-linear and lumped-model representations of devices, and application to switching and waveshaping circuits. Instructor: Middlebrook.

EE 191 abc. Physics of Semiconductors and Semiconductor Devices. *9 units. (3-0-6); three terms.* Introduction to the concepts of semiconductor devices. Includes topics such as the solid state, electric properties of solids, Boltzmann and Fermi statistics, properties of regular arrays, mechanical and electrical filter, band theory of crystal electrons, holes, semiconductors, theory of p-n junctions and p-n junction transistors. Instructor: Nicolet.

EE 200. Advanced Work in Electrical Engineering. Special problems relating to electrical engineering will be arranged to meet the needs of students wishing to do advanced work. The Institute is equipped to an unusual degree for the following lines of work: electronic devices and their application, physical electronics, microwave tubes, transistor applications, electromechanical devices, control systems, communications and information theory, electromagnetic wave propagation and antennas, analog and digital computers, engineering analysis requiring large scale computing techniques.

EE 220. Research Seminar in Electrical Engineering. *2 units.* Meets once a week for discussion of work appearing in the literature and in industry. All advanced students in electrical engineering and members of the electrical engineering staff are expected to take part. In charge: Staff.

EE 240 abc. Advanced Communication Theory. *9 units (3-0-6). Prerequisite: EE 140 abc.* A continuation of EE 140 with a more detailed treatment of stochastic processes, random time series, information theory and optimum linear filters. Emphasis will be on recent developments in the field. Course content will vary. Typical subjects are: time varying systems and signals, finite time delay coding, two-way channels, matched filters, finite time and finite order filters. Instructor: H. Martel.

EE 250 abc. Advanced Electromagnetic Field Theory. *9 units (3-0-6); first, second, third terms. Prerequisite: EE 150 abc or equivalent.* This course covers the application of Maxwell's equations to problems involving antennas, waveguides, cavity resonators, and diffraction. It includes the solution of problems by the classical methods of retarded potentials and orthogonal expansions and lectures in the modern techniques of Schwinger that employ the calculus of variations and integral equations. Text: *Static and Dynamic Electricity*, Smythe; *Randwertprobleme der Mikrowellenphysik,* Borgnis and Papas. Instructors: Smythe, Papas.

EE 260 abc. Topics in Physical Electronics. *4 units (1-0-3); first, second, and third terms. Prerequisite: EE 164 abc.* Principles of electromagnetic interaction with solids and ionized gases and current applications. Content to vary from year to year. Typical topics are: microwave noise in electron beams, magnetic resonance and relaxation, cyclotron resonance, oscillations and waves in plasmas. Instructor: Gould.

EE 280 abc. Advanced Course in Machine Computing Methods for Engineering Analysis. *9 units (2-3-4); first, second, third terms.* The application of analog and digital methods to problems in engineering analysis. Specific system and design analysis problems in such fields as electricity and magnetism, solid mechanics, fluid mechanics, aeroelasticity and thermal conductivity will be solved by both analog and digital methods with the comparison of various machine computing techniques. Course open only to advanced graduate students and by permission of instructor. Instructors: Franklin, McCann, Wilts.

EE 281. Seminar in Electronic Computers. *4 units (1-0-3); first, second, third terms.* Special topics on new developments in digital and analog computers and their applications to engineering analysis. Instructors: McCann, Wilts.

EE 290. Topics in Solid State Devices and Circuits. *5 units (1-0-4); third term. Prerequisite: EE 190 ab.* Advanced seminar in solid state devices and circuits. A term paper will be required. Instructors: Middlebrook, Nicolet.

Engineering

E 10 ab. Technical Presentations. *2 units (1-0-1); first and second terms.* A course concerned with oral presentations of technical material. Instructors: Clark, Thomas.

E 11 ab. Technical Presentations. *2 units (1-0-1); first and second terms.* A course concerned with oral presentations of technical material coordinated with EE 7 ab. EE 7 ab must be taken concurrently with E 11 ab. Instructors: Staff, Thomas.

Engineering Graphics

Gr 1. Basic Graphics. *3 units (0-3-0); first term.* The study of geometrical forms and their representation by means of freehand orthographic and perspective drawings. Instruction includes the techniques of freehand pencil rendering, lettering forms, analysis of the elements of three-dimensional shapes and their proportional relationships, introduction to the principles of orthographic and perspective projection, principal views, visualization, shading techniques, sections and conventions. Problems are given involving the drawing of basic geometrical forms, machine parts and scientific apparatus as well as elementary space solutions of straight lines and planes. Emphasis is placed on a constructive approach, careful observation and accuracy. Instructors: Welch, Wilcox.

Gr 5. Descriptive Geometry. *6 units (0-6-0); third term. Prerequisite: Gr 1.* The course is primarily for geology students and is designed to supplement the study of shape description as given in Gr 1 and to present a graphical means of solving the more difficult three-dimensional problems. The student reviews geometrical relationships of straight lines and planes, then advances to curved lines, single and double curved surfaces, warped surfaces and intersections. Methods of combining the analytical solution of the simpler problems with the graphical solution are discussed and applied. Emphasis is placed throughout the course on practical problems in mining and earth structures and on the development of an ability to visualize in three dimensions. Instructors: Tyson, Wilcox.

Gr 7. Advanced Graphics. *Maximum of 6 units. Elective; any term. Prerequisites: Gr 1; Me 1.* Further study in the application of graphics to the solution of engineering problems and in the basic elements of design for production. Emphasis is placed on one of the following subjects to be selected as the need requires: analysis of the more complex machine mechanisms; basic elements of product design; solution of rector problems by graphical and algebraic techniques; graphical calculus; nomography. Instructors: Tyson, Welch.

English

UNDERGRADUATE SUBJECTS

En 1 abc. Composition and Literature. *6 units (3-0-3); first, second, third terms.* A study of literary documents illustrating Rationalism, Romanticism and the Modern Reaction with frequent analytical and critical papers assigned. Instructors: Bowerman, Clark, Eagleson, Langston, Mayhew, D. Smith, Stanton.

En 7 abc. Introduction to Literature. *8 units (3-0-5); first, second, third terms. Prerequisite: En 1 abc.* This course is designed to give the student a discriminating acquaintance with a selected group of principal literary works. The reading for the first term is concentrated on Shakespeare; for the second and third terms, on representative English authors. Instructors: Bowerman, Clark, Eagleson, Eaton, Jones, Langston, Mayhew, Miller, Piper, D. Smith, Stanton.

En 8. Contemporary English and European Literature.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A survey of English and Continental literature from 1859 to the present time. Emphasis is placed on the influence of science, particularly biological and psychological theory, on content and techniques. Instructor: Eagleson.

En 9. American Literature.* *9 units (3-0-6). Senior Elective. Prerequisite: En 7.* A study of major literary figures in the United States from Whitman and Mark Twain to those of the present time. The larger part of the course is concerned with contemporary writers. An emphasis is placed on national characteristics and trends as reflected in novel and short story, biography, poetry, and drama. Instructor: Piper.

En 10. Modern Drama.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A study of leading European, British, and American dramatists from Ibsen to writers of the present time. Special attention is given to dramatic technique, and to the plays both as types and as critical comments upon life in the late nineteenth and twentieth centuries. Instructor: Stanton.

En 11. Literature of the Bible.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A study of the Old and New Testaments, and the Apocrypha, exclusively from the point of view of literary interest. The history of the English Bible is reviewed, and attention is brought to new translations. Opportunity is offered for reading modern fiction, poetry, and drama dealing with Biblical subjects. Instructor: H. Smith.

En 12 abc. Debating. *4 units (2-0-2).* A study of the principles of argumentation; systematic practice in debating; preparation for intercollegiate debates. Instructor: Thomas.

*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

En 13. Reading in English and History. *Units to be determined for the individual by the department.* Collateral reading in literature and related subjects, done in connection with regular courses in English or history, or independently of any course, but under the direction of members of the department.

En 14. Special Composition. *2 units (1-0-1).* This subject may be prescribed for any student whose work in composition, general or technical is unsatisfactory.

En 15 abc. Journalism. *3 units (1-0-2); first, second, third terms.* A study of the elementary principles of newspaper writing and editing, with special attention to student publications at the Institute. Instructor: Hutchings.

En 16. Spelling. *No credit.* This subject may be prescribed for any student whose spelling is unsatisfactory.

En 17. Technical Report Writing.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* Practice in writing reports and articles in engineering, science, or business administration. The course ncludes some study of current techncal and scientific periodicals. The major project is the preparation of a full-length report. Instructor: Piper.

En 18. Modern Poetry.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A study of three or four major poets of the twentieth century, such as Yeats, T. S. Eliot and W. H. Auden. Modern attitudes toward the world and the problem of Belief. Some consideration of recent theories of poetry as knowledge. Instructor: Clark.

En 19. Seminar in Literature.* *9 units (3-0-6); second term. Senior elective. Prerequisite: En 7.* The subject matter of this course arises from the interest of the students registered in any given term. Each student is required to give a long oral report to the class on some humanistic subject selected by himself with the approval of the instructor. The number registered for the course in any term is strictly limited and is by permission of the instructor. Hours by arrangement. Instructor: Eagleson.

En 20. Summer Reading. *Units to be determined for the individual by the department. Maximum 8 units. Elective.* Reading in literature, history, philosophy, and other fields during summer vacation, books to be selected from a recommended reading list, or n consultation with a member of the staff. Critical essays on reading will be required.

En 21. Literature and Art in 18th Century England. *9 units (3-0-6). Senior elective. Prerequisite, En 7.* Studies in the literature of the eighteenth century in the context of English creative activity in other arts, particularly architecture and painting. Reading, discussion, lectures with slides, and visits to the Huntington Library and Art Gallery.

ADVANCED SUBJECTS

En 100 abc. Seminar in Literature. *9 units (2-0-7); first, second, third terms.* A survey of recent critical methods, from I. A. Richards to the present time, and the application of these methods to the work of such major writers as Joyce, Yeats, Eliot and Mann. The influence of modern psychology and anthropology on creative writing and criticism. Instructor: H. Smith.

*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

French

(See under Languages)

Geological Sciences

UNDERGRADUATE SUBJECTS

Ge 1. Physical Geology. *9 units (4-2-3); first term. Prerequisites: Ch 1 abc, Ph 1 abc.* An introduction to the basic principles of the earth sciences. Geology, geochemistry and geophysics in relation to materials and processes acting upon and within the earth's crust. Consideration is given to: rocks and minerals, structure and deformation of the earth's crust, earthquakes, volcanism, and the work of wind, running water, ground water, the oceans and glaciers upon the earth's surface with the aim of stimulating the student's interest in the geological aspects of the environment in which he will spend his life. Text: *Principles of Geology,* Gilluly, Waters, and Woodford. Instructors: Allen, Sharp, and Teaching Fellows.

Ge 2. Geophysics. *9 units (3-0-6); third term. Prerequisites: Ge 1, Ma 2 ab, Ph 2 ab.* A selection of topics in the field of geophysics using, as fully as possible, the prerequisite background. Included are consideration of the earth's gravity and magnetic fields, geodesy, seismology, and the deformation of solids, tides, thermal properties, radioactivity, age determinations, the continents, the oceans, and the atmosphere. Observations followed by their analysis in terms of physical principles. Not offered in 1960-61. Instructor: Dix.

Ge 3. Mineralogy. *9 units (3-3-3); second term. Prerequisites: Ge 1, Ch 1, Ph 1.* A study of the fundamental structure of minerals, rocks, and other earth materials and their behavior under the varying physical conditions of the earth's crust. Topics discussed include crystallography, stability relations of minerals, solid-state transformations, and mechanisms of material transfer with strong emphasis on the basic atomistic relations. This course is intended to provide fundamental information needed for subsequent studies in mineralogy, petrology, and structural geology. Instructor: Wasserburg.

Ge 5. Geobiology. *9 units (3-0-6); second term. Prerequisites: Ge 1, Ch 1, Bi 1.* An examination, chiefly in biological terms, of processes and environments governing the origin and differentiation of secondary materials in the crust throughout the span of earth history. Consideration is given to the environmental influence of the change from a reducing to an oxidizing atmosphere upon the evolution of life processes and to the subsequent progression of organisms and organic activity throughout the oxidizing era as recorded in the sedimentary rocks of the earth's crust. Special attention is devoted to organic progression and differentiation in time and space in terms of environment. Instructors: Lowenstam, Brown.

Ge 30. Introduction to Geochemistry. *10 units (3-0-7); third term. Prerequisites: Ch 14, Ch 24 ab, Ma 2 abc, Ph 2 abc, Ge 1.* A lecture and problem course to include topics in stable and radioactive isotopic geochemistry. Instructors: Brown, Epstein, Patterson.

ADVANCED SUBJECTS

Courses given in alternate years are so indicated. Courses in which the enrollment is less than five may, at the discretion of the instructor, not be offered.

Ge 100. Geology Club. *1 unit (1-0-0); all terms.* Presentation of papers on research in geological science by the students and staff of the Division of the Geological Sciences and by guest speakers. Generally required of all senior and graduate students in the Division; optional for sophomores and juniors. Instructor: Patterson.

Ge 102. Oral Presentation. *1 unit (1-0-0); first, second, or third term.* Training in the technique of oral presentation. Practice in the effective organization and delivery of reports before groups. Successful completion of this course is required of all candidates for the bachelor's, master's, and doctor's degrees in the Division. The number of terms taken will be determined by the proficiency shown in the first term's work. Instructors: Jones, Thomas.

Ge 104 a. Igneous Petrology. *8 units (3-3-2); first term. Prerequisite: Ge 3.* A study of the origin, occurrence, and classification of the igneous rocks, with training in the megascopic identification, description and interpretation of these rocks and their constituent minerals. Problems of genesis are considered mainly in the light of chemical equilibria and features of geologic occurrence. Instructor: Silver.

Ge 104 b. Sedimentary Petrology. *10 units (3-4-3); second term. Prerequisites: Ge 1, Ge 3.* A study of the origin, occurrence, and classification of the sedimentary rocks, training in the identification, description, and interpretation of these rocks, using megascopic methods and the binocular microscope; consideration of the chemical, physical, and biologic processes involved in the origin, transport, and deposition of sediments, and their subsequent diagenesis. Field trips supplement the laboratory study. Texts: *Sedimentary Rocks,* Pettijohn; *Principles of Geochemistry,* Mason. Instructor: Degens.

Ge 104 c. Metamorphic Petrology. *7 units (2-3-2); third term. Prerequisites: Ge 3, Ch 24 ab.* A study of the origin, occurrence, and classification of the principal metamorphic rocks, with training in the megascopic identification, description, and interpretation of these rocks. Emphasis is placed upon problems of genesis, which are viewed mainly in the light of chemical equilibria and features of geologic occurrence. Text: *Igneous and Metamorphic Petrology,* Turner and Verhoogen. Instructor: Taylor.

Ge 105. Optical Mineralogy. *12 units (2-8-2); first term. Prerequisite: Ge 3.* The principles of optical crystallography; training in the use of the petrographic microscope in identification of crystalline substances, especially natural minerals, both in thin section and as unmounted grains. Text: *Optical Crystallography,* Wahlstrom. Instructor: Helsley.

Ge 106 ab. Petrography. *9 units (2-6-1) second term; 9 units (2-4-3) third term. Prerequisites: Ge 105, Ch 24 ab.* A systematic study of rocks and rock-forming minerals; training in the use of the petrographic microscope in the study of rocks; intepretation of mineral assemblages and textures; problems of genesis. Text: *Optical Mineralogy,* Kerr. Instructor: Albee.

Ge 108. Mathematical Techniques for Geologists. *6 units (3-0-3); first term.* A review of some of the mathematical methods used in formulating and solving geologic problems. The purpose of this course is to give new graduate students a reasonable proficiency with those mathematical techniques which will be used in advanced courses in the earth sciences. Instructor: Wasserburg.

Ge 109. Structural Geology. *6 units (1-3-2); first term. Prerequisites: Ge 1, Ge 2, Ge 3.* A problem course in the interpretation and description of geologic structures. Includes use of descriptive geometry and stereographic projection in solution of geologic problems; mechanical properties of rocks; geologic scale models. Text: *Structural Geology,* Billings. Instructor: Allen.

Ge 111 ab. Invertebrate Paleontology. *10 units (2-6-2); second, third terms. Prerequisite: Ge 1.* Morphology and geologic history of the common groups of the lower invertebrates, with emphasis on their evolution and adaptive modifications. Second term: consideration of the higher invertebrates groups; preparation of fossils and problems of invertebrate paleontology. Instructor: Lowenstam.

Ge 120 abc. Field Geology. *10 units (4-5-1), first term; 10 units (0-8-2), second term; 10 units (0-6-4), third term. Prerequisites: Ge 1, Ge 3.* An introduction of the interpretation of geologic features in the field, and to the fundamental principles and techniques of geologic mapping. Classroom and field studies include the interpretation of geologic maps, megascopic investigation of rock types, the solution of field problems in structure and stratigraphy, geologic computations, and an introduction to the use of aerial photographs for field mapping. To these ends, small areas are mapped in great detail and reports are prepared in professional form. Text: *Field Geology,* Lahee. Instructors: Helsley (120 a); Taylor (120 b); Allen (120 c).

Ge 121 abc. Advanced Field Geology. *14 units (4-8-2), first term; 10 units (0-8-2), second term; 11 units (0-5-6), third term. Prerequisites: Ge 3, Ge 120 abc.* Interpretation of geologic features in the field, with emphasis on problems of the type encountered in professional geologic work. Advanced techniques of investigation are discussed. The student investigates limited but complex field problems in igneous, sedimentary, and metamorphic terranes. Individual initiative is developed, principles of research are acquired, and practice gained in field techniques, including the use of the plane table in geologic mapping. The student prepares reports interpreting the results of his investigations. Instructors: Jahns, Kamb (121 a); Silver (121 b); Taylor (121 c).

Ge 123. Summer Field Geology. *30 units. Prerequisites: Ge 4 abc, Ge 120 abc.* Intensive field study of a 10-15 square mile area from a centrally located, temporary camp. Emphasis is placed on stratigraphic and structural interpretation, and on detailed mapping techniques, including the use of aerial photographs. Each student prepares a geologic map, stratigraphic and structural sections, and a complete geologic report. The work is performed under close supervision of regular staff members. The area chosen generally lies in a part of the Rocky Mountains, or the Basin and Range Province. The course is designed to complement the field training in southern California afforded by the regular school year courses, Ge 20 and Ge 121. The course begins the Monday following commencement (about June 12) and lasts for six weeks. It is required at the end of the junior year of candidates for the bachelor's degree in the geology and geochemistry options; of candidates for the Master of Science degree; and, at the discretion of the staff, of candidates for other advanced degrees in the Division of Geological Sciences. Registration is limited to students regularly enrolled in the California Institute of Technology or to those entering the following term. Text: *Suggestions to Authors,* Wood and Lane. Instructors: Taylor and Lowenstam.

GE 126. Geomorphology. *10 units (4-0-6); second term. Prerequisite: Ge 9.* Primarily a consideration of dynamic processes acting on the surface of the earth, and the genesis of landforms. Offered in 1961-62. Instructor: Sharp.

Ge 130. Introduction to Geochemistry. *6 units (3-0-3); third term.* This subject is the same as Ge 30 but with reduced credit for graduate students.

Ge 150 abcdef. The Nature and Evolution of the Earth. *6 units (3-0-3). Ge 150 cd offered in 1958-59; Ge 150 ef offered in 1959-60, first and second terms.* Discussions at an advanced level of problems of current interest in the earth sciences. The course is designed to give graduate students in the geological sciences and scientists from other fields a broad sampling of data and thought concerning current problems. The lectures are given by members of the staff of the Division of the Geological Sciences. Staff members from other divisions and visiting lecturers from the outside also participate in the instruction. Students may enroll for any or all terms of this course without regard to sequence. Instructors: Brown (in charge), and other members of the staff.

Ge 150 e. Submarine Geology. To be announced.

Ge. 151. Laboratory Techniques in the Earth Sciences. *5 units (0-5-0); second term.* Introductory training in the use of tools and techniques used in earth sciences research. Experiments of geological interest are done using the emission spectrograph, spectrophotometer, x-ray spectrometer, alpha and beta counters, mass spectrometers, wet chemical techniques and other available tools and techniques. The course carries a minimum of 5 units but additional units may be elected. In charge: Epstein.

Ge 165. General Geophysics. *6 units (3-0-3); third term.* A survey course in the physics of the earth. Among topics included are Seismology, Gravity, Terrestrial Magnetism, Thermal History of the Earth and Submarine Geophysics. Suitable for students in geology and as an elective in physics and engineering. Instructor: Press.

Ge 171. Applied Geophysics I. *10 units (4-2-4); second term.* The use of gravity, magnetic and seismic methods applied to geological field problems. Theoretical background and field practice. Instructor: Dix.

Ge 172 ab. Applied Geophysics II. *5 units (2-0-3), first term; 6 units (2-1-3), second term.* Magnetic and electric methods applied to geological problems. Content of course is altered somewhat from year to year depending mainly upon student needs. *Not offered 1960-61.* Instructor: Potapenko.

Ge 174. Well Logging. *5 units (3-0-2); second term.* Physical principles of various methods of well logging and their applications. Electrical, radioactive, chemical, fluoroscopic and mechanical methods will be studied. Offered in 1960-61. Instructor: Potapenko.

Ge 175. Introduction to Applied Geophysics. *6 units (3-0-3); third term.* A survey of pure and applied geophysics designed mainly for geological, engineering, and other students who do not expect to enroll in specialized subjects in this field. Text: *Introduction to Geophysical Prospecting,* Dobrin. Instructor: Potapenko.

Ge 176. Elementary Seismology. *6 units (3-0-3); third term. Prerequisites: Ge 1, Ma 2 ab.* A survey of the geology and physics of earthquakes. Not offered in 1959-60. Text: *Elementary Seismology,* Richter. Instructor: Richter.

Geology

Ge 209. Sedimentary Petrology. *10 units (2-4-4); third term. Prerequisite: Ge 105.* A study of the processes and products of sedimentation in relation to their geologic environment. Emphasis is given to major lithologic facies and their interpretation. The laboratory work affords an introduction to techniques of sedimentary analysis. Occasional field trips. Instructor: Degens.

Ge 211 abc. Topics in Advanced Petrology. *15 units each term (4-4-7).* Integrated lecture, laboratory and seminar treatments of topics in igneous and metamorphic petrology and the mechanics of rock deformation at an advanced level. Laboratory and field studies will be pursued in close association with the classwork. Consideration of petrologic problems in terms of basic principles and modern investigative approaches will be emphasized.

211 a. Problems in igneous petrology: the origin, nature, distribution, and behavior of magmas and analogous chemical systems. Critical comparison of theoretical predictions and natural systems. *Prerequisites: Ge 106 ab, Ch 124 ab.* Instructor: Wasserburg.

211 b. Topics in metamorphic petrology, including the facies principle and the thermodynamic equilibrium of metamorphic mineral assemblages. These problems are attacked using the tools of thermodynamics, chemical kinetics and isotope geology, and are evaluated in terms of field evidence. *Prerequisites: Ge 211 a.* Instructors: Silver, Epstein.

211 c. Mechanics of rock deformation: Tensors; analysis of stress and strain; deformation of single crystals and polycrystals; plasticity; fracture patterns; recrystallization; petrofabrics; thermodynamic theory of non-hydrostatic stress. *Prerequisites: GE 211 b, or Ph 108 abc.* Instructors: Kamb and Allen.

Ge 213. Mineralogy-Petrology (Seminar). *5 units; first term. Prerequisite: Ge 211 ab.* Discussion of special problems and current literature related to the general provinces of mineralogy and petrology. Topics in such broad fields as crystal structure, mechanics of crystallization, geochemistry, techniques of mineral identification, and the origin of rocks and mineral deposits are selected for critical attention during the term, largely on the basis of trends of interests among members of the group. Instructor: Wasserburg.

Ge 229. Glacial Geology. *10 units (3-0-7); second term. Prerequisite: Ge 126.* Origin of glaciers, existing glaciers, glaciology and glacial mechanics, erosional and depositional features of mountain and continental glaciers, chronology of the Pleistocene. Text: *Glacial and Pleistocene Geology,* Flint. Offered in 1960-61. Instructor: Sharp.

Ge 230. Geomorphology (Seminar). *5 units; second term.* Discussion of research and current literature in geomorphology. In charge: Sharp.

Ge 237. Tectonics. *8 units (3-0-5); third term. Prerequisites: Ge 9 or equivalent.* Advanced structural and tectonic geology. Structure of some of the great mountain ranges; theories of origin of mountains, mechanics of crustal deformation; isostasy, continental drift. Instructor: Allen.

Paleontology

Ge 244. Invertebrate Paleontology and Paleoecology (Seminar). *5 units; first term.* Critical review of classic and current literature in paleoecology, biogeochemistry and invertebrate paleontology. Study of paleontologic principles and methods.

Geophysics

Ge 261. Advanced Seismology: Theoretical. *6 units (3-0-3); first term. Prerequisite: Ph 108 abc.* Discusses essential material not covered in Ge 264 (Elastic Waves), including equations of electromagnetic seismographs and paths of seismic rays within the earth. Instructor: Richter.

Ge 264 ab. Elastic Waves. *8 units (4-0-4); first and second terms. Prerequisites: Ph 106 abc.* Experimental and theoretical aspects of elastic wave propagation in a layered half space, in plates, cylinders, and spheres, with application to seismic waves and underwater acoustics. Not offered in 1960-61. Instructor: Press.

Ge 268 ab. Selected Topics in Theoretical Geophysics. *6 units (3-0-3); second and third terms. Prerequisite: Ph 129 abc or equivalent.* Discussion of seismic wave propagation, gravitational and magnetic fields, stress systems, and general thermodynamics as applied to earth processes. Content of course is altered somewhat from year to year depending mainly upon student needs. Instructor: Dix.

Ge 282 abc. Geophysics-Geochemistry (Seminar). *1 unit; first, second, third terms. Prerequisite: At least two subjects in geophysics or geochemistry.* Discussion of papers in geochemistry, general and applied geophysics. In charge: Epstein, Press.

General

Ge 295. Master's Thesis Research. *Units to be assigned. Listed as to field according to the letter system under Ge 299.*

Ge 297. Advanced Study. Students may register for 8 units or less of advanced study in fields listed under Ge 299. Occasional conferences; final examination.

Ge 299. Research. Original investigation, designed to give training in methods of research, to serve as theses for higher degrees, and to yield contribution to scientific knowledge. These may be carried on in the following fields.

(E) engineering geology,

(F) petroleum geology,

(G) ground water geology,

(H) metalliferous geology,

(I) nonmetalliferous geology,

(J) geochemistry,

(M) mineralogy,

(N) areal geology,
(O) stratigraphic geology,
(P) structural geology,
(Q) geomorphology,
(R) petrology,
(S) vertebrate paleontology,
(T) invertebrate paleontology,
(U) seismology,
(W) general geophysics,
(X) applied geophysics,
(Y) geophysical instruments,
(Z) glacial geology.

German

(See under Languages)

History and Government

UNDERGRADUATE SUBJECTS

H 1 abc. History of European Civilization. *5 units (2-0-3); first, second, third terms.* An introduction to the history of Europe from 1648 to the present. The course will include discussions of political, social, and economic problems, and of the more important theoretical concepts of the period. Instructors: Ellersieck, Elliott, Fay, Huttenback.

H 2 abc. History and Government of the United States. *6 units (2-0-4); first, second, third terms.* The United States since the Revolution. Particular attention will be given to the great questions of domestic and foreign policy which the United States has faced in recent times. The course will include a study of the Constitution and form of government of the United States and the State of California, and will trace the evolution of national and local political institutions and ideas. Instructors: J. Davies, Paul, Piper, Strout.

H 4. The British Empire and the Commonwealth.* *9 units (3-0-6). Senior elective.* The growth of the imperial idea and the institutional development of the Empire and the Commonwealth with particular reference to Africa and Asia. Instructor: Huttenback.

H 5 abc. Public Affairs. *2 units (1-0-1); first, second, third terms.* In this course a selection of important contemporary problems connected with American political and constitutional development, economic policies, and foreign affairs will be considered. Instructors: Elliot, Sweezy; occasional lectures by other members of the department.

H 7. Modern and Contemporary Germany.* *9 units (3-0-6). Senior elective.* A study of what is sometimes called "The German Problem." Attention will be focused on

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

the rise of Prussia, on Prussian leadership in the unification and direction of Germany, and on the place of Germany in the economy of Europe. Particular stress will be placed upon the German experience since the first World War.

H 8. Modern and Contemporary Russia.* *9 units (3-0-6). Senior elective.* An attempt to discover and interpret the major recurring characteristics of Russian history and society, with attention particularly to developments in the Soviet period. Instructor: Ellersieck.

H 15. Europe Since 1914.* *9 units (3-0-6). Senior elective.* Since 1914 the world has felt the impact of two great wars and powerful revolutionary ideas. This course will analyze these upheavals of the twentieth century and their effect on domestic and international organization. Instructor: Fay.

H 16. American Foreign Relations.* *9 units (3-0-6). Senior elective.* How American foreign policy has been formed and administered in recent times: the respective roles of the State Department, Congress, and the President, of public opinion and pressure groups, of national needs and local politics. Instructor: Paul.

H 17. The Far West and the Great Plains.* *9 units (3-0-6) Senior elective.* A study of the development of the great regions that compose the western half of the United States. Especial attention will be paid to the influence of the natural environment on the men who settled the West, from pioneer days to the present time, and the exploitation of natural resources, through such industries as mining, ranching, oil, and farming. Instructor: Paul.

H 19. Modern America.* *9 units (3-0-6). Senior elective.* An experimental course in which the main theme will be the conflict between government regulation and private enterprise in Twentieth-Century America. Classes will be conducted as discussions under the joint leadership of an historian and an economist. Instructors: Paul, Sweezy.

H 20. Modern and Contemporary France.* *9 units (3-0-6). Senior elective.* A study of modern France in the light of her revolutionary tradition. A consideration of the French Revolution followed by an examination of selected episodes between 1815 and 1944 (the June Days, the Paris Commune, the Dreyfus affair, the Stavisky riots, the Vichy regime) which reflect continuing revolutionary strain. Instructor: Fay.

H 21. Medieval England.* *9 units (3-0-6).* Feudalism as a political system, and its part in the early development of parliamentary democracy, approached principally through the study of selected political episodes in English history, 1066-1485. Instructor: Fay.

H 22. Modern Britain.* *9 units (3-0-6). Senior elective.* A study of Britain's recent past with particular emphasis upon the development of the working class movement. Instructor: Elliot.

H 23. Modern War.* *9 units (3-0-6). Senior elective.* The course will trace the major developments within the military establishment, such as the growth of the general staff and mass armies. It will discuss the major strategic concepts of the nineteenth and twentieth centuries and the problems of modern war, with some consideration of the political, economic, and social aspects of waging war. Instructor: Ellersieck.

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

H 24. The Dynamics of Political Behavior.* *9 units (3-0-6). Senior elective.* An examination of general behavior patterns and tendencies of individuals as related to their political behavior and to appropriate types of political institutions. Relevant psychological and sociological theory and research will be discussed in an effort to find the kinds of government suitable to people living in modern technological and industrial society. Instructor: J. Davies.

H 25. Political Parties and Pressure Groups.* *9 units (3-0-6). Senior elective.* A study of those institutions through which individuals and groups seek to control governmental policy and administration. Particular attention will be focused on parties as formulators of individuals' political wants, fears, and expectations and as transmitters of these programs to government. Instructor: J. Davies.

H 26. The Political Novel.* *9 units (3-0-6). Senior elective.* A political and literary appraisal of modern novels that attempt to explain and to judge relationships between the individual and the state in both free and totalitarian societies. The class will meet under the joint supervision of a professor of English and a political scientist. Instructors: J. Davies, Stanton.

H 28. American Political Idea.* *9 units (3-0-6).* Historical and analytical examination of liberal, conservative and radical thought with an emphasis on reading in original sources. Instructor: Strout.

H 29. American Philosophical Ideas.* *9 units (3-0-6).* Historical and analytical examination of major patterns of religious, philosophical and historical thought with an emphasis on reading in original sources. Instructor: Strout.

H 35. Modern India and Pakistan.* *9 units (3-0-6).* The course will deal with the growth of Indian nationalism in the years before independence, and developments in India and Pakistan since partition. Special emphasis will be placed on the philosophical conflict between British and indigenous Indian attitudes and the consequent effect on contemporary India and Pakistan. Instructor: Huttenback.

H 40. Reading in History. *Units to be determined for the individual by the department. Elective, in any term. Approval of the Registration Committee is required where excess units are involved.* Reading in history and related subjects, done either in connection with the regular courses or independently of any course, but under the direction of members of the department. A brief written report will usually be required.

H 41. Summer Reading. *Units to be determined for the individual by the department. Maximum, 8 units. Elective.* Reading in history and related subjects during summer vacation. Topics and books to be selected in consultation with members of the department. A brief written report will usually be required.

ADVANCED SUBJECTS

H 100 abc. Seminar in History and Government. *9 units (2-0-7).* Studies in American culture, civilization and character. Reading and analysis of classic contemporary commentaries (historical, sociological and literary) on American society, culture and character. Instructor: Strout.

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

H 123. The Growth of Industrial Civilzation.* *9 units (3-0-6). Senior elective.* An analysis and study of some of the major factors affecting the past, present and future development of industrial civilization with emphasis on projections into the next century. Among the factors to be considered are population changes, material, food and energy resources and technical manpower. Lectures and discussions will be given by staff members from various Institute divisions. Instructors in charge: Weir, Bonner, Brown.

H 124. Seminar in Foreign Area Problems.* *9 units (3-0-6); second term. Senior elective.* The object of this course is to give students an opportunity to study in some detail problems current in certain selected foreign areas. Three or four areas will be considered each time the course is given, and the selection will normally vary from year to year. Instruction will be given mainly by area specialists of the American Universities Field Staff. Instructors: Elliot and members of AUFS.

H 125. Select Topics in International Law and Organization. *9 units (3-0-6).* The course will examine some of the problems created by the developing relationships between independent national states, and will consider efforts that have been and are being made to regulate these relationships. Illustrative material—mostly contemporary —will be drawn from the operation of international organizations and from the functioning of international law. Instructor: Elliot.

H 140. Reading and Research in History and Government. *Units to be determined for the individual by the department.*

HYDRAULICS

UNDERGRADUATE SUBJECTS

Hy 11. Fluid Mechanics Laboratory. *6 units (0-6-0); second term. Prerequisites: ME 15 ab or Hy 2 ab.* A laboratory course designed to give the student experience in making engineering measurements, observing and analyzing basic flow phenomena, and preparing engineering reports. Instructor: Vanoni.

ADVANCED SUBJECTS

Hy 100. Hydraulics Problems. *Units to be based upon work done, any term.* Special problems or courses arranged to meet the needs of fifth-year students or qualified undergraduate students.

Hy 101 abc. Fluid Mechanics. *9 units (3-0-6); first, second, third terms. Prerequisites: Hy 1 or Hy 2 ab and Hy 11 or equivalent.* Continuity, momentum, and energy equations for viscous, compressible fluids; circulation and the production of vorticity; potential flow and applications to flow around bodies; gravity waves; laminar flow; laminar boundary layers; turbulence and turbulent shear flow; transport of sediment; introduction to fluid mechanics of turbomachines. Instructor: Marble.

Hy 103 a. Advanced Hydraulics. *9 units (3-0-6); first term. Prerequisite: Hy 2 ab.* Ideal fluid flow, turbulence and diffusion, boundary layer, dimensional analysis, theory and use of hydraulic models, resistance of flow, steady flow in open channels, hydraulic jump, backwater curves and flood routing. Instructor: Vanoni.

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

Hy 103 b. Hydraulic Structures. *9 units (3-0-6); second term. Prerequisite: Hy 103 a.* High velocity flow in open channels, sediment transportation, theory and design of hydraulic structures, surface waves and coastal engineering. Instructor: Vanoni.

Hy 104. Advanced Hydraulics Laboratory. *6 or more units as arranged; any term. Prerequisite: Consent of instructor.* A laboratory course primarily for fifth-year students dealing with flow in open channels, sedimentation, waves, hydraulic structures, hydraulic machinery, or other phases of hydraulics of special interest. Students may perform one comprehensive experiment or several shorter ones, depending on their needs and interests. Instructor: Staff.

Hy 134. Flow in Porous Media. *9 units (3-0-6); third term. Prerequisites: AM 15 abc or AM 115 ab or equivalent. AM 116 is also recommended. (AM 15 c or AM 115 b may be taken concurrently).* A study of the hydrodynamics of flow through porous media, with applications primarily in the field of ground water flow, including seepage through earth dams and levees, uplift pressures on dams and foundations, flow toward wells, ground water recharge, drainage, and dewatering for excavations. Emphasis is placed on flow-net analysis and mathematical methods. Instructor: Brooks.

Hy 200. Advanced Work in Hydrodynamics or Hydraulic Engineering. *Units to be based upon work done; any term.* Special courses on problems to meet the needs of students beyond the fifth year.

Hy 201 abc. Hydraulic Machinery. *6 units (2-0-4); first, second, third terms. No prerequisite.* A study of such rotating machinery as turbines, pumps, and blowers and their design to meet specific operating conditions. This course will be given in seminar form led by members of the Hydrodynamics and Mechanical Engineering staffs. Not given every year. Check with your instructor.

Hy 203. Cavitation Phenomena. *6 units (2-0-4). Prerequisite: Graduate standing.* Study of the experimental and analytical aspects of cavitation and allied phenomena. Problems will be considered in the field of hydraulic machinery and also for bodies moving in a stationary fluid. Instructor: Ellis.

Hy 210 ab. Hydrodynamics of Sediment Transportation. *9 units (3-0-6). Prerequisite: AM 115 ab, Hy 103 a.* A study of the mechanics of the entrainment, transportation, and deposition of solid particles by flowing fluids. This will include problems of water and wind erosion, and density currents. Instructor: Vanoni.

Hy 211. Advanced Hydraulics Seminar. *4 units (2-0-2); every term.* A seminar course for advanced graduate students to discuss and review the recent technical literature in hydraulics and fluid mechanics. Emphasis will be on topics related to civil engineering which are not already available in courses offered by the Engineering Division. The subject matter will be variable depending upon the needs and interests of the students. It may be taken any number of times with permission of the instructor. Instructor: Brooks.

Hy 300. Thesis.

Jet Propulsion

Advanced Subjects

JP 121 abc. Rocket. *9 units (3-0-6); each term. Prerequisites: AM 115 ab, ME 17 ab or ME 19 ab.* Study of flow through rocket nozzle; over- and under-expanded nozzles. Combustion chamber and grain proportions for solid propellant rocket motors; properties and burning characteristics of solid propellants. Combustion and combustion instability in solid propellant rockets. Combustion chamber, propellant supply, and injection system for mono- and bipropellant rocket motors. Turbopump power-plants for liquid rocket propellant supply. Low and high frequency instability in liquid rocket motors. Problems of heat transfer and cooling in rocket motor injectors, combustion chambers, and nozzles. Exterior ballistics and performance analysis of rocket-propelled vehicles. Instructor: Rannie.

JP 130 abc. Thermal Jets. *6 units (2-0-4); first, second and third terms. Prerequisites: AM 115 ab, AM 116, ME 17 ab.* Cycle analysis of ramjet engines. Detailed study of ramjet diffuser performance and stability, combustion and flame stabilization problems, nozzle flow with and without chemical reaction, off-design performance, and starting problems. Performance cycle analysis of turbojet, turbopropeller, and ducted fan or by-pass engines. Operating principles, design, and performance of compressor, turbine, and combustion chamber and afterburner components. Component matching, engine-diffuser matching, and calculation of complete engine performance; study of turbine cooling, liquid injection, regenerative systems, and other modifications to basic cycles. Performance analysis of thermal jet propelled aircraft and vehicles. Instructor: Zukoski.

JP 170. Jet Propulsion Laboratory. *9 units (0-9-0); third term.* Laboratory experiments related to jet propulsion problems.

JP 200 abc. Chemistry Problems in Jet Propulsion. *9 units (3-0-6); each term. Prerequisite: Graduate standing.* Descriptive discussions on atomic and molecular structure. Chemistry of propellants. Thermodynamics of combustion. Quantitative evaluation of rocket propellants. Combustion of liquid and solid propellants. Principles of ignition. Phenomenological chemical kinetics. Chemical reactions during nozzle flow. Diffusion flames, detonation, flame propagation, mechanism of burning of solid propellants, heterogeneous combustion. Scaling of combustion devices. Text: *Chemistry Problems in Jet Propulsion.* Instructor: Penner.

JP 201 abc. Physical Mechanics. *6 units (3-0-6); two terms. Prerequisite: JP 200 or equivalent.* Relation between molecular parameters and observable physical properties. Use of quantum mechanics and statistical methods for the calculation of thermodynamic functions, transport properties, equations of state, and chemical reaction rates. Ionized gases. Offered in 1961-62. Instructors, Penner, Marble, Jahn.

JP 202 abc. Gas Emissivities. *3 units (3-0-6); one term. Prerequisite: JP 201 abc or a course in quantum mechanics.* Blackbody radiation laws, Einstein coefficients, integrated intensities and f-numbers. Spectral line widths and shapes; the curves of growth. Infrared gas emissivities and absorptivities for combustion products. Equilibrium radiation from heated air. Radiant heat transfer to hypersonic vehicles during reentry of the atmosphere. Flame temperatures. Influence of radiation on the burning of liquid and solid propellants. Emission of radiation behind shock fronts. Offered in 1960-61. Text: *Quantitative Molecular Spectroscopy and Gas Emissivities.* Instructor: Penner.

JP 210. High Temperature Design Problems. *6 units (2-0-4); third term. Prerequisites: PM 5, and Ae 107 a or AM 110 a.* Temperature distribution and thermal stress under non-uniform and unsteady conditions. Applications to thermal shock analysis and high temperature designs. General survey of the physical and the mechanical properties of metals, ceramels, and ceramics with reference to high temperature applications. Not given every year.

JP 220 abc. Theory of Stability and Control. *6 units (2-0-4); each term. Prerequisite: AM 125 or AM 126.* Stability and control of systems with constant coefficients, principles of feed-back servomechanisms, automatic control of propulsion systems. Stability and control of system with time lag, Satche diagram. Stability of systems with time varying coeffiicients. Ballstic disturbance theory, applications to the problem of control and guidance of ballistic vehicles. Control design by specified criteria. Reliability and control of error. Not given every year.

JP 230 abc. Space Propulsion and Power Generation. *6 units (2-0-4); each term. Prerequisites: JP 121 abc, JP 200 abc, or equivalent.* Analysis of orbits and trajectories within the solar system. Propulsion and power plant requirements to accomplish those missions. Performance of low-thrust propulsion systems, the ion rocket, plasma accelerators of both study and pulsed types, analysis of factors that limit their performance. The nuclear rocket of both heat transfer and gaseous fission types, criticality, weight estimates and shielding requirements. Turbogenerator systems utilizing solar and nuclear power sources, radioisotope power supply, the silicon solar cell and the plasma diode as primary power sources. Some previous knowledge of Electromagnetic Theory and Modern Physics is advisable. Instructors: Marble, Kerrebrock.

JP 270. Special Topics in Jet Propulsion. *6 units (2-0-4).* The topics covered will vary from year to year. Critical and systematic review of current literature in various fields connected with jet propulsion. Instructors: Staff Members.

JP 280 abc. Research in Jet Propulsion. *Units to be arranged.* Theoretical and experimental investigations in jet propulsion power plants and their applications. Instructors: Staff Members.

JP 290 abc. Advanced Seminar in Jet Propulsion. *2 units (1-0-1); each term.* Seminar on current research problems in jet propulsion. Instructors: Staff Members.

Languages

UNDERGRADUATE SUBJECTS

L 1 ab. Elementary French. *10 units (4-0-6); second, third terms.* A subject in grammar, pronunciation, and reading that will provide the student with a vocabulary and with a knowledge of grammatical structure sufficient to enable him to read at sight French scientific prose of average difficulty. Accuracy and facility will be insisted upon in the final tests of proficiency in this subject. Students who have had French in the secondary school should not register for this subject without consulting the department of languages. Instructor: Stern.

L 5. French Literature.* *9 units (3-0-6); second term. Senior elective. Prerequisite: L 1 ab, or the equivalent.* The reading of selected classical and modern literature, accompanied by lectures on the development of French literature. Elective and offered when there is sufficient demand. Instructors: Bowerman, Stern.

L 32 abc. Elementary German. *10 units (3-1-6); first, second, third terms.* This subject is presented in the same manner as the Elementary French. Students who have had German in the secondary school or junior college should not register for this subject without consulting the department of languages. One session in the language laboratory will be scheduled each week. Instructors: Bowerman, Stern, Wayne.

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

L 35. Scientific German. *10 units (4-0-6); first term. Prerequisite: L 32 abc, or equivalent.* This is a continuation of L 32 abc, with special emphasis on the translation of scientific material in the student's field. Instructor: Bowerman.

L 39 abc. Reading in French or German. *Units to be determined for the individual by the department.* Reading in scientific or literary French or German under the direction of the department.

L 40. German Literature.* *9 units (3-0-6); third term. Senior elective. Prerequisite: L 35, or L 32 abc with above average grades.* The reading of selected classical and modern literature, accompanied by lectures on the development of German literature. Instructor: Stern.

L 50 abc. Elementary Russian. *10 units (4-0-6); first, second, third terms.* A subject in pronunciation, grammar, and reading that is intended to enable a beginner to read technical prose in his field of study. Students are expected to become familiar with a basic scientific vocabulary. Articles from current Russian scientific periodicals are used in the second and third terms. Instructor: Kosloff, Kishkovsky.

L 51 abc. Intermediate Russian. *10 units (4-0-6); first, second, third terms. Prerequisite: L 50 abc or the equivalent.* A continued study of the Russian language with increased emphasis on conversation. The reading of selected classical and modern literature. Discussions in Russian. Continuation of reading and translation of scientific material. Instructor: Kosloff.

ADVANCED SUBJECTS

L 105. Same as L 5. For graduate students.

L 140. Same as L 40. For graduate students.

MATHEMATICS

UNDERGRADUATE SUBJECTS

Ma 1 abc. Freshman Mathematics. *12 units (4-0-8); first, second, third terms. Prerequisites: High school algebra and trigonometry.* An introduction to the calculus; vector algebra; analytic geometry and infinite series. Professors in charge: Fuller, Hall.

Ma 2 abc. Sophomore Mathematics. *12 units (4-0-8); first, second, third terms.* A continuation of the freshman mathematics course including: an extension of the calculus to functions of several variables; introduction to probability; vector analysis; differential equations. Professor in charge: Apostol.

Ma 5 abc. Introduction to Abstract Algebra. *9 units (3-0-6); three terms.* Groups, rings, fields, and vector spaces are presented as axiomatic systems. Their subsystems, factor systems and direct products are studied. The algebraic techniques of decomposition and extension are presented. A large portion of the course is devoted to linear algebra and matrix theory with applications to geometry. Included are determinants, characteristic roots, Hermitian matrices and canonical forms. Instructors: Block Dean, J. Todd, Ward.

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

Ma 31. Introduction to the Constructive Theory of Functions. *9 units (3-0-6); first term. Prerequisites: Ma 1 abc.* Polynomial approximation. The Weierstrass theorem and the Bernstein polynomials. Extremal properties of the Chebyshev polynomials. Markoff's theorems. Classical orthogonal polynomials. Applications to interpolation and approximation integration. Not offered in 1960-61.

Ma 91. Special Course. *9 units (3-0-6); third term.* Each year, during the third term, a course will be given in one of the following topics:

(a) Some field of number theory. Given in 1959-60.
(b) Some field of algebra or logic. (Given in 1953-54).
(c) Combinatorial Topology. (Given in 1958-59).
(d) Game Theory. (Given in 1955-56).
(e) Theory of Probability. (Given in 1956-57).

Ma 92 abc. Senior Thesis. *9 units (0-0-9); three terms. Prerequisite: Approval of adviser.* Open only to seniors who are qualified to pursue independent reading and research. The work must begin in the first term and will be supervised by a member of the staff. Students will consult periodically with their supervisor, and will submit a thesis at the end of the year.

Ma 98. Reading. *3 units or more by arrangement.* Occasionally a reading course under the supervision of an instructor will be offered. Topics, hours, and units by arrangement. Only qualified students will be admitted after consultation with the instructor in charge of the course.

ADVANCED SUBJECTS

[A] The following courses are open to undergraduate and graduate students:

Ma 102. Differential Geometry. *9 units (3-0-6); third term.* Selected topics in metrical differential geometry. Given in 1960-61 and alternate years. Instructor: F. Bohnenblust.

Ma 104. Projective and Algebraic Geometry. *9 units (3-0-6); first term.* Homogeneous coordinates, projective group. Duality principle. Singular points of curves. Birational transformations. Given in 1961-62 and alternate years.

Ma 105 ab. Introduction to Numerical Analysis. *11 units (3-2-6); second and third terms. Prerequisites: Ma 108 or AM 15 or equivalent, Ma 5, Ma 31 or AM 180 or equivalent, and familiarity with coding procedures by the middle of the first quarter of the course.* The topics considered include: Interpolation and quadrature. Numerical solution of algebraic and transcendental equations. Matrix inversion and determination of eigenvalues. Numerical solution of ordinary differential equations. Numerical solution of elliptic, parabolic, and hyperbolic partial differential equations. Instructor: J. N. Franklin.

Ma 108 abc. Advanced Calculus. *12 units (4-0-8); three terms. Prerequisite: Ma 2.* In this course, a sequel to Ma 2, more advanced techniques and applications of calculus are treated. Point set topology is the point of departure for the theory of convergence, and applications are made to implicit functions, partial differentiation, infinite series and infinite products of real and complex numbers. Other topics treated include: uniform convergence of sequences of functions; functions defined by integrals; Fourier series and integrals; analytic functions of a complex variable. Instructors: Erdélyi. Luxemburg, Ryan, Wright.

Ma 109. Operational Calculus. *9 units (3-0-6); second term.* Introduction to operational calculus and to delta functions. Applications to ordinary and partial differential equations. Given in 1961-62 and alternate years.

Ma 112. Elementary Statistics. *9 units (3-0-6); first and repeated in second terms. Prerequisites: Ma 1, Ma 2.* This course is intended for anyone interested in the application of statistics to science and engineering. The topics treated will include the preparation and systematization of experimental data, the fundamental statistical concepts; population, sample, mean and dispersion, curve fitting and least squares, significance tests and problems of statistical estimation. Instructor: Dilworth.

Ma 116 ab. Mathematical Logic and Axiomatic Set Theory. *9 units (3-0-6); first and second terms. Prerequisites: Ma 5 abc or equivalent.* The predicate calculus and functional calculi of first order are presented and problems in the foundations of mathematics are studied. Included are Boolean algebra, theorems of Gödel, axiomatic set theory, and the theory of cardinal and ordinal numbers. Instructor: Dean.

Ma 120 abc. Abstract Algebra. *9 units (3-0-6); three terms. Prerequisite: Ma 5.* Abstract development of the basic structure theorems of groups, commutative and non-commutative rings, lattices, and fields. Instructor: Ward.

Ma 121 ab. Combinatorial Analysis. *9 units (3-0-6); first and second terms. Prerequisite: Ma. 5.* Elementary and advanced theory of permutations and combinations. Theory of partitions. Theorems on choice including Ramsey's theorem, the Hall-König theorem. Existence and construction of block designs with reference to statistical design of experiment, linear programming, and finite geometries. Instructor: Hall.

Ma 137. Introduction to Lesbesgue Integrals. *9 units (3-0-6); first term. Prerequisite: Ma 108 or equivalent.* Sets, topology, metric spaces. Functions of bounded variation. Lebesgue integrals of functions of one or two real variables. Fourier integrals. L^2 spaces. Linear functionals on Hilbert spaces and Banach spaces. This is an introductory course designed as a preparation for graduate courses in analysis and probability theory. Instructor: Wilcox.

Ma 142 ab. Introduction to Partial Differential Equations. *9 units (3-0-6); second and third terms. Prerequisite: Ma 137 or equivalent.* Topics will include the following: Equations of the first order. Linear equations of the second order. Boundary value and eigenvalue problems for elliptic equations. Initial value and initial boundary value problems for parabolic and hyperbolic equations. Applications to problems of mathematical physics.

Ma 144 ab. Probability. *9 units (3-0-6); second and third terms. Prerequisite: Ma 137 or equivalent.* Basic concepts of probability, limit theorems, random walks, Markow chains, stochastic processes with applications. Instructor: Knowles.

Ma 150 abc. Combinatorial Topology. *9 units (3-0-6); three terms.* Introduction to combinatorial topology. The course covers homology and co-homology theory with applications to fixed point theorems and homotopy theory. Selected topics from the theory of fibre bundles. Instructor: Fuller.

Ma 160 abc. Analytic Number Theory. *9 units (3-0-6); three terms. Prerequisite: Ma 108 abc or equivalent.* The first term, Ma 160 a, is a review of the elementary theory of numbers including congruences, numerical functions, elementary theory of primes, quadratic residues. The second and third terms, Ma 160 bc, include topics selected from: zeta functions, distribution of primes, elliptic modular functions, asymptotic theory of partitions, geometry of numbers. Instructor: Apostol.

Ma 165 a. Diophantine Analysis. *9 units (3-0-6); third term. Prerequisite: Ma 5.* The study of rational or integral solutions of equations. Theory of rational approximations to irrational numbers, and theory of continued fractions. The theorems of Thue-Siegel and Roth will be included. Instructor: Hall.

[B] The following courses are open primarily to graduate students.

Ma 190 abc. Elementary Seminar. *9 units; three terms.* This seminar is restricted to first year graduate students and is combined with independent reading. The topics will vary from year to year. In charge: DePrima, Luxemburg.

[C] The following courses and seminars are intended for advanced graduate students. They are research courses and seminars, offered according to demand, and covering selected topics of current interest. The courses offered, and the topics covered will be announced at the beginning of each term.

Ma 305 abc Seminar in Numerical Analysis. 6 units. Three terms.

Ma 320 abc Special topics in Algebra. 9 units. Three terms.

Ma 325 abc Seminar in Algebra. 6 units. Three terms.

Ma 340 abc Special topics in Analysis. 9 units. Three terms.

Ma 345 abc Seminar in Analysis. 6 units. Three terms.

Ma 350 abc Special topics in Geometry. 9 units. Three terms.

Ma 355 abc Seminar in Geometry. 6 units. Three terms.

Ma 360 abc Special topics in Number Theory. 9 units. Three terms.

Ma 365 abc Seminar in Number Theory. 6 units. Three terms.

Ma 380 abc Special topics in Applied Mathematics. 9 units. Three terms.

Ma 385 abc Seminar in Applied Mathematics. 6 units. Three terms.

Ma 390 Research. Units by arrangement.

Ma 392 Research Conference. 2 units.

Ma 205 abc. Numerical Analysis. *9 units (3-0-6); three terms. Prerequisite: Ma 105 or equivalent.* Discussion of areas of current interest in numerical analysis and related mathematics; such as: matrix inversion and decomposition, ordinary differential equations, partial differential equations, integral equations, conformal mapping, discrete problems, linear programming and game theory, approximation theory, applications of functional analysis, theory of machines, theory of programming, estimates for characteristic value of matrices.

Each quarter will be treated as a separate unit. Where appropriate, accompanying laboratory periods will be arranged as a separate reading course. Instructor: J. N. Franklin (1st term). J. Todd (2nd and 3rd terms).

Ma 222 ab. Group Theory. *9 units (3-0-6); two terms. Prerequisite: Ma 120 or permission of instructor.* An introduction to the basic properties of finite and infinite groups. Theorems on homomorphisms, the theory of abelian groups, permutation groups, free groups, automorphisms. The Sylow theorems. Study of solvable, supersolvable, and nilpotent groups. A large part of the second term will be devoted to the theory of group representation, and will include applications to theoretical physics. Not offered in 1960-61.

Ma 223. Matrix Theory. *9 units (3-0-6); second term. Prerequisites: Ma 108, 120 or equivalent.* Algebraic, arithmetic and analytic aspects of matrix theory. Instructor: O. Todd.

Ma 224 abc. Lattice Theory. *9 units (3-0-6); three terms. Prerequisite: Ma 120 or permission of instructor.* Systematic development of the theory of Boolean algebras, distributive, modular, and semi-modular lattices. Includes the study of lattice congruences, decomposition theory, and the structure of free lattices. Instructor: Dilworth.

Ma 237 abc. Real Variable Theory. *9 units (3-0-6); three terms. Prerequisite: Ma 137 or equivalent.* The axiom of choice and its relation to the other axioms of set theory. Measure theory; the theory of integration; and related topics such as differentiation of set functions, Banach function spaces, and ergodic theory. Topological linear spaces, introduction to Banach algebras, the Stone-Weierstrass theorem. Instructor: Zaanen.

Ma 238 abc. Complex Variable Analysis. *9 units (3-0-6); three terms. Prerequisite: Ma 108 or equivalent.* The basic results of the theory of analytic functions (Cauchy's theorem, singularities, residues, contour integration, analytic continuation) are reviewed. The main part of the course is devoted to topics selected from: entire functions, linear spaces of analytic functions, conformal mapping, algebraic functions, special functions, Riemann surfaces, functions of several complex variables. Instructor: Erdélyi.

Ma 280 abc. Applied Mathematics. *9 units (3-0-6); three terms. Prerequisites: Ma 137 and Ma 143 or equivalent.* Spectral theory of self-adjoint operators in Hilbert spaces with applications to boundary value problems and to functional equations. Nonlinear problems in functional analysis applied to the theory of partial differential equations and to approximation processes. Not offered in 1960-61.

Ma 290. Reading. Occasionally advanced work is given by a reading course under the direction of an instructor. Hours and units by arrangement.

APPLIED MATHEMATICS COURSES OFFERED BY OTHER DEPARTMENTS

AM 115 Engineering Mathematics. *See Applied Mechanics section, for description.*

AM 116 Complex variables and applications. *See Applied Mechanics section, for description.*

AM 125 Engineering Mathematical Principles. *See Applied Mechanics section, for description.*

AM 180 Matrix Algebra. *See Applied Mechanics section, for description.*

AM 225 Advanced Topics in Applied Mathematics. *See Applied Mechanics section, for description.*

Ph 107 Electricity and Magnetism. *See Physics section, for description.*

Ph 108 Theoretical Mechanics. *See Physics section, for description.*

Ph 129 Methods of Mathematical Physics. *See Physics section, for description.*

EE 280 Advanced Course in Mechanical Computing Methods. *See Electrical Engineering section, for description.*

Mechanical Engineering

UNDERGRADUATE SUBJECTS

ME 1. Introduction to Design. *9 units (0-9-0); first, second, or third term. Prerequisite: Gr 1.* Supplements first year graphics with more advanced applications of graphical and algebraic techniques to spatial delineation and to problems in plane and three-dimensional kinematics. Emphasis is placed on creative ingenuity and a rational approach to new design problems as well as on the development of the student's ability to recognize fundamental principles in analyzing existing systems. The following subjects are introduced for study through a coordinated series of lecture discussions and laboratory problems: displacements, velocities, and accelerations in machines and systems; development and applications of the general equation for motion; cam design; the kinematics of analog computation, and epicyclic and gyroscopic systems, in relation to design. Instructors: Tyson. Welch.

ME 3. Materials and Processes. *9 units (3-3-3); first, second or third term. Prerequisites: Ph 1 ab, Ch 1 abc.* A study of the materials of engineering and of the processes by which these materials are made and fabricated. The fields of usefulness and the limitations of alloys and other engineering materials are studied, and also the fields of usefulness and limitations of the various methods of fabrication and of processing machines. The student is not only made acquainted with the technique of processes but with their relative importance industrially and with the competition for survival which these materials and processes continually undergo. Text: *Engineering Materials and Processes,* Clark. Instructors: Buffington, Clark.

ME 5 abc. Design. *9 units (2-6-1); first, second, and third terms. Prerequisites: ME 1, ME 3, ME 17 ab, AM 8 abc, AM 115 ab.* The purpose of this course is to develop creative ability and engineering judgment through work in design and engineering analysis. Existing devices are analyzed to determine their characteristics and the possibilities for improving their performance or economy and to evaluate them in comparison with competitive devices. Practice in the creation or synthesis of new devices is given by problems in the design of machines to perform specified functions. The fundamental principles of scientific and engineering knowledge and appropriate mathematical techniques are employed to accomplish the analysis and designs. Text: *Design and Production,* Kent. Instructor: Morelli.

ME 17 ab. Thermodynamics. *9 units (3-0-6); first and second terms. Prerequisites: Ma 1 abc, Ph 1 abc.* Basic laws of thermodynamics, fundamental properties and interrelationships between properties. Maxwell relations, Joule-Thomson effect, Clapeyron-Clausius equation. Application to gases as well as to other systems. Elements of kinetic theory. Analyses of energy conversion cycles and propulsion devices. One-dimensional flow in a duct, normal and oblique shocks, expansion through nozzles. Basic chemical thermodynamics and theory of equilibrium of a reacting mixture. Text: *Elements of Engineering Thermodynamics,* Sabersky. Instructor: Sabersky.

ME 18. Heat Transfer. *9 units (3-0-6); third term. Prerequisites: Ma 2 ab, ME 17 ab.* Conduction in solids. Solution of problems by analytical, graphical, and numerical methods. Basic equations governing convective heat transfer. Similarity requirements. Special problems in laminar and turbulent flow. Free convection. Heat transfer in condensing and boiling fluids. Energy exchange by radiation. Instructor: Sabersky.

ME 19 ab. Fluid Mechanics and Gas Dynamics. *9 units (3-0-6); first and second terms. Prerequisites: Ma 2 abc, Ph 1 abc.* Basic equations of fluid mechanics, theorems of energy, linear and angular momentum, potential flow, elements of airfoil theory. Flow of real fluids, similarity parameters, flow in closed ducts. Compressibility effects in one-dimensional flow with friction and heat addition. The flow through nozzles and diffusers, shock and detonation phenomena. Boundary layer theory in laminar and turbulent flow. Flow and wave phenomena in open conduits. Instructor: Acosta.

ME 19 c. Principles of Energy Conversion. *9 units (3-0-6); third term. Prerequisites: Ma 2 abc, ME 17 ab or equivalent.* Availability of chemical, nuclear, and solar energy. Systems for the conversion into mechanical or electrical power. Analysis of principal system components, such as fans, compressors, pumps and turbines. To include topics from two- and three-dimensional design theories of turbomachines. Instructor: Acosta.

ME 25. Mechanical Laboratory. *9 units (0-6-3); third term. Prerequisite: ME 17 ab.* Principles of engineering measurements. Instructor: Zukoski.

ADVANCED SUBJECTS

ME 100. Advanced Work in Mechanical Engineering. The staff in mechanical engineering will arrange special courses or problems to meet the needs of fifth-year students or qualified undergraduate students.

ME 101 abc. Advanced Design. *9 units (1-6-2); first, second, and third terms. Prerequisite: ME 5 abc or equivalent.* Creative design and analysis of machines and engineering systems is developed at an advanced level. Laboratory problems are given in terms of the need for accomplishing specified end results in the presence of broadly defined environments. Investigations are made of environmental conditions to develop quantitative specifications for the required designs. Searches are made for the possible alternate designs and these are compared and evaluated. Preferred designs are developed in sufficient detail to determine operational characteristics, material specifications, general manufacturing requirements and costs. Instructor: Morelli.

ME 118 abc. Advanced Thermodynamics and Energy Transfer. *9 units (3-0-6); first, second, and third terms. Prerequisites: ME 18, ME 19 ab.* Equilibrium of chemical systems including dilute solutions, elements of non-equilibrium thermodynamics, basic concepts of statistical mechanics. Special problems in heat conduction involving non-isotropic media, moving sources, and changes of phase. Exact solutions of heat transfer problems in laminar flow for compressible and incompressible fluids. Problems in turbulent flow and the application of Reynolds analogy. Principles of mass transfer and problems involving the simultaneous transfer of heat and mass. Theory of black body radiation and radiation characteristics of solids and gases. Instructors: Acosta, Sabersky.

ME 126. Fluid Mechanics and Heat Transfer Laboratory. *9 units (0-6-3); third term. Prerequisites: ME 17 ab, ME 18, ME 19 ab, or equivalent. Students with other background shall obtain instructor's permission.* Introduction to some of the basic measurements and phenomena in fluid mechanics and heat transfer. The student will become acquainted with the use of hot wire equipment, thermocouples, thermistors, velocity probes, as well as with electrical and hydraulic analogues. The experiments in which these instruments will be used will include, for example, the flow over a flat plate, heat transfer and flow through a supersonic nozzle, the use of a water table, and electric analog techniques for solving two-dimensional potential problems. Instructors: Acosta, Sabersky, Wu.

ME 127. High Frequency Measurements in Fluids and Solids. *9 units (2-6-1); second term. Prerequisites: AM 8 abc, AM 115 ab.* The course will treat the theory and application of modern instrumentation to dynamic problems in fluid mechanics and elasticity which will be selected by provide familiarity with a wide range of electronic devices, transducers, and high speed photoelastic and schieren photographic techniques. Instructor: Ellis.

ME 150 abc. Seminar. All candidates for the M.S. degree in Mechanical Engineering are required to attend a graduate seminar in any Division of the Institute each week of each term.

ME 200. Advanced Work in Mechanical Engineering. The staff in mechanical engineering will arrange special courses on problems to meet the needs of students beyond the fifth year.

ME 217 abc. Turbomachines. *6 units (2-0-4); first, second, and third terms. Prerequisites: Hy 101 abc or Ae 101 abc or equivalent.* The fluid mechanics of turbomachines; potential flow through two-dimensional cascades of airfoils; the theory of three-dimensional rotational flow in axial turbomachines; stall propagation in compressors; tip clearance flow and losses; boundary layer and other secondary flows in turbomachines; applications of the above to the design of turbomachines. Not given every year. Instructor: Rannie.

ME 300. Thesis Research.

Many advanced courses in the field of Mechanical Engineering may be found listed in other engineering options such as:

Applied Mechanics, page 235.

Hydraulics, page 276.

Jet Propulsion, page 277.

Physical Metallurgy, page 289.

Music

Mu 1 abc. Music History and Analysis. *5 units (2-0-3).* The development of Western music studied through the analysis of historically significant compositions. Musical notation, melodic techniques, harmonic and polyphonic forms will be studied in relation to stylistic use during the principal periods of music history. An understanding of the musical score will be emphasized by means of correlated studies in analysis and record listening. Instructor: Oschse.

Paleontology

(See under Geological Sciences)

PHILOSOPHY AND PSYCHOLOGY

UNDERGRADUATE SUBJECTS

Pl 1. Introduction to Philosophy.* *9 units (3-0-6). Senior elective.* A study of the major problems of philosophy in terms of the most influential contemporary world views, including naturalism, idealism, theism, pragmatism, and positivism. Instructors: Mead, Bures.

Pl 2. Logic.* *9 units (3-0-6). Senior elective.* A study of modern and traditional logic. An analysis of knowledge into basic symbolic forms. Detailed consideration of such logical concepts as: proposition, truth, variable, definition, implication, inference, class, syllogism, logical law, deductive system. Emphasis on the fundamental role of logical methods in the rational approach to knowledge. Instructor: Bures.

Pl 3. Contemporary European Philosophy.* *9 units (3-0-6). Senior elective.* A critical analysis of the main trends in contemporary European philosophy, especially in France, Germany, Italy, and Spain. The course will include neo-Kantianism, neo-Hegelianism, Bergsonism, Logical-Positivism, Phenomenology, neo-Thomism, and Existentialism, in their influence on the whole of modern culture. Instructor: Stern.

Pl 4. Ethics.* *9 units (3-0-6). Senior elective.* A study of ethical values in relation to human nature and culture. Among the major topics considered are: the moral systems of some representative cultures; the development of personality and values in these cultures; the possibility of a rational basis for ethics; competing views of human nature; ethical conflicts in American culture. Instructor: Bures.

Pl 6. General Psychology.* *9 units (3-0-6). Senior elective.*

Pl 6 a. Introduction to Modern Psychology.* *9 units (3-0-6). Senior elective; first term.* An historical introduction to contemporary psychology. The central concepts of the field are studied as they have developed, particularly during the last century and a half. The focus is upon those concepts which now appear to be permanent parts of psychology, rather than upon those briefly popular at some particular period. The developing theories of intelligence, personality, motivation (both conscious and unconscious) and abnormal behavior are emphasized. Recommended as preparation for Pl 6 b and Pl 6 c. Instructor: Mead.

Pl 6 b. The Psychology of Personality Development.* *9 units (3-0-6). Senior elective; second term.* A study of psychological development from birth to maturity. Attention is paid to stages of development, roles, emotional and motivational patterns. A positive conception of growth and creativity and factors inhibiting growth are emphasized in terms of a basic vocabulary. Recommended as preparation for Pl 6 c. Instructor: Bures.

Pl 6 c. The Psychology of Behavioral Processes.* *9 units (3-0-6). Senior elective; third term.* A study of the individual, social and cultural factors that contribute to the development of human behavior and human interaction. Both theoretical and empirical formulations will be used in the analysis of the content and process of behavior especially as it occurs within the student's experiential field. Pl 6 a and Pl 6 b are recommended as preparation for this course. Instructor: Weir.

Pl 7. Human Relations. *7 units (3-0-4); third term.* An introduction to the principles of human relations with major emphasis on the development of groups. Psychological and emotional factors influencing group behavior, group leadership and group co-operation will be explored. Instructors: Ferguson, Weir.

*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

Pl 13. Reading in Philosophy. *Units to be determined for the individual by the department. Elective, with the approval of the Registration Committee, in any term.* Reading in philosophy, supplementary to, but not substituted for, courses listed; supervised by members of the department.

ADVANCED SUBJECTS

Pl 100 abc. Philosophy of Science. *9 units (2-0-7).* A full-year sequence. The relation between science and philosophy. The functions of logical analysis in knowledge and the analysis of the language of science. A study of the nature of formal science (logic and mathematics) and of factual science, their methods and interrelationships. Concept formation in the sciences. Analysis of some basic problems in the philosophy of science: measurement, casuality, probability, induction, space, time, reality. Scientific method and social problems. Instructor: Bures.

Pl 101 abc. History of Thought. *9 units (2-0-7).* A full-year sequence. A study of the basic ideas of Western Civilization in their historical development. The making of the modern mind as revealed in the development of philosophy and in the relations between philosophy and science, art and religion. The history of ideas in relation to the social and political backgrounds from which they came. Instructor: Mead.

Pl 102 abc. Philosophy and Literature. *9 units (2-0-7). A full year sequence.* A philosophical analysis and interpretation of literature as an art and as a vehicle of philosophical thought, exemplified in great works of world literature, beginning with Homer and the pre-Socratic poems on nature and ending with the literature of Existentialism and Surrealism. The course includes a study of the main philosophical theories of the different forms of literary expression (tragedy, comedy, poetry, the novel) and the reading of original works or translations. Instructor: Stern.

Pl 113. Reading in Philosophy. Same as Pl 13 but for graduate credit.

PHYSICAL METALLURGY

UNDERGRADUATE SUBJECTS

PM 5 abc. Principles of Engineering Materials. *9 units (3-0-6); first, second and third terms. Prerequisites: Ch 1 abc, Ph 2 abc, AM 8 abc.* The purpose of this course is to acquaint the student with the principles underlying the behavior of solid materials. The behavior of materials is to be considered from the point of view of bonding between atoms and from the standpoint of structure. This is then followed by a fundamental discussion of specific properties of materials of ionic, metallic, molecular, and covalent types of bonds. The principles are illustrated by means of examples of engineering material behavior and problems of forming. Instructors: Wood, Buffington.

PM 10. Engineering Physical Metallurgy. *9 units (3-0-6); first term. Prerequisite: PM 5 abc.* A study of the properties of ferrous and non-ferrous metals and alloys with respect to their application in engineering; the principles of the treatment of ferrous and non-ferrous alloys for a proper understanding by engineers for application of alloys in fabrication and design. Text: *Physical Metallurgy for Engineers,* Clark and Varney. Instructors: Clark, Buffington.

PM 11. Metallography Laboratory. *9 units (0-6-3); second term. Prerequisite: PM 10.* The technique of metallographic laboratory practice including microscopy, preparation of specimens, etching reagents and their use, photomicrography. The study of the microstructure of ferrous and non-ferrous metals and alloys for different conditions of treatment. Text: *Principles of Metallographic Laboratory Practice,* Kehl. Instructors: Clark, Buffington.

PM 15. Behavior of Solids Laboratory. *9 units (0-6-3); third term. Prerequisite: PM 5 abc, or concurrent registration.* Experimental studies of the physical and mechanical behavior of solid materials which may be correlated with the fundamental principles of material behavior. A few examples of investigations which the student may elect to undertake are: The thermal and electrical conductivities of a metal and a semi-conductor as functions of temperature. The influence of temperature on the stress-strain behavior of rubber-like polymers and temperature changes produced by deformation of such materials. The influence of grain size on the brittle fracture stress of mild steel at low temperatures and observations of microcracks. The generation and direct observation of dislocations in lithium fluoride crystals under applied stress. Instructor: Wood.

ADVANCED SUBJECTS

PM 102. Pyrometry. *9 units (1-6-2); third term. Prerequisite: Ph 2 abc.* Study of the principles of thermometry and the theory underlying instruments that are used to measure temperatures. Experiments will be conducted with a variety of such instruments to illustrate their applications and limitations. Instructor: Staff.

PM 103 ab. Physical Metallurgy Laboratory. *9 units (0-9-0); first term. 6 units (0-6-0); second term. Prerequisite: PM 11.* Experimental studies concerned with the structures and properties of metals and alloys associated with heat treatment and recrystallization phenomena. Studies of hardenability characteristics of steel with respect to prediction by thermodynamic considerations. The determination of grain size of metals and alloys in relation to properties. Instructor: Clark.

PM 104. Photography. *9 units (1-6-2); first term. Prerequisite: Ph 2 abc.* Study and synthesis of optical systems in the use of photographic methods in research. Experiments will be conducted with various systems to illustrate the effectiveness of photographic methods as research tools. Instructor: Staff.

PM 105. Mechanical Behavior of Metals. *6 units (2-0-4); first term. Prerequisites: AM 9 abc, PM 5 abc.* A study of the various types of behavior of metals under applied load which are of significance for engineering applications. Properties under simple tension and compression loading, hysteresis and damping capacity, the influence of temperature, behavior under rapidly applied and impact loads, fatigue, mechanical wear, behavior under combined stress, and selection of working stresses. Text: *Strength and Resistance of Metals,* Lessells. Instructor: Wood.

PM 112 ab. Advanced Physical Metallurgy. *9 units (3-0-6); second and third terms. Prerequisites: PM 115, PM 120.* Ternary phase diagrams; order-disorder transformations; solid state diffusion; semiconductors and semiconductor devices; theory of gas-metal reactions; advanced consideration of magnetic properties; effects of radiation on materials. Instructor: Buffington.

PM 115 ab. Crystal Structure and Properties of Metals and Alloys. *9 units (3-0-6); second and third terms. Prerequisite: PM 5.* Physics of X-rays, elementary crystal structure, symmetry operations, symmetry classes, space groups. Stereographic projections. Reciprocal lattice. Von Laue and Debye-Scherrer methods of crystal structure analysis. Use of the diffractometer and intensity measurements. The texture of plastically deformed metals. Electron and neutron diffraction. Relationships between the structure of metals, solid solutions and intermetallic compounds and their physical properties. Text: *Elements of X-ray Diffraction, Cullity and Atomic Theory for Students in Metallurgy,* Hume-Rothery. Instructor: Duwez.

PM 116. X-Ray Metallography Laboratory I. *9 units (0-6-3); third term. Prerequisite: PM 115 a.* Experiments on X-ray emission spectra and absorption edges. Determination of crystal structures by the Von Laue and Debye-Scherrer methods. Use of the X-ray spectrometer. Study of preferred orientation in cold worked metals. Application of X-ray diffraction methods to the study of phase diagrams. Instructor: Duwez.

PM 120. Physics of Metals. *9 units (3-0-6); first term. Prerequisite: AM 115 ab or equivalent.* Introduction to wave mechanics; band theory of solids; physical properties of solids. Instructor: Buffington.

PM 135. Radioisotopes Laboratory. *9 units (0-9-0); third term. Prerequisites: AM 103, PM 112 a.* Experiments illustrating the use of radioisotopes in the field of physical metallurgy. Typical examples are studies of solid state diffusion and the determination of chemical inhomogeneities in metals and alloys. Instructor: Buffington.

PM 205. Theory of the Mechanical Behavior of Metals. *9 units (3-0-6); third term. Prerequisites: AM 110 a, PM 115.* A study of the nature and physical theory of the deformation of metals under the influence of applied stress. Elasticity of single crystals, plastic flow in crystals by slip and twinning, the concept of dislocations, stress fields of dislocations, dislocation interactions, generation of dislocations, dislocations in crystal lattices, arrays of dislocations, application of dislocaton theory. Text: *Dislocations and Plastic Flow in Crystals, Cottrell.* Instructor: Wood.

PM 217. X-Ray Metallography Laboratory II. *9 units (0-6-3); any term. Prerequisite: PM 116.* An advanced laboratory course for students carrying out research involving the use of X-ray diffraction techniques. Methods of X-ray diffraction requiring the use of single crystals, rotating crystal and Weisenberg methods. Accurate measurements of diffracted intensities. Quantitative analysis of phases in alloys. Special problems will be assigned, depending on the student's field of interest. Instructor: Duwez.

PM 225. Industrial Physical Metallurgy. *9 units (0-6-3); any term. Prerequisites: PM 103, PM 116.* Application of the principles of physical metallurgy and the techniques of metallographic laboratory practice to the solution of problems concerning the causes of failure of commercial parts. Typical cases are used as problems to be solved by the student and presented and discussed before the class and staff in the form of reports. Instructor: Clark.

PM 250 abc. Advanced Topics in Physical Metallurgy. *6 units (2-0-4); first, second, and third terms.* The content of this course will vary from year to year. Topics of current interest will be chosen according to the interests of students and staff. Visiting professors may present portions of this course from time to time. Instructor: Staff.

PM 300. Thesis Research.

PHYSICS

UNDERGRADUATE SUBJECTS

Ph 1 abc. Mechanics, Molecular Physics, Heat and Sound. *12 units (3-3-6); first, second, third terms. Prerequisites: High school physics, algebra and trigonometry.* The first year of a general college course in physics extending through two years. The course work consists of class recitations in which the basic material of physics is presented largely by means of analytical solutions to problems. Bi-weekly demonstration lectures by staff members from various divisions illustrate some of the more interesting application of physics. The weekly laboratory allows some choice of problem on the part of the student. In addition to many standard experiments, some opportunity is provided for original experiments. Text: *Introduction to Mechanics and Heat,* Frank. Instructors: Sutton, Leighton, Sands, Strong, and Graduate Assistants.

Ph 2 abc. Electricity, Optics, and Modern Physics. *12 units (3-3-6); first, second, and third terms. Prerequisites: Ph 1 abc, Ma 1 abc, or their equivalent.* A continuation of Ph 1 abc to form a well-rounded two-year course in general physics. The first two terms deal with electricity and physical optics, and the third term with modern physics. Texts: *Introduction to Electricity and Optics,* Frank; *Physics of the Atom,* Wehr, Richards. Instructors: Peterson, Neher, Wilts, and Graduate Assistants.

Ph 77. Experimental Physics Laboratory. *6-9 units (subject to arrangement with instructor). Either first or second term.* A one-term laboratory course open to senior physics majors. The purpose of the course is to familiarize the student with laboratory equipment and procedures that are used in the research laboratory. The experiments are designed to illustrate fundamental physical phenomena, such as Compton scattering, nuclear and paramagnetic resonance, the photoelectric effect, the interaction of charged particles with matter, etc. Instructors: Whaling, Hellwarth.

ADVANCED SUBJECTS

Ph 107 abc. Electricity and Magnetism. *9 units (3-0-6); first, second, third terms. Prerequisites: Ph 2 abc; Ma 2 abc.* A course in classical electricity and magnetism. Topics include electrostatics, magnetostatics, and current flow; electromagnetic induction; electromagnetic radiation, including plane waves, spherical waves, and dipole radiation; electromagnetic field energy and momentum. The emphasis is upon the more general aspects of the subject, and upon physical principles. Graduate students majoring in physics or astronomy will be given only 6 units credit for this course. Text: *Electromagnetism,* Slater and Frank. Instructors: Cowan, Boehm, Kavanagh, Tollestrup.

Ph 108 abc. Theoretical Mechanics. *9 units (3-0-6); first, second and third terms. Prerequisites: Ph 1 abc, Ph 2 abc, and preferably Ph 107 abc.* An intermediate course in the application of mathematical methods to problems in mechanics. Topics include particle mechanics, Lagrange and Hamilton equations, damped vibrations, coupled vibratory systems, rigid body dynamics. Graduate students majoring in physics or astronomy will receive only 6 units credit for this course. Text: *Classical Mechanics,* Goldstein. Instructors: Anderson, Mercereau, Weidenmuller.

Ph 110 ab. Kinetic Theory of Matter. *9 units (3-0-6); second and third terms. Prerequisites: Ph 1 abc; Ma 2 abc.* A lecture course in kinetic theory and its basic applications (and limitations) to the "stable" and "steady" state phenomena in gases. Specific discussion of transfer, surface and low pressure phenomena, Brownian movement and kinetics of airborne particulate matter (aerosols) and condensation phenomena in such systems. Text: *Kinetic Theory of Gases,* Kennard, Loeb and selected chapters from literature. Instructor: Goetz.

Ph 111 abc. Structure of Matter. *9 units (3-0-6); first, second, third terms. Prerequisites: Ph 1 abc; Ph 2 abc.* A course dealing with those properties of matter which can be treated from a relatively simple, largely classical, point of view. The connection between the properties of matter and the properties of the atoms of which it is composed is stressed. Topics include electron theory of dielectrics and magnetic materials; electrical conduction in gases; kinetic theory of gases; transport phenomena; degenerate gases; free electron theory of metals; quantum theory of specific heats; mechanical properties of gases, liquids and solids. Quantum concepts are introduced but no formal development of quantum mechanics is included. Graduate students majoring in physics or astronomy will receive only 6 units credit for this course. Instructor: T. Lauritsen.

Ph 112 abc. Atomic and Nuclear Physics. *12 units (4-0-8); first, second, third terms. Prerequisites: Ph 107 abc and Ph 111 abc, or equivalent.* A problem and lecture course in the experimental and theoretical foundations of modern atomic and nuclear physics. Topics include an introduction to quantum mechanics with illustrative applications to the harmonic oscillator, the free particle, the one-electron atom, and selection rules. Also treated, but on a less analytical basis, are the exclusion principle and atomic shell structure; optical spectroscopy; molecular binding and molecular spectra; quantum statistics; the band theory of solids; X-rays; radioactivity and nuclear structure; nuclear reactions; elementary particles; high energy physics. Text: *Principles of Modern Physics,* Leighton. Instructor: Barnes.

Ph 115 ab. Geometrical and Physical Optics. *9 units (3-0-6); first and second terms. Prerequisite: Ph 2 abc.* An intermediate lecture and problem course dealing with the fundamental principles and applications of geometrical optics, interference, diffraction and other topics of physical optics. Given in alternate years. Offered in 1960-61. Instructor: King.

Ph 129 abc. Methods of Mathematical Physics. *9 units (3-0-6); first, second, third terms. Prerequisites: Ph 107 abc and Ph 108 abc or the equivalents (may be taken concurrently), and some knowledge of complex variables.* Aimed at developing familiarity with the mathematical tools useful in physics, the course discusses practical methods of summing series, integrating, and solving differential equations, including numerical methods. The special functions (Bessel, Elliptic, Gamma, etc.) arising in physics are described, as well as Fourier series and transforms, partial differential equations, orthogonal functions, eigenvalues, calculus of variations, integral equations, matrices and tensors, and non-commutative algebra. The emphasis is toward applications, with special attention to approximate methods of solution. Instructor: Mathews.

Ph 131 abc. Electricity and Magnetism. *9 units (3-0-6); first, second, and third terms. Prerequisite: An average grade of C in Ph 107 abc.* A problem course in electricity, magnetism and electromagnetic waves for students who are doing or plan to do graduate work. The first two terms cover potential theory as applied to electrostatics, magnetostatics and current flow in extended mediums; eddy currents; and the laws of electromagnetic induction as applied to linear circuits. The third term covers electromagnetic waves and the motion of charged particles in electromagnetic fields. Text: *Static and Dynamic Electricity,* Smythe. Instructor: Smythe.

Ph 172. Experimental Research in Physics. *Units in accordance with the work accomplished. Approval of the department must be obtained before registering.*

Ph 173. Theoretical Research in Physics. *Units in accordance with the work accomplished. Approval of the department must be obtained before registering.*

Ph 201 ab. Analytical Mechanics. *A 2-term 9-unit course to be replaced by Ph 201 abc, Analytical Mechanics, 9 units (3-0-6), first, second, and third terms. Prerequisites: Ph 108 abc or AM 15 abc, Ph 129 ab is desirable.* A problem and lecture course dealing with the various formulations of the laws of motion of systems of particles and rigid bodies, and with both exact and approximate solutions of the resulting equations. Topics considered include Lagrange's and Hamilton's equations, canonical transformations, the dynamics of axially symmetric rigid bodies, and vibrations about equilibrium and steady motion. Additional topics will be selected from such subjects as elasticity, hydrodynamics, non-linear vibrations, dynamics of particles in accelerators, potential theory, and hydromagnetics. Given in alternate years. Offered in 1960-61. Instructor: Davis.

Ph 203 abc. Nuclear Physics. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 112 abc or equivalent.* A problem and lecture course in nuclear physics. Subjects include fundamental properties and structure of nuclei, including the liquid drop, shell, and collective models, nuclear forces, modes of nuclear decay, nuclear reactions, interaction of particles and radiation with matter, and particle acceleration and detection. The third term is usually devoted to such specialized topics as nuclear processes in stars including energy generation and element synthesis. Text: *The Atomic Nucleus,* Evans. Instructor: Fowler.

Ph 204 abc. Low Temperature Physics. *9 units (3-0-6); first, second, third terms. Prerequisite: Ph 112 abc. Recommended: Ph 205 abc, Ph 227 abc.* First and second terms: Introductory exposition of the subject of cryogenics. General coverage of topics includes (1) liquid helium II, (2) superconductivity, and (3) adiabatic demagnetization and nuclear alignment. Emphasis to be based on correlating behavior of matter at low temperatures with existing theoretical interpretations. Third term. Advanced topics on specific aspects of low temperature physics to be covered by special reading assignments. Given in alternate years. Not offered in 1960-61. Instructor: Pellam.

Ph 205 abc. Principles of Quantum Mechanics. *9 units (3-0-6); first, second and third terms. Prerequisites: Ph 112 abc or equivalent; Ph 129 abc is desirable.* Subjects include Schroedinger equation (hydrogen atom, etc.); particle scattering; operators and transformation theory; angular momentum; atomic structure; perturbation theory and other approximation methods useful in atomic, molecular, and nuclear problems; introduction to the quantum theory of radiation. Instructor: Gell-Mann.

Ph 207 abc. X- and Gamma-rays. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 112 abc, or equivalent.* Covers the generation of X-rays and gamma-rays and the various interactions of these with matter both in practical applications to research physics and in theory. The first term is devoted to a descriptive general survey of the subject. The second term deals with nuclear gamma-ray and

X-ray emission spectra, the mean lives of excited states, elementary theory of multipole radiation, theories of the generation and intensities of characteristic X-ray line spectra and also of the continuous X-ray spectrum covering briefly under the latter topic the theories of Sommerfield and of Heitler and their experimental verifications. The third term covers in considerable detail the scattering of these radiations by matter, both coherent and incoherent processes being considered, and presents the resulting physical conclusions regarding the structure of atoms, molecules, liquids, solids and the Compton effect with its manifold implications. Other interactions between radiation and matter are also treated. Solution of a moderate number of illustrative problems required in all three terms. Instructor: DuMond.

Ph 209 abc. Electromagnetism and Electron Theory. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 107 abc.* Electromagnetic fields in vacuum and in matter; classical electron theory, retarded potentials, radiation, dispersion, and absorption; theories of the electric and magnetic properties of materials; selected topics in wave propagation; special relativity. Instructor: Gould.

Ph 217. Spectroscopy. *9 units (3-0-6); third term. Prerequisite: Ph 112 ab or the equivalent.* Atomic line spectra. Experimental techniques of excitation and observation of the spectra of atoms and ions. A discussion of observed spectra, including complex spectra, in terms of atomic structure theory. Given in alternate years. Offered in 1960-61 Instructor: King.

Ph 218 ab. Electronic Circuits and their Application to Physical Research. *9 units (3-0-6); first and second terms.* Permission of the instructor is required in order to register for this course. A course on electronic circuits with primary emphasis on basic factors entering into the design and use of electronic instruments for physical research. Topics considered will include the theory of response of linear networks to transient signals, linear and nonlinear properties of electron tubes and practical circuit components, basic passive and active circuit combinations, cascade systems, amplifiers, feedback in linear and nonlinear systems, statistical signals, noise, and practical construction. Particular examples will be taken from commonly used research instruments. Given in alternate years. Not offered in 1960-61. Instructor: Tollestrup.

Ph 219 abc. Advanced Electromagnetic Field Theory. *9 units (3-0-6); first, second, and third terms.* This course covers the applications of Maxwell's equations to problems involving antennas, waveguides, cavity resonators, and diffraction. It includes the solution of problems by the classical methods of retarded potentials and orthonogal expansions and lectures in the modern techniques of Schwinger that employ the calculus of variations and integral equations. (Identical with EE 250 abc.) Texts: *Static and Dynamic Electricity*, Smythe; *Randwertprobleme der Microwellenphysik*, Borgnis and Papas. Instructors: Smythe and Papas.

Ph 227 abc. Thermodynamics, Statistical Mechanics, and Kinetic Theory. *9 units (3-0-6); first, second and third terms. Prerequisites: Ph 108 abc, 205 ab (may be taken concurrently) or the equivalent.* The fundamental concepts and laws of thermodynamics. Entropy and other characteristic functions. Nernst's theorem. Kinetic theory of gases. Classical and quantum statistical mechanics. The relation between statistical mechanics and thermodynamics. Illustrative applications of thermodynamics and statistical mechanics. Given in alternate years. Not offered in 1960-61. Instructor: Davis.

Ph 231 ab. High Energy Physics. *9 units (3-0-6); first and second terms.* A course covering the properties of the elementary particles and their interactions, especially at high energies. Topics discussed include the classification of the particles and their properties, strangeness theory, pion nucleon and nucleon-nucleon interactions, photoproduction of pions, high energy electron scattering, high energy electromagnetic interactions, production of strange particles, hyperfragments, and the principles of high energy accelerators. Given in alternate years. Offered in 1960-61. Instructor: Walker.

Ph 234 abc. Topics in Theoretical Physics. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 205 or equivalent.* The content of this course will vary from year to year. Topics presented will include: General methods in quantum mechanics such as operator calculus, group theory and its application; theory of meson and electromagnetic fields; atomic and molecular structure; theory of solids; theoretical nuclear physics. Instructor: Zachariasen.

Ph 235 abc. Relativity and Cosmology. *9 units (3-0-6); first, second and third terms.* A systematic exposition of Einstein's special and general theories of relativity; the conflict between Newtonian relativity and the Maxwellian theory of the electromagnetic fields; its resolution in the special theory of relativity. The geometrization of the gravitational field accomplished by the general theory of relativity. The search for a unified theory of the electromagnetic and gravitational fields. Applications of the relativity theories to cosmology and cosmogony. Topics in the more advanced mathematical disciplines (tensor analysis, Riemannian geometry) will be developed as required as appropriate tools for the formulation of physical law. The first term, Ph 235a may be taken separately by students who are interested only in the principles and applications of the special theory of relativity. Given in alternate years. Offered in 1960-61. Instructor: Robertson.

Ph 238 abc. Seminar on Theoretical Physics. *4 units; first, second, and third terms.* Recent developments in theoretical physics for specialists in mathematical physics. In charge: Gell-Mann, Mathews, Zachariasen.

Ph 241. Research Conference in Physics. *4 units; first, second, and third terms.* Meets once a week for a report and discussion of the work appearing in the literature and that in progress in the laboratory. Advanced students in physics and members of the physics staff take part. In charge: Bacher.

Ph 300. Research in Physics. *Units in accordance with work accomplished. Approval of the Department must be obtained before registering.* Ph 300 is elected in place of Ph 172 when the student has progressed to the point where his research leads directly toward the thesis of the degree of Doctor of Philosophy.

PSYCHOLOGY

(See under Philosophy)

RUSSIAN

(See under Languages)

Section VII

DEGREES CONFERRED JUNE 10, 1960

Doctor of Philosophy

Carl S. Benson (Geology). *B.A., University of Minnesota, 1950; M.S., 1955.* Thesis: Stratigraphic Studies in the Snow and Firn of the Greenland Ice Sheet.

Harry Hobart Bingham, Jr. (Physics). *A.B., Princeton University, 1952.* Thesis: π° Photoproduction from Deuterium in the Energy Range ½ to 1 Bev.

Thomas Kelman Boehme (Mathematics). *B.S., University of Oklahoma, 1952; M.S., Oklahoma Agricultural and Mechanical College, 1957.* Thesis: Operation Calculus and the Finite Part of Divergent Integrals.

Henry Hursell Dearman (Chemistry). *B.S., University of North Carolina, 1956.* Thesis: I. Studies of the Spin Distribution in Aromatic Radicals. II. Electron Resonance Studies of Some Sandwich Compounds.

William Edwin Dibble (Physics). *B.S., California Institute of Technology, 1954.* Thesis: Design and Construction of a Point-Focusing Berreman Type Single Crystal X-Ray Monochromator and Its Application to Low-Angle Scattering Studies of Biological Specimens.

Franklin Painter Dixon (Physics). *B.S., University of Texas, 1954; M.S., California Institute of Technology, 1957.* Thesis: Photoproduction of Positive Pions from Hydrogen in the 600 to 1000 Mev Region.

Bruce Roger Doe (Geology). *B.S., University of Minnesota, 1954; B.Geol.E., 1954; M.S., Missouri School of Mines, 1956.* Thesis: The Distribution and Composition of Sulfide Minerals at Balmat, New York.

William Farrell Edwards (Physics). *B.S., University of Utah, 1955; M.S., California Institute of Technology, 1957.* Thesis: Experimental Studies of Conversion Coefficients in Some Deformed Nuclei.

Edward Richard Fleming (Aeronautics). *B.S., University of Notre Dame, 1949; M.S., 1950.* Thesis: Non-linear Flutter.

Edward Ambrose Flinn, III (Geophysics). *S.B., Massachusetts Institute of Technology, 1953.* Thesis: Exact Transient Solution of Some Problems of Elastic Wave Propagation.

Donald Charles Forster (Electrical Engineering). *B.S., University of Southern California, 1955; M.S., California Institute of Technology, 1957.* Thesis: Theory of Parametrically-Pumped Longitudinal-Field Electron Beams.

Herbert Seymour Glick (Aeronautics). *B.E.Ph., Cornell University, 1951; M.Ae.E., 1953.* Thesis: Modified Crocco-Lees Mixing Theory for Supersonic Separated and Reattaching Flows.

Jacek Piotr Gorecki (Aeronautics). *Dipl. Ing., Ecole Centrale des Arts et Manufactures (Paris, France), 1940.* Thesis: An Investigation of Temperature Fluctuations on Bluff Bodies.

Meredith Charles Gourdine (Engineering Science). *B.S., Cornell University, 1953.* Thesis: On Magnetohydrodynamics Flow over Solids.

Henry Hoyt Hilton (Physics). *B.S., Yale University, 1952; M.S., 1952.* Thesis: Comparison of the Beta-Spectra of Boron 12 and Nitrogen 12.

Charles Ray Hobby (Mathematics). *B.S., University of California, 1951; M.S., University of Houston, 1957.* Thesis: The Derived Series of a P-Group.

Din-Yu Hsieh (Engineering Science). *B.Sc., National Taiwan University, 1954; M.Sc., Brown University, 1957.* Thesis: Theory of Gas Bubble Dynamics in Oscillating Pressure Fields.

Herbert Erwin Hunter (Aeronautics). *B.S., University of Maryland, 1956; M.S., California Institute of Technology, 1957.* Thesis: Application of Asymptotic Expansion Procedures to Low Reynolds Number Flows about Infinite Bodies of Revolution.

William Day Hutchinson (Chemistry). *B.S., Morehouse College, 1955; M.S., California Institute of Technology, 1957.* Thesis: Physical Chemical Studies of Reactions of Human Hemoglobins.

Carl Kenneth Iddings (Physics). *B.A., Harvard College, 1955.* Thesis: Nuclear Size Corrections to the Hyperfine Structure of Hydrogen.

Theodore Alan Jacobs (Engineering Science). *A.B., Emory University, 1950; M.S., University of Southern California, 1954.* Thesis: I. An Investigation of Relaxation Processes. II. Studies in Combustion.

Peter M. Kelly (Electrical Engineering). *B.S., Union College, 1950; M.S., California Institute of Technology, 1952.* Thesis: A Unified Approach to Two-Terminal Network Synthesis.

John Fisher Kennedy (Civil Engineering). *B.S., University of Notre Dame, 1955; M.S., California Institute of Technology, 1956.* Thesis: Stationary Waves and Antidunes in Alluvial Channels.

Thomas Richard Koehler (Physics). *B.S., Seattle University, 1954.* Thesis: Rayleigh Disk Measurements in Pure Superflow.

Abraham Nathan Kurtz (Chemistry). *B.A., Brooklyn College, 1937; M.A., 1943.* Thesis: I. Structural Analogs of Typical Substrates of *alpha*-Chymotrypsin. II. 1-Acetyl-2-[L-Tyrosyl] Hydrazine: An Inhibitor of *alpha*-Chymotrypsin. III. Binuclear Aromatics as Inhibitors of *alpha*-Chymotrypsin Catalyzed Hydrolyses. IV. Applicability of the pH-Stat to *alpha*-Chymotrypsin Catalyzed Hydrolyses that Produce a Buffer.

Marshall Lapp (Engineering Science). *B.Eng.Ph., Cornell University, 1955.* Thesis: I. Emissivity Calculations for CO_2. II. Shock Tube f-Number Measurement for OH.

Ronald Michael Lloyd (Geology). *B.S., University of Illinois, 1952; M.S., 1953.* Thesis: The Shell Chemistry of Some Recent and Pleistocene Mollusks and its Environmental Significance.

Dean MacGillivray (Aeronautics). *B.A.Sc., University of British Columbia, 1955; M.A.Sc., 1956; M.S., California Institute of Technology, 1957.* Thesis: Asymptotic Solutions for a Problem in Low Conductivity Magnetohydrodynamics.

Jacob Valentine Maizel, Jr. (Biology). *B.S., Pennsylvania State University, 1955; M.S., 1957.* Thesis: Isolation and Partial Characterization of Avenacin, an Antibiotic-like Substance from Oats.

Carver A. Mead (Electrical Engineering). *B.S., California Institute of Technology, 1956; M.S., 1957.* Thesis: Transistor Switching Analysis.

John Jay Merrill (Physics). *B.S., California Institute of Technology, 1955; M.S., 1956.* Thesis: Precision Measurement of X-Ray Spectra with Application to the L X-Ray Spectra of Uranium, Neptunium, Plutonium, and Americium.

Carleton Bryant Moore (Chemistry). *B.S., Alfred University, 1954.* Thesis: I. Kinetics of the Reactions of Silver, Lead and Thallium with Thioacetamide in Solution. II. The Distribution of Barium, Titanium, Manganese, Iron, Nickel, Cobalt and Chromium in Stony Meteorites.

Arthur H. Muir, Jr. (Physics). *A.B., Williams College, 1953; M.S., California Institute of Technology, 1955.* Thesis: An Investigation of the Ta^{181} Nucleus.

Henry Richard Myers (Physics). *S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute of Technology, 1955.* Thesis: Photodisintegration of the Deuteron from 500 to 900 Mev.

Charl François Naudé (Mechanical Engineering). *B.S., University of Stellerbosch, 1955; M.S., California Institute of Technology, 1957.* Thesis: On the Mechanism of Cavitation Damage by Non-Hemispherical Cavities Collapsing in Contact with a Solid Boundary.

Gerry Neugebauer (Physics). *B.A., Cornell University, 1954.* Thesis: The Ratio of Negative to Positive Pion Photoproduction from Deuterium by Photons with Energies between 500 and 1000 Mev.

Peter David Noerdlinger (Physics). *A.B., Harvard College, 1956.* Thesis: Stability of Uniform Plasmas.

Daniel Burrhus Olfe (Engineering Science). *B.S.E., Princeton University, 1957.* Thesis: Gas Emissivities and Radiative Transfer Studies.

Philip Moss Platzman (Physics). *S.B., Massachusetts Institute of Technology, 1956; M.S., California Institute of Technology, 1957.* Thesis: Meson-Theoretical Origin of the Two Body Spin Orbit Force.

Bimalendu Raychaudhuri (Geology). *B.Sc., Presidency College (Calcutta, India), 1948; M.Sc., 1951; M.S., California Institute of Technology, 1955.* Thesis: Studies of Amphibolites and Constituent Hornblendes from an Area of Progressive Metamorphism near Lead, South Dakota.

David Francis Rearick (Mathematics). *B.S., University of Florida, 1950; M.S., Adelphi College, 1956.* Thesis: Some Visibility Problems in Point Lattices.

Roy Earl Reichenbach (Mechanical Engineering). *B.M.E., Ohio State University, 1956; M.S., 1956.* Thesis: Combustion Research.

Eli Reshotko (Aeronautics). *B.M.E., The Cooper Union, 1950; M.M.E., Cornell University, 1951.* Thesis: Stability of the Compressible Laminar Boundary Layer.

Richard Earl Robertson (Chemistry). *B.A., Occidental College, 1955.* Thesis: I. Isotropic Nuclear Resonance Shifts. II. The Magnetic Resonance Properties of Some Sandwich Molecules.

Robert Dean Ryan (Mathematics). *B.S., California Institute of Technology, 1954.* Thesis: Fourier Transforms of Certain Classes of Integrable Functions.

Roy Ryosuke Sakaida (Chemical Engineering). *B.S., University of California at Los Angeles, 1953; M.S., California Institute of Technology, 1957.* Thesis: I. A study of the Catalytic Decomposition of Nitric Oxide. II. A Chromatographic Apparatus and Technique for the Analysis of Nitric Oxide in Nitrogen. III. Kinetics and Mechanism of the Air Oxidation of the Dithionite Ion (S_2O_4=) in Aqueous Solution.

Bertrand Alva Schoomer, Jr. (Chemistry). *B.S., Louisiana Polytechnic Institute, 1955.* Thesis: I. The Crystal Structure of Cyclohex-l-enylcyclobutenedione. II. The Crystal Structure of 3,6-dimethylpiperazine-2,5-dione. III. Programs for the Burroughs Model 205 Computer.

Henry Philip Schwarcz (Geology), *B.A., University of Chicago, 1952; M.S., California Institute of Technology, 1955.* Thesis: I. Geology of the Winchester-Hemet Area, Riverside County, California. II. Geochemical Investigations of an Arkosic Quartzite of the Winchester-Hemet Area, California.

John Robert Simmons (Biology). *B.S., Utah State Agricultural College, 1955; M.S., 1956.* Thesis: Studies on Amino Acid Incorporation in the Larvae of Drosophila Melanogaster.

Edward Harvey Simon (Biology). *B.S., Rutgers University, 1956.* Thesis: I. Transfer of DNA from Parent to Progeny Cell. II. A Study of the Possible Role of DNA in Viral RNA Synthesis during the Multiplication of an Animal Virus.

Dale Rodekohr Simpson (Geology). *B.S., Pennsylvania State University, 1956; M.S., California Institute of Technology, 1958.* Thesis: Geology of the Ramona Pegmatites, San Diego County, California.

Robert James Stanton, Jr. (Geology). *B.S., California Institute of Technology, 1953; M. A., Harvard University, 1956.* Thesis: Paleoecology of the Upper Miocene Castaic Formation, Los Angeles County, California.

William Albert Steyert, Jr. (Physics). *S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute of Technology, 1956.* Thesis: Effects of Ionic Couplings on Nuclear Alignment of Co^{58} in (Zn, Ni) $SiF_6.6H_2O$.

William Allen Strohl (Biology). *B.A., Lehigh University, 1955.* Thesis: Studies on the Modification, by Various Agents, of the Heat Sensitivity of Poliovirus.

Henry John Stumpf (Mechanical Engineering). *B.S., Newark College of Engineering, 1951; M.S., California Institute of Technology, 1957.* Thesis: Response of Mechanical Systems to Random Excitation.

Bradford Sturtevant (Aeronautics). *B.E., Yale University, 1955; M.S., California Institute of Technology, 1956.* Thesis: The Effusion of Charged Particles from a Shock Heated Gas.

Salvatore Philip Sutera (Mechanical Engineering). *B.M.E., Johns Hopkins University, 1954; M.S., California Institute of Technology, 1955.* Thesis: Streaming Birefringence as a Hydrodynamic Research Tool.

Raymond Leonard Taylor (Chemistry). *B.S., Brown University, 1955.* Thesis: I. A Study of Vibrational Relaxation in Carbon Monoxide by Shock-Waves and Infra-Red Emission. II. A study of the Effect of a Resonant Transfer of Energy on the Vibrational Relaxation of Gas Mixtures.

Howard M. Temin (Biology). *B.A., Swarthmore College, 1955.* Thesis: The Interaction of Rous Sarcoma Virus and Cells *in Vitro.*

Don Dean Thompson (Chemistry). *B.A., University of California at Riverside, 1956.* Thesis: I. Molecular Transfer of Non-equilibrium Nuclear Spin Magnetization. II. Electron Resonance of an Organic Free Radical in Zero Field.

Robert Charles Thompson (Mathematics). *B.A., University of British Columbia, 1954; M.A., 1956.* Thesis: Commutators in the Special and General Linear Groups.

Ben Robert Turner (Physics). *B.S., State College of Washington, 1955.* Thesis: A Study of Exploding Wires.

Walter D. Wales (Physics). *B.A., Carleton College, 1954; M.S., California Institute of Technology, 1955.* Thesis: Charged Photopion Production from Deuterium for Photon Energies Between 500 and 1000 Mev.

Paul Morris Weichsel (Mathematics). *B.S., The City College of New York, 1953; M.S., New York University, 1954.* Thesis: A Decomposition Theory for Finite Groups with Applications to P-Groups.

Tetsuo Yamane (Chemistry). *B.S., California Institute of Technology, 1956.* Thesis: I. Complexes of Mercury (I) with Polyphosphate and Dicarboxylate Anions and Mercury (II) Pyrophosphate Complexes. II. The Interaction of Mercuric Chloride with Deoxyribonucleic Acid.

Engineer's Degree

AERONAUTICAL ENGINEER

David Ellsworth Anderson. *B.S.A.E., West Virginia University, 1954; M.S., California Institute of Technology, 1958.*

David Max Wadsworth Lindquist, Lt. Col., U.S.A.F. *A.B., Grove City College, 1938.*

William Mohlenhoff, Lt. Cdr., U.S.N. *B.S., United States Naval Postgraduate School, 1959.*

Louis Robert Sarosdy, Lt., U.S.N. *B.S., United States Naval Academy, 1951; B.S.Ae., United States Naval Postgraduate School, 1959.*

Paul Wilson Utterback, Lt., U.S.N. *B.S., United States Naval Academy, 1951; B.S.Ae., United States Naval Postgraduate School, 1959.*

Allen Dean Williams, Lt., U.S.N. *B.S., United States Naval Academy, 1951; B.S.Ae., United States Naval Postgraduate School, 1959.*

MECHANICAL ENGINEER

Jerry Dice Griffith. *B.S., Michigan State University, 1955; M.S., 1957.*

Hans-Dieter Linhardt. *Dipl. Ing., Technische Hochschule (Munich), 1955.*

Master of Science in Science

ASTRONOMY

Dimitri Manuel Mihalas. *B.A., University of California, 1959.*

CHEMISTRY

William Phillip Helman. *B.S., California Institute of Technology, 1958.*
William Wendell Porterfield. *B.S., University of North Carolina, 1957.*

CHEMICAL ENGINEERING

Gerald Jack Arenson. *B.S., California Institute of Technology, 1959.*
Noundas Cocoltchos. *B.S., Worcester Polytechnic Institute, 1959.*
Robert Fredrick Cuffel. *B.S., Iowa State University, 1959.*
Edward Rae Held McDowell. *B.Ch.E., Cornell University, 1955.*
Eugene Byrd Nebeker. *B.S., Stanford University, 1959.*
Max Cotner Richardson. *B.S., University of Missouri, 1956.*
Stephen George Sawochka. *B.S., Purdue University, 1959.*
Irving George Snyder, Jr. *B.E., Yale University, 1959.*
William Frederick Wagner. *Ch.E., University of Cincinnati, 1959.*

GEOLOGY

Norman Sam Farha. *B.S., University of Kansas, 1958.*
Bevan Meredith French. *A.B., Dartmouth College, 1958.*
Richard Leroy Mauger. *B.S., Franklin and Marshall College, 1958.*
Garnett Howell Pessel. *B.S., California Institute of Technology, 1960.*
Fred Glenn Rueter. *B.S., University of Kansas, 1958.*
Christian Claude Weber. *Baccalauréat, Sciences Experimentales, Lycée Michelet, 1954; Lic. Sciences, Sorbonne, 1957.*

GEOCHEMISTRY

Noel William Hinners. *B. Sc., Rutgers University, 1958.*

GEOPHYSICS

Armando Cisternas. *I.C. de M., Universidad de Chile, 1958.*
Stéphane Dopp. *Dipl. d'Ing. Civil Electricien, 1955; Lic. Sciences Géologiques et Minéralogiques, Université Catholique de Louvain, 1959.*
Guy Emile Fayet. *Lic. Sciences Mathématiques, Université de Marseille, 1957; Dipl. d'Ing., Ecole Nationale Supérieure du Pétrole et des Moteurs, 1959.*
Clint Wellington Frasier. *B.S., California Institute of Technology, 1959.*
Jimmy Carl Larsen. *B.A., University of California, 1958.*
Mehmet Nafi Toksöz. *Gp.E., Colorado School of Mines, 1958.*

MATHEMATICS

William Dean Squire. *B.S., California Institute of Technology, 1950.*

PHYSICS

Thomas Mark Bieniewski. *B.S., University of Detroit, 1958.*
Richard Edwin Bradbury. *B.A., Johns Hopkins University, 1957.*
Berken Chang. *B.S., California Institute of Technology, 1958.*
Robert Ernest Diebold. *B.S., University of New Mexico, 1958.*
Howard Burt Greenstein. *Sc.B., Brown University, 1956.*
Ralph Fraley Miles, Jr. *B.S., California Institute of Technology, 1955.*
John Carl Nickel. *B.A., University of California, 1958.*

Master of Science in Engineering

AERONAUTICS

Bruce Allesina. *B.S., California Institute of Technology, 1959.*
Louis Joseph Alpinieri. *B.Ae.E., Polytechnic Institute of Brooklyn, 1957.*
William Leland Anderson, Jr. *B.A., 1958, B.S., University of Notre Dame, 1959.*
Vladimir Vadim Baicher. *B.S., California Institute of Technology, 1959.*
Woody Brofman. *B.Ae.E., Polytechnic Institute of Brooklyn, 1957.*
Thomas Safrit Davis. *B.M.E., 1957, M.S., North Carolina State College, 1960.*
Douglas Dean Duhon. *B.S., Louisiana State University, 1958.*
Kenneth Norman Easley. *B.S., University of Illinois, 1959.*
David Arthur Evensen. *B.S., Worcester Polytechnic Institute, 1959.*
Vittorio Fiorini. *Laurea in Ing. Industriale, Universita di Bologna, 1954; Laurea in Ing. Aeronautica, Politecnico di Torino, 1955.*
Gary Arnold Flandro. *B.S., University of Utah, 1957.*
James Joseph Geiger. *B.S., Purdue University, 1959.*
Matthew Morgan Grogan. *B.S., University of Notre Dame, 1958.*
Kenneth Edwin Harwell. *B.S., University of Alabama, 1959.*
Gilbert Arthur Hegemier. *B.E.S., Brigham Young University, 1959.*
Anthony Joseph Iorillo. *B.S., California Institute of Technology, 1959.*
Delbert Harold Jacobs. *B.S., United States Military Academy, 1955.*
Walter Adrian Johnson, Jr. *B.S., California Institute of Technology, 1959.*
Louis Kingsland, Jr. *B.S., United States Air Force Academy, 1959.*
James Howard Mauldin. *B.S., 1953, M.S., Georgia Institute of Technology, 1955.*
Maurice Mizrahi. *Dipl. d'Ing., Ecole Nationale Supérieure de l'Aéronautique, 1959.*
Peter Ernest Oettinger. *B.Agr.E., Cornell University, 1959.*
Ralph Bailey Owen. *B.A., Whitman College, 1959; B.S., California Institute of Technology, 1959.*
James Sibley Petty. *B.S., California Institute of Technology, 1959.*
Peter G. Simpkins. *Dipl. Northampton College of Advanced Technology, 1957; Dipl., Training Center for Experimental Aerodynamics, 1959.*
Timothy Lay Sullivan, *B.Ae.E., University of Detroit, 1959*
Evan Otto Weiner. *B.S., California Institute of Technology, 1959.*

CIVIL ENGINEERING

Eduardo Basso. *Ing. Civil, Universidad de Chile, 1953.*
Charles Edward Brockway. *B.S., University of Idaho, 1959.*

Henry Thomas Falvey. *B.C.E., Georgia Institute of Technology, 1958.*

Paul Christian Jennings. *B.S., Colorado State University, 1958.*

Richard Alvin Johnson. *B.S., California Institute of Technology, 1956.*

Jean Maurice Meuris. *Ing. Civil des Constructions, Université Libre de Bruxelles, 1957.*

Raymond Pittman, Jr. *B.S., University of Illinois, 1959.*

Allan Ray Porush. *B.S., California Institute of Technology, 1959.*

Wai Keung Tso. *B.Sc., University of London, 1959.*

ELECTRICAL ENGINEERING

Tracy Leon Atherton, Jr. *B.S., California Institute of Technology, 1958.*

Gordon Edward Baird. *B.S., California Institute of Technology, 1959.*

Thomas Brooke Ballard. *B.E.E., Rensselaer Polytechnic Institute, 1959.*

Richard Alan Baugh. *B.S., California Institute of Technology, 1959.*

Billy Rae Blanchard. *B.S., Louisiana Polytechnic Institute, 1959.*

Robert Eugene Chandos. *B.S., California Institute of Technology, 1959.*

René Clément Collette. *Ing. Civil A.I.Lg., 1957, Ing. Civil A.I.M., Université de Liège, 1958.*

Mert Cramer. *B.A., University of California, 1954; M.S., California Institute of Technology, 1959.*

Jacques de Barbeyrac Saint-Maurice. *Dipl. d'Ing., Ecole Nationale Supérieure de l'Aéronautique, 1959.*

Narsingh Deo. *B.Sc., Patna University, 1956; Dipl. I.I.Sc., Indian Institute of Science, 1959.*

Solomon De Picciotto. *B.S., California Institute of Technology, 1959.*

Harry Dym. *B.E.E., The Cooper Union, 1959.*

Ronald Alvin Forbess. *B.S., California Institute of Technology, 1959.*

Alain Nestor Genko. *Bachelier de l'enseignement secondaire, Université de Paris, 1955; Dipl. Ing., Ecole Supérieure d'Electricité, 1959.*

Egbert Graeve. *Dipl. Ing., Technische Hochschule Aachen, 1955.*

L. Dale Green. *B.S., California Institute of Technology, 1959.*

Rogers Wyman Harder. *B.S., California State Polytechnic College, 1959.*

Andres Oliver Holdo. *Ing. en Telecomunicaciones, Universidad de Buenos Aires, 1952.*

Gordon Frierson Hughes. *B.S., California Institute of Technology, 1959.*

William Norris Huse. *B.S., California Institute of Technology, 1959.*

Vladimir A. Khvostchinsky. *Ing. Dipl. Ecole Polytechnique de l'Université de Lausanne, 1954.*

Murray Arnold Koerner. *B.S., California Institute of Technology, 1959.*

Dennis Wayne Kuli. *B.S., California Institute of Technology, 1959.*

Jean Bernard Lagarde. *Dipl. d'Ing. Arts et Métiers, Ecole Nationale d'Ingénieurs Arts et Métiers, 1959.*

Robert Mark Lebovitz. *B.S., California Institute of Technology, 1959.*

Lanny Louis Lewyn. *B.S., California Institute of Technology, 1959.*

Richard Bruce MacAnally. *B.S., California Institute of Technology, 1959.*

Raymond Edward Magdaleno. *B.S., California Institute of Technology, 1959.*

Donald MacMurray Malone. *B.E.E., Cornell University, 1959.*

William Thomas Peters. *B.S., Duke University, 1959.*

Edward Richard Petersen. *B.Sc., University of Alberta. 1959*
James Rodney Pousson. *B.S., Southwestern Louisiana Institute, 1959.*
Ira Richer. *B.E.E., Rensselaer Polytechnic Institute, 1959.*
James Gordon Robins. *B.S., California Institute of Technology, 1955.*
William George Scheerer. *B.S., Syracuse University, 1959.*
John Joseph Schuster. *B.S., California Institute of Technology, 1959.*
Ivan Edward Sutherland. *B.S., Carnegie Institute of Technology, 1959.*
Terry Olin Teigen. *B.S., California Institute of Technology, 1959.*
Roger Allen Urban. *B.S., Carnegie Institute of Technology, 1959.*
William Louis Waggoner. *B.S., California Institute of Technology, 1959.*
William Yuh Wong. *B.S., California Institute of Technology, 1959.*

ENGINEERING SCIENCE

Gordon Kramer. *B.M.E., The Cooper Union, 1959.*

MECHANICAL ENGINEERING

Kenneth Hoyt Adams. *B.S., California Institute of Technology, 1959.*
Edward Raymond Bate, Jr. *B.S., California Institute of Technology, 1959.*
David Hastings Crimmins, Jr. *B.E.E., University of Detroit, 1957.*
Robert Dewey dePencier. *B.Sc., Queen's University, 1959.*
Edward George Gibson. *B.S., University of Rochester, 1959.*
Robert Goldstein. *A.B., Columbia College, 1958; B.S., Columbia School of Engineering, 1959.*
Pierre Eugène Joffres. *Dipl. d'Ing., Ecole Centrale des Arts et Manufactures, 1958.*
Charles Richard Johnson. *B.S., California Institute of Technology, 1959.*
Gerhard Joachim Klose. *B.S., California Institute of Technology, 1959.*
Karl Kent Knapp. *B.S., California Institute of Technology, 1959.*
Donald Arthur Kugath. *B.E.S., Brigham Young University, 1959.*
Richard Frederick Long. *B.S., California Institute of Technology, 1959.*
Thomas J. McGean. *B.M.E., New York University, 1959.*
Karl Louis Meier. *B.S., Washington University, 1959.*
Michael Edmond James O'Kelly. *B.E., National University of Ireland, 1958.*
John William Porter, Jr. *B.A., The Rice Institute, 1959.*
William Lewis Shackleford. *B.E., Yale University, 1959.*
Roy T. Stake. *B.S., California Institute of Technology, 1957.*
Alfred Henry Sturtevant, III. *B.S., California Institute of Technology, 1953.*
Lovic Pierce Thomas, III. *B.S., Clemson College, 1957.*
Harry Warren Townes. *Sc.B., Brown University, 1959.*
Donald Martin Wiberg. *B.S., California Institute of Technology, 1959.*
Jack Wireman. *B.S., University of Kentucky, 1958.*

Bachelor of Science in Science

Eric George Adelberger, Arlington, Virginia. *Physics.*
Donald Werner Anderson, Van Nuys, California. *Mathematics.*
Dean Wesley Anschultz, Lakewood, California. *Physics.*
Charles Edward Antoniak, San Diego, California. *Physics.*
William Barnes Arveson, San Gabriel, California. *Mathematics.*
David Saal Bailey, Denver, Colorado. *Physics.*
John Andress Bard, Winnetka, Illinois. *Mathematics.*
William Frank Benisek, Los Angeles, California. *Chemistry.*
Alan Paul Berg, Los Angeles, California. *Biology.*
Thomas Karl Bergstresser, Los Alamos, New Mexico. *Physics.*
Thomas Kieth Bjorklund, Phoenix, Arizona. *Geology.*
Neville Anthony Black, Hollywood, California. *Physics.*
Graeme Arden Blake, Portland, Oregon. *Physics.*
David Jordan Blakemore, Napa, California. *Physics.*
Pedro Bolsaitis, Caracas, Venezuela. *Chemical Engineering.*
Philip Russell Brooks, Hazel Crest, Illinois. *Chemistry.*
David William Butterfield, East Tawas, Michigan. *Physics.*
John Howland Campbell, Monrovia, California. *Biology.*
David Giske Cassel, Ainsworth, Nebraska. *Physics.*
Joseph Michael Cauley, Pasadena, California. *Physics.*
John Neale Cooper, San Antonio Texas. *Chemistry.*
Lawrence Everett Curfman, III, Wichita, Kansas. *Chemistry.*
Douglas James Dunham, La Canada, California. *Physics.*
Bradley Efron, St. Paul, Minnesota. *Mathematics.*
Michael Burt Engelberg, Los Angeles, California. *Astronomy.*
Dennis Charles Evans, Whittier, California. *Geology.*
James Lee Farmer, South Gate, California. *Chemistry.*
Jonathan Francis, Rochester, New York. *Chemistry.*
Robert Allen Fuller, Temple City, California. *Physics.*
Gary Charles Goodman, Mount Vernon, New York. *Astronomy.*
Walter Carl Gottschall, Jr., Pittburgh, Pennsylvania. *Chemistry.*
Fletcher Ivan Gross, La Canada, California. *Mathematics.*
Alfred Washington Hales, Pasadena, California. *Mathematics.*
Lester Larsen Hirst, Jr., Morgantown, West Virginia. *Physics.*
Leroy Edward Hood, Great Falls, Montana. *Biology.*
Ernest Alan Isaacs, Detroit, Michigan. *Physics.*
Gerald Roy Jantscher, Fontana, California. *Physics.*
David Kenoss Jefferson, Oakland, California. *Mathematics.*
Anthony Earl Johnson, Denver, Colorado. *Chemistry.*
Thomas Michael Jovin, Mexico City, Mexico. *Biology.*
Donald J. Krotser, Santa Cruz, California. *Geophysics.*
Allan Laderman, Los Angeles, California. *Physics.*
Ronald George Lawler, Seattle, Washington. *Chemistry.*

Students whose names appear in boldface type are being graduated with scholastic honor in accordance with a vote of the Faculty.

Michael Alfred Levine, Silver Spring, Maryland. *Physics.*
Erick LeRoy Lindman, Jr., Los Angeles, California. *Physics.*
Norman Ewen Maclean, San Marino, California. *Physics.*
Leonard Alvin Maley, Jr., Modesto, California. *Chemical Engineering.*
Jarold Alan Meyer, Glendale, Arizona. *Chemical Engineering.*
William Leo Mock, Santa Ana, California. *Chemistry.*
Loren Cameron Mosher, Santa Barbara, California. *Geology.*
John Herbert Munson, Burbank, California. *Physics.*
James Carr Nearing, Hawthorne, California. *Physics.*
James Kent Neeland, Silver Spring, Maryland. *Physics.*
Melvin King Neville, Tucson, Arizona. *Chemistry.*
Richard Allan Newcomer, La Verne, California. *Mathematics.*
Fred Luther Newman, Santa Monica, California. *Chemistry.*
David Harlan Nissen, Arcadia, California. *Chemistry.*
Jerald Vawer Parker, Portland, Oregon. *Physics.*
Gerald Albert Pearson, Redondo Beach, California. *Chemistry.*
Walter Eugene Pelton, Great Valley, New York. *Physics.*
Garnett Howell Pessel, Washington, D.C., *Geology.*
David Allen Resnik, Kenmore, New York. *Mathematics.*
John Robert Rix, Bay Village, Ohio. *Physics.*
Peter Roland Rony, Los Angeles, California. *Chemical Engineering.*
Daniel Ross, Tujunga, California. *Mathematics.*
Sidney Ronald Roth, Milwaukee, Wisconsin. *Biology.*
Stanley Arthur Sawyer, Seattle, Washington. *Mathematics.*
William Randall Schmus, Naperville, Illinois. *Geology.*
Wesley Loren Shanks, Northlake, Illinois. *Physics.*
Neil Rolfson Sheeley, Jr., Ridgewood, New Jersey. *Physics.*
John Shouse Shier, Golden, Colorado. *Physics.*
Paul Bundesen Skov, Lancaster, California. *Physics.*
James Christian Sorensen, Portland, Oregon. *Chemical Engineering.*
John Frederick South, Carlsbad, New Mexico. *Physics.*
Stephen Vinson Stephens, Falls Church, Virginia. *Physics.*
Thomas Henry Tebben, Whittier, California. *Chemistry.*
Robert Campbell Thompson, Larchmont, New York. *Biology.*
Michael Raymond Thomson, Pueblo, Colorado. *Physics.*
Laurence Munro Trafton, Los Angeles, California. *Astronomy.*
David Lawell Tucker, Jr., Long Beach, California. *Chemistry.*
John P. Van Dyke, Medford, Oregon. *Physics.*
Donald Herman Voet, Borger, Texas. *Chemistry.*
John Bradstreet Walsh, Tucson, Arizona. *Physics.*
Robert Thomas Walsh, Tucson, Arizona. *Physics.*
Robert LeRoy Wax, Berkeley, California. *Physics.*
Howard Louis Weisberg, Cleveland, Ohio. *Physics.*
Paul Richard Widess, Ft. Worth, Texas. *Physics.*
Stanley Gill Williamson, Santa Barbara, California. *Mathematics.*
John Marlin Wright, Mill Valley, California. *Chemistry.*
Gary Alan Zimmerman, Seattle, Washington. *Chemistry.*

BACHELOR OF SCIENCE IN ENGINEERING

Ronald Barthold Arps, Dallas, Texas. *Electrical Engineering.*
Brent Banta, Rolling Hills, California. *Civil Engineering.*
Stephen Michael Barro, Bronx, New York. *Electrical Engineering.*
Samuel Bergman, New York City, New York. *Electrical Engineering.*
Thomas Eugene Bowman, Burlingame, California. *Mechanical Engineering.*
Paul Robert Calaway, Pasadena, California. *Electrical Engineering.*
Martin Carnoy, Mexico City, Mexico. *Electrical Engineering.*
Robert Glenn Chamberlain, Los Altos, California. *Mechanical Engineering.*
Lowell Eugene Clark, Fort Collins, Colorado. *Electrical Engineering.*
Joseph Delma Cointment, Ill., Plaquemine, Louisiana. *Electrical Engineering.*
Frank Howard Cormia, Colorado Springs, Colorado. *Civil Engineering.*
William Keith Davis, Long Beach, California. *Electrical Engineering.*
George Allen Davison, Jr., San Bernardino, California. *Electrical Engineering.*
Kendal Lochridge Dinwiddie, San Rafael, California. *Mechanical Engineering.*
Robert Bruce Eglinton, South Pasadena, California. *Mechanical Engineering.*
Albert T. Funada, Silver Spring, Maryland. *Mechanical Engineering.*
Harold Lee Gier, Manhattan, Kansas. *Mechanical Engineering.*
Samuel Ginsburg, Tujunga, California. *Electrical Engineering.*
David Leonard Goff, Denver, Colorado. *Electrical Engineering.*
Robert Ray Golden, Phoenix, Arizona. *Mechanical Engineering.*
Anthony Paul Grande, San Pedro, California. *Electrical Engineering.*
William Franklin Greenman, Omaha, Nebraska. *Mechanical Engineering.*
Herman Guenther Hartung, Burbank, California. *Mechanical Engineering.*
Melvin E. Holland, Chino, California. *Civil Engineering.*
Richard Jenson, Berkeley, California. *Mechanical Engineering.*
Peter A. Johanson, Coon Rapids, Minnesota. *Electrical Engineering.*
Gerald Bryce Johnston, North Bend, Oregon. *Mechanical Engineering.*
Martin Alan Kaplan, Kansas City, Missouri. *Civil Engineering.*
Robert Ching-Yee Koh, Hong Kong. *Mechanical Engineering.*
Ronald Charles Kunzelman, Pasadena, California. *Electrical Engineering.*
Kelvin Shun Hung Lee, Hong Kong. *Electrical Engineering.*
Gordon David Long, Portland, Oregon. *Electrical Engineering.*
Michael Martin Mann, San Jose, California. *Electrical Engineering.*
Douglas Richard McLane, Hilo, Hawaii. *Mechanical Engineering.*
David Lee Mitchell, Seattle, Washington. *Mechanical Engineering.*
Meredith Burton Mitchell, Los Angeles, California. *Electrical Engineering.*
Carl Neracher Morris, San Diego, California. *Mechanical Engineering.*
Robert Lawrence Norton, Placerville, California. *Mechanical Engineering.*
Michael Holmes O'Malley, Agoura, California. *Electrical Engineering.*
John George Price, Van Nuys, California. *Electrical Engineering.*
Lannes S. Purnell, Ellensburg, Washington. *Electrical Engineering.*
Jan Rampacek, Omaha, Nebraska. *Electrical Engineering.*
Herman Lee Renger, Hermosa Beach, California. *Electrical Engineering.*
Arthur Myron Rubin, Chicago, Illinois. *Electrical Engineering.*
Kenneth Philip Scholtz, Ventura, California. *Electrical Engineering.*
William Alex Sinoff, Los Angeles, California. *Electrical Engineering.*

Keith Alan Taylor, Portland, Oregon. *Electrical Engineering.*
Louis Edmund Toth, Easton, Connecticut. *Mechanical Engineering.*
Samuel Banks Trotter, Darien, Connecticut. *Electrical Engineering.*
Gustav Nicholas Wassel, Alhambra, California. *Electrical Engineering.*
Frank Wight Weber, Pasadena, California. *Electrical Engineering.*
Lawrence Randolph Weill, Long Beach, California. *Electrical Engineering.*
Malcolm Lee Whitt, San Diego, California. *Civil Engineering.*
Gerald Gordon Wilhelmy, Los Angeles, California. *Electrical Engineering.*
Donald Clark Wilson, Jr., San Francisco, California. *Electrical Engineering.*
Martin Wolff, Downey, California. *Mechanical Engineering.*
James Alfred Wooster, Bartlesville, Oklahoma. *Mechanical Engineering.*

CANDIDATES FOR COMMISSIONS
UNITED STATES AIR FORCE
RESERVE OFFICERS' TRAINING CORPS

Robert Glenn Chamberlain

Harold Lee Gier

Harold Jenson

Douglas Richard McLane

Jarold Alan Meyer*

William Randall Schmus

Laurence Munro Trafton

**Distinguished Air Force Reserve Officers' Training Corps Graduate.*

The following candidates have completed all academic requirements, and will be commissioned 16 July 1960, upon completion of Summer Training.

Gerald Bryce Johnston

David Lee Mitchell

HONORS AND AWARDS

Honor Standing

The undergraduate students listed below have been awarded honor standing for the current year, on the basis of excellence of their academic records for the year 1959-60.

CLASS OF 1961

Bauer, W. R.	Huld, B.	Smith, T. B.
Benson, C. T.	Kleban, R. A.	Stark, H. M.
Brown, L. D.	Klein, S. A.	Thompson, R. S.
Elconin, T. H.	Leibovich, S.	Vogt, P. R.
Friedman, D.	Moler, C . B.	Wersel, O. A.
Hartwell, L. H.	Poe, R. F.	Wilkinson, J. F.
Hechler, S. H.	Ruecker, M. R.	Zaidins, C. S.
	Shampine, L. F.	

CLASS OF 1962

Armstrong, J. T., Jr.	Hughes, E. E., Jr.	Russ, J. C.
Baum, C. E.	Johnson, J. H.	Sallee, G. T.
Charette, W. P.	Kabakow, H. A.	Schultz, M. H.
Crow, S. C.	Kugler, L. D.	St. Cyr, G. J.
Eltgroth, P. G.	Lorden, G. A.	Taylor, L. J.
Emerson, W. R.	Manning, R. J.	Teitelman, W.
Fraley, G. S.	Miller, E. S.	Tenenbaum, J.
Gordon, B. A.	Mullin, F. E.	Thorne, K. S.
Hess, R. I.	Newmeyer, J. A.	Zacher, A. R.
Hogan, W. J.	Ruddick, R. C.	Zame, A.

CLASS OF 1963

Abarbanel, H. D.	Hill, R. C.	Plaut, R. H.
Alderson, D. J.	Letcher, J. S.	Prata, S. W.
Anderson, K. S.	Lindsey, J.H.	Robertson, R. S.
Barker, D. L.	Manly, K. F.	Rothschild, B. L.
Bender, E. A.	McCoy, B. M.	Shuey, R. T.
Causey, R. L.	Mekjian, A.	Stewart, H. A.
Couzin, D. I.	Morrow, J. A.	Thornber, K. K.
Dvornychenko, W.	Perlman, M. D.	Yellin, S. J.
Gershwin, L. K.		Young, R. H.

Frederic W. Hinrichs, Jr., Memorial Award

Awarded annually to "the senior who, in the opinion of the undergraduate Deans, has throughout his years at the Institute made the greatest contribution to the welfare of the student body and whose qualities of leadership, character and responsibility have been outstanding."

LEROY E. HOOD

Don Baxter, Inc. Prizes in Chemistry

Awarded to the three undergraduate students who during the year have carried out the best original researches in chemistry.

First Prize: PHILIP R. BROOKS

Second Prizes: JOHN N. COOPER
WILLIAM L. MOCK

Conger Peace Prize Oration

Established in 1912 by the late Everett D. Conger, D.D.

First Prize: DAVID JEFFERSON

Second Prize: CARL HAMILTON

Institute of the Aeronautical Sciences Scholastic Award

Awarded to the student member of the I.A.S. attaining the best scholastic record in engineering or the physical sciences.

MONTY D. COFFIN

David Joseph Macpherson Prize

Awarded annually for the winning essay in a contest open to Seniors in the Division of Engineering. The award is made in order to stimulate interest and excellence in written communication.

WILLIAM ALEX SINOFF

Mary A. Earle McKinney Prize in English

Established in 1946 by the late Samuel P. McKinney, M.D., as a memorial to his mother.

First Prize: LESTER LARSEN HIRST, JR.

Second Prize: DAVID K. EDWARDS

Third Prize: RAY C. BARGLOW

Don Shepard Award

Awarded annually to one or more outstanding residents of the Student Houses in order to pursue cultural opportunities which they might otherwise not be able to enjoy.

BEN GRAHAM BURKE

GARY ORVILLE WALLA

GENERAL INDEX