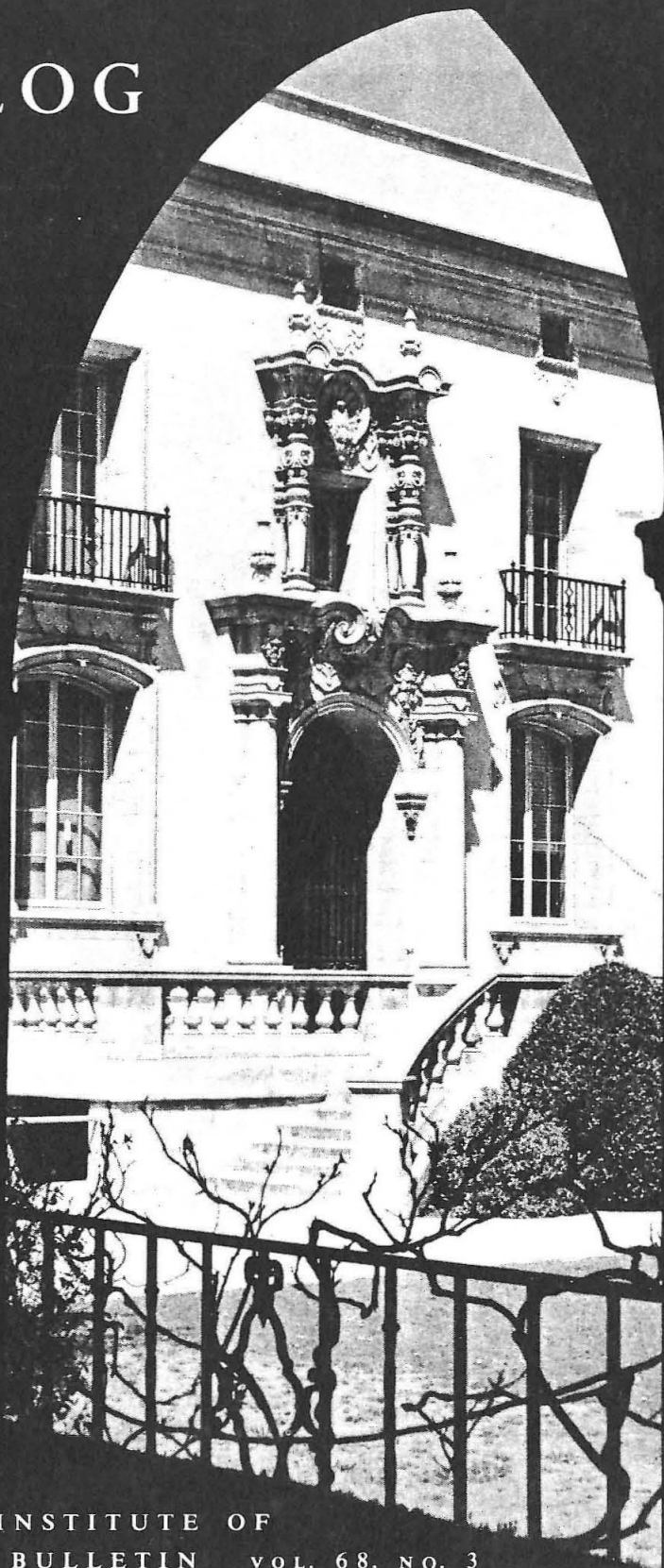


# CATALOG

1959-1960



CALIFORNIA INSTITUTE OF  
TECHNOLOGY BULLETIN VOL. 68, NO. 3

# 1959

SEPTEMBER							OCTOBER							NOVEMBER							DECEMBER						
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# 1960

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INSTITUTE OF TECHNOLOGY

Volume 68 Number 3

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CATALOG  
1959-1960



CALIFORNIA INSTITUTE  
OF TECHNOLOGY

PASADENA • CALIFORNIA

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# ACADEMIC CALENDAR

1959-60

1959

## FIRST TERM

September 24	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 24	Registration of students transferring from other colleges—8:00 a.m. to 12 noon.
September 24-26	Student Camp.
September 28	General Registration—8:30 a.m. to 3:30 p.m.
September 29	Beginning of instruction—8:00 a.m.
October 16	Last day for adding courses.
October 17	Examinations for the removal of conditions and incompletes.
October 24	Parent's Day.
November 2-7	Mid-Term Week.
November 7	MID-TERM.
November 9	Mid-Term deficiency notices due—9:00 a.m.
November 13	Last day for dropping courses.
November 13	French examination for admission to candidacy for degree of Doctor of Philosophy.
November 20	German examination for admission to candidacy for degree of Doctor of Philosophy.
November 23-27	Pre-registration for second term, 1959-60.
November 26-29	Thanksgiving recess.
November 26-27	Thanksgiving holidays for employees.
December 5	College entrance Board examinations for admission to the freshman class, September 1960.
December 14-18	Final examinations—first term, 1959-60.
December 18	Last day for admission to candidacy for the degree of Doctor of Philosophy in June 1960.
December 19	End of first term, 1959-60, 12M.
December 19-	
January 4	Christmas vacation.
December 24	One-half day holiday for employees.
December 25	Christmas holiday for employees.

1960

## SECOND TERM

January 1	New Year's holiday for employees.
January 2	Registration Committee—9:00 a.m.
January 4	General Registration—8:30 a.m. to 3:30 p.m.
January 5	Beginning of instruction—8:00 a.m.
January 9	College Entrance Board examinations for admission to the freshman class, September 1960. Scholastic Aptitude test only.
January 16	Student's Day.
January 22	Last day for adding courses.
January 23	Examinations for the removal of conditions and incompletes.
February 1-5	Mid-Term Week.
February 6	MID-TERM.
February 6	College Entrance Board examinations for admission to the freshman class, September 1960. Scholastic Aptitude test only.
February 8	Mid-Term deficiency notices due—9:00 a.m.
February 12	Last day for dropping courses.
February 12	French examination for admission to candidacy for the degree of Doctor of Philosophy.
February 19	German examination for admission to candidacy for the degree of Doctor of Philosophy.
February 22-26	Pre-registration for third term, 1959-60.
March 12	College Entrance Board examinations for admission to the freshman class, September 1960.

## 1960

## SECOND TERM

March 14-18	Final examinations—second term, 1959-60.
March 19	End of second term, 1959-60, 12M.
March 25	Registration Committee—9:00 a.m.
March 19-27	Spring Recess.

## 1960

## THIRD TERM

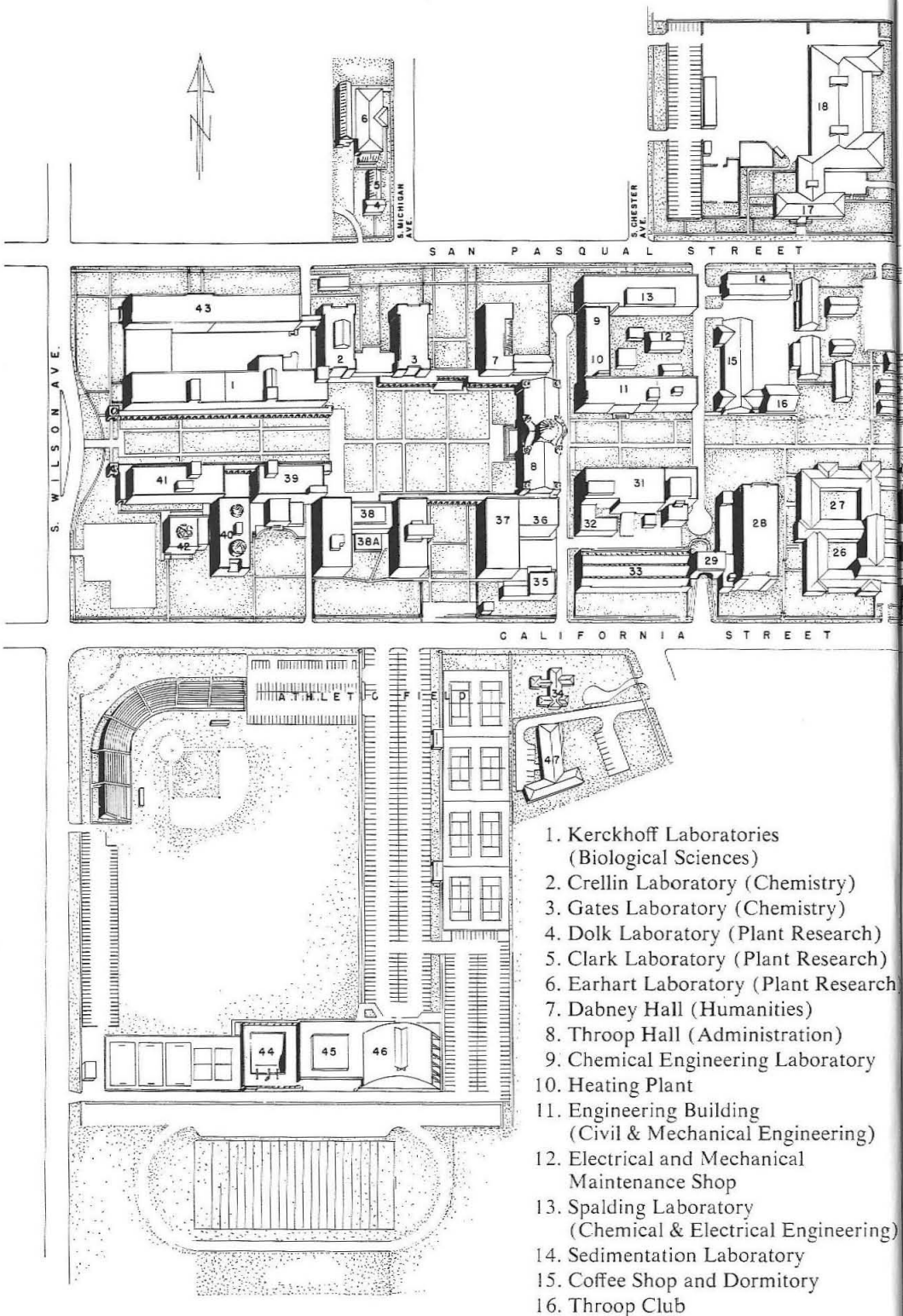
March 28	General Registration—8:30 a.m. to 3:30 p.m.
March 29	Beginning of instruction—8:00 a.m.
April 15	Last day for adding courses.
April 16	Examinations for the removal of conditions and incompletes.
April 25-30	Mid-Term Week.
April 30	Last day for obtaining admission to candidacy for Engineers' degrees.
April 30	MID-TERM.
May 2	Mid-Term deficiency notices due—9:00 a.m.
May 6	Last day for dropping courses.
May 6	French examination for admission to candidacy for the degree of Doctor of Philosophy.
May 13	German examination for admission to candidacy for the degree of Doctor of Philosophy.
May 16-20	Pre-registration for first term, 1960-61.
May 27	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy.
May 27	Last day for presenting theses for Engineers' degrees.
May 30	Memorial Day holiday.
May 30	Memorial Day holiday for employees.
May 31-June 3	Final examinations for senior and graduate students, third term, 1959-60.
June 3-4	Examinations for admission to upper classes, September 1960.
June 6-10	Final examinations for undergraduate students, third term.
June 8	Meetings of committees on Courses in Science and Engineering 10:00 a.m.
June 8	Faculty meeting—2:00 p.m.
June 9	Class Day.
June 10	Commencement.
June 11	End of third term, 1959-60, 12M.
June 17	Registration Committee—9:00 a.m.
July 4	Independence Day holiday for employees.

## 1960

## FIRST TERM, 1960-61

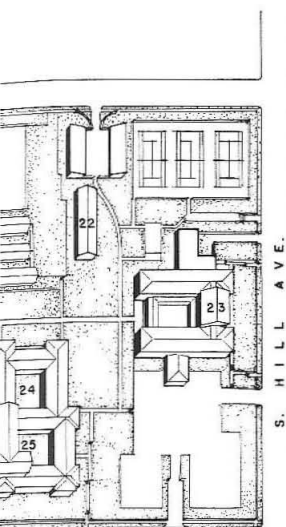
September 5	Labor Day holiday for employees.
September 22	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 22	Registration of students transferring from other colleges—8:00 a.m. to 12 noon.
September 22-24	Student Camp.
September 26	General Registration—8:30 a.m. to 3:30 p.m.
September 27	Beginning of instruction—8:00 a.m.

# CAMPUS · CALIFORNIA





# 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.

- |   |   |
|---|---|
| 17. Physical Plant Office   | 34. Arden House   |
| 18. Physical Plant Shops  | 35. Receiving Room & Central Warehouse  |
| 19. Bldg. T-1 (Y.M.C.A.; Air Force ROTC; Sanitary Engineering Laboratory) | 36. Kellogg Laboratory (Physics)  |
| 20. Bldg. T-2 (Offices and Graduate Students' Studies)                    | 37. Alfred P. Sloan Laboratory of Mathematics and Physics (formerly High Voltage Research Laboratory) |
| 21. Building T-3  | 38. Bridge Laboratory (Physics)   |
| 22. Building T-4  | 39. Arms Laboratory (Geological Sciences)   |
| 23. Athenaeum   | 40. Robinson Laboratory (Astrophysics)  |
| 24. Ricketts House  | 41. Mudd Laboratory (Geological Sciences)   |
| 25. Blacker House   | 42. Culbertson Hall (Auditorium; Industrial Relations)  |
| 26. Dabney House  | 43. Church Laboratory (Chemical Biology)  |
| 27. Fleming House   | 44. Alumni Swimming Pool  |
| 28. Synchrotron Laboratory  | 45. Locker Rooms  |
| 29. Merrill Wind Tunnel   | 46. Scott Brown Gymnasium   |
| 30. Cosmic Ray Laboratory   | 47. Archibald Young Health Center   |
| 31. Guggenheim Aeronautical Laboratory                                    |   |
| 32. Hydrodynamics Laboratory  |   |
| 33. Central Engineering Machine Shop                                      |   |



# Section I

## CALIFORNIA INSTITUTE OF TECHNOLOGY OFFICERS AND FACULTY

### BOARD OF TRUSTEES

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James R. Page, *Honorary Chairman*

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John O'Melveny .....	<i>Vice-President</i>
Shannon Crandall, Jr. ....	<i>Vice-President</i>
John E. Barber .....	<i>Vice-President and Treasurer</i>
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Robert B. Gilmore .....	<i>Asst. Comptroller and Asst. Secretary</i>

L. A. DuBridge

*President of the California Institute*

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*(Arranged in order of seniority of service with dates of first election)*

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James R. Page (1931) .....	<i>Los Angeles</i>
William C. McDuffie (1933) .....	<i>Santa Barbara</i>
Albert B. Ruddock (1938) .....	<i>Santa Barbara</i>
P. G. Winnett (1939) .....	<i>Los Angeles</i>
John O'Melveny (1940) .....	<i>Los Angeles</i>
Norman Chandler (1941) .....	<i>Los Angeles</i>
Keith Spalding (1943) .....	<i>Pasadena</i>
Lee A. DuBridge (1947) .....	<i>Pasadena</i>
Edward R. Valentine (1948) .....	<i>San Marino</i>
Leonard S. Lyon (1950) .....	<i>Los Angeles</i>
Elbridge H. Stuart (1950) .....	<i>Bel Air</i>
Harry J. Volk (1950) .....	<i>Los Angeles</i>
Arnold O. Beckman (1953) .....	<i>Altadena</i>
Charles S. Jones (1953) .....	<i>Pasadena</i>
John E. Barber (1954) .....	<i>Pasadena</i>
Lawrence A. Williams (1954) .....	<i>San Marino</i>
Robert L. Minckler (1954) .....	<i>Pasadena</i>
Howard G. Vesper (1954) .....	<i>Oakland</i>
Shannon Crandall, Jr. (1955) .....	<i>Pasadena</i>
F. Marion Banks (1955) .....	<i>San Marino</i>
Herbert L. Hahn (1955) .....	<i>Pasadena</i>
Richard R. Von Hagen (1955) .....	<i>Encino</i>
Earle M. Jorgensen (1957) .....	<i>Los Angeles</i>
John Simon Fluor (1958) .....	<i>Santa Ana</i>
Lindley C. Morton (1959) .....	<i>Pasadena</i>
John G. Braun (1959) .....	<i>Pasadena</i>

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L. A. DuBridge  
Herbert L. Hahn  
William C. McDuffie  
Robert L. Minckler

John O'Melveny  
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<i>Civil, Electrical, and Mechanical Engineering and Aeronautics</i> ..	Frederick C. Lindvall
<i>Geological Sciences</i> .....	Robert P. Sharp
<i>Humanities</i> .....	Hallett D. Smith
<i>Physics, Mathematics, and Astronomy</i> .....	Robert F. Bacher

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<i>Dean of Graduate Studies</i> .....	Frederick Bohnenblust
<i>Dean of Admissions</i> .....	L. Winchester Jones
<i>Dean of Students</i> .....	Paul C. Eaton
<i>Dean of Freshmen</i> .....	Foster Strong

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<i>Director of Personnel</i> .....	James Ewart
<i>Director of Physical Plant</i> .....	Wesley Hertenstein
<i>Manager of Graphic Arts</i> .....	Lowell E. Peterson
<i>Patent Officer</i> .....	J. Paul Youtz
<i>Purchasing Agent</i> .....	K. A. Jacobson
<i>Safety Engineer</i> .....	Charles W. Easley

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<i>Assistant Secretary</i> .....	R. B. Gilmore
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<i>Director of Athletics and Physical Education</i> .....	Harold Z. Musselman
<i>Director of Health Services</i> .....	Richard F. Webb, M.D.
<i>Director of Institute Libraries</i> .....	Roger F. Stanton
<i>Director of Undergraduate Scholarships</i> .....	L. Winchester Jones
<i>Assistant Director of Admissions</i> .....	Peter M. Miller
<i>Director of Placements</i> .....	Donald S. Clark
<i>Director of News Bureau</i> .....	James R. Miller
<i>Editor of Engineering and Science Monthly</i> .....	Edward Hutchings, Jr.
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<i>Master of Student Houses</i> .....	Robert A. Huttenback
<i>Superintendent of the Guggenheim Aeronautical Laboratory</i> .....	Wm. H. Bowen



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1959-60

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*Vice-Chairman:* J. W. DuMond

*Secretary:* G. W. Housner

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

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

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MUSICAL ACTIVITIES—*Mead*, Dulbecco, Duwez, Erdelyi, Frodsham, Gilbert, Hudson, Ingersoll, Lagerstrom.

NOMINATIONS—*Watson*, Beadle, Bohnenblust, DuMond, Eaton, Housner, Jones, Niemann, Sharp, Strong.

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REGISTRATION—*Langmuir*, Dean, Eaton, Hammond, Hudson, Huttenback, Jones, Leighton, Lewis, Maxstadt, Press, Strong.

## 14 *Officers and Faculty*

RELATIONS WITH SECONDARY SCHOOLS—*Sutton*, 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, Sabersky, Taylor, 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*, Apostol, Dean, Eaton, Haagen-Smit, Huttenback, Langmuir, H. Martel, Sabersky, Strong, Sutton, Sweezy, Waser, Wood.

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

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

USE OF THE ATHLETIC CENTER—*Lindvall*, D. S. Clark, Eaton, Green, Hertenstein, 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. . . . . *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*  
 Norman H. Horowitz, 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*

### VISITING PROFESSORS

Robert L. Bandurski, Ph.D. . . . . *Biology*  
 Boris Ephrussi, D.Sc. . . . . *Biology*  
 Jerome Lejeune, M.D. . . . . *Biology*  
 Willis E. Pequegnat, Ph.D. . . . . *Zoology*

### RESEARCH ASSOCIATES

Gordon A. Alles, Ph.D. . . . . *Biology*  
 Esther Bogen, Ph.D., M.D. . . . . *Biology*  
 Henry O. Eversole, M.D. . . . . *Plant Physiology*  
 Gustave Freeman,<sup>1</sup> M.D. . . . . *Biology*  
 Albert E. Longley,<sup>2</sup> Ph.D. . . . . *Biology*  
 William S. Stewart, Ph.D. . . . . *Biology*  
 Jean J. Weigle, Ph.D. . . . . *Biophysics*

### SENIOR RESEARCH FELLOWS

Jacob W. Dubnoff, Ph.D. . . . . *Biology*  
 Henry Hellmers,<sup>3</sup> Ph.D. . . . . *Biology*  
 Geoffrey L. Keighley, Ph.D. . . . . *Biology*  
 Marguerite Vogt, M.D. . . . . *Biology*

<sup>1</sup>Stanford Research Institute

<sup>2</sup>U. S. Department of Agriculture

<sup>3</sup>U. S. Forest Service

\*On leave of absence in 1959-60

## GOSNEY FELLOWS

Harriet Ephrussi-Taylor, Ph.D.	<i>Biology</i>
Alfred Gierer, Ph.D.*	<i>Biology</i>
Inge Rasmussen, Ph.D.*	<i>Biology</i>

## RESEARCH FELLOWS

Gordon Alderton, <sup>1</sup> M.S.	Peter Lowy, Doctorandum
Harbans L. Arora, Ph.D.	William D. McBride, <sup>17</sup> D.D.S.
Giuseppe Attardi, M.D.	Alexander Miller, <sup>11</sup> Ph.D.
Albert Boeye, <sup>2</sup> D.Sc.*	Mary B. Mitchell, M.A.
Joseph E. Bogen, <sup>3</sup> M.D.	David L. Nanney, <sup>10</sup> Ph.D.*
Valentin H. Bonifas, <sup>4</sup> M.D.*	David Norman, Ph.D.
Hans J. Burkhardt, Ph.D.	Granville Norton, <sup>18</sup> Ph.D.*
Joseph Butros, <sup>5</sup> Ph.D.	Masahiro Ogaki, <sup>10</sup> D.Sc.
Edward A. Carusi, <sup>6</sup> Ph.D.	Eiji Ohnishi, B.S.
Oswaldo Caso, <sup>7</sup> D.Sc.*	Kenneth Paigen, Ph.D.*
Pen Ching Cheo, Ph.D.	Thomas O. Perry, <sup>10</sup> Ph.D.
Margaret Chipchase, Ph.D.	Lajos Piko, <sup>20</sup> D.V.M.
Lionel Crawford, <sup>8</sup> Ph.D.	R. L. C. Pilgrim, <sup>5</sup> Ph.D.
John H. Curme, <sup>9</sup> Ph.D.	Richard L. Potter, Ph.D.
Rowland H. Davis, <sup>10</sup> Ph.D.	Albert E. Purcell, <sup>1</sup> Ph.D.
Andree Dubert, Ph.D.	Lise Quirsin-Thiry, <sup>21</sup> M.D.
Jean-Marie Dubert, <sup>8</sup> M.D.	John A. Romberger, <sup>22</sup> Ph.D.
Robert S. Edgar, <sup>3</sup> Ph.D.	Elizabeth S. Russell, <sup>15</sup> Ph.D.*
Richard H. Epstein, <sup>11</sup> Ph.D.*	Clifford S. Sato, Ph.D.
Marguerite Fling, Ph.D.	John D. Smith, Ph.D.
Mitchell E. Glickstein, <sup>11</sup> Ph.D.	Robert G. Stanley, <sup>22</sup> Ph.D.
Clyde R. Goodheart, <sup>12</sup> M.D.	Peter Starlinger, <sup>23</sup> M.D.*
Bertrand F. Harrison, <sup>13</sup> Ph.D.*	G. P. Steinbauer, <sup>24</sup> Ph.D.*
Francis A. Haskins, <sup>14</sup> Ph.D.*	M. G. P. Stoker, <sup>5</sup> M.D.*
Harry R. Highkin, Ph.D.	Alfred S. Sussman, <sup>10</sup> Ph.D.
Donald E. Hoard, <sup>11</sup> Ph.D.	J. Herbert Taylor, <sup>15</sup> Ph.D.*
George M. Hughes, Ph.D.*	Lloyd P. Tevis, Jr., B.A.
Homer Jacobson, <sup>15</sup> Ph.D.	Paul O. P. Ts'o, Ph.D.
Hendrik J. Ketellapper, Ph.D.	Harold B. Tukey, <sup>10</sup> Ph.D.
Hildegard Lamfrom, Ph.D.	Gordon Von Abrams, <sup>25</sup> B.S.*
James A. Lockhart, Ph.D.	Yasushi Watanabe, <sup>26</sup> Ph.D.
John B. Loefer, <sup>16</sup> Ph.D.	

1U. S. Department of Agriculture

2Belgian-American Educational Foundation Fellow

3National Research Council Fellow

4St. Louis University School of Medicine

5National Academy of Sciences Fellow

6Jane Coffin Childs Memorial Fund for Medical Research Fellow

7Argentine National Research Council Fellow

8Rockefeller Foundation Fellow

9Campbell Soup Company

10National Science Foundation Fellow

11U. S. Public Health Service Fellow

12American Cancer Society Fellow

13Brigham Young University

14University of Nebraska

15John Simon Guggenheim Memorial Foundation Fellow

16U. S. Department of the Navy, Office of Naval Research

17U. S. Public Health Service

18W. K. Kellogg Foundation Fellow

19Osaka University

20Lalor Foundation Fellow

21Pasteur Institute, Belgium

22U. S. Forest Service

23German National Research Council Fellow

24Michigan State College

25Peterson-Dering

26International Cooperation Administration Fellow

\*In residence 1958-59

GRADUATE FELLOWS AND ASSISTANTS, 1958-59

Peter Albersheim, B.S.  
Dennis Barrett, A.B.  
Harris Bernstein, B.S.  
Thomas A. Cole, B.A.  
Cedric I. Davern, M.Sc.Agr.  
Paul H. Deal, A.B.  
Benjamin S. Friesen, M.A.  
George D. Guthrie, A.B.  
Charles R. Hamilton, B.S.  
Boyd A. Hardesty, M.S.  
Robert L. Heath, S.M.  
Jacob V. Maizel, M.S.  
Dennis R. McCalla, M.Sc.  
Martin Mendelson, A.B.  
Eduardo Orias, M.S.

Alan P. Roberts, B.A.  
Ann Roller, M.S.  
Donald C. Shreffler, M.S.  
John R. Simmons, M.S.  
Edward H. Simon, B.S.  
Richard F. Squires, B.S.  
William A. Strohl, B.A.  
F. William Studier, B.S.  
Millard Susman, A.B.  
Howard M. Temin, B.A.  
Guy A. Thompson, Jr., B.S.  
Colwyn B. Trevarthen, M.Sc.  
Robert A. Weisberg, A.B.  
David Zipser, B.S.

## DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

Ernest H. Swift, *Chairman*J. H. Sturdivant, *Executive Officer*

## PROFESSORS EMERITI

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

## PROFESSORS

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

## RESEARCH ASSOCIATES

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

## ASSOCIATE PROFESSORS

Paul A. Longwell, Ph.D. ....	<i>Chemical Engineering</i>
Cornelius J. Pings, Ph.D. ....	<i>Chemical Engineering</i>
G. Wilse Robinson, Ph.D. ....	<i>Physical Chemistry</i>

## SENIOR RESEARCH FELLOWS

Marjorie C. Caserio, Ph.D. ....	<i>Chemistry</i>
Justine S. Garvey, Ph.D. ....	<i>Chemistry</i>
Richard E. Marsh, Ph.D. ....	<i>Chemistry</i>
Chester M. McCloskey, Ph.D. ....	<i>Chemistry</i>
H. Hollis Reamer, M.S. ....	<i>Chemical Engineering</i>
Kenneth N. F. Shaw, Ph.D. ....	<i>Chemistry</i>
William G. Sly, Ph.D. ....	<i>Chemistry</i>

\*On leave of absence 1959-60



## VISITING ASSOCIATES

Jerome A. Berson, <sup>1</sup> Ph.D. ....	<i>Chemistry</i>
Joseph A. Duke, S.J., <sup>2</sup> Ph.D. ....	<i>Chemistry</i>
Robert B. Fischer, Ph. D. ....	<i>Chemistry</i>
Henry G. Kuivila, <sup>1,3</sup> Ph.D. ....	<i>Chemistry</i>
Paul R. Shafer, <sup>2</sup> Ph.D. ....	<i>Chemistry</i>
Otis L. Updike, <sup>2</sup> Ph.D. ....	<i>Chemistry</i>
Harold E. Wilcox, <sup>2</sup> Ph.D. ....	<i>Chemistry</i>

## ASSISTANT PROFESSORS

Fred C. Anson, Ph.D. ....	<i>Analytical Chemistry</i>
Robert M. Mazo, Ph.D. ....	<i>Physical Chemistry</i>
Matthew S. Meselson, Ph.D. ....	<i>Physical Chemistry</i>
John H. Richards, Ph.D. ....	<i>Organic Chemistry</i>
George Neal Richter, Ph.D. ....	<i>Chemical Engineering</i>

## INSTRUCTOR

David H. Klein, Ph.D. ....	<i>Chemistry</i>
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## RESEARCH FELLOWS

Albert C. Claus,* Ph.D.	Uma Sankar Nandi, D.Phil.
Ricardo deC. Ferreira, <sup>4</sup> L.Docente	Ernst J. Peterli, Ph.D.
Gideon Fraenkel, Ph.D.	John A. Petruska, M.Sc.
Elvira Goettsch,* M.D.	Richard E. Pincock, <sup>8</sup> Ph.D.
Howard W. Gould,* Ph.D.	Dorothy Redlich, Ph.D.
Melvin W. Hanna, <sup>5</sup> Ph.D.	Mark N. Rerick, Ph.D.
George E. Hein, Ph.D.	Don Ridgeway, Ph.D.
Arthur A. Hirata, <sup>5</sup> Ph.D.	Robert G. Rinker, Ph.D.
Karst Hoogsteen, D.Sc.	Sten Samson, Fil. Lic.
William T. Jackson, Ph.D.	Eugene I. Snyder, Ph.D.
Richard T. Jones, M.D.	Richard H. Stanford, Jr., Ph.D.
Russell T. Jordan, Ph.D.	Dieter H. Sussdorf, <sup>9</sup> Ph.D.
Lois M. Kay, M.S.	Harry Svensson,* Ph.D.
Karl R. Kopecky, Ph.D.	Ignatius L. Trapani, Ph.D.
Roland Lefebvre, <sup>6</sup> Ph.D.	Wilton E. Vannier, <sup>10</sup> M.D., Ph.D.
William J. Link, <sup>5</sup> Ph.D.	John Warkentin,* Ph.D.
Andrew D. McLachlan, <sup>7</sup> Ph.D.	Donald A. Wright, Ph.D.
Walter M. Meier, Ph.D.	Malcolm R. Wright, Ph.D.
Denise M. Meyer, D.Sc.	Chin-Hua Wu, Ph.D.
Kuppuswamy Nagarajan, Ph.D.	Emile Zuckerkandl, Ph.D.

<sup>1</sup>National Science Foundation Senior Postdoctoral Fellow<sup>2</sup>National Science Foundation Science Faculty Fellow<sup>3</sup>John Simon Guggenheim Memorial Foundation Fellow<sup>4</sup>Rockefeller Foundation Fellow<sup>5</sup>National Science Foundation Postdoctoral Fellow<sup>6</sup>Fellow of the Centre National de la Recherche Scientifique<sup>7</sup>Harkness Fellow of the Commonwealth Fund<sup>8</sup>Associate of the Air Force Office of Scientific Research<sup>9</sup>United States Public Health Service Fellow<sup>10</sup>Staff Member, National Institute of Allergy and Infectious Diseases

\*In residence during 1958-59

## GRADUATE FELLOWS AND ASSISTANTS, 1958-59

- Henry I. Abrash, A.B.  
 Harold R. Almond, Jr., B.S.  
 William F. Beach, B.S.  
 Louis N. Bathish, B.A.  
 Stuart B. Berger, B.A.  
 Ernest R. Boller, B.Sc.  
 Frank B. Booth, M.S.  
 J. Philip Bromberg, S.B.  
 John C. Carney, M.S.  
 Robert E. Carter, A.B.  
 Henry H. Dearman, B.S.  
 Robert S. Deverill, B.S.  
 William F. Dove, Jr., A.B.  
 Alan Emanuel, B.S.  
 Rolf Engleman, Jr., B.S.  
 Grover L. Farrar, B.S.  
 Louis D. Ferretti, B.A.  
 Robert P. Foss, B.A.  
 Donald C. Garwood, B.A.  
 Concetto R. Giuliano, B.S.  
 Thomas P. Gordon, M.S.  
 R. Clive Greenough, S.B.  
 David W. Hall, B.S.  
 Björn W. B. Hansen, Cand. Real.  
 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.  
 Neilen W. Hultgren, B.S.  
 William D. Hutchinson, M.S.  
 Albert Hybl, B.A.  
 James B. Ifft, B.S.  
 Kenneth E. Johnson, B.S.  
 Richard T. Jones, M.D.  
 John J. Kalvinskis, S.M.  
 Glenn L. Keldsen, B.S.  
 Philip R. Kennicott, B.S.  
 James W. Kessel, B.S.  
 Edgar F. Kiefer, B.S.  
 Donald M. King, B.S.  
 William Kozicki, M.A.Sc.  
 Abraham N. Kurtz, M.A.  
 Alvin L. Kwiram, B.A.  
 James D. Lamb, B.S.  
 Peter A. Leermakers, B.A.  
 Milton I. Levenberg, B.S.  
 Raymond P. Lutz, M.S.  
 William B. Mather, Jr., A.B.  
 Richard B. McGriff, B.S.  
 Arthur W. Merkl, B.S.  
 Hugh T. Millard, Jr., B.A.  
 Lawrence K. Montgomery, B.S.  
 Carleton B. Moore, B.S.  
 William M. Moore, B.A.  
 Francis G. Moses, B.A.  
 J. Eric Nordlander, B.A.  
 Carole L. Olson, B.S.  
 Manuel Panar, B.Sc.  
 James M. Peterson, B.S.  
 William W. Porterfield, B.S.  
 Odell F. Raper, B.S.  
 Robert G. Rinker, M.S.  
 Richard E. Robertson, B.A.  
 James S. Rode, B.S.  
 Ronald E. Rolfe, M.D.  
 Charles D. Russell, S.B.  
 Roy R. Sakaida, M.S.  
 B. Alva Schoomer, Jr., B.S.  
 David I. Schuster, B.A.  
 Clayton S. Smith, B.S.  
 Himan Sternlicht, B.S.  
 Robert F. Stewart, B.A.  
 Raymond L. Taylor, B.S.  
 Don D. Thompson, B.A.  
 Richard S. Tunder, B.S.  
 John R. Valbert, B.S.  
 Janis Vasilevskis, B.S.  
 Emilio C. Venezian, B.Eng.  
 Martin Vogel, B.S.  
 John Walden, B.Ch.E.  
 Frederic A. Wallace, A.B.  
 Yui-Loong Wang, M.S.  
 James H. Waters, S.B.  
 John P. Wolf III, B.A.  
 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. ....	<i>Mechanical and Hydraulic Engineering</i>
Aladar Hollander, M.E. ....	<i>Mechanical Engineering</i>
William W. Michael, B.S. ....	<i>Civil Engineering</i>
Royal W. Sorensen, E.E., D.Sc. ....	<i>Electrical Engineering</i>
Theodore von Kármán, Ph.D., Dr. Ing., Sc.D., LL.D., Eng. D. ....	<i>Aeronautics</i>

PROFESSORS

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

RESEARCH ASSOCIATES

Simon Ramo, Ph.D. ....	<i>Electrical Engineering</i>
Octavio G. de Souza Ricardo, D.I.C. ....	<i>Aeronautics</i>

ASSOCIATE

Henry Dreyfuss ....	<i>Industrial Design</i>
---------------------	--------------------------

\*Leave of absence

## ASSOCIATE PROFESSORS

Allan J. Acosta, Ph.D. ....	<i>Mechanical Engineering</i>
Norman H. Brooks, Ph.D. ....	<i>Civil Engineering</i>
Francis S. Buffington, Sc.D. ....	<i>Mechanical Engineering</i>
Thomas K. Caughey, Ph.D. ....	<i>Applied Mechanics</i>
Donald E. Coles, Ph.D. ....	<i>Aeronautics</i>
Charles E. Crede, M.S. ....	<i>Mechanical Engineering</i>
Albert T. Ellis, Ph.D. ....	<i>Applied Mechanics</i>
Joel N. Franklin, Ph.D. ....	<i>Applied Mechanics</i>
Roy W. Gould, Ph.D. ....	<i>Electrical Engineering</i>
Charles D. Hendricks, Jr., Ph.D. ....	<i>Electrical Engineering</i>
Alfred C. Ingersoll, Ph.D. ....	<i>Civil Engineering</i>
Harold Lurie, Ph.D. ....	<i>Applied Mechanics</i>
Caleb W. McCormick, Jr., M.S. ....	<i>Civil Engineering</i>
Hardy C. Martel, Ph.D. ....	<i>Electrical Engineering</i>
Francis W. Maxstadt, Ph.D. ....	<i>Electrical Engineering</i>
Robert D. Middlebrook, Ph.D. ....	<i>Electrical Engineering</i>
Julius Miklowitz, Ph.D. ....	<i>Applied Mechanics</i>
Dino A. Morelli, Ph.D. ....	<i>Applied Mechanics</i>
Anatol Roshko, Ph.D. ....	<i>Aeronautics</i>
Rolf H. Sabersky, Ph.D. ....	<i>Mechanical Engineering</i>
Howell N. Tyson, B.S. ....	<i>Mechanical Engineering and Engineering Graphics</i>
Thad Vreeland, Jr., Ph.D. ....	<i>Mechanical Engineering</i>
Max L. Williams, Jr., Ph.D. ....	<i>Aeronautics</i>
David S. Wood, Ph.D. ....	<i>Mechanical Engineering</i>
Theodore Y. Wu, Ph.D. ....	<i>Applied Mechanics</i>

## SENIOR RESEARCH FELLOWS

Paul J. Blatz, Ph.D. ....	<i>Aeronautics</i>
Charles R. Illingworth, B.A. (Camb.) ....	<i>Aeronautics</i>
Saul Kaplun, Ph.D. ....	<i>Aeronautics</i>
Jack L. Kerrebrock, Ph.D. ....	<i>Jet Propulsion</i>
Hans D. Krumhaar, Dr., D.Sc. ....	<i>Aeronautics</i>
Haruo Takeyama, Ph.D. ....	<i>Engineering</i>
Sitaram Rao Valluri, Ph.D. ....	<i>Aeronautics</i>

## ASSISTANT PROFESSORS

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

## RESEARCH FELLOWS

Dang Dinh Ang, Ph.D. ....	<i>Aeronautics</i>
Robert Asimow, Ph.D. ....	<i>Engineering</i>

I-dee Chang, Ph.D. ....	<i>Aeronautics</i>
Ellis Cumberbatch, Ph.D. ....	<i>Applied Mechanics</i>
Anthony Demetriades, Ph.D. ....	<i>Aeronautics</i>
Kinzo Hida, D.Sc. ....	<i>Aeronautics</i>
Ièuan R. Jones, Ph.D. ....	<i>Engineering</i>
Arthur F. Messiter, Ph.D. ....	<i>Aeronautics</i>
Robert Nathan, Ph.D. ....	<i>Electrical Engineering</i>
John L. Wilson, Ph.D. ....	<i>Aeronautics</i>
David B. Wittry, Ph.D. ....	<i>Engineering</i>
Shih-Cheng Zien, Dr.Ing. ....	<i>Aeronautics</i>

## INSTRUCTORS

Robert L. Harder, M.S. ....	<i>Electrical Engineering</i>
Kenneth Lock, M.S. ....	<i>Electrical Engineering</i>
Peter V. Mason, M.S. ....	<i>Electrical Engineering</i>
Carver A. Mead, M.S. ....	<i>Electrical Engineering</i>

## GRADUATE FELLOWS AND ASSISTANTS

1958-59

Frank Addison Albini, B.S.	Roger K. Farrar, B.S.
William Judson Anderson, M.S.	Donald Charles Forster, M.S.
Richard Michael Aron, M.S.	Alan K. Forsythe, B.S.
John Frederick Asmus, B.S.	Andre Jean Pierre Fossard, Dipl.Ing..
Boris Auksmann, M.S.	Nick George, M.S.
Charles Dwight Babcock, Jr., M.S.	Herbert S. Glick, M.Ae.E.
Victor Cyriel E. Baekelandt, C.E.	Roger M. Golden, M.S.
Andrew B. Bauer, M.Sc.	Jacek Piotr Gorecki, Dipl.Ing.
Robert H. Bond, B.S.	Jerry Dice Griffith, M.S.
Gary Delane Boyd, M.S.	Michel Pierre Guillemet, Dipl.Ing.
Wilbur Brown, M.S.E.	Andrew Guttman, M.S.
George M. Canova, B.S.	Armando Hamel-Armengolli, C.E.
I-dee Chang, M.S.	Lance G. Hays, B.S.
Carl S. Christensen, B.S.A.E.	William H. Heiser, M.S.
Ronald A. Christensen, B.S.E.E.	Robert H. Hertel, S.B.
Thomas F. Clancy, B.S.M.E.	Robert Hickling, M.Sc.
William Kent Clarkson, B.S.E.	Din-Yu Hsieh, M.Sc.
Rene C. L. A. Collette, Ing.Civil A.I.M.	Herbert E. Hunter, M.S.
Daniel J. Collins, M.S.	Izzat Muhammad Idriss, B.C.E.
Joseph Michael Colucci, B.S.	Marcos Intaglietta, M.S.
Glenn L. Converse, B.S.	Edgar Towar Irons, B.S.E.
Richard K. Cooper, B.S.	Wilfred D. Iwan, M.S.
Michael A. Cowan, M.S.	Earl D. Jacobs, M.S.
Richard T. Cowley, B.S.	Orval E. Jones, M.S.
Brinton S. Deighton, Jr., B.Ch.E.	John F. Kennedy, M.S.
Harold R. Dessau, M.S.	Jirair L. Kevorkian, M.A.E.
Charles W. Dickinson, S.B.	William J. Klenk, M.S.
John I. Dick-Peddie, B.S.	Wolfgang Gustav Knauss, B.S.
Aldo Gene Di Loreto, M.S.	Akira Kobayashi, B.E.
Georges Duvaut, Lic.es Sci.	Kalman I. Kraskow, B.Eng.
Michel Abel Ebertin, M.S.	Daniel J. Krause, B.Met.E.
Everett T. Eiselen, M.S.	Robert J. Kwik, M.E.
Arvid Lennart Ejewall, C.E.	Theodore E. Lang, M.S.
George F. Engelke, B.S.	Raymond W. Latham, B.Eng.
Viktor Evtuhov, M.S.	Kaye Don Lathrop, B.S.

## 24 Officers and Faculty

Joseph L. Le May, B.E.E.  
 Alfred G. Lieberman, B.S.  
 Chung-Yen Liu, M.S.  
 James R. Lloyd, M.S.  
 Kenneth Lock, M.Sc.  
 Yen-Mow Lynn, M.S.  
 Gerald A. Marxman, B.A.  
 Malcolm McColl, M.S.  
 William True McDonald, M.S.  
 Robert J. McElvain, B.S.  
 Bruce T. McKeever, B.S.  
 Chiang-Chung Mei, M.S.  
 Remi-Noel J. R. Menegaux, Ing.  
 Howard C. Merchant, S.M.  
 Roger Edwin Messick, M.S.  
 Kenneth M. Mitzner, S.B.  
 Harry Moerjono, B.S.  
 Didier Morane, Ing.  
 Richard Stephen Muller, M.S.  
 Moratagere B. Murarappa, B.E.  
 Xavier Felix Namy, Ing.  
 Charl Francois Naude, M.S.  
 Henri L. Neuville, Dip.E.E.  
 Richard C. Neville, B.S.  
 Gordon C. Oates, M.Sc.  
 Daniel Burrhus Olfe, B.S.E.  
 Patrick Gerard O'Regan, B.E.  
 Jerry Clifford Peck, M.S.  
 Max Bruno Peltier, Ing.  
 Elliot Neil Pinson, S.M.  
 Francoise Renee Pioline, Dipl.

Bernard Charles Reardon, B.E.  
 Eli Reshotko, M.M.E.  
 Xavier M. Rouvillois, Ing.Civ.  
 David A. Russell, M.S.  
 Richard Allan Schapery, M.S.  
 Robert Max Schmidt, S.B.  
 Andrew Charles Sergi, B.Ch.E.  
 Yun-Yuan Shi, M.Sc.  
 Fred Ichiro Shimabukuro, S.M.  
 Michael Stewart Shumate, M.S.E.  
 Alex Shumka, M.S.  
 Joe Nelson Smith, Jr., B.S.  
 Lawrence Shepard Smith, B.S.  
 Peter Raymond Smith, B.S.  
 Alan Soler, B.S.  
 Jack Justin Stiffler, M.S.  
 Wilfried E. Stockmair, Ing.  
 Edwin Jule Stofel, M.S.  
 Henry John Stumpf, M.S.  
 Salvatore Philip Sutera, M.S.  
 Robert L. Tambling, Jr., B.S.  
 Robert Hugh Taylor, M.S.  
 Robert E. Tokheim, B.S.  
 Richard R. Tracy, M.S.  
 Charles W. VanAtta, M.S.E.  
 Frank Lee Vernon, Jr., M.S.  
 George C. Vlases, B.S.  
 Duen-pao Wang, M.S.  
 Neng-Ming Wang, M.S.  
 James Norman Weaver, B.S.

### DIVISION OF THE GEOLOGICAL SCIENCES

Robert P. Sharp, *Chairman*

Ian Campbell, *Executive Officer*

Frank Press, *Director of the Seismological Laboratory*

### PROFESSOR EMERITUS

Beno Gutenberg, Ph.D. .... *Geophysics*

### PROFESSORS

Hugo Benioff, Ph.D. .... *Seismology*  
 Harrison S. Brown, Ph.D. .... *Geochemistry*  
 \*Ian Campbell, Ph.D. .... *Geology*  
 Charles Hewitt Dix, Ph.D. .... *Geophysics*  
 \*\*Albert E. J. Engel, Ph.D. .... *Geology*  
 Samuel Epstein, Ph.D. .... *Geochemistry*  
 Richard H. Jahns, Ph.D. .... *Geology*  
 Heinz A. Lowenstam, Ph.D. .... *Paleoecology*  
 James A. Noble, Ph.D. .... *Economic Geology*  
 Frank Press, Ph.D. .... *Geophysics*  
 \*\*Charles F. Richter, Ph.D. .... *Seismology*  
 Robert P. Sharp, Ph.D. .... *Geology*

°Leave of absence, 1959

°°Leave of absence, 1959-60



## VISITING PROFESSORS

Arden L. Albee, Ph.D. ....	<i>Geology</i>
Henry W. Menard, Ph.D. ....	<i>Submarine Geology</i>
John F. Nye, Ph.D. ....	<i>Glaciology</i>
George W. Wetherwill, Ph.D. ....	<i>Geochemistry</i>

## ASSOCIATE PROFESSORS

Clarence R. Allen, Ph.D. ....	<i>Geology</i>
Gennady W. Potapenko, <sup>1</sup> Ph.D. ....	<i>Geophysics</i>
Gerald J. Wasserburg, Ph.D. ....	<i>Geology</i>

## SENIOR RESEARCH FELLOWS

Charles R. McKinney, B.S. ....	<i>Geochemistry</i>
Claire C. Patterson, Ph.D. ....	<i>Geochemistry</i>

## ASSISTANT PROFESSORS

Egon T. Degens, Ph.D. ....	<i>Geology</i>
W. Barclay Kamb, Ph.D. ....	<i>Geology</i>
Leon T. Silver, Ph.D. ....	<i>Geology</i>
Hugh P. Taylor, Jr., Ph.D. ....	<i>Geology</i>

## RESEARCH FELLOWS

Keiiti Aki, Ph.D. ....	<i>Geophysics</i>
Michael I. Behr, Ph.D. ....	<i>Geophysics</i>
Admar Cervellini, Ing.Agron. ....	<i>Geochemistry</i>
Sankar K. Datta, Ph.D. ....	<i>Geology</i>
Margaret B. Davis, Ph.D. ....	<i>Pollen Analysis</i>
Trevor Hatherton, Ph.D. ....	<i>Geophysics</i>
Dolly Ledent, Ph.D. ....	<i>Geochemistry</i>

## CURATOR OF MINERALOGY

William C. Oke .....	<i>Mineralogy</i>
----------------------	-------------------

## GRADUATE FELLOWS AND ASSISTANTS, 1958-59

Shelton Alexander, B.S.	R. Michael Lloyd, M.S.
Don L. Anderson, B.S.	Richard L. Mauger, B.S.
Philip O. Banks, S.B.	Francis C. McMichael, B.S.
Carl S. Benson, M.S.	Harvey Meyer, B.A.
William Chapple, M.S.	Carleton B. Moore, B.S.
James E. Conel, M.S.	Robert C. Newton, M.A.
Edward J. Cotter, B.S.	Gerald D. Pollock, M.S.
James P. Dodd, A.M.	Dean C. Presnall, B.S.
Bruce R. Doe, M.S.	Bimalendu Raychaudhuri, M.S.
Michael B. Duke, B.S.	James H. Richardson, B.S.
Bevan M. French, A.B.	Henry P. Schwarcz, M.S.
Richard H. Frische, M.S.	Robert V. Shull, B.S.
Roy J. Greenfield, B.S.	Dale R. Simpson, M.S.
M. Grant Gross, A.B.	Stewart W. Smith, B.S.
P. Edgar Hare, M.S.	Robert J. Stanton, M.S.
David G. Harkrider, M.A.	Hugh P. Taylor, M.S.
T. Neil Irvine, M.S.	M. Nafi Toksoz, Gph.Eng.
Marvin A. Lanphere, M.S.	Kenneth Watson, B.A.
Jimmy C. Larsen, B.S.	John C. Wilson, M.S.
Nelson Liberman, M.A.	Robert E. Zartman, B.S.

<sup>1</sup>Member of the Division of Physics, Mathematics, and Astronomy

## DIVISION OF THE HUMANITIES

Hallett D. Smith, *Chairman*

## PROFESSORS EMERITI

John R. MacArthur, Ph.D. ....	<i>Languages</i>
George R. MacMinn, A.B. ....	<i>English</i>

## PROFESSORS

Harvey Eagleson, Ph.D. ....	<i>English</i>
Horace N. Gilbert, M.B.A. ....	<i>Business Economics</i>
Robert D. Gray, B.S. ....	<i>Industrial Relations</i>
Hunter Mead, Ph.D. ....	<i>Philosophy and Psychology</i>
Rodman W. Paul, Ph.D. ....	<i>History</i>
Hallett D. Smith, Ph.D. ....	<i>English</i>
Roger Stanton, Ph.D. ....	<i>English</i>
Alan R. Sweezy, Ph.D. ....	<i>Economics</i>
Ray E. Untereiner, Ph.D. ....	<i>Economics</i>

## VISITING PROFESSOR

Robert J. Allen, Ph.D. ....	<i>English</i>
-----------------------------	----------------

## ASSOCIATE

Michael T. Wermel, Ph.D. ....	<i>Industrial Relations</i>
Sidney Kingsley, A.B. ....	<i>English</i>

## ASSOCIATE PROFESSORS

Paul Bowerman, A.M. ....	<i>Languages</i>
Melvin D. Brockie, Ph.D. ....	<i>Economics</i>
Charles E. Bures, Ph.D. ....	<i>Philosophy</i>
J. Kent Clark, Ph.D. ....	<i>English</i>
James C. Davies, <sup>1</sup> Ph.D. ....	<i>Political Science</i>
Paul C. Eaton, A.M. ....	<i>English</i>
David C. Elliot, Ph.D. ....	<i>History</i>
L. Winchester Jones, A.B. ....	<i>English</i>
Beach Langston, <sup>1</sup> Ph.D. ....	<i>English</i>
H. Dan Piper, Ph.D. ....	<i>English</i>
Alfred Stern, Ph.D. ....	<i>Languages and Philosophy</i>
Cushing Strout, Ph.D. ....	<i>History</i>
John R. Weir, Ph.D. ....	<i>Psychology</i>

## LECTURERS

Charles K. Ferguson, Ed.D. ....	<i>Psychology</i>
Edward Hutchings, Jr. ....	<i>Journalism</i>
Robert Huttenback, Ph.D. ....	<i>History</i>
Alexander Kosloff, Ph.D. ....	<i>Russian</i>
Peter Miller, Ph.D. ....	<i>English</i>

## VISITING LECTURERS

Robert A. Burton, B.A. ....	<i>International Affairs</i>
Edward A. Bayne, Ph.D. ....	<i>International Affairs</i>
Charles F. Gallagher, B.A. ....	<i>International Affairs</i>
K. H. Silvert, Ph.D. ....	<i>International Affairs</i>

<sup>1</sup>On leave of absence, 1959-60

## ASSISTANT PROFESSORS

Heinz Ellersieck, Ph.D. ....	History
Peter Fay, Ph.D. ....	History
George P. Mayhew, Ph.D. ....	English

## INSTRUCTORS

Arnold M. Paul, Ph.D. ....	History
David Smith, M.A. ....	English
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. ....	Mathematics
John G. Bolton, B.A. ....	Radio Astronomy
R. F. Christy, Ph.D. ....	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. . .	<i>Richard Chace Tolman Professor of Theoretical Physics</i>
William A. Fowler, Ph.D. ....	Physics
Murray Gell-Mann, <sup>1</sup> 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. ....	Physics
Fritz Zwicky, Ph.D. ....	Astrophysics

<sup>1</sup>On leave of absence

## VISITING PROFESSORS

G. Bailey Price, Ph.D. ....	<i>Mathematics</i>
Fred Hoyle, M. A. ....	<i>Addison White Greenway Visiting Professor of Astronomy</i>

## RESEARCH ASSOCIATES

T. M. Cherry, Ph.D., Sc.D., F.R.S. ....	<i>Mathematics</i>
Russell A. Fisher, Ph.D. ....	<i>Physics</i>
Harry A. Kirkpatrick, Ph.D. ....	<i>Physics</i>
Olga T. Todd, Ph.D. ....	<i>Mathematics</i>

## ASSOCIATE PROFESSORS

T. M. Apostol, Ph.D. ....	<i>Mathematics</i>
Charles A. Barnes, Ph.D. ....	<i>Physics</i>
Felix Boehm, Ph.D. ....	<i>Physics</i>
Eugene W. Cowan, Ph.D. ....	<i>Physics</i>
Richard A. Dean, Ph.D. ....	<i>Mathematics</i>
F. Brock Fuller, Ph.D. ....	<i>Mathematics</i>
Alexander Goetz, Ph.D. ....	<i>Physics</i>
Maarten Schmidt, Ph.D. ....	<i>Astronomy</i>
Alvin V. Tollestrup, Ph.D. ....	<i>Physics</i>
Ward Whaling, Ph.D. ....	<i>Physics</i>

## VISITING ASSOCIATE PROFESSORS

M. Altman, Ph.D. ....	<i>Mathematics</i>
Russell G. Athay, Ph.D. ....	<i>Astronomy</i>
J. D. Weston, Ph.D. ....	<i>Mathematics</i>

## SENIOR RESEARCH FELLOWS

Ricardo Gomez, Ph.D. ....	<i>Physics</i>
Ralph W. Kavanagh, Ph.D. ....	<i>Physics</i>
Thomas A. Matthews, Ph. D. ....	<i>Radio Astronomy</i>
Andrew R. Mitchell, Ph.D. ....	<i>Mathematics</i>
James A. Roberts, Ph.D. ....	<i>Radio Astronomy</i>
Gordon J. Stanley, Dipl.E.E. ....	<i>Radio Astronomy</i>
John M. Teem, Ph.D. ....	<i>Physics</i>

## ASSISTANT PROFESSORS

W. A. J. Luxemburg, Ph.D. ....	<i>Mathematics</i>
Jon Mathews, Ph.D. ....	<i>Physics</i>
James E. Mercereau, Ph.D. ....	<i>Physics</i>
J. B. Oke, Ph.D. ....	<i>Astronomy</i>
Vincent Z. Peterson, <sup>1</sup> Ph.D. ....	<i>Physics</i>
Foster Strong, M.S. ....	<i>Physics</i>
Calvin H. Wilcox, <sup>1</sup> Ph.D. ....	<i>Mathematics</i>

## INSTRUCTOR

Helge Skovgaard, M.Sc. ....	<i>Mathematics</i>
-----------------------------	--------------------

## RESEARCH FELLOWS

Stanley Bashkin, Ph.D. ....	<i>Physics</i>
Richard E. Block, <sup>2</sup> Ph.D. ....	<i>Mathematics</i>
Hugh Burkhardt, Ph.D. ....	<i>Theoretical Physics</i>

<sup>1</sup>On leave of absence<sup>2</sup>Harry Bateman Research Fellow

Ralph Dressel, Ph.D. ....	Physics
Ulrich Hauser, Ph.D. ....	Physics
Dale F. Hebbard, Ph.D. ....	Physics
Maurice Jacob, Lic.Sc. ....	Physics
Joe H. Mullins, Ph.D. ....	Physics
Richard E. Norton, <sup>1</sup> Ph.D. ....	Theoretical Physics
Othmar Preining, Ph.D. ....	Physics
Charles E. Roos, Ph.D. ....	Physics
V. Radhakrishnan, B.Sc. ....	Radio Astronomy
Cornelius van del Leun, Ph.D. ....	Physics
Thomas R. Waite, Ph.D. ....	Physics
Walter Watson, Ph.D. ....	Physics
H. A. Weidenmuller, Ph.D. ....	Physics
G. Westerhout, Ph.D. ....	Radio Astronomy

#### LECTURERS

Robert W. Hellwarth, Ph.D. ....	Physics
---------------------------------	---------

#### GRADUATE FELLOWS AND ASSISTANTS, 1958-59

Norman W. Albright, B.S.	James L. C. Ford, Jr., B.A.
Raymond W. Allard, Jr., B.A.	Lyman J. Fretwell, Jr., B.S.
Ethan D. Alyea, Jr., A.B.	George Gerson, B.S.
John P. Andelin, Jr., B.S.	Victor Gilinsky, B.E.Ph.
Hugh R. Anderson, B.A.	Murlin F. Gillis, B.S.
R. Keith Bardin, B.S.	Howard B. Greenstein, Sc.B.
Sam M. Berman, M.S.	David E. Groce, B.S.
Thomas M. Bieniewski, B.S.	Donald E. Groom, A.B.
Harry H. Bingham, Jr., A.B.	Daniel A. Guinier, Lic. es Sci.Phys.
Harvey H. Bird, M.S.	Gerhard E. Hahne, B.S.
Ronald Blum, S.M.	Daniel E. Harris, M.S.
Alan G. Bodine, B.S.	Thomas M. Helliwell, B.A.
Thomas K. Boehme, M.S.	Henry H. Hilton III, M.S.
James H. Boyden, M.S.	Charles R. Hobby, M.S.
Richard E. Bradbury, B.A.	Klaus Hoechsmann, M.S.
Howard M. Brody, M.S.	John L. Honsaker, B.S.
Ronald E. Brown, B.S.	Elisha R. Huggins, B.S.
William D. Burnett, B.S.	Richard O. Hundley, B.S.
David G. Byles, B.S.	Carl K. Iddings, B.A.
Berken Chang, B.S.	Earl D. Jacobs, M.S.
David B. Chang, B.S.	Joseph R. Kilner, B.S.
James T. Chang, B.S.	Tatsuro Kodama, M.S.
Marvin Chester, B.S.	Thomas R. Koehler, B.S.
Donald D. Clayton, B.S.	Andrew S. Lebor, B.S.
Richard L. Cohen, B.A.	Arnold V. Lesikar, B.A.
Sidney R. Coleman, B.S.	Michael J. Levine, B.S.
Donald G. Coyne, B.S.	Paul Levine, M.S.
Peter L. Crawley, B.S.	Robert L. Luttermoser, M.S.
Melvin D. Daybell, B.S.	Robert J. Macek, B.S.
William E. Dibble, B.S.	John O. Maloy, B.S.
Robert E. Diebold, B.S.	J. Howard Marshall III, B.S.
Franklin P. Dixon, M.S.	James A. McCray, M.S.
Richard Dolen, B.E.Ph.	James E. Mercereau, M.S.
John J. Domingo, B.S.	John J. Merrill, M.S.
Donald F. DuBois, B.A.	F. Curtis Michel, B.S.
Ian M. Duck, M.Sc.	James E. Midgley, B.S.E.
W. Farrell Edwards, M.S.	Ralph F. Miles, Jr., B.S.
Christian A. Engelbrecht, B.Sc.	Catalin D. Mitescu, B.E.Ph.
Victor A. Erma, M.A.	Alan T. Moffet, B.A.
Thornton R. Fisher, B.A.	Norton L. Moise, M.A.

<sup>1</sup>Richard Chace Tolman Research Fellow

Fernando B. Morinigo, B.S.  
 Arthur H. Muir, Jr., M.S.  
 Joe H. Mullins, M.S.  
 Henry R. Myers, M.S.  
 Gerry Neugebauer, A.B.  
 John Carl Nickel, B.A.  
 Peter D. Noerdlinger, A.B.  
 Thomas W. Noonan, B.S.  
 M. Emery Nordberg, Jr., B.S.  
 Harris A. Notarys, S.B.  
 Robert H. Norton, B.S.  
 Robert W. Noyes, B.A.  
 Jack C. Overly, S.B.  
 Peter D. M. Parker, B.A.  
 Robert A. R. 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. Pollock, M.S.  
 R. Darden Powers, M.S.  
 Andrew P. Proudian, B.S.  
 Richard B. Read, B.S.  
 David F. Rearick, M.S.  
 James H. Renken, M.Sc.  
 John R. Rice, M.S.  
 Rogers, John D., M.S.  
 Henry Ruderman, B.S.  
 Howard C. Rumsey, B.S.

Robert D. Ryan, B.S.  
 Philip A. Seeger, B.A.  
 Lionel S. Senhouse, M.S.  
 Edward J. Seppi, B.S.  
 Jon Hardy Shirley, A.B.  
 George W. Simon, A.B.  
 Richard K. Sloan, M.S.  
 Theodore W. Speiser, B.S.  
 John R. Stevens, B.A.  
 William A. Steyert, M.S.  
 D. Gary Swanson, B.S.  
 Richard M. Talman, M.A.  
 Terence C. Terman, M.S.  
 John R. Thomas, B.S.  
 Robert C. Thompson, M.A.  
 Ben Turner, B.S.  
 John R. Trollope, M.S.  
 Lorin L. Vant-Hull, M.S.  
 Joseph L. Vogl, Jr., A.B.  
 Mark H. Wagner, A.B.  
 William G. Wagner, B.S.  
 Walter D. Wales, M.S.  
 Paul M. Weichsel, M.S.  
 Robert L. Wildey, B.S.  
 Kenneth G. Wilson, A.B.  
 Robert W. Wilson, B.A.  
 William M. Woodruff, M.S.  
 Joshua T. Yamada, B.A.  
 Norman J. Zabusky, S.M.

MOUNT WILSON AND PALOMAR OBSERVATORIES  
*Operated Jointly with the Carnegie Institution of Washington*

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

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 Robert F. Bacher

Jesse L. Greenstein  
 Rudolph L. Minkowski  
 Earnest C. Watson

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.

Rudolph L. Minkowski, 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

Geoffrey R. Burbidge, Ph.D.	Satoshi Matsushima, Ph.D.
Alastair G. W. Cameron, Ph.D.	Evry Schatzman, Ph.D.
H. Lawrence Helfer, Ph.D.	

RESEARCH FELLOWS IN ASTRONOMY

Walter K. Bonsack, Ph.D.	George W. Preston, Ph.D.
E. Margaret Burbidge, Ph.D.	Alexander W. Rodgers, Ph.D.
Giuseppa de Strobel Cayrel, D.Sc.	W. L. W. Sargent, Ph.D.
Roger Cayrel, Ph.D.	Gerhard Traving, Ph.D.
Alercio M. Gomes, B.Sc.	Carlos M. Varsavsky, Ph.D.
Colin S. Gum, Ph.D.	George Wallerstein, Ph.D.
Jun Jugaku, Ph.D., D.Sc.	Ray Weymann, Ph.D.
Abrahao de Moraes, Ph.D.	

ENGINEERS

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

PROFESSOR

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

ASSISTANT PROFESSORS

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

ASSISTANTS

M/Sgt. Leon E. Bemis  
T/Sgt. Willard J. Garner  
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, B.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.  
John Lamb

Dennis V. Long, M.S.  
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., *Assistant Research Director,  
Benefits and Insurance Research Center*  
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*

L. W. Martin, M.D. . . . . *Institute Physician*  
N. Y. Matossian, M.D. . . . . *Institute Physician*  
R. Stewart Harrison, M.D. . . . . *Consultant in Radiology*  
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

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B.S., Oregon State College, 1939; M.S., 1941. Chemist, U.S. Department of Agriculture, Western Regional Research Laboratory, Albany, California, 1941-. California Institute, 1958-59.

Clarence Roderic Allen, Ph.D., *Associate Professor of Geology*

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Robert Joseph Allen, Ph.D., *Visiting Professor of English*

A.B., University of Illinois, 1923; A.M., Harvard University, 1928; Ph.D., 1929. Professor; Chairman, Department of English, Williams College, 1949-. California Institute, 1959-60.

Gordon Albert Alles, Ph.D., *Research Associate in Biology*

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Ph.D., University of Tashkent, 1948. Professor of Mathematics; Chief, Section of Numerical Analysis, Polish Academy of Sciences, 1957-. California Institute, 1958-59.

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*

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B.S., University of Chicago, 1946; M.S., 1947; Ph.D., 1949. Associate Professor of Botany, Michigan State University, 1954-. Research Fellow, California Institute, 1950-52; Senior Research Fellow, 1952-53; Visiting Professor, 1959.

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B.S., Columbia University, 1940; M.S., 1941; Ph.D., Purdue University, 1952. Professor; Head, Department of Chemical Engineering, Rose Polytechnic Institute, 1953-. California Institute, 1958-59.

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American Universities Field Staff. California Institute, 1954; 1955; 1959.

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Eric Temple Bell, Ph.D., *Professor of Mathematics, Emeritus*

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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.) 811 West Inverness Drive.

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B.S., City College of New York, 1944; M.A., Columbia University, 1947; Ph.D., 1949. Professor of Chemistry, University of Southern California, 1958-. California Institute, 1959-60.

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- Richard E. Block, Ph.D., *Bateman Research Fellow in Mathematics*  
A.B., University of Chicago, 1949; S.B., 1950; S.M., 1952; Ph.D., 1956. California Institute, 1959-60.
- 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.
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M.B., University of Cincinnati, 1926; M.D., 1927; M.S., 1929; Ph.D., 1935. California Institute, 1947-. Suite 11, 1700 Brooklyn Avenue, Los Angeles.
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A.B., Whittier College, 1949; M.D., University of Southern California, 1956. California Institute, 1958-. (336 Kerckhoff) 432 San Pasqual Drive, Alhambra.
- 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; 256-A Church) 1798 North Pepper Drive.
- 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) 701 South Catalina Avenue.
- Valentin Henri Bonifas, M.D., *Research Fellow in Biology*  
M.D., University of Geneva, 1951. Head, Virus Laboratory, University of Geneva, 1955-. California Institute, 1958.
- 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.
- Walter Karl Bonsack, Ph.D., *Research Fellow in Astronomy*  
B.S., Case Institute of Technology, 1954; Ph.D., California Institute, 1959. Research Fellow, 1958-. (202 Robinson) 1715 Locust Street.
- 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*  
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- Paul Bowerman, A.M., *Associate Professor of Modern Languages*  
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- Melvin David Brockie,\* Ph.D., *Associate Professor of Economics*  
B.A., University of California at Los Angeles, 1942; M.A., 1944; Ph.D., 1948. Instructor, California Institute, 1947-49; Assistant Professor, 1949-53; Associate Professor, 1953-. (5 Dabney) 1730 North Roosevelt Avenue, Altadena.
- Norman Herrick Brooks, Ph.D., *Associate Professor of Civil Engineering*  
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- 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-. (361 Crellin) 2258 Midlothian Drive, Altadena.
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B.S., University of Bristol, 1946; Ph.D., University of London, 1951. Staff Member, Yerkes Observatory, 1958-. Research Fellow, California Institute, 1958; Senior Research Fellow, 1959.

\*Leave of absence, 1959-60

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Ph.D., University of Birmingham, England, 1957. California Institute, 1959-60.

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**Admar Cervellini, Ing.Agron., *Research Fellow in Geochemistry***

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B.S., National Central University, China, 1944; M.S., Kansas State College, 1954; Ph.D., California Institute, 1959. Research Fellow, 1959-60. (Guggenheim) Old Dormitory, Campus.

**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.

**Thomas MacFarland Cherry, Sc.D., *Research Associate in Mathematics***

Ph.D., University of Cambridge, 1929; Sc.D., 1950. Professor of Applied Mathematics; Chairman, Mathematics Department, Melbourne University, 1929-. California Institute, 1959-60.

\*Leave of absence, 1959-60

- Margaret I. H. Chipchase, Ph.D., *Research Fellow in Biology*  
Ph.D., University of Cambridge, 1959. California Institute, 1959-60.
- Robert Frederick Christy, Ph.D., *Professor of Theoretical Physics*  
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- 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.
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- Julian David Cole, Ph.D., *Professor of Aeronautics*  
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- 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.
- Frederick James Converse,\* B.S., *Professor of Soil Mechanics*  
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- William Harrison Corcoran, Ph.D., *Professor of Chemical Engineering*  
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- 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*  
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B.A., University of Cambridge, 1955; Ph.D., 1958. California Institute, 1959-60.
- Charles Edwin Crede, M.S., *Associate Professor of Mechanical Engineering*  
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\*Leave of absence, 1959-60

## 38 *Officers and Faculty*

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B.A., Oberlin College, 1939; Ph.D., University of California, 1952. Assistant Professor, California Institute, 1953-56; Associate Professor, 1956-. (3 Dabney) 2444 Highland Avenue, Altadena.

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.

Margaret Bryan Davis, Ph.D., *Research Fellow in Pollen Analysis*

A.B., Radcliffe College, 1953; Ph.D., Radcliffe Graduate School, Harvard University, 1957. California Institute, 1959-60. (355 Arms) 560 East California Boulevard.

Rowland H. Davis, Ph.D., *Research Fellow in Biology*

A.B., Harvard College, 1954; Ph.D., Harvard University, 1958. California Institute, 1958-. (207 Kerckhoff) 560 East California Boulevard.

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-. (271 Church) 1434 North Grand Oaks 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., *Research Fellow in Aeronautics*

B.A., Colgate University, 1951; Ph.D., California Institute, 1958. Research Fellow, 1958-. (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.

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-. (263 Church) 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.

Gordon Klene Douglass, B.A., *Instructor in Economics*

B.A., Pomona College, 1950. California Institute, 1958-59.

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.

Ralph William Dressel, Ph.D., *Research Fellow in Physics*

B.S., Union College, 1944; Ph.D., University of Illinois, 1950. Associate Professor, New Mexico State University, 1950-. California Institute, 1960.

Henry Dreyfuss, *Associate in Industrial Design*

Industrial Designer, California Institute, 1947-. 500 Columbia Street, South Pasadena.

Andree Jacqueline Dubert, M.D., *Research Fellow in Biology*

M.D., Toulouse University, 1950. California Institute, 1959-60. (01 Kerckhoff) 20 South Greenwood.

Jean-Marie Dubert, M.D., *Research Fellow in Biology*

M.D., University of Paris, 1952; D.Sc., 1959. Staff Member, Pasteur Institute, 1950-. California Institute, 1959-60. (01 Kerckhoff) 20 South Greenwood.

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 260.)

\*Leave of absence, 1959-60



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.

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.

Robert Stuart Edgar, Ph.D., *Research Fellow in Biology*

B.Sc., McGill University, 1953; Ph.D., University of Rochester, 1957. California Institute, 1957; 1958-59.

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., *Associate 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-. (4 Dabney) 1628 East Braeburn Road, Altadena.

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) Apt. 2, 2254 Cahuenga Boulevard, Hollywood.

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).

Boris Ephrussi, D.Sc., LL.D., *Visiting Professor of Biology*

Lic.Sc., Sorbonne, 1922; D.Sc., 1932; LL.D., University of Glasgow, 1954. Professor of Genetics, Sorbonne. California Institute, 1959.

Harriett Taylor Ephrussi, Ph.D., *Gosney Research Fellow in Biology*

A.B., Radcliffe College, 1938; Ph.D., Columbia University, 1945. Research Associate, Department of Genetics, Sorbonne. California Institute, 1959.

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-. (259 Church) 2121 Lambert Drive.

\*Leave of absence, 1959-60

## 40 Officers and Faculty

### Ziaoddin Esmailbeigi, D.Sc., *Research Associate in Seismology*

Lic.Sc., Tehran Teachers College, 1932; D.Sc., Nancy University, France, 1937. Professor of Physics, Faculty of Science, Tehran University. California Institute, 1959.

### 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 Fay, Ph.D., *Assistant Professor of History*

B.A., Harvard University, 1947; B.A., Oxford University, 1949; Ph.D., Harvard University, 1954; California Institute, 1955-. (11 Dabney) 400 Churchill Road, Sierra Madre.

### Charles K. Ferguson, \*\* Ed.D., *Lecturer in Psychology*

A.B., University of California (Los Angeles), 1938; M.A., 1942; Ed.D., 1952. Assistant Head, Department of Conferences and Special Activities, University Extension, University of California (Los Angeles), 1952-. California Institute, 1955; 1956; 1957; 1958; 1959.

### Ricardo deCarvalho Ferreira, L.Doc., *Research Fellow in Chemistry*

B.S., Catholic University of Pernambuco, Brazil, 1952; L.Docente, University of Recife, 1957. Professor of Inorganic Chemistry, University of Recife, 1958-. California Institute, 1959.

### Richard Phillips Feynman, Ph.D., *Richard Chase 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.

### Robert Blanchard Fischer, Ph.D., *Visiting Associate in Chemistry*

B.S., Wheaton College, 1942; Ph.D., University of Illinois, 1946. Associate Professor, Indiana University, 1952-. California Institute, 1959-60.

### Russell Arden Fisher, Ph.D., *Research Associate in Physics*

A.B., University of Michigan, 1927; A.M., 1929; Ph.D., 1931. Professor; Chairman, Department of Physics, Northwestern University, 1950. California Institute, 1959.

### 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.

### Gideon Fraenkel, Ph.D., *Research Fellow in Chemistry*

B.S., University of Illinois, 1952; Ph.D., Harvard University, 1956. Research Fellow, California Institute, 1957-. Noyes Fellow, 1958-59. (260 Crelin) 375 West 43rd Avenue, Los Angeles.

### 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.

### Gustave Freeman, M.D., *Research Fellow in Biology*

Ph.B., Brown University, 1929; M.D., Duke University School of Medicine, 1933. Head Clinical Pharmacology and Therapeutics Section, National Cancer Institute, 1957-. California Institute, 1958-59.

### 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-. (260-B Church) 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.

### Charles F. Gallagher, Ph.D., *Visiting Lecturer in International Affairs*

Ph.D., Harvard University, 1951. American Universities Field Staff, California Institute, 1957; 1958.

### 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.

\*Leave of absence, 1959-60

\*\*Part-time



- 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.)
- 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.
- Elvira Goettsch, M.D., *Research Fellow in Chemistry*  
M.D., University of Cincinnati, 1930. California Institute, 1959.
- Mitchell E. Glickstein, Ph.D., *Research Fellow in Biology*  
B.A., University of Chicago, 1951; Ph.D., 1958. California Institute, 1958-. (313 Kerckhoff) 719 North Yale, Claremont.
- Alexander Goetz, Ph.D., *Associate Professor of Physics*  
Ph.D., University of Göttingen, 1921; Habilitation, 1928. California Institute, 1930-. (61 W. Bridge) 1317 Boston Street, Altadena.
- Alercio Moreira Gomes, B.Sc., *Research Fellow in Astronomy*  
B.Sc., Civ. Engr., University of Brazil. Professor of Astronomy, Naval Academy; Instructor, University of Brazil, 1954-. California Institute, 1959-60. (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-. (666 Church) 2712 Doolittle Avenue, Arcadia.
- Howard Woodham Gould, Ph.D., *Research Fellow in Chemistry*  
B.S., McKendree College, 1918; M.S., University of Illinois, 1922; Ph.D., The State University of Iowa, 1929. Professor; Head, Department of Physical Sciences, Northern Illinois University, 1927-. California Institute, 1958-59.
- Roy Walter Gould, Ph.D., *Associate Professor of Electrical Engineering*  
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.
- Colin S. Gum, Ph.D., *Carnegie Fellow in Astronomy*  
B.S., University of Adelaide, Australia, 1948; M.S., 1951; Ph.D., Australian National University, 1955. Research Officer, Division of Radiophysics, Commonwealth Scientific and Industrial Research Organization, Sydney, 1956-. California Institute, 1959-60. (Mt. Wilson Office) 1080 North Lake Avenue.
- Beno Gutenberg, Ph.D., *Professor of Geophysics, Emeritus*  
Ph.D., University of Göttingen, 1911. Professor, California Institute, 1930-59; Director, Seismological Laboratory, 1947-57; Professor Emeritus, 1959-. (313 Mudd) 526 South Sierra Vista Avenue.
- 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.
- Marshall Hall, Jr., Ph.D., *Professor of Mathematics*  
B.A. Yale University, 1932; Ph.D., 1936. California Institute, 1959-. (267 Church) 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.

## 42 Officers and Faculty

### 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, 1959-60. (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-. (184 Spalding) 551 South Hill Avenue.

### Francis Arthur Haskins, Ph.D., *Research Fellow in Biology*

B.S., University of Nebraska, 1943; M.Sc., 1948; Ph.D., California Institute, 1951. Associate Professor, University of Nebraska, 1955-. Research Fellow, California Institute, 1951-52; 1955; 1959.

### Trevor Hatherton, Ph.D., *Research Fellow in Geophysics*

B.Sc., University of London, D.I.C., Imperial College of Science and Technology, 1950; Ph.D., University of London, 1954. Geophysicist, Commonwealth Scientific and Industrial Research Organization, Wellington, N.Z., 1953-. California Institute, 1959-60. 1820 Kenneth Way.

### Ulrich Hauser, Ph.D., *Research Fellow in Physics*

Ph.D., University of Heidelberg, 1957. Research Associate, University of Heidelberg. California Institute, 1960-61.

### Richard Francis Cavanaugh Hayden, LL.B., *Lecturer in Business Law*

A.B., University of California (Los Angeles), 1939; LL.B., University of California, 1947. California Institute, 1956; 1957-58; 1959. (Dabney) 267 West State Street.

### Dale Furneaux Hebbard, Ph.D., *Research Fellow in Physics*

B.A., University of Melbourne, 1950; B.S., 1951; M.S., 1953; Ph.D., 1957. California Institute, 1957-. (04 Kellogg) 659 South Lake Avenue.

### 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, 1959-60.

### 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.

### 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) 11677 Montana Avenue, Los Angeles.

### Captain Andrew Henry, B.S., *Assistant Professor of Air Science and Tactics*

B.S., University of Southern California, 1950; California Institute, 1958-. (Bldg. T). 3945 Gibraltar Drive, Los Angeles.

### Kinzo Hida, D.Sc., *Research Fellow in Aeronautics*

B.S., Osaka Imperial University, 1944; D.Sc., Kyoto University, 1956. Assistant Professor, University of Osaka Prefecture, 1949-. California Institute, 1959. (203 Guggenheim) 454-B South Oakland Avenue.

### Harry R. Highkin, Ph.D., *Research Fellow in Biology*

B.S., University of Connecticut, 1944; M.S., University of Minnesota, 1946; Ph.D., 1951. California Institute, 1952-. (Earhart Lab.) 237 West Las Flores Drive, Altadena.

### Arthur Atsonobu Hirata, Ph.D., *Research Fellow in Chemistry*

B.S., Duke University, 1949; M.A., 1951; Ph.D., University of California (Los Angeles), 1958. California Institute, 1958-. (320 Church) 103 North Mar Vista Avenue.

### Donald Ellsworth Hoard, Ph.D., *Research Fellow in Biology*

B.S., University of Washington, 1952; Ph.D., University of California, 1957. California Institute, 1957-. (112 Kerckhoff) 421 West Figueroa Drive, Altadena.

### 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 Bridgen 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.

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.

Donald Ellis Hudson, Ph.D., *Professor of Mechanical Engineering*  
B.S., California Institute, 1938; M.S., 1939; Ph.D., 1942. Instructor, 1941-43; Assistant Pro-  
fessor, 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.

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., *Lecturer in History; Master of Student Houses*  
B.A., University of California (Los Angeles), 1951; Ph.D., 1959. California Institute, 1958-.  
(Blacker Basement) 1245 Arden Road.

Charles Raymond Illingworth, B.A., *Senior Research Fellow in Aeronautics*  
B.A., University of Cambridge, 1938. Senior Lecturer in Mathematics, Manchester University,  
England, 1954-. California Institute, 1959.

Alfred Cajori Ingersoll, Ph.D., *Associate Professor of Civil Engineering*  
B.S., University of Wisconsin, 1942; M.S., 1948; Ph.D., 1950. Instructor, California Institute,  
1950-51; Assistant Professor, 1951-57; Associate Professor, 1957-. (111 Engineering Bldg.)  
525 South Wilson Avenue.

William Thomas Jackson, Ph.D., *Research Fellow in Chemistry*  
B.S., University of Illinois, 1955; M.S., University of Wisconsin, 1957; Ph.D., 1959. California  
Institute, 1959-60.

Maurice Jacob, Lic.Sc., *Research Fellow in Physics*  
Lic.Sc., University of Paris, 1955. California Institute, 1958-59. (25 Bridge) 91 North Mar Vista  
Avenue.

Homer Jacobson, Ph.D., *Research Fellow in Biology*  
B.S., California Institute, 1941; M.S., Columbia University, 1942; Ph.D., 1948. Assistant Pro-  
fessor of Chemistry, Brooklyn College, 1950-. Gosney Fellow, California Institute, 1959-60.

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.

Richard Henry Jahns, Ph.D., *Professor of Geology*  
B.S., California Institute, 1935; M.S., Northwestern University, 1937; Ph.D., California Insti-  
tute, 1943. Assistant Professor, 1946-47; Associate Professor, 1947-49; Professor, 1949-. (210  
Mudd) 1800 Highland Oaks Drive, Arcadia.

John L. Jinks, Ph.D., *Research Fellow in Biology*  
B.Sc., University of Birmingham, England, 1950; Ph.D., 1952. Senior Scientific Officer, Agricul-  
tural Research Council's Unit of Biometrical Genetics, University of Birmingham, 1956-. Cal-  
ifornia Institute, 1959-60.

Ieuan Rinallt Jones, Ph.D., *Research Fellow in Engineering*  
B.Sc., University College of Wales, 1954; Ph.D., 1958. California Institute, 1958-. (151 Hydro  
Lab.) 83 South Berkeley Avenue.

Thomas G. Jones, Ph.D., *Research Fellow in Aeronautics*  
B.Sc., University College of Wales; Ph.D., 1959. California Institute, 1959-60.

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 Professor, 1943-; Dean of Admissions, 1937-. (112 Throop) 361 California  
Terrace.

Russell Thomas Jordan, Ph.D., *Research Fellow in Chemistry*  
B.S., University of Arkansas, 1949; M.S., 1951; Ph.D., University of Michigan, 1953. Clinical  
Assistant Professor of Microbiology, University of California (Los Angeles), 1954-. California  
Institute, 1959-60. (Crellin) 340 North Melrose Avenue, Monrovia.

## 44 *Officers and Faculty*

**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, 1959-60.

**Walter Barclay Kamb, Ph.D., *Assistant Professor of Geology***

B.S., California Institute, 1952; Ph.D., 1956. Assistant Professor, 1956-. (310 Mudd) 430 North Mountain Trail, Sierra Madre.

**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) 384 South Mentor Avenue.

**Theodore von Karman, Ph.D., Dr.Ing., Sc.D., LL.D., Sng.D., *Professor of Aeronautics, Emeritus***

M.E., Budapest, 1902; Ph.D., Göttingen, 1908. California Institute, 1928-49; Professor Emeritus, 1949-. 1501 South Marengo Avenue.

**Ralph William Kavanagh, Jr., Ph.D., *Senior Research Fellow in 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-. (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, 1953-58; 1959-. (208 Church) 4905 Lockhaven Street, Los Angeles.

**Wells H. Keddle, A.B., *Instructor in Economics***

A.B., Stanford University, 1948. California Institute, 1959.

**Geoffrey Lorrimer Keighley, Ph.D., *Senior Research Fellow in Biology***

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B.S., Occidental College, 1914; Ph.D., California Institute, 1931. Professor of Physics, Emeritus, Occidental College, 1957-. California Institute, 1958-. (163 West Bridge) 5340 Kincheloe Drive, Los Angeles.

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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-. (226 Guggenheim) 437 via Almar, Palos Verdes Estates.

**David Henry Klein, Ph.D., *Instructor in Chemistry***

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**James Kenyon Knowles, Ph.D., *Assistant Professor of Applied Mechanics***

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**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.

**Karl Rudolph Kopecky, Ph.D., *Research Fellow in Chemistry***

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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.

Robert Vose Langmuir, Ph.D., *Professor of Electrical Engineering*  
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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.

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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*  
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D.Sc., Brussels University, 1958. Research Assistant, Laboratory of Mineralogy, Brussels University. California Institute, 1958-59.

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Roland Lefebvre, Ph.D., *Research Fellow in Chemistry*  
Lic.Sc., University of Paris, 1948; Ph.D., University of London, 1953; D.Sc., University of Paris, 1958. Staff Member, National Center for Scientific Research, Paris, 1956-. California Institute, 1959.

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.

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B.A., University of California (Los Angeles), 1935; M.A., 1938; Ph.D., 1941. Associate Professor of Physiology, Northwestern University Medical School, 1947-. Visiting Professor, California Institute, 1954-55; Research Associate, 1958.

Jerome Lejeune, M.D., *Visiting Professor of Genetics*  
M.D., University of Paris, 1951. Head of Research in Human Genetics, Faculty of Medicine, Sorbonne, California Institute, 1958.

\*Leave of absence, 1959-60

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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.

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William James Link, Ph.D., *Research Fellow in Chemistry*

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B.S., Battersea Polytechnic, London, 1955; M.S., Imperial College, London, 1957. Instructor, California Institute, 1959-60. (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.

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B.S., Acadia University, 1920; M.A., Harvard University, 1922; Ph.D., 1923. Cytologist, U. S. Department of Agriculture, 1943-. California Institute, 1947-. (318 Kerckhoff) 6453 North Oak Street, Temple City.

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.

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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., Ohio State University, 1907; M.A., 1908; D.Sc., 1953. California Institute, 1913-55; Professor Emeritus, 1955-. 561 South Wilson Avenue.

Wilbur Marshall Luce, Ph.D., *Research Fellow in Biology*

B.S., Bates College, 1924; M.S., University of Illinois, 1926; Ph.D., 1929. Professor of Zoology, University of Illinois, 1952-. California Institute, 1959-60.

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B.A., University of Manitoba, 1892; Ph.D., University of Chicago, 1903. California Institute, 1920-45; Dean of Freshmen, 1923-37; Professor Emeritus, 1945-. 253-A Bridges Walk, Chula Vista.

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, B.S., *Professor of Air Science and Tactics*

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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.

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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.

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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.

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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*

S.B., Brown University, 1912. Instructor, California Institute, 1918-20; Assistant Professor, 1920-21; Associate Professor, 1921-30; Professor, 1930-. (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-. (83 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) 457 West Loma Alta, Altadena.

Satoshi Matsushima, Ph.D., *Senior Research Fellow in Astronomy*

M.A., University of Kyoto, 1946; Ph.D., University of Utah, 1954. Assistant Professor of Astronomy, Florida State University, 1958-. California Institute, 1959.

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) 722 South Euclid Avenue.

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.

George P. Mayhew, Ph.D., *Assistant Professor of English*

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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-. (357 Crellin; 110 Throop) 1981 Sinaloa Avenue.

Harden Marsden McConnell, Ph.D., *Professor of Chemistry*

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\*Leave of absence, 1959-60

## 48 *Officers and Faculty*

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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 Sanitary Engineering*

B.S., Carnegie Institute of Technology, 1936; M.S., Harvard University, 1939; Sc.D., 1941. Associate Professor, California Institute, 1949-56; Professor, 1956-. (113 Engineering Bldg.) 2026 Oakdale Street.

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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.

### Andrew David McLachlan, Ph.D., *Research Fellow in Chemistry*

B.A., Trinity College, University of Cambridge, 1956; Ph.D., 1959. California Institute, 1959-60.

### Carver Andress Mead, M.S., *Instructor in Electrical Engineering*

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### 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.

### Walter Max Meier, Ph.D., *Research Fellow in Chemistry*

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### Matthew Stanley Meselson, Ph.D., *Assistant Professor of Chemistry*

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### 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) 570 Wilson Avenue, San Marino.

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B.S., University of Michigan, 1943; Ph.D., 1949. California Institute, 1956-. (317 Engineering Bldg.) 10112 Woodward Avenue, Sunland.

### Peter McNaughton Miller, Ph.D., *Lecturer in English; Assistant Director of Admissions and Undergraduate Scholarships*

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- Rudolph Leo Minkowski, Ph.D., Staff Member, Mount Wilson and Palomar Observatories**  
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- 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.
- Abraham de Moraes, Ph.D., Research Fellow in Astronomy**  
B.S., University of Sao Paulo, 1938; Ph.D., 1947. Director, Institute of Astronomy and Geophysics, University of Sao Paulo, 1955-. California Institute, 1959-60.
- Dino Antonio Morelli, Ph.D., Associate Professor of Mechanical Engineering**  
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- Albrecht W. Moschel, Dr.rer.nat., Research Fellow in Chemistry**  
Dipl.Chem., Technische Hochschule, Karlsruhe, Germany, 1953; Dr.rer.nat., 1956. California Institute, 1958-59.
- 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) 654 South Oak Knoll.
- Joe Hill Mullins, Ph.D., Research Fellow in Physics**  
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- 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)
- 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.
- Jean-Pierre Naets, M.D., Research Fellow in Biology**  
M.D., University of Brussels, 1945. California Institute, 1959.
- Kuppuswamy Nagarajan, Ph.D., Research Fellow in Chemistry**  
B.Sc., Madras University, India, 1950; Ph.D., 1954. California Institute, 1959-60.
- Hideo Nagasu, B.S., Research Fellow in Aeronautics**  
B.S., University of Tokyo, 1947. Research Official, Aerodynamics Division, National Aeronautical Laboratory, 1956-. California Institute, 1959-60.
- Uma Sankar Nandi, Ph.D., Research Fellow in Chemistry**  
B.Sc., Benares University, 1946; M.Sc., 1949; Ph.D., 1956. Research Officer, Indian Association for the Cultivation of Science, Calcutta, 1957-. California Institute, 1958-. (469 Crellin) 1055 Del Mar Boulevard.

\*Leave of absence, 1959-60

## 50 *Officers and Faculty*

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### 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.

### Marc-Aurele Nicolet, Ph.D., *Assistant Professor of Electrical Engineering*

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### 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.

### David Norman, Ph.D., *Research Fellow in Biology*

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### Richard E. Norton, Ph.D., *Richard Chace Tolman Research Fellow in Theoretical Physics*

B.S., Lehigh University, 1952; Ph.D., University of Pennsylvania, 1957. California Institute, 1957-. (303 East Bridge) 376 West Poppyfields Drive, Altadena.

### John Frederick Nye, Ph.D., *Visiting Professor of Glaciology*

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### Masahiro Ogaki, D.Sc., *Research Fellow in Biology*

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### Eiji Ohnishi, B.S., *Research Fellow in Biology*

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### John Beverley Oke, Ph.D., *Assistant Professor of Astronomy; Staff Member, Mount Wilson and Palomar Observatories*

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### Ray David Owen, Ph.D., *Professor of Biology*

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### Kenneth Paigen, Ph.D., *Research Fellow in Biology*

A.B., Johns Hopkins University, 1946; Ph.D., California Institute, 1950. Research Fellow, 1958.

### 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.

### 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) 4551 Loma Vista, La Cañada.

### 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.

### 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.

**Willis Eugene Pequegnat, Ph.D., *Visiting Professor of Biology***

B.A., University of California, 1936; M.A., 1938; Ph.D., 1942. Professor of Zoology, Pomona College, 1952-. California Institute, 1957; 1958; 1959.

**Ernst Peterli, Ph.D., *Research Fellow in Chemical Engineering***

Ph.D., University of Basle, 1957. California Institute, 1959-60. (311 Spalding) 188 South Catalina Avenue.

**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 Chemistry***

B.Sc., Bishop's University, Quebec, 1953; M.Sc., McMaster University, Ontario, 1954. California Institute, 1958-60. (212 Church) 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-.

**Robert Louis Cecil Pilgrim, Ph.D., *Research Fellow in Biology***

B.S., Canterbury University College, 1942; M.Sc., 1957; Ph.D., University College, London, 1951. Senior Lecturer in Zoology, University of Canterbury, Christchurch, New Zealand, 1946-. California Institute, 1959-60. (320-A Kerckhoff) 826 Sacramento, Altadena.

**Richard E. Pincock, Ph.D., *Research Fellow in Chemistry***

B.S., University of Utah, 1956; A.M., Harvard University, 1957; Ph.D., 1959. California Institute, 1959-60.

**Cornelius John Pings, Jr., Ph.D., *Associate Professor of Chemical Engineering***

B.S., California Institute, 1951; M.S., 1952; Ph.D. 1953. Associate Professor, 1959-. (Spalding) Fleming House.

**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.

**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.

**Othmar Preining, Ph.D., *Research Fellow in Physics***

Ph.D., University of Vienna, 1951. Assistant Physicist, University of Vienna Institute of Physics, 1951-. California Institute, 1958-. (362 W. Bridge) 1094 Steuben Street.

**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, 1953; Director, 1957-. (314 Mudd; Seismological Lab.) 1972 Skyview Drive, Altadena.

\*Leave of absence, 1959-60

\*\*Part-time

## 52 Officers and Faculty

**George Worrall Preston, III, Ph.D., *Research Fellow in Astronomy***

B.S., Yale University, 1952; Ph.D., University of California, 1959. California Institute, 1959-. (Mt. Wilson Office) 1320 North Maryland, Glendale.

**Griffith Bailey Price, Ph.D., *Visiting Professor of Mathematics***

A.B., Mississippi College, 1950; M.A., Harvard University, 1928; Ph.D., 1932. Professor; Chairman, Mathematics Department, University of Kansas, 1951-. California Institute, 1959-60.

**Albert Ernest Purcell, Ph.D., *Research Fellow in Biology***

B.S., Brigham Young University, 1947; M.S., Purdue University, 1949; Ph.D., 1951. Biochemist, USDA, Weslaco, Texas, 1955-. California Institute, 1957; 1959-60. (012 Kerckhoff) 1865 East Villa Street.

**Alois Theobald Purgathofer, Ph.D., *Research Fellow in Astronomy***

Ph.D., University of Graz, Austria, 1952. Assistant, University Observatory, Vienna, 1954-. California Institute, 1958-59.

**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.

**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.

**Inge Eleonora Rasmussen, D.Sc., *Research Fellow in Biology***

D.Sc., University of Pavia, Italy, 1954. Assistant, Institute of Genetics, University of Pavia, 1954-. California Institute, 1958-59. (303 Kerckhoff) 1288 Oak Grove Avenue, San Marino.

**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 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) 258 South Hudson Avenue.

**Martin A. Reif, B.A., *Instructor in History***

B.A., University of California (Los Angeles), 1954. California Institute, 1958-59.

**Mark Newton Rerick, Ph.D., *Research Fellow in Chemistry***

B.S., Lemoyne College, 1955; Ph.D., University of Notre Dame, 1958. California Institute, 1959-60.

**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 1959-60. 131 South Chester Avenue.

**Octavio Gaspar de Souza Ricardo, D.I.C., *Research Associate in Aeronautics***

B.Sc., Sao Paulo University, 1944; D.I.C., Imperial College, London University, 1948. Associate Professor of Structures, Technical Institute of Aeronautics; Sao Paulo, 1949-. California Institute, 1959-60. (Guggenheim Lab.) 374 South Catalina Avenue.

**John Hall Richards, Ph.D., *Assistant Professor of Chemistry***

B.A., University of California, 1951; Ph.D., University of California, 1955. California Institute, 1957-. (361 Crellin) 8544 Lorain, San Gabriel.

**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.)

**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., *Research Fellow in Chemical Engineering***

B.S., Rose Polytechnic Institute, 1951; M.S., California Institute, 1955; Ph.D., 1959. Research Fellow, 1959-. (313 Spalding) 836 North Catalina Avenue.

\*Leave of absence, 1959-60

**James Alfred Roberts, Ph.D., Senior Research Fellow in Radio Astronomy**

B.S., University of Sidney, 1948; M.S., 1949; Ph.D., Cambridge University, 1953. California Institute, 1958-. (103 Robinson) 1080 North Lake Avenue.

**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 Tanobole 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.

**Alexander Willima Rodgers, Ph.D., Research Fellow in Astronomy**

B.S., New England University College, Sydney, Australia, 1953; Ph.D., Australian National University, 1958. Mount Wilson and Palomar Observatories, 1959-60. (Mt. Wilson office).

**Captain George Rokuhara, B.S., Assistant Professor of Air Science and Tactics**

B.S., University of Hawaii, 1952. California Institute, 1958-. (Bldg. T-1) 275 North Oakland Avenue, Apt. 6.

**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.

**Charles Edwin Roos, Ph.D., Research Fellow in Physics**

B.A., University of Texas, 1948; Ph.D., Johns Hopkins University, 1953. Associate Professor of Physics, Vanderbilt University, 1959-. Research Fellow, California Institute, 1955; 1956; 1957-59.

**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 T. 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, 1954-. California Institute, 1959-62.

**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) 365 Naomi, Arcadia.

**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.

**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-. (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.

**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.) 2049 Beverly Drive.

**Wallace Leslie William Sargent, Ph.D., Research Fellow in Astronomy**

B.S., University of Manchester, England, 1956; Ph.D., 1959. California Institute, 1959-60.

**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.

\*Leave of absence, 1959-60

## 54 Officers and Faculty

Evry Schatzman, Ph.D., *Senior Research Fellow in Astronomy*

Ph.D., University of Paris. Professor of Astrophysics, University of Paris. California Institute, 1959.

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-.

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, 1958-. (121 Engineering) 2321 Sinaloa Avenue, Altadena.

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.

Paul Richard Shafer, Ph.D., *Visiting Associate in Chemistry*

B.A., Oberlin College, 1947; Ph.D., University of Wisconsin, 1951. Associate Professor of Chemistry, Dartmouth College, 1958-. California Institute, 1959-60.

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.

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.

Kal H. Silvert, Ph.D., *Visiting Lecturer in International Affairs*

B.A., University of Pennsylvania, 1942; M.A., 1947; Ph.D., 1948. American Universities Field Staff, 1955-. California Institute, 1956; 1959.

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-. (114 Kerckhoff) 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-.

Helge Erling Skovgaard, M.Sc., *Instructor in Mathematics*

M.Sc., University of Copenhagen, 1945. Assistant Professor of Mathematics, Technical University of Denmark, 1951-. California Institute, 1959-61. (266-A Church) 260 South Oakland 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, 1959-60.

David Rodman Smith, M.A., *Instructor in English*

B.A., Pomona College, 1944; M.A., Claremont Colleges, 1950. California Institute, 1958-. (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.

Richard Thomas Smith, M.D., *Research Associate in Chemistry*

B.A., University of Texas, 1944; M.D., Tulane University, 1950. Professor of Pediatrics, University of Florida, 1958-. California Institute, 1958.

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.

\*Leave of absence, 1959-60



- Eugene Irving Snyder, Ph.D., *Research Fellow in Chemistry*  
B.S., Temple University, 1955; Ph.D., University of Chicago, 1959. California Institute, 1959-60.
- 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-. (Spalding) 384 South Holliston Avenue.
- 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.
- Domenico Spinelli, M.D., *Gosney Research Fellow in Biology*  
M.O., University of Milan, Italy, 1957. California Institute, 1958-59. (332 Kerckhoff) 159 North Catalina Avenue.
- Richard Henry Stanford, Jr., Ph.D., *Research Fellow in Chemistry*  
B.A., The Rice Institute, 1954; Ph.D., 1958. California Institute, 1958-. (230 Church) 441 South Catalina Avenue, Apt. A.
- 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.
- Robert G. Stanley, Ph.D., *Research Fellow in Biology*  
B.S., Michigan State University, 1948; Ph.D., University of California, 1955. Plant Physiologist, U.S. Forest Service, Berkeley, 1957-. California Institute, 1958-59.
- 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.
- 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).
- Alfred Stern, Ph.D., *Associate 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-. (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.
- Michael George Parke Stoker, M.D., *Research Fellow in Biology*  
B.A., University of Cambridge, 1939; M.B., 1942; M.A., 1946; M.D., 1947. Staff Member, Department of Virology, Glasgow University. California Institute, 1958-59.
- 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, 1934-; Dean of Freshmen, 1952-. (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) 1371 San Pasqual Street.
- 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.
- 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.
- 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, 1959-60.
- Alfred S. Sussman, Ph.D., *Research Fellow in Biology*  
Ph.D., Harvard University, 1949; Associate Professor of Botany, University of Michigan, 1957-. California Institute, 1959-60.

\*Leave of absence, 1958-60

## 56 Officers and Faculty

- 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.
- Harry Svensson, Fil.Dir., *Research Fellow in Chemistry*  
Fil.Cand., University of Uppsala, 1936; Fil.Lic., 1942; Fil.Dr., 1946. Director of Research, LKB-Produkter, Stockholm, 1949-. California Institute, 1959.
- 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.
- Haruo Takeyama, \*\* D.Sc., *Senior Research Fellow in Engineering*  
D.Sc., Kyoto University, 1951. Professor of Physics, Hiroshima University, 1952-. California Institute, 1958-. (167 Hydro Lab.) 155 South Grand Oaks Avenue.
- 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, 1959-60. (218 Mudd) 2001 Hanscom Drive, South Pasadena.
- James Herbert Taylor, Ph.D., *Research Fellow in Biology*  
B.S., Southeast Oklahoma State College, 1939; M.S., 1941; Ph.D., 1944. Professor of Cell Biology, Columbia University, 1958-. California Institute, 1959.
- John McCorkle Teem, Ph.D., *Senior Research Fellow in Physics*  
M.A., Harvard University, 1950; Ph.D., 1954. Research Fellow, California Institute, 1954-56; Senior Research Fellow, 1956-. (Synchrotron) 51 Olive Street, Sierra Madre.
- Lloyd Pacheco Tevis, Jr., A.B., *Research Fellow in Biology*  
A.B., University of California, 1939; California Institute, 1956-. (Desert Mobile Lab.) Box 308, Rancho Mirage.
- 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., Queens University, Ireland, 1931. California Institute, 1957-. (275 Church). 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-. (275 Church) 1625 Sierra Bonita Lane.
- 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.
- Ignatius Louis Trapani, Ph.D., *Research Fellow in Chemistry*  
B.S., University of San Francisco, 1948; M.S., 1950; Ph.D., Stanford University, 1956. California Institute, 1956-. (317 Church) 449 West Grand View, Sierra Madre.
- Gerhard Karl Edlef Traving, Ph.D., *Research Fellow in Astronomy*  
Dipl.Phys., University of Gottingen, 1951; Ph.D., 1954; Habilitation, 1956. Docent, University of Kiel, 1956-. California Institute, 1959-. (217 Robinson) 1709 Locust Street.
- 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 Kerckhoff) 93 South Oak Knoll.
- Harold Bradford Tukey, Jr., Ph.D., *Research Fellow in Biology*  
B.S., Michigan State University, 1955; M.S., 1956; Ph.D., 1958. California Institute, 1958-59.
- 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*

B.A., 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.

Otis Lee Updike, Jr., Ph.D., *Visiting Associate in Chemistry*

B.Ch.E., University of Virginia, 1941; Ph.D., University of Illinois, 1944. Associate Professor of Chemical Engineering, University of Virginia, 1955-. California Institute, 1959-60.

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) 379 South Chester 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.

Carlos Manuel Varsavsky, Ph.D., *Research Fellow in Astronomy*

B.S., University of Colorado, 1955; A.M., Harvard University, 1957; Ph.D., 1959. California Institute, 1959-60. (Mount Wilson Office) 595 North Los Robles Avenue.

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.

Gordon J. Von Abrams, B.S., *Research Fellow in Biology*

B.S., University of California (Los Angeles), 1941; Staff Member, Research Division, Peterson-Dering, Scappoose, Oregon, California Institute, 1959.

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.) 422 North Gerona Street, San Gabriel.

Thomas Richard Waite, Ph.D., *Research Fellow in Physics*

B.S., Westminster College, 1952; Ph.D., University of Pittsburgh, 1956. Member, Technical Staff, Bell Telephone Laboratories, 1956-. California Institute, 1958-60. (305 Kellogg) 10440 Plainview, Tujunga.

Robert Lee Walker, Ph.D., *Associate 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.

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.

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-. (261 Church) 1550 San Pasqual Street.

John Warkentin, Ph.D., *Research Fellow in Chemistry*

B.S., University of Manitoba, 1954; M.S., 1955; Ph.D., Iowa State College, 1959. California Institute, 1959. (251 Crellin) 360 North Mentor Avenue.

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.

## 58 *Officers and Faculty*

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) 482 South El Molino Avenue.

Earnest Charles Watson, Sc.D., *Professor of Physics; Dean of the Faculty*

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-. (114 East Bridge) 1000 San Pasqual Street.

Walter Watson, Ph.D., *Research Fellow in Physics*

Ph.B., University of Chicago, 1943; Ph.D., 1958. Assistant Professor of Natural Sciences, University of Chicago, 1958-. California Institute, 1958-59.

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.

John Rodney Weber, Ph.D., *Research Fellow in Chemistry*

B.Sc., Liverpool University, 1955; Ph.D., 1958. California Institute, 1958. (128 Gates) 1634 Asbury Drive.

Hans Arwed Weidenmuller, Ph.D., *Research Fellow in Physics*

Ph.D., Institut fur Theoretical Physik, University of Heidelberg, 1957-. California Institute, 1959-60.

Jean J. Weigle, Ph.D., *Research Associate in Biophysics*

Ph.D., University of Geneva, 1923. California Institute, 1949-. (207 Kerckhoff) 551 South Hill Avenue.

Roger Weil, M.D., *Research Fellow in Biology*

M.D., University of Bern, 1954. Fellow in Clinical Chemotherapy, Sloan-Kettering Institute, 1958-. California Institute, 1960.

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 Suida Drive, Los Angeles.

Gart Westerhout, Ph.D., *Research Fellow in Radio Astronomy*

Ph.D., University of Leiden, 1956. Scientist in Charge, Dwingeloo Station, Leiden Observatory. California Institute, 1959.

Jeffrey Dennis Weston, Ph.D., *Visiting Associate Professor of Mathematics*

Ph.D., University of London. Lecturer in Mathematics, University of Durham. California Institute, 1960.

George W. Wetherill, Ph.D., *Visiting Professor of Geochemistry*

Ph.B., University of Chicago, 1948; S.B., 1949; S.M., 1951; Ph.D., 1953. Staff Member, Department of Terrestrial Magnetism, Carnegie Institution, 1953-. California Institute, 1959.

Ray Weyman, Ph.D., *Research Fellow in Astronomy*

B.S., California Institute, 1956; Ph.D., Princeton University, 1959. California Institute, 1959-60.

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.

\*Leave of absence, fall term, 1959-60

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., *Assistant Professor of Mathematics*

B.A., Harvard University, 1951; Ph.D., 1955. Instructor, California Institute, 1955-57; Assistant Professor, 1957-. (260-B Church)

Harold Edwin Wilcox, Ph.D., *Visiting Associate in Chemistry*

B.A., Ohio Wesleyan University, 1934; M.Sc., Ohio State University, 1937; Ph.D., 1939. Professor; Head, Department of Chemistry, Birmingham-Southern College, 1946-. California Institute, 1959-60.

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., *Associate 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-. (226-A Guggenheim) 409 Bonita Avenue.

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.

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.) 450 East Highland Avenue, Sierra Madre.

Donald Allan Wright, Ph.D., *Research Fellow in Chemistry*

B.Sc., Auckland University College, 1955; M.Sc., 1956; Ph.D., University of Canterbury, 1958. California Institute, 1958-. (230 Church) 626 Magnolia, South Pasadena.

Malcolm R. Wright, Ph.D., *Research Fellow in Chemistry*

B.Sc., Sheffield University, 1955; Ph.D., 1958. Research Fellow in Physical Chemistry, Sheffield University, 1958-. California Institute, 1959-60.

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.

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.

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-.

Shih-Cheng Zien, Dr.Ing., *Research Fellow in Aeronautics*

Dip.Ing., Technische Hochschul, Berlin, 1937; Dr. Ing., 1938. Professor of Mechanics, Taiwan Provincial Cheng-Kung University, 1953-. California Institute, 1958-59.

Emile Zuckerkandl, D.Sc., *Research Fellow in Chemistry*

M.S., University of Illinois, 1948; D.Sc., University of Paris, 1959. California Institute, 1959-60.

\*Leave of absence, 1959-60

## 60 *Officers and Faculty*

Sir Solly Zuckerman, M.D., D.Sc., C.B., F.R.S., *Visiting Professor of Biology*

Professor of Anatomy, Medical School, University of Birmingham, England. California Institute, 1959.

Edward Edom Zukoski, Ph.D., *Assistant 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; Assistant Professor, 1957-. (227 Engineering Bldg.) 1946 Pasadena Glen Road.

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.

# GRADUATE FELLOWS, SCHOLARS AND ASSISTANTS, 1958-59

- Henry Ivan Abrash, *Dow Chemical Company Fellow, Chemistry*  
B.A., Harvard College, 1956
- Daniel Kuo Yi Ai, *Institute Scholar, Aeronautics*  
B.S., Swarthmore College, 1953; M.S., University of Wisconsin, 1954
- Peter Albersheim, *National Science Foundation Fellow, Biology*  
B.S., Cornell University, 1956
- Frank Addison Albini, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Mechanical Engineering*  
B.S., California Institute, 1958
- Norman Webster Albright, *National Science Foundation Fellow, Physics*  
B.S., California Institute, 1956
- Shelton Setzer Alexander, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.S., University of North Carolina, 1956
- Raymond Wallace Allard, Jr., *Woodrow Wilson Foundation Fellow, Physics*  
B.A., University of Minnesota, 1958
- Harold Russell Almond, Jr., *United States Rubber Company Postgraduate Fellow, 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
- Don Lynn Anderson, *National Science Foundation Fellow, Geological Sciences*  
B.S., Rensselaer Polytechnic Institute, 1955
- Hugh Riddell Anderson, *Graduate Research Assistant, Institute Scholar, Physics*  
B.A., State University of Iowa, 1954
- William Judson Anderson, *National Science Foundation Fellow, Aeronautics*  
B.S., Iowa State College, 1957; M.S., 1958
- Robert James Arenz (S.J.), *Murray Scholar, Aeronautics*  
B.S., Oregon State College, 1945; M.S. Lic. in Phil., St. Louis University, 1957
- Richard Michael Aron, *Bendix Aviation Corporation Fellow, Electrical Engineering*  
B.S.E., Princeton University, 1956; M.S., California Institute, 1957
- John Fredrich Asmus, *Graduate Research Assistant, Drake Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Boris Auksmann, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
B.A.Sc., University of British Columbia, 1955; M.S., California Institute, 1958
- Charles Dwight Babcock, Jr., *Douglas Aircraft Fellow, Aeronautics*  
B.S., Purdue University, 1957; M.S., California Institute, 1958
- Victor Cyriel Eric Baekelandt, *Graduate Teaching Assistant, Civil Engineering*  
C.E., University of Ghent, 1958
- Philip Oren Banks, *National Science Foundation Fellow, Geological Sciences*  
S.B., Massachusetts Institute of Technology, 1958
- R. Keith Bardin, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., California Institute, 1953
- Dennis Barrett, *Graduate Teaching Assistant, Institute Scholar, Biology*  
A.B., University of Pennsylvania, 1957

## 62 Graduate Appointments

- Louis Najib Bathish, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*  
B.A., Pomona College, 1957
- Andrew Burkhard Bauer, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.Aero.E., Ohio State University, 1951; M.Sc., 1951
- William Frederick Beach, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., Rutgers University, 1957
- Carl Sidney Benson, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.A., University of Minnesota, 1950; M.S., 1955
- 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
- Thomas Mark Bieniewski, *Woodrow Wilson Foundation Fellow, Physics*  
B.S., University of Detroit, 1958
- Harry Hobart Bingham, Jr., *Graduate Research Assistant, Institute Scholar, Physics*  
A.B., Princeton University, 1952
- Harvey Harold Bird, *Graduate Teaching Assistant, Dobbins Scholar, Astronomy*  
A.B., The Johns Hopkins University, 1956
- Ronald Blum, *Convair Fellow, Institute Scholar, Physics*  
A.B., University of Chicago, 1954; S.B., 1955; S.M., 1956
- Alan George Bodine, *National Science Foundation Fellow, Physics*  
B.S., University of Illinois, 1957
- Thomas Kelman Boehme, *Graduate Teaching Assistant, Institute Scholar, Mathematics*  
B.S., University of Oklahoma, 1952; M.S., Oklahoma Agricultural and Mechanical College, 1957
- Ernest Russell Boller, *Graduate Research Assistant, Institute Scholar, Chemical Engineering*  
B.S., Purdue University, 1958
- Robert Harold Bond, *Graduate Teaching Assistant, Dobbins Scholar, Electrical Engineering*  
B.S., Colorado State University, 1958
- Frank Bliss Booth, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*  
B.S., University of California at Los Angeles, 1953; M.S., 1954
- David Alan Boots, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
B.A., Montana State University, 1956; M.A., Indiana University, 1957
- Gary Delane Boyd, *Francis J. Cole Fellow, Electrical Engineering*  
B.S., California Institute, 1954; M.S., 1955
- James Harrison Boyden, *Corning Glass Works Foundation Fellow, Physics*  
B.S., Carnegie Institute of Technology, 1954; M.S., 1955
- Richard Edwin Bradbury, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.A., The Johns Hopkins University, 1957
- Richard Harald Briceland, *Institute Scholar, Mechanical Engineering*  
B.S., State University of Iowa, 1954; M.S., 1955
- Howard M. Brody, *Graduate Research Assistant, Institute Scholar, Physics*  
S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute, 1956
- Gunnar Erik Broman, *Institute Scholar, Mechanical Engineering*  
C.E.(Ae.), Royal Institute of Technology (Stockholm), 1947; M.S., California Institute, 1955
- J. Philip Bromberg, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
S.B., Massachusetts Institute of Technology, 1956
- 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

- William Davis Burnett, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., Texas Western College, 1955
- David Guthrie Byles, *Graduate Research Assistant, Blacker Scholar, Physics*  
B.S., California Institute, 1958
- Richard Bradford Campbell, *Institute Scholar, Geological Sciences*  
B.A.Sc., University of British Columbia, 1948; M.S., California Institute, 1951
- Gordon Lawrence Cann, *Institute Scholar, Aeronautics*  
B.S., University of Toronto, 1949; M.S., California Institute, 1956
- George Melvin Canova, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- John Cleverley Carney, *Dow Chemical Company Fellow, Chemical Engineering*  
B.S., California Institute, 1956; M.S., 1957
- Robert Everett Carter, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*  
A.B., Columbia College, 1958
- Berken Chang, *Graduate Research Assistant, Bennett Scholar, Physics*  
B.S., California Institute, 1958
- David Bing Jue Chang, *National Science Foundation Fellow, Physics*  
B.S., University of Washington, 1956
- I-dee Chang, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.S., National Central University (Nanking), 1944; M.S., Kansas State College, 1954
- James Tseng-hsu Chang, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Columbia University, 1955
- William Massee Chapple, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.S., California Institute, 1956; M.S., 1957
- Marvin Chester, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., The City College of New York, 1952
- Carl Spencer Christensen, *Graduate Teaching Assistant, Dobbins Scholar, Aeronautics*  
B.S.A.E., Purdue University, 1958
- Ronald Arlie Christensen, *Graduate Teaching Assistant, Theodore S. Brown Scholar, Mechanical Engineering*  
B.S.E.E., Iowa State College, 1958
- Thomas Francis Clancy, *Graduate Teaching Assistant, Dobbins Scholar, Mechanical Engineering*  
B.S.M.E., University of Pennsylvania, 1958
- William Kent Clarkson, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*  
B.S.E., Princeton University, 1958
- Donald Delbert Clayton, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Southern Methodist University, 1956
- Richard Lewis Cohen, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Haverford College, 1957
- Thomas Alan Cole, *Nutrition Foundation Fellow, 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, *Rotary International Foundation Fellow, Electrical Engineering*  
Ing. Civil A.I.M., University of Liège, 1958
- Daniel Joseph Collins, *Graduate Research Assistant, Institute Scholar, Engineering Science*  
B.A., Lehigh University, 1954; M.S., California Institute, 1955

## 64 Graduate Appointments

- Joseph Michael Colucci, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
B.S., Michigan State University, 1958
- James Ekstedt Conel, *Standard Oil of California Fellow, Geological Sciences*  
B.A., Occidental College, 1955; M.S., California Institute, 1957
- Martin Leo Conneally, *La Verne Noyes Scholar, Mechanical Engineering*  
B.S., California Institute, 1958
- Glenn Leland Converse, *Graduate Teaching Assistant, Roeser Scholar, Mechanical Engineering*  
B.S., California Institute, 1958
- Richard Kent Cooper, *Graduate Research Assistant, Dobbins Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Edward Joseph Cotter, *National Science Foundation Fellow, Geological Sciences*  
B.S., Tufts University, 1958
- Michael Anthony Cowan, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*  
B.S., Purdue University, 1957; M.S., California Institute, 1958
- Richard Truman Cowley, *Boeing Fellow, Mechanical Engineering*  
B.S., California Institute, 1958
- Donald Gerald Coyne, *Woodrow Wilson Foundation Fellow, Physics*  
B.S., University of Kansas, 1958
- Peter Linton Crawley, *Graduate Teaching Assistant, Institute Scholar, Mathematics*  
B.S., California Institute, 1957; M.S., 1958
- Cedric Inglis Davern, *Commonwealth Scientific and Industrial Research Organization Fellow, Biology*  
B.S.Agr., University of Sydney, 1953; M.S.Agr., 1956
- Thomas Gene Davis, *Laws Scholar, Physics*  
B.A., University of California at Riverside, 1958
- Victor Charles Douglas Dawson, *Institute Scholar, Mechanical Engineering*  
S.B., Massachusetts Institute of Technology, 1948; M.S., Harvard University, 1950
- Melvin Drew Daybell, *National Science Foundation Fellow, Physics*  
B.S., New Mexico College of Agriculture and Mechanic Arts, 1956
- Paul Hugh Deal, *Graduate Teaching Assistant, Institute Scholar, Biology*  
A.B., Sacramento State College, 1958
- Henry Hursell Dearman, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., University of North Carolina, 1956
- Brinton Stanley Deighton, Jr., *Daniel and Florence Guggenheim Fellow, Institute Scholar, Mechanical Engineering*  
B.Ch.E., Cornell University, 1958
- Harold Ralph Dessau, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.S., California Institute, 1957; M.S., 1958
- Robert Stanford Deverill, *Woodrow Wilson Foundation Fellow, Chemistry*  
B.S., California Institute, 1958
- William Edwin Dibble, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., California Institute, 1954
- Charles Wayne Dickinson, *Graduate Teaching Assistant, Aeronautics*  
S.B., Massachusetts Institute of Technology, 1950
- John Irvine Dick-Peddie, *Graduate Teaching Assistant, Dobbins Scholar, Mechanical Engineering*  
B.S., Iowa State College, 1953
- Robert Ernest Diebold, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., University of New Mexico, 1958



- John Kalman Dienes, *Institute Scholar, Mechanical Engineering*  
B.A., Pomona College, 1957; M.S., California Institute, 1958
- Aldo Gene Di Loreto, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.S., California Institute, 1956; M.S., 1957
- Franklin Painter Dixon, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., University of Texas, 1954; M.S., California Institute, 1957
- James Robert Dodd, *National Science Foundation Fellow, Geological Sciences*  
A.B., Indiana University, 1956; A.M., 1957
- Bruce Roger Doe, *Kennecott Copper Corporation Fellow, Geological Sciences*  
B.S., University of Minnesota, 1954; B.Geol.E., 1954; M.S., Missouri School of Mines, 1956
- Richard Dolen, *Charles A. Coffin Fellow, Physics*  
B.Eng.Phy., Cornell University, 1957
- John Jacob Domingo, *National Science Foundation Fellow, Physics*  
B.S., California Institute, 1955
- William Franklin Dove, Jr., *National Science Foundation Fellow, Chemistry*  
A.B., Amherst College, 1958
- Ian Morley Duck, *Imperial Oil Graduate Research Fellow, Graduate Teaching Assistant, Institute Scholar, Physics*  
B.Sc., Queen's University, 1955; M.Sc., University of British Columbia, 1956
- Michael B. Duke, *General Petroleum Scholar, Geological Sciences*  
B.S., California Institute, 1957; M.S., Pennsylvania State University, 1958
- Georges Duvaut, *French Ministry of Foreign Affairs Fellow, Graduate Teaching Assistant, Engineering Science*  
Lic. ès Sci., Ecole Normale Supérieure (Paris), 1958
- Michel Abel Ebertin, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*  
B.S.E.E., Polytechnic Institute of Brooklyn, 1957; M.S., California Institute, 1958
- W. Farrell Edwards, *Schlumberger Foundation Fellow, Physics*  
B.S., University of Utah, 1955; M.S., California Institute, 1957
- Everett Truman Eiselen, *Graduate Teaching Assistant, Drake Scholar, Mechanical Engineering*  
B.S., California Institute, 1956; M.S., 1957
- Arvid Lennart Ejewall, *L. M. Ericsson Telephone Company Fellow, Electrical Engineering*  
C.E., Chalmers Institute of Technology (Gothenburg, Sweden), 1951
- David Duncan Elliott, *Institute Scholar, Physics*  
B.S., Stanford University, 1951; M.S., California Institute, 1953
- Alan Emanuel, *Richfield Oil Corporation Fellow, Chemical Engineering*  
B.S., California Institute, 1958
- Christian Albertus Engelbrecht, *Standard-Vacuum Oil Company (South Africa) Fellow, Physics*  
B.Sc., University of Pretoria, 1955
- George Frederick Engelke, *Graduate Teaching Assistant, Mechanical Engineering*  
B.S., California Institute, 1958
- Rolf Engleman, Jr., *Shell Companies Foundation Fellow, Chemistry*  
B.S., University of Oklahoma, 1955
- Victor Ado Erma, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., University of Texas, 1953; M.A., 1955
- Marshall Paul Ernstene, *Institute Scholar, Physics*  
A.B., Harvard College, 1952
- Viktor Evtuhov, *Howard Hughes Fellow, Electrical Engineering*  
B.S., University of California at Los Angeles, 1956; M.S., California Institute, 1957
- Grover Louis Farrar, *Allied Chemical and Dye Corporation Fellow, Chemistry*  
B.S., Randolph-Macon College, 1956

## 66 Graduate Appointments

- Roger Keith Farrar, *Graduate Teaching Assistant, Dobbins Scholar, Mechanical Engineering*  
B.S., Stanford University, 1958
- Jean C. Ferrand, *Institute Scholar, Geological Sciences*  
Dipl. Ing., Ecole de l'Air, 1953
- Louis Domenic Ferretti, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.A., University of Pennsylvania, 1957
- Thornton Roberts Fisher, *National Science Foundation Fellow, Physics*  
B.A., Wesleyan University, 1958
- James Lawrence Collier Ford, Jr., *Graduate Research Assistant, Institute Scholar, Physics*  
B.A., Montana State University, 1955
- Donald Charles Forster, *Howard Hughes Fellow, Electrical Engineering*  
B.S., University of Southern California, 1955; M.S., California Institute, 1957
- Alan K. Forsythe, *Graduate Teaching Assistant, Mechanical Engineering*  
B.S., California Institute, 1958
- Robert Paul Foss, *Graduate Teaching Assistant, Laws Scholar, Chemistry*  
B.A., Northwestern University, 1958
- André Jean Pierre Fossard, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*  
Dipl. Ing., Ecole Nationale Supérieure de l'Aéronautique (Paris), 1958
- Bevan Meredith French, *National Science Foundation Fellow, Geological Sciences*  
A.B., Dartmouth College, 1958
- Lyman Jefferson Fretwell, Jr., *National Science Foundation Fellow, Physics*  
B.S., California Institute, 1956
- Benjamin S. Friesen, *Kirk Macomber Fellow, Institute Scholar, Biology*  
B.A., Kansas University, 1952; M.A., 1954
- Richard Henry Frische, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
A.B., Miami University, 1954; M.S., New Mexico Institute of Mining and Technology, 1956
- Donald Charles Garwood, *National Science Foundation Fellow, Chemistry*  
B.A., Kalamazoo College, 1957
- Nick George, *Howard Hughes Fellow, Electrical Engineering*  
B.S., University of California, 1949; M.S., University of Maryland, 1956
- George Gerson, *Graduate Teaching Assistant, Institute Scholar, Mathematics*  
B.S., Queens College, 1951; M.S., California Institute, 1958
- Victor Gilinsky, *National Science Foundation Fellow, Physics*  
B.E.Ph., Cornell University, 1956
- Murlin Fern Gillis, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., University of Washington, 1956
- Concetto Richard Giuliano, *National Science Foundation Fellow, Chemistry*  
B.S., University of Southern California, 1957
- Herbert Seymour Glick, *Curtiss-Wright Fellow, Aeronautics*  
B.E.Ph., Cornell University, 1951; M.Ae.E., 1953
- Stuart Goff, *Graduate Teaching Assistant, Mathematics*  
B.S., California Institute, 1958
- Roger Morse Golden, *Consolidated Electrodynamics Corporation Fellow, Electrical Engineering*  
B.S., California Institute, 1954; M.S., 1955
- Thomas Pascoe Gordon, *du Pont Postgraduate Teaching Assistant, Chemistry*  
A.B., Princeton University, 1954; M.S., California Institute, 1956
- Jacek Piotr Gorecki, *National Research Council of Brazil Fellow; Institute Scholar, Aeronautics*  
Dipl. Ing., Ecole Centrale des Arts et Manufactures, Paris, 1940

- Roy Jay Greenfield, *Graduate Research Assistant, Roesser Scholar, Geological Sciences*  
S.B., Massachusetts Institute of Technology, 1958
- R. Clive Greenough, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
S.B., Massachusetts Institute of Technology, 1953
- Howard Burt Greenstein, *Graduate Research Assistant, Institute Scholar, Physics*  
Sc.B., Brown University, 1956
- Jerry Dice Griffith, *Atomic Energy Commission Fellow, Mechanical Engineering*  
B.S., Michigan State University, 1955; M.S., 1957
- David Eiben Groce, *Graduate Research Assistant, Laws Scholar, Physics*  
B.S., California Institute, 1958
- Donald Eugene Groom, *National Science Foundation Fellow, Physics*  
A.B., Princeton University, 1956
- Meredith Grant Gross, Jr., *National Science Foundation Fellow, Geological Sciences*  
A.B., Princeton University, 1954
- Michel Pierre Guillemet, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*  
Dipl. Ing., Ecole Nationale d'Ingénieurs Arts et Métiers (France), 1958
- Daniel André Guinier, *Graduate Research Assistant, Institute Scholar, Physics*  
Lic. ès Sci. Phys., Sorbonne University, 1957
- George Drake Guthrie, *Graduate Teaching Assistant, Institute Scholar, Biology*  
A.B., Wabash College, 1954
- Andrew Guttman, *Daniel and Florence Guggenheim Fellow, 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
- Armando Hamel-Armengolli, *Rotary International Foundation Fellow, Civil Engineering*  
C.E., University of Chile, 1954
- Charles Robert Hamilton, *Graduate Teaching Assistant, Institute Scholar, Biology*  
B.S., University of the South, 1957
- Bjorn Walther Bergsnov Hansen, *Graduate Research Assistant, Dobbins Scholar, Chemical Engineering*  
Cand. Real., University of Oslo, 1958
- Boyd Archer Hardesty, *Nutrition Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Biology*  
B.S., State College of Washington, 1953; M.S., 1956
- Peter Edgar Hare, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.S., Pacific Union College, 1954; M.S., University of California, 1955
- David Garrison Harkrider, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
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
- Lance Gregory Hays, *Garrett Corporation Fellow, Mechanical Engineering*  
B.S., California Institute, 1958
- John Holding Healy, *Institute Scholar, Geological Sciences*  
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, *National Science Foundation Fellow, Biology*  
S.B., Massachusetts Institute of Technology, 1956; S.M., 1958

## 68 Graduate Appointments

- William Henry Heiser, *Graduate Teaching Assistant, Murray Scholar, Mechanical Engineering*  
B.M.E., The Cooper Union, 1956; M.S., California Institute, 1957
- Thomas McCalfree Helliwell, *National Science Foundation Fellow, Physics*  
B.A., Pomona College, 1958
- William Phillip Helman, *Graduate Teaching Assistant, Drake Scholar, Chemistry*  
B.S., California Institute, 1958
- Robert Henry Hertel, *International Business Machines Fellow, Electrical Engineering*  
S.B., Massachusetts Institute of Technology, 1958
- Robert Hickling, *International Nickel Company, Inc. Fellow, 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 III, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Yale University, 1952; M.S., 1952
- Noel William Hinnners, *Institute Scholar, Geological Sciences*  
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, *National Science Foundation Fellow, Chemistry*  
B.S., Tufts University, 1957
- Klaus Hoechsmann, *National Research Council of Canada Fellow, Laws Scholar, Mathematics*  
B.A., University of British Columbia, 1957; M.A., McGill University, 1958
- John Leonard Honsaker, *National Science Foundation Fellow, Physics*  
B.S., California Institute, 1955
- David Parks Hoult, *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
- 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
- Glen Owen Hultgren, *National Science Foundation Fellow, Chemistry*  
B.S., University of California, 1958
- Neilen Wood Hultgren, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., University of California, 1955
- Richard O'Neil Hundley, *National Science Foundation Fellow, Physics*  
B.S., California Institute, 1957
- Herbert Erwin Hunter, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.S., University of Maryland, 1956; M.S., California Institute, 1957
- William Day Hutchinson, *Paul E. Lloyd Fellow, Chemistry*  
B.S., Morehouse College, 1955; M.S., California Institute, 1957
- Albert Hybl, *Graduate Teaching Assistant, Chemistry*  
B.A., Coe College, 1954
- Carl Kenneth Iddings, *Rand Corporation Fellow, Physics*  
B.A., Harvard College, 1955
- Izzat Muhammad Idriss, *Graduate Teaching Assistant, Murray Scholar, Civil Engineering*  
B.C.E., Rensselaer Polytechnic Institute, 1958
- James Brown Ifft, *Graduate Teaching Assistant, Institute Scholar, 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
- Edgar Towar Irons, *Westinghouse Educational Foundation Fellow, Electrical Engineering*  
B.S.E., Princeton University, 1958
- Thomas Neil Irvine, *Foster Hewett Fellow, Institute Scholar, Geological Sciences*  
B.Sc., University of Manitoba, 1953; M.Sc., 1954
- Wilfred Dean Iwan, *Francis J. Cole 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, *Drake Scholar, Engineering Science*  
A.B., Emory University, 1950; M.S., University of Southern California, 1954
- Kenneth Eugene Johnson, *Graduate Teaching Assistant, Murray Scholar, Chemistry*  
B.S., University of Alabama, 1955
- Orval Elmer Jones, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
B.S., Colorado State University, 1956; M.S., California Institute, 1957
- Richard Theodore Jones, *National Research Council Fellow, Chemistry*  
B.S., University of Oregon, 1953; M.S. and M.D., 1956
- John Joseph Kalvinskas, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*  
S.B., Massachusetts Institute of Technology, 1951; S.M., 1952
- Glenn Lloyd Keldsen, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*  
B.S., Antioch College, 1958
- John Fisher Kennedy, *Graduate Research Assistant, Institute Scholar, 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, Dobbins 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
- Edgar Francis Kiefer, *National Science Foundation Fellow, Chemistry*  
B.S., Stanford University, 1957
- Joseph Roland Kilner, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Case Institute of Technology, 1957
- Donald Menford King, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., State College of Washington, 1957
- William John Klenk, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.S.S., University of Dayton, 1957; M.S., California Institute, 1958
- Wolfgang Gustav Knauss, *Graduate Teaching Assistant, Murray Scholar, Aeronautics*  
B.S., California Institute, 1958
- Akira Kobayashi, *Japanese Government Fellow, Aeronautics*  
B.E., University of Tokyo, 1954
- Tatsuro Kodama, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Hiroshima University, 1954; M.S., 1956
- Thomas Richard Koehler, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Seattle University, 1954
- William Kozicki, *California Research Corporation Fellow, Chemical Engineering*  
B.A.Sc., University of Toronto, 1953; M.A.Sc., 1957

## 70 Graduate Appointments

- Kalman Issie Krakow, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
B.Eng., McGill University, 1958
- Daniel Julius Krause, *Kaiser Aluminum and Chemical Corporation Fellow, Mechanical Engineering*  
B.Met.E., The Ohio State University, 1958
- Abraham Nathan Kurtz, *Institute Scholar, Chemistry*  
B.A., Brooklyn College, 1937; M.A., 1943
- Robert Julius Kwik, *Atomic Energy Commission Fellow, Mechanical Engineering*  
M.E., Stevens Institute of Technology, 1958
- Alvin Lloyd Kwiram, *Woodrow Wilson Foundation Fellow, Chemistry*  
B.S., Walla Walla College, 1958
- Robert Lallement, *Institute Scholar, Mechanical Engineering*  
Ing. Civ., Ecole Nationale Supérieure des Mines (Paris), 1958
- James Douglas Lamb, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., University of Maryland, 1958
- Theodore Edmund Lang, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
B.S., California Institute, 1957; M.S., 1958
- Marvin Alder Lanphere, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
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, Geological Sciences*  
B.S., University of California at Riverside, 1958
- James Daniel Larson, *Institute Scholar, Physics*  
S.B., Massachusetts Institute of Technology, 1957
- Raymond Walter Latham, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*  
B.Eng., McGill University, 1958
- Kaye Don Lathrop, *Atomic Energy Commission Fellow, Mechanical Engineering*  
B.S., United States Military Academy, 1955
- 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
- Joseph Louis Le May, *Firestone Tire and Rubber Company Fellow, Electrical Engineering*  
B.E.E., University of Detroit, 1957
- Arnold Vincent Lesikar, *National Science Foundation Fellow, Physics*  
B.A., The Rice Institute, 1958
- Milton Irwin Levenberg, *National Science Foundation Fellow, 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, *Howard Hughes Fellow, Physics*  
S.B., Massachusetts Institute of Technology, 1956; M.S., California Institute, 1957
- Nelson Liberman, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.A., University of Buffalo, 1954; M.A., 1957
- Alfred George Lieberman, *Graduate Teaching Assistant, Dobbins Scholar, Electrical Engineering*  
B.S., Polytechnic Institute of Brooklyn, 1958
- Joe Edward Lingerfelt, *Institute Scholar, Mechanical Engineering*  
B.S., California Institute, 1957; M.S., 1958

- Hans-Dieter Linhardt, *Institute Scholar, Mechanical Engineering*  
Dipl. Ing., Technische Hochschule (Munich), 1955
- Chung-Yen Liu, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.S., Taiwan College of Engineering, 1955; M.S., Brown University, 1958
- James Reilly Lloyd, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
B.S., California Institute, 1956; M.S., 1957
- Ronald Michael Lloyd, *National Science Foundation Fellow, Geological Sciences*  
B.S., University of Illinois, 1952; M.S., 1953
- Kenneth Lock, *General Electric Educational and Charitable Fund Fellow, Electrical Engineering*  
B.Sc., Battersea Polytechnic Institute (London), 1955; M.Sc., Imperial College of London, 1957
- Malcolm Harvey Lock, *Institute Scholar, Aeronautics*  
Higher Natl. Cert., Hatfield Technical College (England), 1954
- Robert Lee Luttermoser, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., University of Michigan, 1948; M.S., 1950
- Raymond Paul Lutz, *Graduate Teaching Assistant, Laws Scholar, Chemistry*  
B.S., University of Florida, 1953; M.S., 1955
- Yen-Mow Lynn, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.S., National Taiwan University, 1956; M.S., California Institute, 1957
- Claude Mahaux, *Institut Interuniversitaire des Sciences Nucléaires (Belgium) Fellow, Physics*  
Lic. Ph., University of Liège, 1958
- Jacob Valentine Maizel, Jr., *Nutrition Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Biology*  
B.S., Pennsylvania State University, 1955; M.S., 1957
- John Owen Maloy, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., University of Arizona, 1954
- Jean François Marin, *Institute Scholar, Mechanical Engineering*  
Ing. Civ., Ecole Nationale Supérieure des Mines (Paris), 1957; M.S., California Institute, 1958
- Gary Lynn Marlotte, *Institute Scholar, Aeronautics*  
B.S.A.E., Purdue University, 1958
- 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, Bennett Scholar, Geological Sciences*  
B.S., Franklin and Marshall College, 1958
- Dennis Robert McCalla, *National Research Council of Canada Fellow, Blacker Scholar, Biology*  
B.Sc., University of Alberta, 1957; M.Sc., University of Saskatchewan, 1958
- Malcolm McColl, *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
- Robert James McElvain, *Graduate Teaching Assistant, Murray Scholar, Aeronautics*  
B.S., Purdue University, 1958



## 72 Graduate Appointments

- Richard Bernard McGriff, *Graduate Research Assistant, Chemistry*  
B.S., Florida Agricultural and Mechanical University, 1955
- Bruce Timoney McKeever, *Graduate Research Assistant, Roeser Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Francis Clay McMichael, *Woodrow Wilson Foundation Fellow, Geological Sciences*  
B.S., Lehigh University, 1958
- Chiang-Chung Mei, *Li Foundation Fellow, Aeronautics*  
B.S.C.E., National Taiwan University, 1955; M.S., Stanford University, 1958
- Martin Mendelson, *Graduate Teaching Assistant, Institute Scholar, Biology*  
A.B., Cornell University, 1958
- Rémi-Noël Justin Roger Menegaux, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*  
Ing., Ecole Centrale des Arts et Manufactures (Paris), 1958
- James Edgar Mercereau, *Hughes Staff Doctoral Fellow, Physics*  
B.A., Pomona College, 1953; M.S., University of Illinois, 1954
- Howard Carl Merchant, *National Science Foundation Fellow, 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
- Harvey John Meyer, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
B.A., University of Minnesota, 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
- 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
- Catalin Dan Mitescu, *Graduate Teaching Assistant, Dobbins Scholar, Physics*  
B.Eng., McGill University, 1958
- Kenneth Martin Mitzner, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*  
S.B., Massachusetts Institute of Technology, 1958
- Harry Moerjono, *Rockefeller Foundation Fellow, Aeronautics*  
B.S., Feati Institute of Technology (Manila), 1956
- Alan Theodore Moffet, *National Science Foundation Fellow, Physics*  
B.A., Wesleyan University, 1957
- Norton Leonard Moise, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., University of Illinois, 1948; M.S., University of California at Los Angeles, 1954
- Lawrence Kernan Montgomery, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., Colorado State University, 1957
- Carleton Bryant Moore, *Graduate Research Assistant, Institute Scholar, Chemistry*  
B.S., Alfred University, 1954
- William Marshall Moore, *Graduate Research Assistant, Chemistry*  
B.A., Colorado College, 1952



- Didier Morane, *French Ministry of Foreign Affairs Fellow, Mechanical Engineering*  
Ing., Ecole Nationale Supérieure du Génie Maritime (Paris), 1958
- Fernando Bernardo Morinigo, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., University of Southern California, 1957
- Francis Guy Moses, *Graduate Teaching Assistant, Drake Scholar, Chemistry*  
B.A., University of Delaware, 1958
- Arthur Hughes Muir, Jr., *Graduate Research Assistant, 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
- Joe Hill Mullins, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., Agricultural and Mechanical College of Texas, 1950; M.S., California Institute, 1954
- Moratagere Balappa Murarappa, *Indian Government Fellow, Civil Engineering*  
B.E., University of Mysore, 1957
- Henry Richard Myers, *Graduate Research Assistant, Institute Scholar, Physics*  
S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute, 1955
- Xavier Félix Namy, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*  
Ing., Ecole Supérieure d'Electricité, 1958
- Roddam Narasimha, *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, Institute Scholar, Mechanical Engineering*  
B.S., University of Stellenbosch, 1955; M.S., California Institute, 1957
- Gerry Neugebauer, *International Business Machines Fellow, Physics*  
B.A., Cornell University, 1954
- Henri Lucien Neuville, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*  
Dip. E.E., Ecole Supérieure d'Electricité, 1958
- Richard Coulston Neville, *National Science Foundation Fellow, Electrical Engineering*  
B.S., California Institute, 1958
- Robert Chaffer Newton, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
B.A., University of California at Los Angeles, 1956; M.A., 1957
- John Carl Nickel, *Woodrow Wilson Foundation Fellow, Physics*  
B.A., University of California at Riverside, 1958
- Peter David Noerdlinger, *United States Steel Foundation 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., *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., University of Rochester, 1957
- John Eric Nordlander, *National Science Foundation Fellow, Chemistry*  
B.A., Cornell University, 1956
- Robert Henry Norton, Jr., *Graduate Teaching Assistant, 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 Teaching Assistant, Institute Scholar, Physics*  
B.A., Haverford College, 1957
- Gordon Cedric Oates, *Graduate Research Assistant, Institute Scholar, Mechanical Engineering*  
B.A.Sc., University of British Columbia, 1954; M.Sc., University of Birmingham, 1956
- Haruo Oguro, *Institute Scholar, Aeronautics*  
B.S., University of Tokyo, 1948; M.S., California Institute, 1957

## 74 Graduate Appointments

- Daniel Burrhus Olfe, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Engineering Science*  
B.S.E., Princeton University, 1957
- Carole Lois Olson, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., Colorado State University, 1958
- Patrick Gerard O'Regan, *Graduate Research Assistant, Drake Scholar, Electrical Engineering*  
B.E., University College (Cork), 1957
- Eduardo Orias, *Nutrition Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Biology*  
B.S., University of Michigan, 1955; M.S., 1958
- 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, *Woodrow Wilson Foundation Fellow, Physics*  
B.A., Amherst College, 1958
- Robert Allan Ridley Parker, *Woodrow Wilson Foundation Fellow, Astronomy*  
B.A., Amherst College, 1958
- Robert Reid Parmerter, *Institute Scholar, Aeronautics*  
B.S., California Institute, 1958
- 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
- Jerry Clifford Peck, *Lockheed Leadership Fellow, Aeronautics*  
B.S., California Institute, 1957; M.S., 1958
- Max Bruno Peltier, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*  
Ing., Ecole Supérieure d'Electricité (Paris), 1958
- James Macon Peterson, *National Science Foundation Fellow, Chemistry*  
B.S., Wake Forest College, 1958
- Lewis Stephen Pilcher, *Howard Hughes Fellow, Physics*  
B.A., Middlebury College, 1955; S.B., Massachusetts Institute of Technology, 1955
- Elliot Neil Pinson, *Space Technology Laboratories Fellow, Electrical Engineering*  
B.S.E., Princeton University, 1956; S.M., Massachusetts Institute of Technology, 1957
- Françoise Renée Pioline, *Amelia Earhart Fellow, Aeronautics*  
Dipl., Ecole Nationale Supérieure de l'Aéronautique, 1958
- Philip Moss Platzman, *Howard Hughes Fellow, Physics*  
S.B., Massachusetts Institute of Technology, 1956; M.S., California Institute, 1957
- Gerald Leslie Pollack, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., Brooklyn College, 1954; M.S., California Institute, 1957
- Gerald Douglas Pollock, *Graduate Teaching Assistant, Murray Scholar, Geological Sciences*  
B.Sc., University of Manitoba, 1955; M.Sc., 1958
- William Wendell Porterfield, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., University of North Carolina, 1957
- R. Darden Powers, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., University of Oklahoma, 1955; M.S., California Institute, 1957
- Dean Carl Presnall, *National Science Foundation Fellow, Geological Sciences*  
B.S., Pennsylvania State University, 1957
- Andrew Peter Proudian, *Graduate Teaching Assistant, Laws Scholar, Physics*  
B.S., Fresno State College, 1953
- Charles Ranunkel, *Murray Scholar, Aeronautics*  
Dipl., Ecole Centrale des Arts et Manufactures (Paris), 1958

- Odell Fred Raper, *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., Indiana University, 1957
- Bimalendu Raychaudhuri, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
B.Sc., Presidency College (Calcutta), 1948; M.Sc., 1951; M.S., California Institute, 1955
- Richard Bradley Read, *Graduate Teaching Assistant, Institute Scholar, Physics*  
B.S., California Institute, 1957
- Bernard Charles Reardon, *Graduate Research Assistant, Dobbins Scholar, Electrical Engineering*  
B.E., University College (Cork), 1957
- 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., Ohio State University, 1957; M.S., 1958
- Eli Reshotko, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Aeronautics*  
B.M.E., The Cooper Union, 1950; M.M.E., Cornell University, 1951
- John Rischard Rice, *Institute Scholar, Mathematics*  
B.S., Oklahoma Agricultural and Mechanical College, 1954; M.S., 1956
- James Howard Richardson, *Graduate Teaching Assistant, Drake Scholar, Geological Sciences*  
B.Sc., The Ohio State University, 1957
- Robert Gene Rinker, *Union Carbide Corporation Fellow, Chemical Engineering*  
B.S., Rose Polytechnic Institute, 1951; M.S., California Institute, 1955
- Alan Proctor Roberts, *Graduate Teaching Assistant, Institute Scholar, Biology*  
B.A., University of New Hampshire, 1958
- Richard Earl Robertson, *General Electric Educational and Charitable Fund Fellow, Chemistry*  
B.A., Occidental College, 1956
- James Steven Rode, *General Petroleum Fellow, Chemical Engineering*  
B.S., California Institute, 1958
- John David Rogers, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., California Institute, 1956; M.S., 1958
- Ronald Efrom Rolfe, *National Institutes of Health Fellow, Chemistry*  
M.D., Stanford University School of Medicine, 1956
- Ann Wolff Roller, *United States Public Health Service Fellow, Biology*  
B.A., Sarah Lawrence College, 1952; M.S., Georgetown University, 1957
- Xavier Marc Rouvillois, *French Ministry of Foreign Affairs Fellow, Graduate Teaching Assistant, Aeronautics*  
Ing.Civ., Ecole Nationale Supérieure de l'Aéronautique (Paris), 1958
- Henry Ruderman, *Dow Chemical Company Fellow, Physics*  
B.S., Rensselaer Polytechnic Institute, 1956
- Howard Calvin Rumsey, Jr., *Graduate Teaching Assistant, Institute Scholar, 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, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.Eng., University of Southern California, 1956; M.S., California Institute, 1957
- Robert Dean Ryan, *Graduate Teaching Assistant, Institute Scholar, Mathematics*  
B.S., California Institute, 1954
- Roy Ryosuke Sakaida, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*  
B.S., University of California at Los Angeles, 1953; M.S., California Institute, 1957

## 76 Graduate Appointments

- Richard Allan Schapery, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.S., Wayne State University, 1957; M.S., California Institute, 1958
- Robert Max Schmidt, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*  
S.B., Massachusetts Institute of Technology, 1958
- B. Alva Schoomer, Jr., *Graduate Teaching Assistant, Institute Scholar, Chemistry*  
B.S., Louisiana Polytechnic Institute, 1955
- David Israel Schuster, *National Science Foundation Fellow, Chemistry*  
B.A., Columbia College, 1956
- Henry Philip Schwarcz, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
B.A., University of Chicago, 1952; M.S., California Institute, 1955
- Philip Arthur Seeger, *Graduate Research Assistant, Laws Scholar, Physics*  
B.A., The Rice Institute, 1958
- Lionel Sydney Senhouse, Jr., *Paul E. Lloyd 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, Murray Scholar, Physics*  
B.S., Brigham Young University, 1952; M.S., University of Idaho, 1956
- Andrew Charles Sergi, *Atomic Energy Commission Fellow, Mechanical Engineering*  
B.ChE., Pratt Institute, 1958
- 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, *Graduate Teaching Assistant, Institute Scholar, Physics*  
A.B., Middlebury College, 1957
- Donald Cecil Shreffler, *National Science Foundation Fellow, Biology*  
B.S., University of Illinois, 1954; M.S., 1958
- Robert Victor Shull, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.S., New Mexico Institute of Mining and Technology, 1957
- Michael Stewart Shumate, *Graduate Teaching Assistant, Murray Scholar, Electrical Engineering*  
B.S., Purdue University, 1955; M.S.E., 1956
- Alex Shumka, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.A.Sc., University of Toronto, 1957; M.S., California Institute, 1958
- John Robert Simmons, *National Science Foundation Fellow, Biology*  
B.S., Utah State Agricultural College, 1955; M.S., 1956
- Edward Harvey Simon, *National Institutes of Health Fellow, Biology*  
B.S., Rutgers University, 1956
- George Warren Simon, *Howard Hughes Fellow, Physics*  
A.B., Grinnell College, 1955
- Dale Rodekohr Simpson, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.S., Pennsylvania State University, 1956; M.S., California Institute, 1958
- Richard Kanne Sloan, *General Electric Educational and Charitable Fund Fellow, Physics*  
B.S., Pennsylvania State University, 1954; M.S., California Institute, 1956
- Clayton Sutherland Smith, *Graduate Research Assistant, Institute Scholar, Chemical Engineering*  
B.S., Purdue University, 1958
- Joe Nelson Smith, Jr., *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.S., California Institute, 1958

- Lawrence Shepard Smith, *Graduate Teaching Assistant, Drake Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Peter Raymond Smith, *Graduate Teaching Assistant, Dobbins Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Stewart Wilson Smith, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute, 1958
- Alan Soler, *Graduate Teaching Assistant, Murray Scholar, Mechanical Engineering*  
B.S., University of Pennsylvania, 1958
- Theodore Wesley Speiser, *Graduate Research Assistant, Murray Scholar, Physics*  
B.S., Colorado State University, 1956
- Richard Felt Squires, *Graduate Teaching Assistant, Institute Scholar, Biology*  
B.S., Michigan State University, 1958
- Robert James Stanton, Jr., *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*  
B.S., California Institute, 1953; M.A., Harvard University, 1956
- Ronald Oran Stearman, *Institute Scholar, Aeronautics*  
B.S., Oklahoma Agricultural and Mechanical College, 1955; M.S., California Institute, 1956
- Himan Sternlicht, *Graduate Teaching Assistant, Blacker Scholar, Chemistry*  
B.S., Columbia University, 1958
- John Richard Stevens, *Graduate Research Assistant, Institute Scholar, Physics*  
B.A., Pomona College, 1956
- Robert Farrell Stewart, *Graduate Teaching Assistant, Laws Scholar, Chemistry*  
B.A., Carleton College, 1958
- William Albert Steyert, Jr., *Graduate Research Assistant, Institute Scholar, Physics*  
S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute, 1956
- Jack Justin Stiffler, *Radio Corporation of America Fellow, Electrical Engineering*  
B.A., Harvard College, 1956; M.S., California Institute, 1957
- Wilfried Erhard Stockmair, *Deutscher Akademischer Austauschdienst Scholar, Aeronautics*  
Cand. Ing., Technische Hochschule (Munich), 1958
- Edwin Jule Stofel, *Gillette-Paper Mate Fellow, Mechanical Engineering*  
B.S., California Institute, 1953; M.S., 1954
- William Allen Strohl, *Graduate Teaching Assistant, Institute Scholar, Biology*  
B.A., Lehigh University, 1955
- F. William Studier, *National Science Foundation Fellow, Biology*  
B.S., Yale University, 1958
- Henry John Stumpf, *Sunray Mid-Continent Oil Company 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, *National Institutes of Health Fellow, Biology*  
A.B., Washington University, 1956
- Salvatore Philip Suter, *Shell Companies Foundation Fellow, Mechanical Engineering*  
B.M.E., The Johns Hopkins University, 1954; M.S., California Institute, 1955
- Donald Gary Swanson, *Woodrow Wilson Foundation Fellow, Physics*  
B.Th., Northwest Christian College, 1958; B.S., University of Oregon, 1958
- Richard Michael Talman, *National Research Council of Canada Fellow, Institute Scholar, Physics*  
B.A., University of Western Ontario, 1956; M.A., 1957

## 78 Graduate Appointments

- Robert Leicester Tambling, Jr., *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Hugh Pettingill Taylor, Jr., *National Science Foundation Fellow, Geological Sciences*  
B.S., California Institute, 1954; A.M., Harvard University, 1955
- Raymond Leonard Taylor, *Graduate Research Assistant, Chemistry*  
B.S., Brown University, 1955
- Robert Hugh Taylor, *Graduate Teaching Assistant, Institute Scholar, Civil Engineering*  
B.A., Swarthmore College, 1949; B.S., University of Colorado, 1957; M.S., California Institute, 1958
- Howard Martin Temin, *United States Public Health Service Fellow, Biology*  
B.A., Swarthmore College, 1955
- 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, *Monsanto Chemical Company Fellow, Chemistry*  
B.A., University of California at Riverside, 1956
- Guy Allen Thompson, Jr., *Du Pont Postgraduate Fellow, Biology*  
B.S., Mississippi State College, 1953
- Robert Charles Thompson, *National Research Council of Canada Fellow, Institute Scholar, Mathematics*  
B.A., University of British Columbia, 1954; M.A., 1956
- Robert Edward Tokheim, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- M. Nafi Toksoz, *Turkish Mineral Research and Development Institute Fellow, Geological Sciences*  
Geoph. Eng., Colorado School of Mines, 1958
- Richard Ripley Tracy, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*  
B.S., California Institute, 1952; M.S., 1957
- Colwyn Boyd Trevarthen, *Graduate Teaching Assistant, Institute Scholar, Biology*  
B.Sc., University of New Zealand, 1952; M.Sc., 1954
- John Reginald Trollope, *National Research Council of Canada Fellow, Institute Scholar, Mathematics*  
B.S., University of Alberta, 1954; M.S., 1955
- Richard Tunder, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*  
B.S., Case Institute of Technology, 1957
- Ben Turner, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., State College of Washington, 1955
- Jon René Valbert, *Stauffer Chemical Company Fellow, Chemical Engineering*  
B.S., California Institute, 1958
- Charles William Van Atta, *Rand Corporation Fellow, Aeronautics*  
B.S.E., University of Michigan, 1957; M.S.E., 1958
- Sarah Ruth Van Dyck, *Graduate Research Assistant, Institute Scholar, Astronomy*  
B.S., University of Rochester, 1958
- Lorin Lee Vant-Hull, *Graduate Research Assistant, Institute Scholar, Physics*  
B.S., University of Minnesota, 1954; M.S., University of California at Los Angeles, 1956
- Janis Vasilevskis, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*  
B.S., University of California, 1958
- Emilio Cesare Venezian, *Graduate Research Assistant, Dobbins Scholar, Chemical Engineering*  
B.Eng., McGill University, 1958
- Frank Lee Vernon, Jr., *Hughes Staff Doctoral Fellow, Electrical Engineering*  
B.S., Southern Methodist University, 1949; M.S., University of California, 1952

- George Charpentier Vlases, *National Science Foundation Fellow, Aeronautics*  
B.S., The Johns Hopkins University, 1958
- 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
- Mark Hoy Wagner, *Graduate Research Assistant, Murray Scholar, Physics*  
A.B., Miami University, 1958
- William Gerard Wagner, *National Science Foundation Fellow, Physics*  
B.S., California Institute, 1958
- John Walden, *Graduate Research Assistant, Dobbins Scholar, Chemical Engineering*  
B.Ch.E., Polytechnic Institute of Brooklyn, 1955
- Walter D. Wales, *Graduate Research Assistant, Institute Scholar, Physics*  
B.A., Carleton College, 1954; M.S., California Institute, 1955
- Frederic Andrew Wallace, *Graduate Teaching Assistant, Drake Scholar, Chemistry*  
A.B., Harvard College, 1958
- Duen-pao Wang, *Graduate Teaching Assistant, Bennett Scholar, Engineering Science*  
B.S., National Taiwan University, 1956; M.S., Virginia Polytechnic Institute, 1958
- Neng-Ming Wang, *Graduate Teaching Assistant, Drake 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 Teaching Assistant, Institute Scholar, Chemistry*  
S.B., Massachusetts Institute of Technology, 1953
- Kenneth Watson, *Pan American Petroleum Foundation Fellow, Geological Sciences*  
B.A., University of Toronto, 1957
- James Norman Weaver, *Graduate Teaching Assistant, Drake Scholar, Electrical Engineering*  
B.S., California Institute, 1958
- Paul Morris Weichsel, *Graduate Teaching Assistant, Institute Scholar, Mathematics*  
B.S., The City College of New York, 1953; M.S., New York University, 1954
- Robert Avrum Weisberg, *National Science Foundation Fellow, Biology*  
A.B., Harvard College, 1958
- Robert Lawrence Wershaw, *Institute Scholar, Geological Sciences*  
B.S., Texas Western College, 1956
- John William Wesner, Jr., *National Science Foundation Fellow, Mechanical Engineering*  
B.S., Carnegie Institute of Technology, 1958
- 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
- John Coe Wilson, *Graduate Research Assistant, Institute Scholar, Geological Sciences*  
B.S., California Institute, 1953; M.A., University of Kansas, 1955
- Kenneth Geddes Wilson, *Bell Telephone Laboratories Fellow, Physics*  
A.B., Harvard College, 1956
- Robert Woodrow Wilson, *National Science Foundation Fellow, Physics*  
B.A., The Rice Institute, 1957
- John Peter Wolf III, *National Institutes of Health Fellow, Chemistry*  
B.A., University of California at Riverside, 1956
- Howard Wong, *Institute Scholar, Aeronautics*  
B.S., University of California, 1955; M.S., 1956
- William Munger Woodruff, *Graduate Teaching Assistant, Laws Scholar, Mathematics*  
B.S., University of Michigan, 1958; M.S., 1958

## 80 Graduate Appointments

Daniel Lewis Wulff, *National Science Foundation Fellow, Chemistry*  
B.S., California Institute, 1958

Joshua Tsunekatsu Yamada, *Graduate Teaching Assistant, Drake Scholar, Mathematics*  
B.A., University of Toronto, 1955

Tetsuo Yamane, *CAPES Fellow (Brazilian Fellowship), Chemistry*  
B.S., California Institute, 1956

Charlie Lee Yates, *Graduate Teaching Assistant, Dobbins Scholar, Mechanical Engineering*  
B.S., Virginia Polytechnic Institute, 1958

Norman Julius Zabusky, *Standard Oil Company of California Fellow, Physics*  
B.E.E., College of the City of New York, 1951; S.M., Massachusetts Institute of Technology, 1953

Robert Eugene Zartman, *National Science Foundation Fellow, Geological Sciences*  
B.S., Pennsylvania State University, 1957

Jack Henry Zeilenga, *Edith Newell Brown Scholar, Physics*  
B.S., California Institute, 1958

David Zipser, *Graduate Teaching Assistant, Institute Scholar, Biology*  
B.S., Cornell University, 1958

Jonas Stasys Zmuidzinias, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*  
B.S., Indiana Technical College, 1958



## 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.

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Herman V. Shirley  
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Ralph L. Smith  
Howard G. Smits  
Keith Spalding  
Mrs. Keith Spalding  
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Mrs. W. L. Valentine  
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J. Benton Van Nuys  
Howard G. Vesper  
Harry J. Volk  
Richard R. Von Hagen  
Charles B. Voorhis  
Mrs. Thomas W. Warner  
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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, 1959, are listed below.

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Lockheed Aircraft Corporation

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Phillips Petroleum Company

Richfield Oil Corporation

Shell Oil Company

Standard Oil Company of California

The Texas Company

Thompson Ramo Wooldridge Inc.

Union Carbide Corporation

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Consolidated Western Steel Division)

Westinghouse Electric Corporation



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## 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 12 brought 34 students with them, including four young ladies who were making up a liberal education from the non-technical courses offered. 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



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*

work done in them would be at the same high level as that in physics and 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.

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.

Today the California Institute has over 7899 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 \$24,000,000 and those invested in endowment over \$45,000,000.

In February 1958 the Trustees announced the launching of a drive to secure \$16,100,000 to finance 16 needed buildings and an enlarged faculty salary fund. By June 1959 the pledges to this campaign totaled over \$14,000,000. The first unit, a physical plant building, was completed in May 1959; and construction was begun on a new mathematics and physics building, a gift from the Alfred P. Sloan Foundation; and on 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. Other gifts which assure buildings to be constructed during 1960-61 include that of Dr. Arnold O. Beckman (Ph.D. '28) and his wife for a new auditorium; of the W. M. Keck Foundation and the Superior Oil Company for an engineering building; of Mr. P. G. Winnett for a student center; of Dr. Seeley G. Mudd for a central library building to be named in honor of Dr. Robert A. Millikan; and others for graduate and undergraduate houses. About 18 acres of land north of San Pasqual Street have been acquired to provide for substantial expansion of the campus.

*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

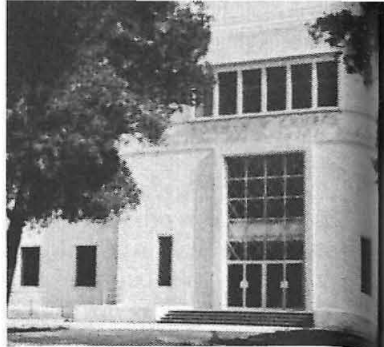
The increasing complexity of business operations has emphasized the fact that a manager must not only know how to do the work being supervised but must also know how to supervise—a separate and distinct function. The expanding demand for training in the knowledge and skills required for supervision caused 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 with various methods and combinations of methods: 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.

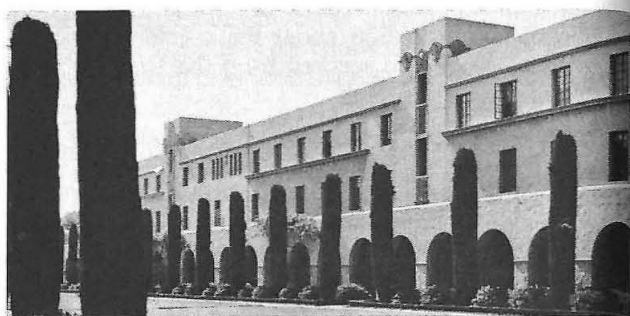
Detailed information about the courses, conferences, and other services available through this Center can be secured from the Director or the Associate Directors of the Management Development Center, Culbertson Hall.



*Throop Hall*



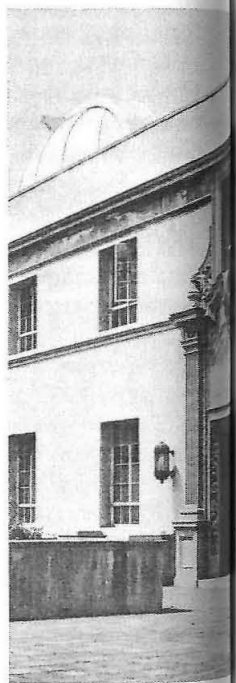
*Church Laboratory for Chemical Biology*



*Kerckhoff Laboratories  
of the Biological Sciences*



*Spalding Laboratory  
of Engineering*



*Robinson Laboratory  
of Astrophysics*



*Athenaeum*



## 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.

**HIGH VOLTAGE RESEARCH LABORATORY, 1923.** Erected with funds provided by the Southern California Edison Company. This building is currently being remodeled into the Alfred P. Sloan Laboratory of Mathematics and Physics.

**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 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 LABORATORY, 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.

#### TEMPORARY BUILDINGS

Living quarters for graduate students, a restaurant for non-resident students, and a club-room for the Throop Club are housed in buildings of temporary construction.

In 1947 the Institute obtained temporary buildings from the government. These provide for Air Force ROTC headquarters, library, and class rooms; The Institute YMCA; a sanitary engineering laboratory; and studies for graduate students.

#### 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 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, Mr. Reuben H. Donnelley.

WILLIAM C. 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.

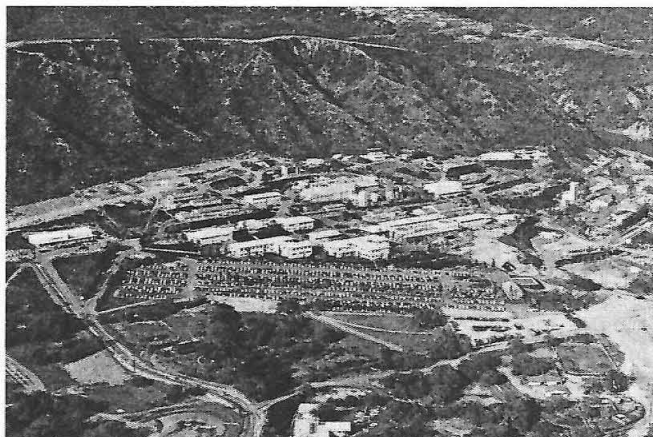
ORLANDO GREENHOUSE (of the Division of Biology), 860 Orlando Road, San Marino, 1942. The gift of Mr. and Mrs. Roy E. Hanson of San Marino, California.

SOUTHERN CALIFORNIA COOPERATIVE WIND TUNNEL, 950 South Raymond Avenue, 1945. Owned by five cooperating aircraft companies and operated under a management agreement by the Institute.

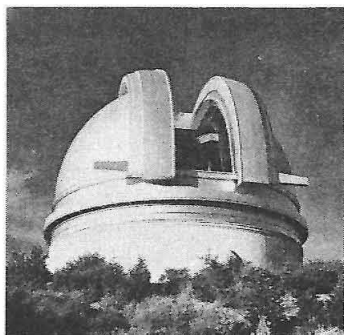
HYDRODYNAMICS LABORATORY, Azusa, 1946. Owned by the Institute together with the Navy Bureau of Yards and Docks and operated by the Institute.

PALOMAR OBSERVATORY, 1948. Owned by the Institute and, with the Mount Wilson Observatory, jointly operated by the Carnegie Institute 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

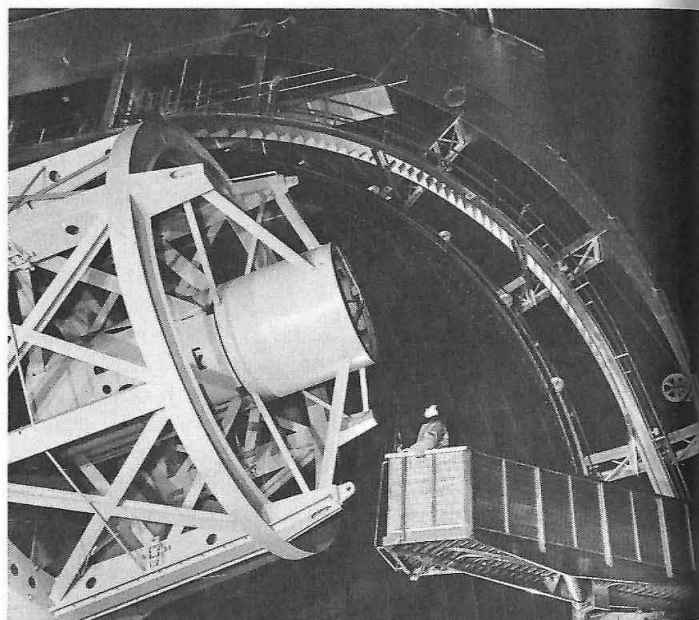
The Rockefeller Boards provided in 1928 for the construction by the Institute of an astronomical observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, 48-inch and 18-inch schmidt wide-angle telescopes and other auxiliary instruments, together with an astrophysical laboratory, 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; and the interstellar gas of the spectra of the brighter stars under very high dispersion; of 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,

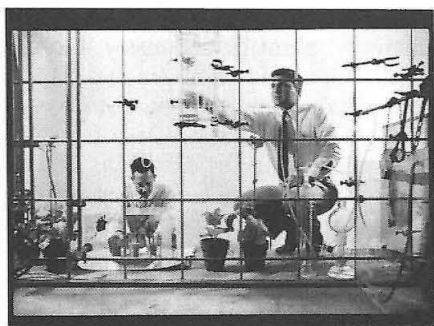
that would attract distinguished investigators to collaborate with the staff of the observatories in scientific matters, and that would draw young men of great ability to graduate studies where they might enjoy the inspiration of leading minds and familiarize themselves with powerful tools of exploration. 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.

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 Norman W. Church Laboratory of Chemical Biology, completed in the summer of 1955, and the William G. Kerckhoff Laboratories of the Biological Sciences consist of three adjacent units. They 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. In addition to standard laboratory equipment for physico-chemical research, there are special facilities for work with radioactive tracers, including automatic counting apparatus; and for work with automatic fraction collectors, phase contrast microscopy, automatic spectrophotometric measurements, liquid and solid phase electrophoresis, and preparative and analytical ultracentrifugation.

Adjacent to the campus there are the Plant Physiology Laboratories, with several air-conditioned greenhouses, and the Earhart Plant Research Laboratory. The Earhart Laboratory is a unique instrument for the study of plant growth under complete weather control. 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 complete reproducibility of experimental results.

At 860 Orlando Road, less than one mile from the campus, the Institute maintains the Orlando Road Greenhouses and Gardens. These greenhouses, which are equipped with insect-proof compartments, are used for the large-scale propagation of plants for biochemical and physiological investigations.

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.

Planned for construction in 1959-60 is the Campbell Plant Research Laboratory—a new greenhouse adjacent to the Earhart, Clark, and Dolk Laboratories. Work is now under way on the Gordon A. Alles Laboratory for Molecular Biology—a laboratory that will link the existing Kerckhoff and Church Laboratories at all floor levels.





*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 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 about 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 Engineering Building 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.

The undergraduate instruction is so arranged that in the last three years of the undergraduate course in science there are offered to students an op-

tion in chemistry and an option in chemical engineering. These options, especially when followed by graduate work in these subjects, prepare students for later experience in positions as teachers and investigators in colleges and universities, as research men in the government service and in industrial laboratories, and as chemists and chemical engineers in charge of the operation and control of manufacturing processes and of the management and development of chemical industries. For students who desire to enter the field of chemical research, for which there are now professional opportunities on both the scientific and applied sides, opportunities for study and research leading to the degree of Doctor of Philosophy are provided at the Institute in the fields of inorganic, analytical, physical, organic, and immunological chemistry, and of chemical engineering.

First-year chemistry, which is taken by all freshman students of the Institute, puts special emphasis on fundamental principles and their use in systematizing descriptive chemistry. Provision is made for the execution in the laboratory of experiments involving quantitative techniques of high precision. Part of the laboratory work is devoted to qualitative analysis.

The second-year work in chemistry consists of studies of the properties and reactions of organic compounds in conjunction with laboratory work in which the fundamental manipulative techniques are acquired through preparations of important pure organic compounds by useful general reactions. In the third term, and also in the subjects of physical and analytical chemistry taken in later years, the abler students may undertake minor researches in place of the regular laboratory work.

The chemical subjects of the junior year consist of courses in physical, analytical, and a wide variety of elective subjects, as described on page 207. A substantial number of elective courses in closely related fields are accepted for credit in the chemistry option. Relatively few of the advanced courses in chemistry are primarily descriptive in nature; most of them are presented largely as series of problems to be solved by the students.

The supervision of the research work of graduate students is distributed among the members of the staff of the Division of Chemistry and Chemical Engineering. Some of the many fields in which researches are being actively prosecuted are listed on pages 247 & 252.

The fifth-year course in chemical engineering leads to the degree of Master of Science in Chemical Engineering. This course contains an intensive problem-study of chemical engineering, a laboratory course in engineering measurement and research methods, a course in business economics, 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 graduate course work arranged with the approval of the Division of Chemistry and Chemical Engineering.

Chemical engineering may be offered as a major subject for the degree of Doctor of Philosophy; it may also be presented as a minor subject in connection with the doctorate in other fields of science or engineering. The lines of research being pursued in chemical engineering include engineering thermodynamics, phase equilibrium of fluids at elevated pressures, thermal transfer, fluid flow, diffusional processes, reaction kinetics, applied mathematics, and combustion.

## 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.

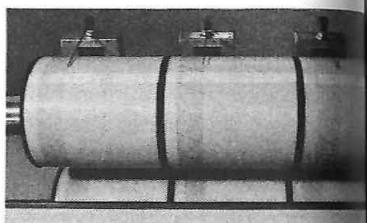
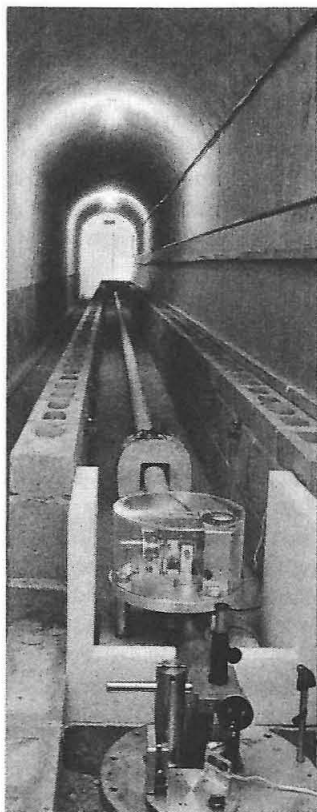
Physical facilities, both natural and man-made, are excellent. All the classroom instruction and most of the laboratory research in geology and geochemistry, as well as part of that in geophysics, are carried on in the Arms and Mudd Laboratories. These are modern, five-story buildings which were specifically 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.

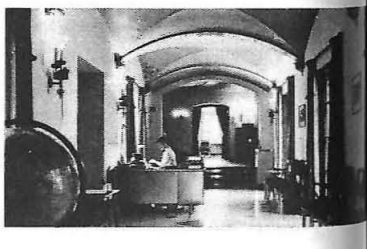
Favorable opportunity for study of dynamic aspects of paleontology and evolution as revealed by morphology, ecology, and biogeochemistry is provided by the combination of personnel, reference collections, and modern geochemical tools and techniques available here. Biologic principles and processes, past 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, 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 Seismological Laboratory*



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.

Since the more interesting academic and industrial positions open to mathematicians require training beyond a Bachelor's degree, the man 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.

*Courses.* The schedule of courses in the undergraduate mathematics option is flexible to enable the student to adapt his program to his needs and mathematical interests and to give him the opportunity of becoming familiar with creative mathematics early in his career. Undergraduates intending to proceed to graduate work in mathematics are expected to choose a full year's graduate course in mathematics for one of their selected courses. They are also urged to include at least one, and preferably two, years of language study in their program.

*Requirements.* 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.

*Library facilities.* There is an excellent mathematics library with a large collection of journals housed in the general library in West Bridge. Students are strongly urged to make use of this facility, and may borrow any books not on reserve for special courses. Current periodicals may be consulted in the library.

## GRADUATE WORK

Graduate work in mathematics is planned to give the student a broad knowledge of classical and modern mathematics and to train him to do creative 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.

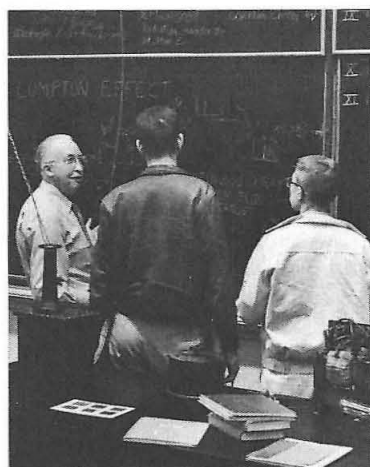
*Courses.* The courses which carry a number between 116 and 199 cover fundamental general topics; those listed with a higher number are more special and more advanced and they include research seminars. Students are urged to take part in one or more of these seminars, and to make extensive use of the library facilities.

*Requirements.* The general requirements for the degree of Ph.D. are listed on pages 179-182; additional requirements for mathematics are found on page 194. The special prerequisites for the course requirements in a minor subject are listed under the separate departments. In particular those for physics are listed on pages 293-297.



*Part time teaching and financial help.* A number of graduate assistantships are available in mathematics giving an opportunity to teach undergraduate classes. As a rule, this teaching is limited to one four-hour a week course. Advanced students of superior research ability may be awarded a graduate fellowship carrying no teaching duties.

*Master's degree.* Students initially planning to take only a master's degree are accepted only under very special circumstances. When the complete Ph.D. requirements cannot be met, a master's degree may be awarded upon passing at least five courses listed under B or C on pages 283-285, taking graduate humanities electives for a total of 27 units or more and submission of a thesis. The thesis requirement may be waived at the discretion of the department.



## 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 rather than merely teachers. The instruction 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. Students who do not expect to go into graduate work are advised to choose electives from among the engineering subjects. 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 193.) 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 auxiliary equipment which make the facilities especially good for precision work in the field of light nuclei. 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. Liquid helium is available and there is a laboratory for work in low-temperature physics. 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.

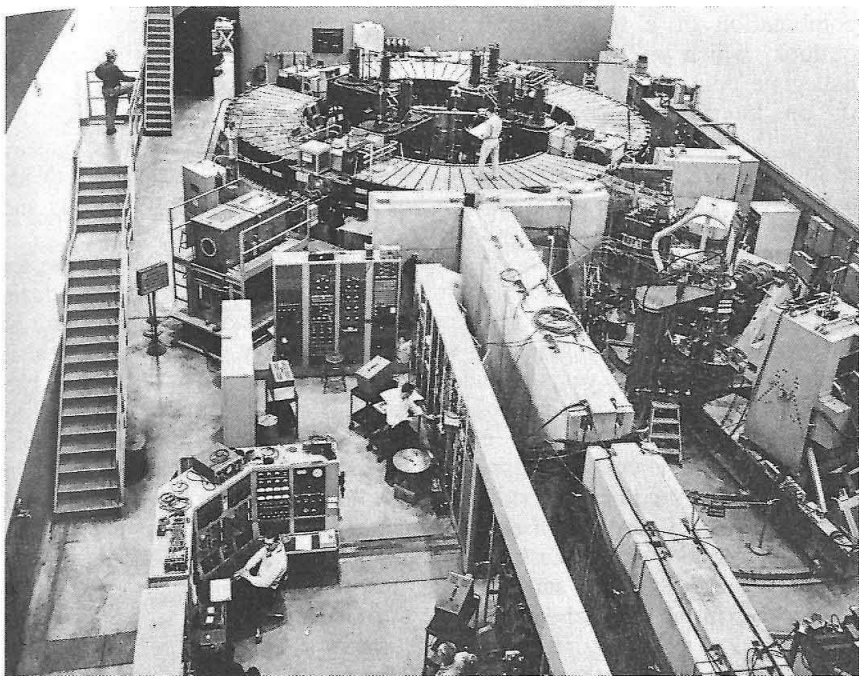
The student either may select his own problem in consultation with the department or may work into some one of the research projects already under way. The average yearly output of the laboratory for many years has been from fifty to sixty major papers.

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 inter-

ested 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 time for this being secured by eliminating some of the more specialized technical subjects commonly included in undergraduate engineering courses. It shall include, however, the professional subjects common to all branches of engineering. It is hoped in this way to provide a combination of a fundamental scientific training with a broad human outlook, which will afford students with engineering interests the type of collegiate education endorsed by leading engineers—one which avoids on the one hand the narrowness common among students in technical schools, and on the other the superficiality and the lack of purpose noticeable in many of those taking academic college courses." The Course is designed to provide a thorough basis for general engineering practice, for advanced study and research, or for industrial and administrative work.

The plan of instruction in engineering embodies a four-year course for the degree of Bachelor of Science in Engineering. The three undergraduate curricula of civil, electrical, and mechanical engineering\* have a core of basic science and the engineering sciences essentially common throughout three years. The three years include, in addition to a year of chemistry, two years of mathematics and two of physics, materials and processes, applied mechanics, basic electrical engineering, thermodynamics and fluid mechanics, and a year's course in advanced engineering mathematics. In the fourth year the three curricula diverge into appropriate areas of technical interest in which methods of engineering analysis and synthesis are emphasized, illustrated with professional subjects. The curricula have the general character of engineering science programs. As elective options within the fourth year in mechanical engineering, three general directions are possible, mechanical engineering, physical metallurgy, and aeronautics, although the latter two are not greatly different from the normal mechanical engineering sequence. Subjects in the Humanities are integral parts of all courses of study during the four years.

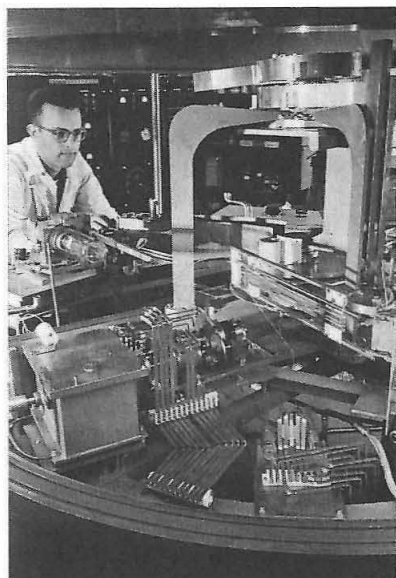
The four-year undergraduate courses in engineering are well balanced foundations for entrance into many opportunities within the respective fields. However, those students who wish to prepare for careers in the more intensive technical phases of engineering, and who have shown capacity to do advanced work, are expected to take the fifth year leading to the Master's degree, which includes additional professional subjects, advanced concepts, and additional Humanities. While the work of the fifth year is prescribed to a considerable extent, latitude in course selection exists, and a student may, if he wishes, engage in research in a field of his own selection under the guidance of a staff representing a wide range of experience and current activity.

\*See pages 105-106 for chemical engineering.

## 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 Digital 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 123). The staffs of these three facilities are actively engaged in the fields of Aeronautics 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 and elasticity, with the underlying mathematics, mechanics, thermodynamics, and physics.
2. A group of practical courses in airplane design 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, and low density.
  - 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 and guided missiles.
  - 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 projectiles.
  - e. Problems in jet propulsion with special emphasis on the underlying fluid mechanics, thermodynamics, dynamics, and chemistry. (See page 123.)

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.

The Aeronautics department has developed a number of interests related



to but not strictly included in its academic, on-campus activities. Two of these now have extensive research facilities with which the department maintains close contact, although they are not located on the Institute campus. The first is the Jet Propulsion Laboratory which consists of a group of about 2500 persons, of whom about 600 are professional engineers and scientists. The Laboratory is supported by the Department of Defense and is administered under the auspices of the Institute; and a number of key personnel share their time between Institute teaching and Laboratory duties. The purpose of the Laboratory is to do research on the fundamental problems of jet propulsion and guided missiles, 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 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 second off-campus facility is the Southern California Cooperative Wind Tunnel which is owned by five aircraft companies. The Laboratory with its equipment was constructed and is operated by the Aeronautics department under a management agreement. This tunnel now has approximately 45,000 installed horsepower, with a number of interchangeable working sections, and is able to devote speeds up to 1.8 times the velocity of sound.

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.

## CIVIL ENGINEERING

In Civil Engineering instruction is offered leading to the degrees of Bachelor of Science, 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) sanitary 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.

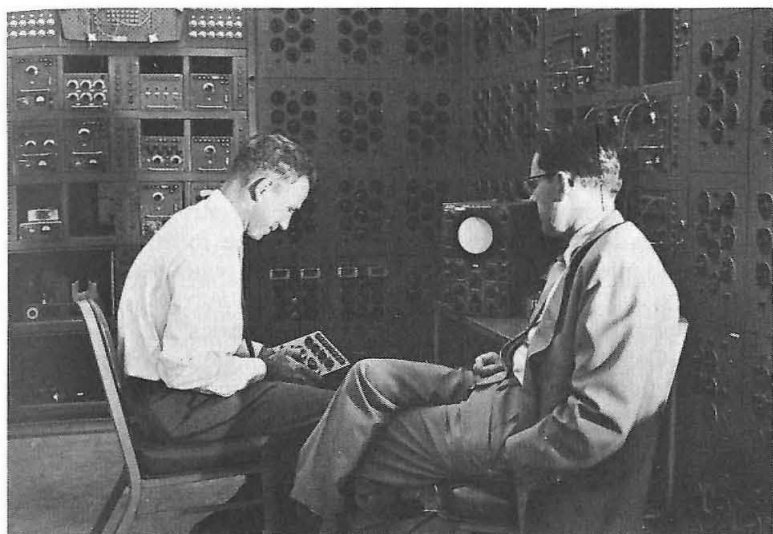
Excellent research facilities are available to qualified graduate students in all the fields above. Laboratories for solid mechanics and soil mechanics are located in the Engineering Building. Hydraulic research is carried on in the Sedimentation Laboratory, which is described in detail under the section "Hydrodynamics" below. Some of the sanitary engineering research is closely integrated with the hydraulic research in the Sedimentation Laboratory, while the main portion is carried on in a separate biological and chemical laboratory.

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 Bachelor of Science, Master of Science, Electrical Engineer, and Doctor of Philosophy.

Electrical engineering affords opportunity for many choices of life work relating to design, research, 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 electrical engineering option 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 greatly strengthens the undergraduate courses by bringing students who feel the fourth- and fifth-year courses best adapted to their needs in close touch with research men and problems.

Of the several electrical engineering laboratories at the California Institute, the Computing Center, the Servomechanism Laboratory, and the Electron and Microwave Tube 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.

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.

The *transistor research group* is undertaking a study of small-signal linear amplifiers. A wide-range equivalent circuit is being used to develop fundamental procedures for the design of wide-band and video transistor amplifiers with specified response characteristics.

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

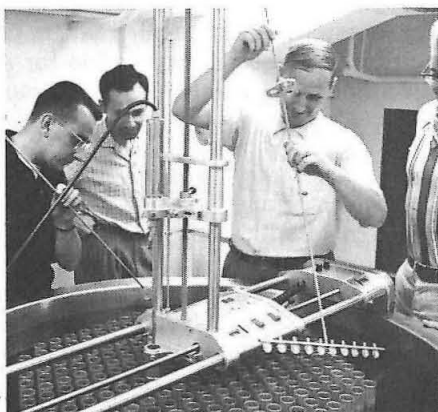
Advanced programs of study leading to the degree of Doctor of Philosophy in Engineering Science are offered by the Division of Engineering. These programs are complementary to those leading to the degrees of Doctor of Philosophy in Civil, Mechanical, Electrical, and Aeronautical Engineering and are designed 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 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 Bachelor of Science, 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 mechanical engineering option 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 with electives in the fourth year in aeronautics, general mechanical engineering, and physical metallurgy. 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 four general areas: (1) hydrodynamics, (2) design, mechanics, and dynamics, (3) physical metallurgy and mechanics of materials, and (4) thermodynamics and heat power. 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. Similarly, it is expected in general that students entering the course work in jet propulsion will have had their undergraduate preparation in mechanical engineering or aeronautics. Thus, the program of instruction in jet propulsion has 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.

The facilities of the Institute, in particular those in Aeronautics and in Mechanical Engineering, 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.

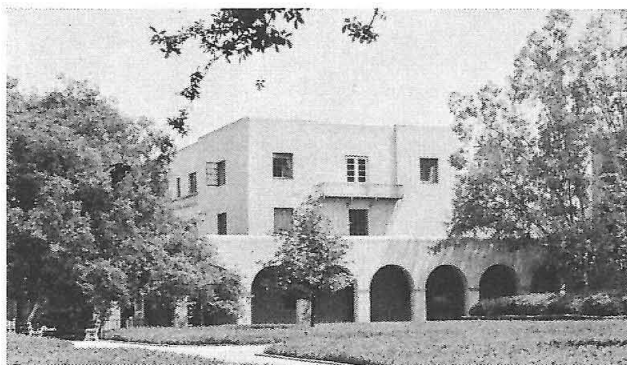
*Hydrodynamics Laboratory.* This laboratory is a three-story wing adjoining the Hydraulic Machinery Laboratory. Its equipment is designed for the determination of the dynamics of the motion of underwater bodies. Major research programs are now being carried on under the sponsorship of the Bureau of Ordnance 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.

*Sedimentation Laboratory.* This laboratory, originally operated for soil conservation studies, has become a center for basic investigations into the mechanism of entrainment, transportation, and deposition of solid particles by flowing fluids. The equipment includes (a) two closed circuit flumes for studying sediment transportation, (b) a sediment analysis laboratory, (c) a water tunnel for studying diffusion and turbulence, and (d) facilities for studying flow problems of the type found in hydraulic structures. Facilities of this installation 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.



*In the Hydrodynamics Laboratory, an investigator works on a fundamental flow problem in fluid mechanics*





*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.

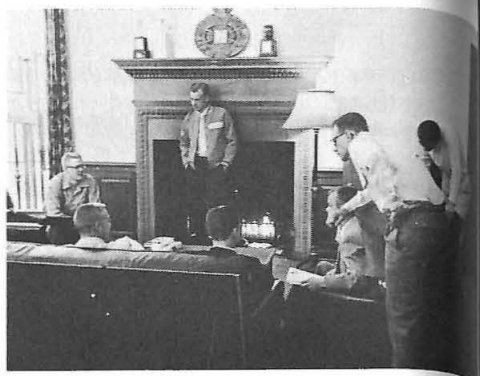
In connection with the acceptance of the gift of Dabney Hall, a special fund of \$400,000 for the support of instruction in the humanistic fields was subscribed by several friends of the Institute. In 1937 the late Mr. Edward S. Harkness gave the Institute an additional endowment fund of \$750,000 for 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.





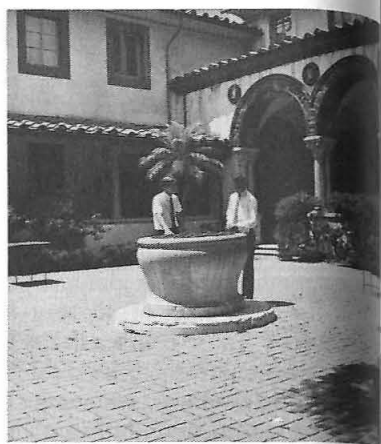
*Blacker*



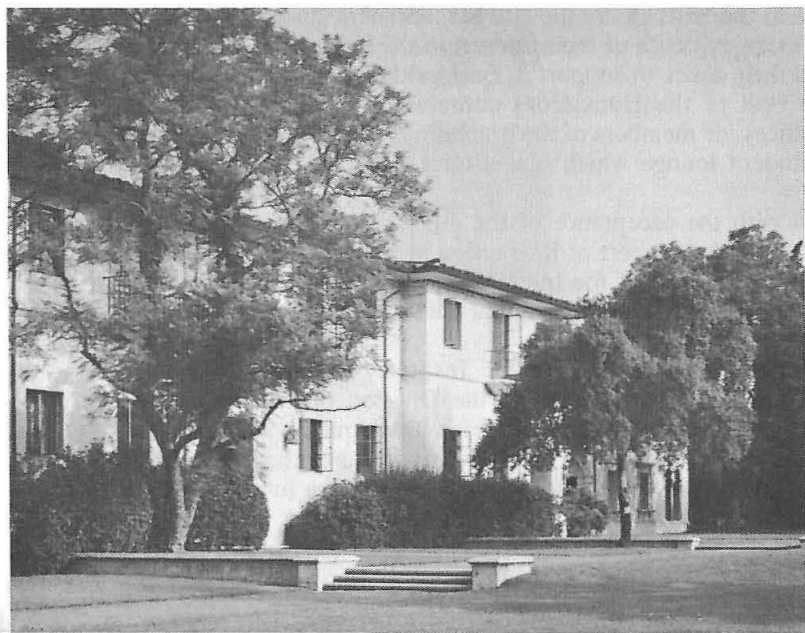
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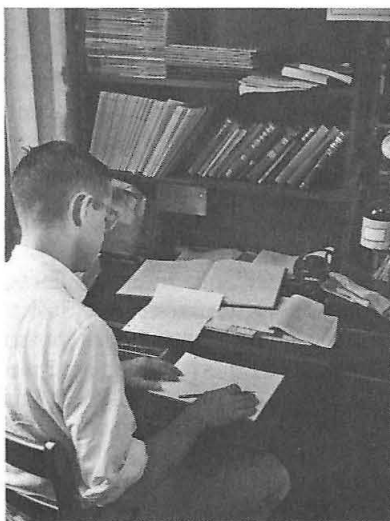
*Fleming*



*Ricketts*



*The Student Houses  
are pleasantly  
located in the  
east campus*



## STUDENT LIFE

*Student Houses.* The four Student Houses are situated on the California Street side of the campus. Planned in the Mediterranean style to harmonize with the Athenaeum, they were, like the latter building, designed by Mr. Gordon B. Kaufmann. While the four Houses constitute a unified group, each House is a separate unit providing accommodations for about ninety students; each has its own dining-room and lounge, but all are served from a common kitchen.

All four Houses have attractive inner courts surrounded by portales. More than half the rooms are doubles, and all are simply but adequately and attractively furnished. The buildings are so planned that within each of the four Houses there are groupings of rooms for from twelve to twenty students, with a separate entry and toilet and kitchenette facilities for each.

Each of the four Houses, Blacker, Dabney, Fleming, and Ricketts, has its own elected officers and is given wide powers in the matter of arranging its own social events, preserving its own traditions, and promoting the general welfare of the House. 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 four 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. When there are not sufficient rooms to satisfy the demand, freshmen are assigned rooms from a priority list based on the geographical distance between the student's home and the Institute. 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.

*Throop Club.* Throop Club, the fifth non-resident House, provides for off-campus students the same sort of focus for undergraduate life that the Student Houses provide for resident students. Throop Club has its own elected officers and committees and carries on a full program of social and other activities. The Throop Club lounge, made possible by the generosity of a group of friends of the Institute, provides a convenient gathering place on the campus and is the center of Throop Club activities. For non-resident students, membership in the Throop Club greatly facilitates participation in undergraduate social life and intramural sports.

*Interhouse Activities.* The presidents and vice-presidents of the four Student Houses and Throop Club make up the Interhouse Committee, which determines matters of general policy for all five 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 four Student Houses and the Throop Club 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.

*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

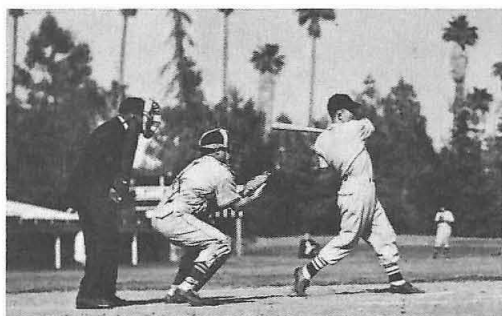
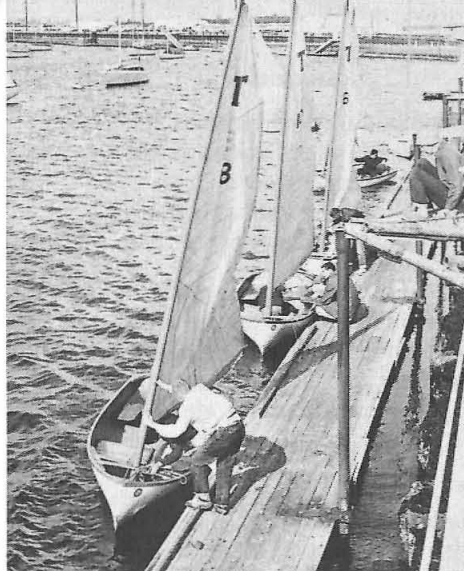
System is the outstanding tradition of the student body, which accepts full responsibility for its operation. The Board of Control, which is composed of elected representatives from each of the four undergraduate classes, is charged with interpreting the Honor System. If any violations should occur, the Board of Control considers them and may recommend appropriate disciplinary measures to the Deans.

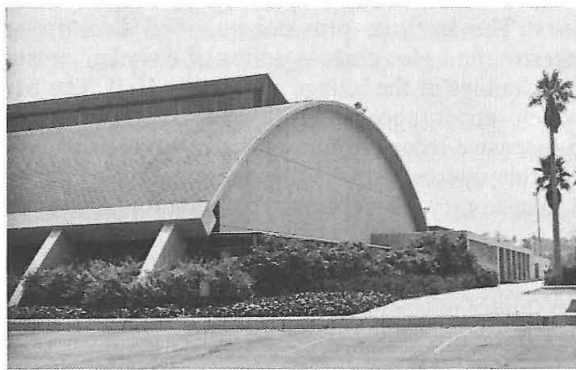
*Faculty-Student Relations.* Faculty-student coordination and cooperation with regard to campus affairs is secured through periodic joint meetings of the Faculty Committee on Student Relations and certain student body officers and elected representatives. These conferences serve as a clearing house for 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 in the sophomore year and continues through graduation.



*An informal discussion  
with a distinguished visitor to the campus*





*Scott Brown Gymnasium and  
Alumni Swimming Pool*

*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, and Whittier—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.

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; 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, orchestra, 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 Instituturs, 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 in one of the service buildings on the campus near the Student Houses. 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 Workshop organization. These applications are acted upon by a governing committee of students, and this committee is charged with the responsibility of admitting only those who



can demonstrate their competence in the operation of the machines in the shop. 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 inter-collegiate 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 intercollegiate 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 only at the beginning of the freshman year. All freshmen may join the unit regardless of the option in engineering or science which they may eventually select. Except, and at discretion of Professor of Air Science, students with prior military service may be given credit for basic course towards Air Force ROTC requirements. Students who remain in the program through graduation may be commissioned as Second Lieutenants in the Air Force Reserve. Students may be enrolled in any of four Categories: Category I, flying training candidates; Category II, Technical and Scientific fields; Category III, non-flying and non-technical fields; 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. During the middle of the sophomore year those in the basic course will be screened for aptitude and must pass the physical examination required for the Category they wish to enter before being admitted to the advanced course in the junior and senior year.

The basic course is designed to indoctrinate and orient the cadet with the major concepts of Air Power in the modern Air-Atomic Age. Objectives of this course are Air Age Citizenship and the development of positive attitudes toward national defense.

Advanced course cadets will receive training and instruction that ultimately lead to commissioned service in the Air Force Reserve. This program emphasizes leadership development and individual experiences designed to promote character, confidence, and ability.

It is expected that those entering the basic course will continue in the program through graduation. However, a student who has neither entered the advanced course nor obtained draft deferment during the basic course may, at the discretion of the Professor of Air Science, be permitted to withdraw. Deferment from Selective Service may be granted to all who remain in good standing with both the Institute and AFROTC. To obtain this deferment, the student must agree to continue in the program until its completion, to accept a commission in the Air Force Reserve, and to serve three years of active duty upon graduation or five years if accepted for flying training. Those who fail to adhere to this agreement will be denied graduation unless a special exception is made by the Air Force. The California Institute can assume no responsibility for the decisions of the Air Force in continuing students in the program. These decisions are necessarily governed by the needs of the Air Force at the time.

Uniforms are furnished by the Air Force and required to be worn only during military exercises or at the request of the Professor of Air Science. Students in the basic course receive no pay. Those in the advanced course receive about \$27.00 per month for subsistence allowance.

Students, including citizens of friendly foreign countries, who for any reason cannot be enrolled or conditionally enrolled in the Air Force ROTC program may be authorized by institutional authorities and the Professor of Air Science to pursue either the basic or advanced course.

For AFROTC course requirements for the first year see page 202.

## 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, 1960. (Application to take entrance examinations must be made directly to the College Board at an earlier date, for which see page 137.)

Applicants living outside of the United States must submit their credentials by December 1, 1959.

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
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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.

Applicants who offer for entrance a total of fifteen recommended units, but whose list of subjects is not in accord with this table, may be admitted at the discretion of the faculty, if they are successful in passing the general entrance examinations; but no applicant will be admitted whose preparation does not include English 2 units, mathematics 3 units, physics 1 unit, chemistry 1 unit. All entrance deficiencies must be made up before registration for the second year.

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 1960 the Scholastic Aptitude Test must be taken no later than the February 6 College Board Test date and the Achievement Tests no later than the March 12 date. *It is important to note that no applicant can be considered with the original group to be admitted in 1960 who has not taken the Scholastic Aptitude Test by February 6 and the required Achievement Tests by March 12.* 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 \$6 for the Scholastic Aptitude Test and \$9 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 1960 a candidate has only two dates on which he can take the required Achievement Tests. These are December 5, 1959, and March 12, 1960. The Scholastic Aptitude Test may be taken on December 5 as well. Most applicants will find that they will be better prepared for the achievement tests if they wait until March 12. The College Board will offer the Scholastic Aptitude Test on January 9 and February 6 in addition, but no Achievement Tests will be offered on these latter dates. *The dates on which a candidate may take the College Board tests are thus: Scholastic Aptitude Tests—December 5, 1959, January 9, 1960, February 6, 1960; Achievement Tests—December 5, 1959, March 12, 1960.* He 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.

*For examination centers located*

<i>To take tests on</i>	In the United States, Canada, the Canal Zone, Mexico, or the West Indies, applications must be received by	In Europe, Asia, Africa, Central and South America, and Australia, applications must be received by
Dec. 5, 1959	November 7	October 17
Jan. 9, 1960 (Aptitude Test only)	December 12	November 21
Feb. 6, 1960 (Aptitude Test only)	January 9	December 19
Mar. 12, 1960	February 13	January 23

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 between 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 18, 1960 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 18, 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 the 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 courses which are taught at the college level and cover the material of a first-year college course. The College Entrance Examination Board gives each year in May a set of Advanced Placement examinations covering this advanced work. The California Institute will allow credit and advanced placement for such work as follows. Credit for the second and third terms (En 1 bc) of freshman English on the basis of a one-year college-level course in English reading and composition and a high score on the College Board Advanced Placement examination in English; advanced placement in English in the second and third terms in English 6, "Literary Masterpieces." Credit for freshman mathematics on the basis of a one-year college-level course covering the topics of the first-year work at the Institute (see course description of Ma 1 abc, page 281) and a high score on the College Board Advanced Placement test in mathematics; advanced placement in sophomore mathematics (Ma 2 abc). Credit for freshman physics on the basis of a one-year college-level course covering the topics of the first-year work at the Institute (see course description of Ph 1 abc, page 292) and a satisfactory grade in the California Institute's transfer examination in physics taken by those applying for admission as sophomores (the College Board Advanced Placement test in physics is not adapted to the first-year work at the Institute and is, therefore, not accepted); advanced placement in sophomore physics (Ph 2 abc). Credit for certain portions of freshman chemistry on the basis of a one-year college-level course covering the topics of the first-year work at the Institute (see course description of Ch 1 abc, page 164. It is not anticipated that all of the topics of Ch 1 abc will have been covered. Those that are not must be taken in the regular way) and a high score on the College Board Advanced Placement test in chemistry; advanced placement for those entering options in which chemistry is required in the sophomore year. 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 152.) 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.

#### SCHOLARSHIPS

For information regarding scholarships for entering freshmen see pages 159-170. 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 159. For information on tuition cost starting in September 1960 and on deferred tuition payment plans see page 157.

#### 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 134.

#### 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 one of the options in engineering or 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 135-139 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 135-139. 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, the branch of engineering or science he wishes to pursue, 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 202-218) 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 143.

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 sopho-

more 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 22, 1960, is as follows:

Chemistry	(3 hours)	1:00 P.M.	June 3, 1960
English	(1 hour )	9:00 A.M.	June 4, 1960
Mathematics	(2 hours)	10:30 A.M.	June 4, 1960
Physics	(3 hours)	2:00 P.M.	June 4, 1960

No other examinations for admission to upper classes will be given in 1960.

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 147-151.) 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 149.)

Physical examinations and vaccination are required as in the case of students entering the freshman class. (See page 140.) 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. This fee covers the cost of the New Student Camp, which all those entering the Institute for the first time are required to attend. (See page 140.) In the event of subsequent

cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute.

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

	<i>Registration Dates</i>	<i>Fees Payable</i>	<i>Instruction Begins</i>
Freshmen and Transfer Students . . . . .	Sept. 24, 1959	Sept. 24, 1959	Sept. 29, 1959
Upperclassmen and Graduate Students	Sept. 28, 1959	Sept. 28, 1959	Sept. 29, 1959

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 151). 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 Satisfactory,\* 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. 148), 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.

*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, sophomore, or new transfer student who fails to receive at least a 1.5 grade-point average during any one term will be required to report to the Dean before registering and may be requested to withdraw from all extracurricular activities and outside employment or reduce the number of subjects he is carrying sufficiently to enable him to meet the scholastic requirements in succeeding terms.

*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 some one option of the course in engineering or 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.

*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 174.

Registration for fewer than 33 units must be approved by the Registration Committee. See page 172 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 enter the engineering course may postpone selection of option until shortly before the close of the sophomore year.

*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 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 140.

## THE DISPENSARY AND INFIRMARY

The new Archibald Young Health Center is located on Arden Road, 50 feet below California Street. 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. Students have priority on the available beds.

The staff consists of attending physicians, retained consultants, and nurses. A medical consultant in radiological safety is on the consulting staff. Diagnostic psychiatric care is available. The infirmary is operated twenty-four hours a day, seven days a week, during the academic year except during holidays (Thanksgiving, Christmas and Spring recesses). The dispensary is open during the academic year from 9 a.m. to 5 p.m. from Monday through Friday, and 9 a.m. to 12 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-operation 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 provides a comprehensive health scheme (not an insurance plan) 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.

#### EMERGENCY HEALTH FUND

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. It is hoped that the plan can be liberalized in the future by the building up of the Fund in this manner.

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 \$1.00. 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 .....	\$519.75		
Room .....	\$259.00 <sup>2</sup>	778.75	
Dues .....		21.00	799.75
Total for Academic Year with Board and Room .....			\$2,210.25

#### 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 will 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 1959-60, 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

<i>Date Due</i>		<i>Fee</i>
Upon notification of admission .....	Registration Fee .....	\$ 10.00 <sup>1</sup>
Sept. 24, 1959: Freshmen and transfer students .....	General Breakage Deposit .....	25.00
Sept. 28, 1959: All others .....	Tuition, 1st term .....	425.00
	Board and Room, 1st term .....	
	21 meals per week ..	275.75 <sup>2</sup>

#### *First Term Incidental Fees:*

	Associated Student Body Dues .....	5.50
	Subscription to Calif. Tech for 1959-60 .....	1.50
	Total .....	7.00
	Locker Rent, 1st term .....	1.00 <sup>3</sup>
	Parking Fee, 1st term .....	1.50 <sup>3</sup>
	Student House Dues, 1st term .....	7.00
January 4, 1960 .....	Tuition, 2nd term .....	425.00
	Board and Room, 2nd term .....	
	21 meals per week ..	255.00 <sup>2</sup>

*Second Term Incidental Fees:*

Associated Student Body Dues .....	6.75
Locker Rent, 2nd term .....	1.00 <sup>3</sup>
Parking Fee, 2nd term .....	1.50 <sup>3</sup>
Student House Dues, 2nd term .....	7.00
March 28, 1960..... Tuition, 3rd term .....	425.00
Board and Room, 3rd term	
21 meals per week ..	248.00 <sup>2</sup>

*Third Term Incidental Fees:*

Associated Student Body Dues .....	6.75
Locker Rent, 3rd term .....	1.00 <sup>3</sup>
Parking Fee, 3rd term .....	1.50 <sup>3</sup>
Student House Dues, 3rd term .....	7.00

## GRADUATE STUDENTS

*First Term:*

September 28, 1959.. Tuition .....	425.00
General Deposit (see page 79) .....	25.00

*Second Term:*

January 4, 1960..... Tuition .....	425.00
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*Third Term:*

March 28, 1960..... 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 <sup>4</sup>	
32 to 25 units .....	\$318.75 per term
24 to 10 units .....	\$12.75 per unit per term
Minimum per term .....	\$127.50 <sup>5</sup>
Auditor's Fee .....	\$21.00 per term, per lecture hour

<sup>a</sup>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.<sup>6</sup> No portion of the Health Fee, Student Body Dues, or Subscription to California Tech, is refundable upon withdrawal at any time.

<sup>1</sup>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.

<sup>2</sup>Rate for rooms will be adjusted for those assigned to rooms with double bunks. Rates for room and board subject to revision prior to beginning of any term upon notice to student.

<sup>3</sup>Optional.

<sup>4</sup>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 196.

<sup>5</sup>Graduate Students see pages 172-173.

<sup>6</sup>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 146) 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.

*Deferred tuition payment plan.* A student in any undergraduate class, including entering freshmen, may if he wishes extend tuition payments over as many as eleven years under one of two types of deferred tuition payment plans. Under plan A a student may defer the entire tuition of \$1275 a year by paying \$50 a month from the date of entering the plan until any outstanding balance has been paid. A freshman starting and continuing under this plan would pay monthly installments of \$50 during his four undergraduate years and for approximately six years after graduation, or a total of ten years. These installments include simple interest (interest on the unpaid balance only) at 5 percent per annum and the premiums on an insurance policy which pays off any outstanding balance in the event of the death of the student during the period of payments or of the parent (or guardian) responsible for his support during his undergraduate years. Thus a student in effect pays \$600 tuition during each of his undergraduate years and the balance, including interest and insurance, after graduation. Plan B is for those who would find the \$600 payments too high, especially in the early years. Under this plan a student may defer up to \$900 of the tuition until after graduation. He would pay each year \$375 of the tuition in three equal installments at the beginning of each term and would pay the interest only (5 percent simple interest) quarterly on the outstanding balance. Six months after graduation he would commence paying the balance due in installments

of \$50 a month for appriximately seven and one-half years. He would be covered by the same insurance as under plan A. A student may enter either of these plans at any time and he may defer any portion of the tuition up to \$1275 under plan A or \$900 under plan B. He may also at any time make larger payments on the outstanding balance than the minimum required.

Financial need is not a factor in the determination of eligibility for these plans. They are open to any student provided only that he has not already contracted indebtedness to the Institute in such an amount as to indicate that he should not assume an additional financial obligation and provided that his grades show that he is making satisfactory progress toward a degree.

An undergraduate who expects to continue his work in graduate school may after his admission to a graduate school consult with the business office regarding adjustment of payments under these plans during his graduate work.

## 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**.

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 161 to 167. 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** (see below), 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 137. 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 137) 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 three 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 195.

**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.

#### 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 CONTEST

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 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 two weeks before the beginning of the fall term. 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 1959-60 academic year for a junior or senior in mechanical engineering.

**R. C. Baker Foundation Scholarship:** The R. C. Baker Foundation of Los Angeles has given \$1000 for an undergraduate scholarship in mechanical engineering.

**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 Corporation Scholarships:** The Bechtel Corporation of San Francisco has provided funds for two scholarships to be awarded to juniors or seniors in any branch of 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 Insti-

tute. 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 1959-60 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 160.

**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 1959-60 academic year to be awarded to a junior or senior in aeronautical engineering, mechanical engineering, electrical 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 electrical engineering.

**Garrett Corporation Scholarships:** The Garrett Corporation of Los Angeles has given \$3000 for scholarships to be awarded to juniors or seniors majoring in mechanical engineering or applied chemistry, 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 1959-60 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 144). 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 applied chemistry.

**Ladish Company Scholarship:** The Ladish Company has given two scholarships to be awarded to freshmen in the amount of \$1250 (apportioned over four years) for each scholarship.

**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-four undergraduate scholarships for the academic year 1959-60. Not open to freshmen.

**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 education, particularly in engineering courses.

**Neely Enterprises Scholarship:** Neely Enterprises has given a \$1000 scholarship for a sophomore student majoring in physics or electrical 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.

**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 a four-year undergraduate scholarship in the amount of \$1400 a year. This four-year award is open to entering freshmen only.

**Radio Corporation of America Scholarship:** The Radio Corporation of America has provided funds for an undergraduate scholarship for 1959-60 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 1959-60 for undergraduates majoring in applied chemistry or mechanical 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.

**Shepherd Machinery Company Scholarship:** The Shepherd Machinery Company of Los Angeles has made possible a four-year scholarship carrying a stipend of \$750 a year to be awarded to a freshman student who is the son of an employee or principal in the earth-moving industry residing in Los Angeles, Orange, or Inyo Counties.

**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.

**Socony Mobil Oil Company-General Petroleum Corporation** has established a scholarship of \$1675 for a junior or senior student in engineering. The Corporation is likewise giving a scholarship for a junior or senior or graduate student in geology.

**Society of Experimental Test Pilots Scholarship:** The Society of Experimental Test Pilots has made provision for a scholarship up to \$1000, depending on need, for the 1959-60 academic year, to be awarded to a student entering the junior class in aeronautical engineering, mechanical 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.

**Standard Oil Company of California Scholarships:** The Standard Oil Company of California has provided a scholarship for an undergraduate majoring in applied chemistry and another scholarship for an undergraduate majoring in mechanical engineering. In addition the company provides two prize awards for which any undergraduate is eligible. Leadership, financial need, and scholastic performance are given equal weight in selection.

**Elizabeth Thompson Stone Scholarship:** Miss Elizabeth Thompson Stone of Pasadena established, by her will, a scholarship known as the Elizabeth Thompson Stone Scholarship.

**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.

**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 1959-60 to be awarded preferably to juniors in mechanical 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 the Electrical Engineering Option. 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.

Crown Zellerbach Foundation  
 Cyprus Mines Corporation  
 Douglas Aircraft Company  
 Garrett Corporation  
 General Motors Corporation  
 Goodyear Foundation  
 Graham Brothers Foundation  
 International Nickel Company  
 International Telephone & Telegraph Corporation  
 Kennecott Copper Corporation  
 Lockheed National Engineering Scholarship  
 Procter & Gamble Fund  
 Radio Corporation of America  
 Socony Mobil—General Petroleum Corporation  
 Alfred P. Sloan Foundation  
 Superior Oil Company  
 Union Carbide Corporation

## 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 Memorial Fund  
 The Ruth Wydman Jarmie Loan Fund  
 The John McMorris Memorial Loan Fund  
 The Noble Loan and Scholarship Fund



The Pasadena Optimists Club Fund  
 The James R. Page Loan 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 157.

### 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 upper-classman, 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 any of the three undergraduate options 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, each member representing one of the three options. The subjects may include those set by national engineering societies for their annual student-paper contests. The three judges of the contest, appointed by the Faculty Committee of three, are engineers who hold no official appointment at the California Institute.

# 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 195) need not make separate application for admission to graduate standing. For requirements in regard to physical examination, see pages 140 and 152.

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 175, 176, 180 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 submission 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. (See page 179.)

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 \$1 must be paid by graduate students who register for summer work. (See page 156.) 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 195 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.

## 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 220-226) 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 145-149 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 147) also apply to students working toward the master's degree. In meeting the graduation requirements on page 150, 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. Candidates for 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 145-149.

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 145-149.

5. A written placement examination is required of incoming graduate students in the Division of Geological Sciences. For details see page 188. 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.

6. Candidates for the master's degree in the Division of Chemistry and Chemical Engineering are required to take placement examinations. See pages 184-185.

7. Candidates for 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 192, 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 180. Regulations governing registration will be found on page 178.

2. *Residence.* At least six terms of graduate residence (as defined on page 172) 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 describing 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 181.)

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. See pages 185, 220.

*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 186, 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 227.

## 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 156), 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 174, 176 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 147), 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 of a general type or concentrated within one discipline, which will be designated as the minor subject.

(a) *General type.* 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) *Minor subject.* A concentrated minor program of study in a minor

subject must include at least 45 units of advanced work in the chosen minor subject 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 181). 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 172 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 close of the first term of the year in which the degree is to be conferred, and must be followed by two terms of further residence (45 units per term; see page 172) before the degree is conferred. *The student himself is responsible for seeing that admission is secured at the proper time.*

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 146). 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 concentrated minor program of study, on the minor 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 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 182.

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 reproduced 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 page 176.

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 179), 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. In exceptional cases, graduate work is offered to women.

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 179.

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.

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.
- d. A student majoring in another division, who selects a minor subject in Biology, and having a minor in one of the special fields of Biology is required to take two candidacy examinations, one in either general botany or general zoology and one in his minor subject.

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 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 the instructors in charge of the major and minor work and such other 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 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 in the following page) which the applicant is prepared to defend during his oral examination.

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 for the Ph.D. degree will be required in the fields of engineering thermodynamics of one-component systems (on the Wednesday before registration), elementary fluid flow (on Tuesday), the unit operations of chemical engineering (on Thursday), and either physical chemistry (on Monday) or industrial chemistry (on Friday). Those students who propose to register for Ch E 166 abc need not take the examination in unit operations. For 1960-61 and subsequent years the placement examination in elementary fluid flow will not be given. The placement examination in the unit operations of chemical engineering will be required and will include fluid flow topics. 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 shall have studied mathematics and physics substantially to the extent that these subjects are covered in the first two years of the Institute undergraduate courses. In case the applicant's training is less extensive than this, the Division of Chemistry and Chemical Engineering may prescribe additional work in these subjects prior to recommending him as a candidate.

3. The units of study offered for satisfaction of 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 in Chemistry or Chemical Engineering elects a minor program of study of the general type, the 45 units or more of advanced work which must be presented for a doctorate must represent an integrated program approved by the Division and for students in Chemistry shall consist of courses other than chemistry and for students in Chemical Engineering shall 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.

The propositions should be about ten in number, of which about four should relate to the minor program of study and to general branches of chemistry, and about six to the branch of chemistry of major interest to the candidate, including his research.

For students in chemical engineering about three propositions should relate to the minor program of study, two to chemistry if this is not the minor subject or to mechanical engineering if chemistry is the minor subject, and about five to chemical engineering. The candidate may also include propositions not relating to his major and minor program of study.

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.

#### 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 subjects with a grade of C or better:

Ph 131 abc	Electricity and Magnetism
EE 132 abc	Circuit Analysis

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.

A student in electrical engineering completing work for the doctor's degree will, in general, be expected to have had six months or more of practical work in manufacturing, operating, or engineering research, in addition to the time required for graduate residence.

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	} considered as one subject
Ae 201 abc	Inviscid Fluid Mechanics	
Ae 204 abc	Mechanics of Real Gases	
JP 121 abc	Rocket	
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.

At the beginning of every term each graduate student will fill out or bring up to date a status form, obtained from the Division office, showing college courses taken. This will be presented upon request to advisers and staff members in charge of registration.

**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  
Geobiology

Geochemistry  
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 179 and 180 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 181). 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 180, item 3.

8. *Thesis and Paper for Publication:* The doctoral candidate must complete his thesis and submit it in final form by April 20 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 February 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 179, 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		<i>Units</i>
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 212	Mechanics of Continuous Media	
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 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 stu-



dent 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 oral examination not later than the end of registration week. The purpose of this examination 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. 111, 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 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 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.

#### 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. When possible, 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 82.

**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

\*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.

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.

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.

#### 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 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, Bell Telephone Laboratories, Bendix Aviation Corporation, Boeing Airplane Company, California Research Corporation, Consolidated Electrodynamics Corporation, Convair, Corning Glass Works Foundation, Curtiss-Wright Corporation, Douglas Aircraft Company, Dow Chemical Company, E. I. duPont de Nemours and Company, Firestone Tire and Rubber Company, Fluor Foundation, Garrett Corporation, General Electric Educational and Charitable Fund, General Petroleum Corporation, D. Foster Hewett, Hughes Aircraft Company, International Business Machines Corporation, International Nickel Company, Inc., Kaiser Aluminum & Chemical Corporation, Kennecott Copper Corporation, Paul E. Lloyd, Lockheed Leadership Fund, Arthur McCallum Fund, Monsanto Chemical Company,

Paper Mate Mfg. Co., Pan American Petroleum Foundation, Radio Corporation of America, Rand Corporation, Raytheon Manufacturing Company, Richfield Oil Corporation, Sidney Schafer, Schlumberger Foundation, Shell Companies Foundation, Space Technology Laboratories, Standard Oil Company of California, Stauffer Chemical Company, Stauffer Foundation, John Stauffer, Sunray Mid-Continent Oil Company, 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.

**The Rockefeller Foundation Fund for Research on Basic Problems of Biology and Chemistry:** This fund is contributed by the Rockefeller Foundation for the support of research in immunology, serological genetics and embryology, chemical genetics, and the structure of proteins which are being carried out in the Division of Chemistry and Chemical Engineering and in the Division of Biology.

**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 note under Engineering Science, page 121.

## 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 for Infantile Paralysis, 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.

**George Ellery Hale Research Fellowships in Radiation Chemistry:** Dr. Arthur Amos Noyes, for many years Professor of Chemistry and Director of the Gates and Crellin Laboratories of Chemistry, by his will, gave the Institute a fund to provide for certain research fellowships to be known as the "George Ellery Hale Research Fellowships in Radiation Chemistry;" these fellowships to be available to competent young investigators who have received the degree of Doctor of Philosophy or have had a corresponding research training, and who will pursue, at the Institute, investigations in radiation chemistry (broadly interpreted to include the study of molecular structure by the methods of modern physics). These fellowships carry stipends, obligations, and privileges similar to those of the National Research Fellowships.

**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, 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).<sup>1</sup>

Besides the subjects shown in the course schedules, students are required to take either military or physical education<sup>2</sup> 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

<sup>1</sup>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.

<sup>2</sup>See page 152 for rule regarding excuses from physical education.

## SENIOR HUMANITIES ELECTIVES

Pl 1	Philosophy	H 4	The British Empire
Pl 2	Logic	H 7	Modern and Contemporary Germany
Pl 3	Contemporary European Philosophies	H 8	The History of Russia
Pl 4	Ethics	H 15	The World Since 1914
Pl 6	Psychology	H 16	American Foreign Relations
En 8	Contemporary English and European Literature	H 17	The Far West and the Great Plains
En 9	American Literature	H 19	Modern America
En 10	Modern Drama	H 21	Medieval England
En 11	Literature of the Bible	H 22	Modern England
En 17	Technical Report Writing	H 23	Modern War
En 18	Modern Poetry	H 25	Political Parties and Pressure Groups
En 19	Seminar in Literature	H 26	The Political Novel
L 5	French Literature	H 35	Modern India and Pakistan
L 40	German Literature	H 124	Foreign Area Problems
Ec 48	Introduction to Industrial Relations	H 125	International Law and Organization
Ec 124	Economics of Underdeveloped Areas		

## 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.<sup>1</sup>

		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 <sup>2</sup>	Physical Education (0-3-0) .....	3	3	3
		<hr/> 53	<hr/> 50	<hr/> 50

<sup>1</sup>Honor electives (3 units) to be given second and third terms. See page 151.

<sup>2</sup>AFROTC students substitute 4 units of Air Science (AS 1abc, 2-1-1) for Physical Education (PE 1 abc, 0-3-0).



**ASTRONOMY OPTION**  
(For First Year see page 202)

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 149.

**SECOND YEAR**

		Units per Term		
		1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8) .	12	12	12
Ph 2 abc	Electrostatics, Electrodynamics, and Optics (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	.	.
Bi 1	Elementary Biology (3-3-3) . . . . .	.	9	.
Ay 1	Introduction to Astronomy (3-1-5) . . . . .	.	.	9
	Electives . . . . .	6-10	6-10	6-10
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		48-52	48-52	48-52

*Electives*

The student may elect any course that is offered in any division in a given term, provided only that he has the necessary prerequisites for that course.

**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	Properties of Matter (3-0-6) . . . . .	9	9	9
Ay 2 abc	General Astronomy (3-3-3) . . . . .	9	9	9
PE 3 abc <sup>2</sup>	Physical Education (0-3-0) . . . . .	3	3	3
	Electives (see below) to make <sup>2</sup> . . . . .	9-15	9-15	9-15
		47-53	47-53	47-53

**FOURTH YEAR**

	Humanities Electives (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 <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
	Electives (see below) to make <sup>3</sup> . . . . .	11-18	9-11	9-11
		46-53	50-52	50-52

*Electives*

*With Approval of Adviser*

L 32 abc	Elementary German (4-0-6) <sup>4</sup> . . . . .	10	10	10
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8) <sup>4</sup> . . . . .	12	12	12
Ma 112	Elementary Statistics (3-0-6) . . . . .	9 or	9	.
Ph 115 ab	Optics (3-0-6) <sup>4</sup> . . . . .	9	9	.
Ph 217	Spectroscopy (3-0-6) . . . . .	.	.	9
Ge 2	Geophysics (3-0-6) . . . . .	.	.	9
EE 160 abc	Electronics (2-0-4) <sup>4</sup> . . . . .	6	6	6
Ay 108 ab	Astronomical Instruments and Radiation Measurements (3-1-5; 3-2-4) <sup>4</sup> . . . . .	9	9	.
Ay 133	Radio Astronomy (3-0-6) . . . . .	.	.	9
Ay 131 abc or	Astrophysics (3-0-6) <sup>4</sup> . . . . .	9	9	9
Ay 132 ab				
Ay 141 abc	Astronomy Research Conference (1-0-1) . . . . .	2	2	2

<sup>1</sup>AFROTC students will substitute AS 2 abc for PE 2 abc.

<sup>2</sup>AFROTC students will substitute AS 3 abc for PE 3 abc and take 6-10 units electives per term.

<sup>3</sup>AFROTC students will substitute AS 4 abc for PE 4 abc and take electives to make 6-10 units each term.

<sup>4</sup>Students who plan to do graduate work in astronomy should elect some of these courses during their 3rd and 4th years.

## BIOLOGY OPTION

(For First Year see page 202)

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 full statement of this regulation will be found on page 149.

## SECOND YEAR

		Units per Term		
		1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8) .	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
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	.	.
Bi 1	Elementary Biology (3-3-3) . . . . .	.	9	.
Bi 2	Genetics (3-3-3) . . . . .	.	.	9
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<u>52</u>	<u>52</u>	<u>52</u>

## Summer Following Second Year

Bi 4	Invertebrate and Vertebrate Zoology (5-10-5) . . . . .	20 units
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## THIRD YEAR

Ch 21 abc	Physical Chemistry (3-0-6) . . . . .	9	9	9
Bi 107 abc	Biochemistry (3-0-7; 3-3-4; 3-5-2) . . . . .	10	10	10
En 7 abc	Introduction to Literature (3-0-5) . . . . .	8	8	8
L 32 abc	Elementary German (4-0-6) . . . . .	10	10	10
Bi 3	Plant Biology (4-6-2) . . . . .	12	.	.
Bi 5	Advanced Plant Biology (3-6-3) . . . . .	.	.	12
Bi 20	Mammalian Anatomy and Histology (2-6-4) . . . . .	.	12	.
PE 3 abc <sup>2</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<u>52</u>	<u>52</u>	<u>52</u>

## FOURTH YEAR

Bi 116 ab	Animal Physiology (3-3-4) . . . . .	10	10	.
Bi 117	Psychobiology (3-3-3) . . . . .	.	.	9
Bi 106	Embryology (2-6-4) . . . . .	12	.	.
Bi 115	Plant Physiology (3-6-3) . . . . .	.	12	.
Bi 110	Microbiology (3-4-5) . . . . .	.	.	12
	Humanities Electives <sup>4</sup> (3-0-6) . . . . .	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	.
PE 4 abc <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
	Biology Electives <sup>5</sup> . . . . .	9-12	6-9	15-18

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1), for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1), for Physical Education (PE 3 abc, 0-3-0).

<sup>3</sup>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.

<sup>4</sup>For list of Humanities electives, see page 202.

<sup>5</sup>The following subjects are offered as fourth year Biology electives:

## FIRST TERM

Bi 114	Immunology (2-4-3) . . . . .	9 units
Bi 125	Topics in Plant Biology (3-3-6) . . . . .	12 units
Bi 129 a	Biophysics (2-0-4) . . . . .	6 units
Ma 112	Elementary Statistics (3-0-6) . . . . .	9 units
Bi 22	Special Problems . . . . .	units by arrangement
Bi 225 a	Special Topics in Genetics (2-0-4) . . . . .	6 units

## SECOND TERM

Bi 218	Virology (2-3-4) . . . . .	9 units
Bi 22	Special Problems . . . . .	units by arrangement
Bi 129 b	Biophysics (2-0-4) . . . . .	6 units
Bi 225 b	Special Topics in Genetics (2-0-4) . . . . .	6 units

## THIRD TERM

Bi 127	Chemical Genetics Laboratory (0-6-0) . . . . .	6 units
Bi 128	Advanced Microtechnique (1-4-1) . . . . .	6 units
Bi 22	Special Problems . . . . .	units by arrangement
Ge 30	Introduction to Geochemistry (3-0-7) . . . . .	10 units

## CHEMICAL ENGINEERING OPTION

(For 1959-60 only)

(For First Year see page 202)

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

		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
ChE 60	Introduction to Chemical Engineering Problems (3-0-6) . . . . .	.	.	9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3) . . . . .	9	or 9	.
	Elective . . . . .	9	or 9	.
PE 2 abc	Physical Education (0-3-0) <sup>1</sup> . . . . .	3	3	3
		52	52	52

## THIRD YEAR

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 Analyses (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 15 abc	Engineering Mathematics (3-0-6) . . . . .	9	9	9
EE 3	Introduction to Electric Circuits and Power (4-0-8) . . . . .	12	.	.
PE 3 abc	Physical Education (0-3-0) <sup>2</sup> . . . . .	3	3	3
		51	52	52

## FOURTH YEAR

	Humanities electives (3-0-6) <sup>3</sup> . . . . .	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 5 a	Applied Mechanics—Dynamics (3-0-6) . . . . .	9	.	.
AM 4 a	Applied Mechanics—Strength of Materials (3-0-6) . . . . .	.	9	.
EE 1 b	Basic Electrical Engineering (3-0-6) . . . . .	.	9	.
ChE 66 abc	Chemical Engineering Operations (3-0-9; 2-0-7) . . . . .	12	12	9
ChE 67	Chemical Engineering Laboratory (0-9-3) . . . . .	.	.	12
	Electives <sup>4</sup> . . . . .	6	.	6
PE 4 abc	Physical Education (0-3-0) <sup>5</sup> . . . . .	3	3	3
		50	53	50

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>AFROTC students will substitute 8 units of Air Science (AS 3 abc, 4-1-3) for Physical Education (PE 3 abc, 0-3-0).

<sup>3</sup>For list of Humanities electives, see page 202.

<sup>4</sup>Electives need not be chemical engineering subjects; however, the following chemical engineering subjects are available: ChE 68, ChE 80, and either ChE 164 or ChE 170.

<sup>5</sup>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.

## CHEMICAL ENGINEERING OPTION

(For 1960-61 and subsequent years)

(For First Year see page 202)

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

		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
ChE 60	Introduction to Chemical Engineering Problems (3-0-6) . . . . .	.	.	9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3) . . . . .	9 or	9	.
	Elective . . . . .	9 or	9	.
PE 2 abc	Physical Education (0-3-0) <sup>1</sup> . . . . .	3	3	3
		52	52	52

## THIRD YEAR

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 15 abc	Engineering Mathematics (3-0-6) . . . . .	9	9	9
EE 3	Introduction to Electric Circuits and Power (4-0-8) . . . . .	12	.	.
PE 3 abc	Physical Education (0-3-0) <sup>2</sup> . . . . .	3	3	3
		51	52	52

## FOURTH YEAR

	Humanities electives (3-0-6) <sup>3</sup> . . . . .	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 5 a	Applied Mechanics—Dynamics (3-0-6) . . . . .	9	.	.
AM 4 a	Applied Mechanics—Strength of Materials (3-0-6) . . . . .	.	9	.
ChE 66 abc	Chemical Engineering Operations (3-0-9; 2-0-7) . . . . .	12	12	9
ChE 67	Chemical Engineering Laboratory (0-9-3) . . . . .	.	.	12
	Electives <sup>4</sup> . . . . .	6	6	6
PE 4 abc	Physical Education (0-3-0) <sup>5</sup> . . . . .	3	3	3
		50	50	50

<sup>1</sup>AFOTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>AFOTC students substitute 8 units of Air Science (AS 3 abc, 4-1-3) for Physical Education (PE 3 abc, 0-3-0).

<sup>3</sup>For list of Humanities electives, see page 202.

<sup>4</sup>Electives need not be chemical engineering subjects, however, the following chemical engineering subjects are available: ChE 68, ChE 80, ChE 168 ab, ChE 170, ChE 171 ab.

<sup>5</sup>AFOTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFOTC 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 202)

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**

		Units per Term		
		1st	2nd	3rd
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
H 2 abc	History and Government of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3) . . . . .	9	.	.
Bi 1	Elementary Biology (3-3-3) . . . . .	.	9	.
Bi 2	Genetics (3-3-3) . . . . .	.	.	9
	or		or	
Ay	Introduction to Astronomy (3-1-5) . . . . .	.	.	9
PE 2 abc	Physical Education (0-3-0) <sup>1</sup> . . . . .	3	3	3
		<hr/> 52	<hr/> 52	<hr/> 52

**THIRD YEAR**

Ec 4 ab	Economic Principles and Problems (3-0-3) . . . . .	.	6	6
L 32 abc	Elementary German <sup>2</sup> (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
	Electives <sup>3</sup> . . . . .	10-14	6-10	6-8
Ch 90	Oral Presentation (1-0-1) <sup>7</sup> . . . . .	.	.	2
En 7 abc	Introduction to Literature (3-0-5) . . . . .	8	8	8
PE 3 abc	Physical Education (0-3-0) <sup>4</sup> . . . . .	3	3	3
		<hr/> 50-54	<hr/> 50-54	<hr/> 50-54

**FOURTH YEAR**

	Humanities electives (3-0-6) <sup>5</sup> . . . . .	9	9	9
H 5 abc	Public Affairs (1-0-1) . . . . .	2	2	2
	Electives <sup>3</sup> . . . . .	36-40	36-40	36-40
PE 4 abc	Physical Education (0-3-6) <sup>6</sup> . . . . .	3	3	3
		<hr/> 50-54	<hr/> 50-54	<hr/> 50-54

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>May be taken in either third or fourth year.

<sup>3</sup>Approved elective courses listed on page 124.

<sup>4</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-1-3) for Physical Education (PE 3 abc, 0-3-0).

<sup>5</sup>For list of Humanities electives see page 202.

<sup>6</sup>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.

<sup>7</sup>May be taken in senior year.

## 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). 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	Electroanalytical Chemistry Laboratory (0-6-0) ....	.	.	6
Ch 125 abc	Advanced Physical Chemistry (3-0-6) .....	9	9	9
Ch 127 ab	Radioactivity and Isotopes (2-0-4) .....	.	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	Principles of Industrial Chemistry (3-0-6) .....	.	9	9
ChE 63 ab	Chemical Engineering Thermodynamics (3-0-6) ...	.	9	9
ChE 63 c	Chemical Engineering Thermodynamics (3-0-6) ...	9	.	.
ChE 66 abc	Chemical Engineering Operations (3-0-9; 2-0-7) ....	12	12	9
ChE 80	Industrial Chemical 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	Properties of Matter (3-0-6) .....	9	9	9
Ph 112 abc	Introduction to 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 15 abc	Engineering Mathematics (3-0-6) .....	9	9	9
AM 102 abc	Applied Nuclear Physics (2-0-4) .....	6	6	6
Bi 107 abc	Biochemistry (3-0-7; 3-3-4; 3-5-2) .....	10	10	10
Bi 110	General Microbiology (3-4-5) .....	.	.	12
Bi 127	Chemical Genetics Laboratory (0-6-0) .....	.	.	6
Ge 3	Materials of the Earth's Crust (3-0-6) .....	.	9	.
Ge 30	Introduction to Geochemistry (3-0-7) .....	.	.	10
Ge 151 b	Laboratory Techniques in the Earth Sciences (0-5-0)	.	.	.
L 35	Scientific German (4-0-6) .....	10	.	.

## CIVIL ENGINEERING OPTION

(For First Year see page 202)

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 149.

## 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
Ec 2 ab	General Economics and Economic Problems (3-0-6) . . . . .	9	9	.
Ec 18	Industrial Organization (3-0-4) . . . . .	.	.	7
	or		or	
Ec 25	Engineering Law (3-0-4) . . . . .	.	.	7
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
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3; Ay 1, 3-1-5)	9	or 9	or 9
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/>	<hr/>	<hr/>
		51	51	49

## THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5) . . . . .	8	8	8
AM 1	Statics (2-3-4) . . . . .	9	.	.
AM 4 ab	Strength of Materials (3-0-6) . . . . .	.	9	9
AM 15 abc	Engineering Mathematics (3-0-6) . . . . .	9	9	9
CE 1	Surveying (2-6-4) . . . . .	.	.	12
EE 1 ab	Basic Electrical Engineering (3-0-6) . . . . .	9	9	.
EE 2 a	Basic Electrical Engineering Laboratory (0-3-0) . . .	.	3	.
Hy 2 ab	Hydraulics (3-2-5) . . . . .	.	10	10
ME 15 a	Thermodynamics (3-2-5) . . . . .	10	.	.
PE 3 abc <sup>2</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/>	<hr/>	<hr/>
		48	51	51

## FOURTH YEAR

	Humanities elective (3-0-6) . . . . .	9	9	9
H 5 abc	Public Affairs (1-0-1) . . . . .	2	2	2
AM 3	Testing Materials Laboratory (0-3-3) . . . . .	.	6	.
AM 5 ab	Dynamics (3-0-6) . . . . .	9	9	.
CE 10 abc	Theory of Structures (2-3-4; 3-3-6; 3-0-6) . . . . .	9	12	9
CE 12	Reinforced Concrete (3-3-6) . . . . .	.	.	12
CE 14 abc	Engineering Conference (1-0-1; 1-0-1; 0-2-0) . . . . .	2	2	2
CE 17	Civil Engineering (3-0-6) . . . . .	.	.	9
CE 20	Introduction to Sanitary Engineering (2-0-4) . . . . .	.	6	.
CE 105	Introduction to Soil Mechanics (2-3-4) . . . . .	9	.	.
CE 155	Hydrology (3-0-6) . . . . .	9	.	.
Hy 11	Fluid Mechanics Laboratory (0-6-0) . . . . .	.	.	6
PE 4 abc <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/>	<hr/>	<hr/>
		52	49	52

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1) for Physical Education (PE 3 abc, 0-3-0).

<sup>3</sup>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.

<sup>4</sup>For list of Humanities electives, see page 202.



## ELECTRICAL ENGINEERING OPTION

(For First Year see page 202)

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 149.

## 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
Ec 2 ab	General Economics and Economic Problems (3-0-6) . . . . .	9	9	.
Ec 18	Industrial Organization (3-0-4) . . . . .	.	.	7
	or		or	
Ec 25	Engineering Law (3-0-4) . . . . .	.	.	7
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
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3; Ay 1, 3-1-5) . . . . .	9	or 9	or 9
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		51	51	49

## THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5) . . . . .	8	8	8
AM 5 ab <sup>2</sup>	Dynamics (3-0-6) . . . . .	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
AM 15 abc <sup>2</sup>	Engineering Mathematics (3-0-6) . . . . .	9	9	9
AM 116 <sup>2</sup>	Complex Variables and Applications (3-0-6) . . . . .	.	.	9
	or			
AM 115 ab <sup>2</sup>	Engineering Mathematics (3-0-6) . . . . .	.	9	9
AM 116 <sup>2</sup>	Complex Variables and Applications (3-0-6) . . . . .	9	.	.
	Elective (To be approved by Electrical Engineering Faculty) . . . . .	.	.	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5) . . . .	10	10	10
PE 3 abc <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		48	51	51

## FOURTH YEAR

(Senior Year for 1958-59 only)

	Humanities elective (3-0-6) . . . . .	9	9	9
H 5 abc	Public Affairs (1-0-1) . . . . .	2	2	2
EE 70 ab	Engineering Conference (1-0-1) . . . . .	2	2	.
EE 104	Electronic Systems (3-0-6) . . . . .	9	.	.
EE 103 abc	Electric Circuit Theory (3-0-6; 2-0-4) . . . . .	9	9	6
EE 7 abc	Experimental Techniques in Electrical Engineering (0-3-2) . . . . .	5	5	5
	Electives . . . . .	11-15	20-24	25-29
PE 4 abc <sup>4</sup>	Physical Education . . . . .	3	3	3
		50-54	50-54	50-54

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>Students with a good record may be permitted to take Ph 107 and Ma 108 instead of AM 15 (or AM 115) and AM 116 and AM 5 but must then take Ph 108 in senior year instead of EE 15.

<sup>3</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-1-3) for Physical Education (PE 3 abc, 0-3-0).

<sup>4</sup>AFROTC students 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.

*Suggested Electives<sup>5</sup>*

EE 15 abc	Electromagnetism (3-0-6; 2-0-4) .....	9	9	6
EE 18	Computers (2-0-4) .....	.	.	6
EE 19	Transistor Circuits (2-0-4) .....	.	.	6
EE 40	Introduction to Information Theory (2-0-4) .....	.	.	6
EE 102 ab	Electromechanical Devices (2-0-4; 3-0-6) .....	.	6	9
EE 162 abc	Physical Electronics (2-0-4) .....	6	6	6
Ph 112 abc	Introduction to Atomic and Nuclear Physics (4-0-8)	12	12	12
Ma 5 ab	Introduction to*Abstract Algebra (3-0-6) .....	9	9	.
Ma 112	Elementary Statistics (3-0-6) .....	9	or 9	.

<sup>5</sup>Selection must be approved by the Electrical Engineering Faculty. Other courses may be allowed with approval.

## GEOLOGICAL SCIENCES OPTION

(For First Year see page 202)

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<sup>3</sup>

		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
CH 14	Quantitative Analysis (2-6-2) . . . . .	10	.	.
H 2 abc	History of the United States (2-0-4) . . . . .	6	6	6
Ge 1	Physical Geology (4-2-3) . . . . .	9	.	.
B 1	Elementary Biology (3-3-3) . . . . .	.	9	.
Ge 2	Geophysics (3-0-6) . . . . .	.	.	9
Ge 3	Mineralogy (3-3-3) . . . . .	.	9	.
Ge 5	Geobiology (3-0-6) . . . . .	.	.	9
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/>	<hr/>	<hr/>
		52	51	51

## THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5) . . . . .	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3) . . . . .	6	.	6
Ge 120 abc	Field Geology (4-5-1; 0-8-2; 0-6-4) . . . . .	10	10	10
Ge 102	Oral Presentation (1-0-0) . . . . .	.	1	.
Ge 176 <sup>5</sup>	Elementary Seismology (3-0-3) . . . . .	.	.	6
PE 3 abc	Physical Education (0-3-0) . . . . .	3	3	3

*Geology and Geochemistry Options<sup>5</sup>*

Ge 104 a	Petrology, Igneous (3-3-2) . . . . .	8	.	.
Ge 104 b	Petrology, Sedimentary (3-4-3) . . . . .	.	10	.
Ge 104 c <sup>5</sup>	Petrology, Metamorphic (2-3-2) . . . . .	.	.	7
Ge 109	Structural Geology (1-3-2) . . . . .	6	.	.
Ch 24 ab	Physical Chemistry for Geologists (4-0-6) . . . . .	10	10	.
Ge 30	Introduction to Geochemistry (3-0-7) . . . . .	.	.	10
	Electives <sup>6</sup> . . . . .	.	6-9	.
		<hr/>	<hr/>	<hr/>
		51	48-51	50

*Geophysics Option*

Ph 107 abc	Electricity and Magnetism (3-0-6) . . . . .	9	9	9
	Electives <sup>6</sup> . . . . .	6-12	11-17	5- 6
		<hr/>	<hr/>	<hr/>
		642-48	642-48	642-48

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1) for Physical Education (PE 3 abc, 0-3-0).

<sup>3</sup>Bi 4 Invertebrate and Vertebrate Zoology (20 units), a six-week summer course, is strongly recommended for those interested in paleontology.

<sup>4</sup>Summer Field Geology, Ge 123, 30 units, required after third year in Geology and Geochemistry Options.

<sup>5</sup>Electives may be substituted for the courses so marked with the advice and permission of the student's adviser. Attention is called to the following courses as possible and desirable electives, but others may be acceptable if consistent with the student's interests and program of study: Ma 112, Ay 1, Bi 2, Ch 123, Ch 129, CE 5, CE 15, Hy 134, CE 155, Hy 210 ab, AM 1, AM 4 ab, AM 5 ab, AM 110 a, L 1 ab, Ge 174, Ge 175, Ge 151.

<sup>6</sup>Add electives to bring unit load up to a minimum of 45 units, but not to exceed the allowable limit, selected from any of the following courses for which prerequisites have been completed: Any Ge course, Ay 1, Ch 21 abc, Ch 24 ab, Gr 5, EE 4 abc, EE 2 ab, Ma 108 abc, L 32 abc, Ph 108 abc. Special attention is called to the opportunity to take L 32 abc.

## GEOLOGICAL SCIENCES OPTION

## FOURTH YEAR

		Units per Term		
		1st	2nd	3rd
	Humanities elective (3-0-6) <sup>1</sup> .....	9	9	9
H 5 abc	Public Affairs (1-0-1) .....	2	2	2
L 32 abc	Elementary German (4-0-6) .....	10	10	10
Ge 100	Geology Club (1-0-0) .....	1	1	1
PE 4 abc <sup>3</sup>	Physical Education (0-3-0) .....	3	3	3

*Geochemistry Option*

AM 102 a	Applied Nuclear Physics (2-0-4) .....	6	.	.
Ch 13 abc <sup>3</sup>	Inorganic Chemistry (2-0-4) .....	6	6	6
Ch 127 ab <sup>3</sup>	Radioactivity and Isotopes (2-0-4) .....	.	6	6
Ch 129 <sup>3</sup>	Surface and Colloid Chemistry (3-0-5) .....	.	.	8
Ge 105 <sup>3</sup>	Optical Mineralogy (2-8-2) .....	12	.	.
Ge 106 ab <sup>3</sup>	Petrography (2-6-1; 2-4-3) .....	.	9	9
Ge 151	Laboratory Techniques in the Earth Sciences (0-5-0) .....	.	5	.
		49	51	54

*Geology Option*

Ge 121 abc	Advanced Field Geology (4-8-2; 0-8-2; 0-5-6) .....	14	10	11
Electives to be selected from any advanced courses in the Division of Geological Sciences or courses in other Science or Engineering Divisions. The elective courses must be approved by the student's adviser ...		9-12	12-15	11-14
		48-51	47-50	47-50

*Geophysics Option*

Ph 108 abc	Theoretical Mechanics (3-0-6) .....	9	9	9
	Geology electives .....	7-10	7-10	7-10
	General electives <sup>4</sup> .....	.	.	.
		41-44	41-44	41-44

<sup>1</sup>For list of Humanities electives, see page 202.<sup>2</sup>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.<sup>3</sup>Electives may be substituted for these courses with the advice and permission of the student's adviser.<sup>4</sup>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.

## MATHEMATICS OPTION

(For First Year see page 202)

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 149.

## 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
Ma 5 ab	Introduction to Abstract Algebra (3-0-6) . . . . .	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
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
	Ma 31, 32, or electives . . . . .	.	.	9-10
		<hr/>	<hr/>	<hr/>
		51	51	51-52

## THIRD YEAR

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 <sup>5</sup> ) (can be taken in senior year) . . . . . Minimum	6	6	.
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8) .	12	12	12
PE 3 abc <sup>2</sup>	Physical Education (0-3-0) . . . . .	3	3	3
	Selected courses in Mathematics . . . . . Minimum	9	9	9
	Electives <sup>4</sup> . . . . . Minimum	9	9	9
		<hr/>	<hr/>	<hr/>
The total number of units must fall within the range		47-52	47-52	47-52

## FOURTH YEAR

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 <sup>5</sup> ) (if not taken in junior year) . . . . . Minimum	6	6	.
PE 4 abc <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
	Selected courses in Mathematics . . . . . Minimum	9	9	9
	Selected courses in the Humanities <sup>5</sup> . . . . .	9	9	9
	Electives <sup>4</sup> . . . . . Minimum	8	8	8
		<hr/>	<hr/>	<hr/>
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. Students intending to proceed to graduate work in Mathematics are encouraged to choose at least one full-year graduate course in Mathematics. They are strongly advised to take one or preferably two full-year courses in languages.

<sup>1</sup>AFROTC students take AS 2 abc (2-1-1) instead of PE 3 abc (0-3-0).

<sup>2</sup>AFROTC students take AS 3 abc (4-3-1) instead of PE 3 abc (0-3-0).

<sup>3</sup>AFROTC students take AS 4 abc (4-1-3) instead of PE 4 abc (0-3-0).

<sup>4</sup>An elective is any course in any subject other than Mathematics.

<sup>5</sup>For list of Electives in the Humanities, see page 202. 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.

## MECHANICAL ENGINEERING OPTION

(For First Year see page 202)

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 Mechanical Engineering, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 149.

## 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
Ec 2 ab	General Economics and Economic Principles (3-0-6)	9	9	.
Ec 18	Industrial Organization (3-0-4) . . . . .	.	.	7
	or		or	
Ec 25	Engineering Law (3-0-4) . . . . .	.	.	7
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
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3; Ay 1, 3-1-5) . . . . .	9	or 9	or 9
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/>	<hr/>	<hr/>
		51	51	49

## THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5) . . . . .	8	8	8
AM 1	Statics (3-0-6) . . . . .	9	.	.
AM 4 ab	Strength of Materials (3-0-6) . . . . .	.	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
AM 15 abc <sup>2</sup>	Engineering Mathematics (3-0-6) . . . . .	9	9	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5) . . . .	10	10	10
PE 3 abc <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/>	<hr/>	<hr/>
		48	51	51

## FOURTH YEAR

	Humanities elective <sup>5</sup> (3-0-6) . . . . .	9	9	9
H 5 abc	Public Affairs (1-0-1) . . . . .	2	2	2
AM 3	Testing Materials Laboratory (0-3-3) . . . . .	.	.	6
AM 5 ab	Dynamics (3-0-6) . . . . .	9	9	.
PM 1	Physical Metallurgy (3-3-6) . . . . .	12	.	.
ME 50 ab	Engineering Conference (1-0-1) . . . . .	.	2	2
PE 4 abc <sup>4</sup>	Physical Education (0-3-0) . . . . .	3	3	3
One of the elective groups on page 134.				

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>Those students who plan to take the Aeronautics elective in the fourth year should, if possible, take AM 116 in the third year.

<sup>3</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1) for Physical Education (PE 3 abc, 0-3-0).

<sup>4</sup>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.

<sup>5</sup>For list of Humanities electives, see page 202.

## FOURTH YEAR

*Aeronautics*

Ae 101 abc	Mechanics and Thermodynamics of Fluids (3-0-6) .	9	9	9
Ae 102 abc	Aircraft Structural Analysis (3-0-6) . . . . .	9	9	9
Ae 106 ab	Experimental Methods in Aeronautics (2-2-2) . . . .	.	6	6
Ae 109	Instrumental Design (2-0-2) . . . . .	.	.	4
		<hr/> 53	<hr/> 49	<hr/> 50

*Mechanical Engineering*

ME 5 abc	Design (2-6-1) . . . . .	9	9	9
ME 16 abc	Thermodynamics (3-0-6) . . . . .	9	9	9
ME 25	Mechanical Laboratory (0-6-3) . . . . .	.	.	9
Hy 11	Fluid Mechanics Laboratory (0-6-0) . . . . .	.	6	.
		<hr/> 53	<hr/> 49	<hr/> 49

*Physical Metallurgy*

ME 5 abc	Design (2-6-1) . . . . .	9	9	9
PM 2	Metallography Laboratory (0-3-0) . . . . .	.	.	3
PM 105	Mechanical Behavior of Metals (2-0-4) . . . . .	6	.	.
PM 110	Thermodynamics of Physical Metallurgy (3-0-6) . . .	.	.	9
PM 115	Crystal Structure of Metals and Alloys (3-0-6) . . . .	.	9	.
PM 116	X-Ray Metallography I (0-6-0) . . . . .	.	.	6
PM 120	Physics of Metals (3-0-6) . . . . .	.	9	.
		<hr/> 50	<hr/> 52	<hr/> 49

*Note:* Substitution for courses in the group electives above may be made with the approval of the student's adviser and the faculty in Mechanical Engineering and the Engineering Course Committee.



**PHYSICS OPTION**  
(For First Year see page 202)

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 149.

		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
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
	Electives . . . . .	6-10	6-10	6-10
PE 2 abc <sup>1</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/> 48-52	<hr/> 48-52	<hr/> 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.

Bi 2	Genetics ((3-3-3) . . . . .	.	.	9
Ec 4 a	Economic Principles and Problems (3-0-3) . . . . .	6	or 6	.
4 b	(3-0-3) . . . . .	.	6	or 6
Ge 2	Geophysics (3-0-6) . . . . .	.	.	9
L 32 abc	Elementary German (4-0-6) . . . . .	10	10	10
Ma 5 ab	Introduction to Abstract Algebra (3-0-6) . . . . .	9	9	.
Ma 31	Constructive Theory of Functions (3-0-6) . . . . .	.	.	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

**THIRD YEAR**

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 <sup>2</sup> . . . . .	18-22	18-22	18-22
PE 3 abc <sup>3</sup>	Physical Education (0-3-0) . . . . .	3	3	3
		<hr/> 47-51	<hr/> 47-51	<hr/> 47-51

*Suggested Electives*

Ay 2 abc	General Astronomy (3-3-3) . . . . .	9	9	9
Bi 2	Genetics (3-3-3) . . . . .	.	.	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
Ge 2	Geophysics (3-0-6) . . . . .	.	.	9
Ge 165	General Geophysics (3-0-3) . . . . .	.	.	6
L 32 abc	Elementary German (4-0-6) . . . . .	10	10	10
L 50 abc	Elementary Russian (4-0-6) . . . . .	10	10	10
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8) . . . . .	12	12	12
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5) . . . . .	10	10	10
Ph 115 ab	Geometrical and Physical Optics (3-0-6) . . . . .	9	9	.
Ph 108 abc <sup>4</sup>	Theoretical Mechanics (3-0-6) . . . . .	9	9	9

Or other subjects

<sup>1</sup>AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

<sup>2</sup>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 mathematics courses.

<sup>3</sup>AFROTC students substitute 8 units of Air Science (AS 3 abc, 4-3-1) for Physical Education (PE 3 abc, 0-3-0).

<sup>4</sup>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.

## 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 abc	Economic Principles and Problems (3-0-3) .....	.	6	6
H 5 abc	Public Affairs (1-0-1) .....	2	2	2
	Humanities elective <sup>1</sup> .....	9	9	9
	Electives .....	9-11	9-11	9-11
PE 4 abc <sup>2</sup>	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<sup>3</sup>

AM 116	Complex Variables and Applications (3-0-6) .....	9	.	.
EE 40	Introduction to Information Theory (2-0-4) .....	.	.	6
EE 103 abc	Electric Circuit Theory (3-0-6; 3-0-6; 2-0-4) .....	9	9	6
EE 160 abc	Electronics and Circuits (2-0-4) .....	6	6	6
GE 165	General Geophysics (3-0-3) .....	.	.	6
L 32 abc	Elementary German (4-0-6) .....	10	10	10
L 50 abc	Elementary Russian (4-0-6) .....	10	10	10
L 35 abc	Scientific German (4-0-6) .....	10	.	.
L 1 ab	Elementary French (4-0-6) .....	.	10	10
Ma 112	Elementary Statistics (3-0-6) .....	9	or 9	.
Ma 115 abc	Introduction to Probability and Statistics (3-0-6) ...	9	9	9
Ph 129 abc	Methods of Mathematical Physics (3-0-6) .....	9	9	9
Ph 172	Experimental Research in Physics (units arranged) .	.	.	.
	Or other subjects			

<sup>1</sup>For list of Humanities electives, see page 202.<sup>2</sup>AFROTC 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.<sup>3</sup>Students who elect EE 160 abc should not elect EE 162 abc, EE 103 abc, or EE 104 abc.

## 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
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 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 103 abc	Aerodynamics of Aircraft (3-0-6)	9	9	9
Ae 107 abc	Elasticity Applied to Aeronautics (3-0-6) <sup>1</sup>	9	9	9
	Mathematics <sup>2</sup>	9-12	9-12	9-12
	Electives <sup>1</sup>	13-9	13-9	13-9
Ae 150 abc	Aeronautics Seminar (1-0-0)	1	1	1
		50	50	50

<sup>1</sup>Students who have not previously had courses equivalent to those listed under the Fourth Year Aeronautics Option must take these courses during the Fifth Year instead of Ae 107 abc and the Elective units.

The elective units may be selected from Aeronautics courses (pages 230-233); Jet Propulsion courses (pages 277-278); or advanced work in other fields, with the approval of the departmental adviser.

<sup>2</sup>Students who have not previously had AM 15 (or AM 115 and AM 116) or its equivalent should take AM 115 ab and AM 116 for their Mathematics units. Otherwise, for these units, a choice may be made between AM 125 abc, AM 126 abc, Ph. 129 abc, and Ph 108 abc with the approval of the departmental adviser.

## AERONAUTICS

## SIXTH YEAR

*(Leading to the degree of Aeronautical Engineer)*

*Note:* To obtain the degree of Aeronautical Engineer in either option, a student must have had the equivalent of the Fifth-Year course program in Aeronautics in addition to the courses listed below.

		Units per Term		
		1st	2nd	3rd
Ae 200 abc	Research in Aeronautics	20	20	20
	Seminar elective <sup>1</sup>	1-3	1-3	1-3
	Electives (not less than) <sup>2</sup>	24-22	24-22	24-22
		45	45	45

<sup>1</sup>Seminar elective should be chosen from one of the following: Ae 208 abc, Ae 209 abc, or JP 280 abc.

<sup>2</sup>Elective subjects are to be chosen from Aeronautics courses (pages 230-233) or advanced courses in other fields, as approved by the departmental adviser.

## 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) <sup>3</sup>	15-13	15-13	15-13
		45	45	45

<sup>3</sup>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)

	1st	Units per Term 2nd	3rd
Humanities elective (3-0-6; 4-0-6) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
Ay 131 abc, or Ay 132 ab, Astrophysics (3-0-6) and 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 188, section 2(a). Ay 108, Ay 112, Ma 108, Ph 108, Ph 107, may be required of those students whose previous training in some of these subjects proves to be insufficient.

<sup>1</sup>For list of Humanities electives, see page 219.

## 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.

## 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.

Candidates must satisfy the modern language department that they are able to read scientific articles in at least one of the following languages: German, French, or Russian.

## CHEMICAL ENGINEERING

(For 1959-60 only)

## 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) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
ChE 166 abc Chemical Engineering (3-0-9) .....	12	12	12
ChE 167 abc Chemical Engineering Laboratory (0-15-0) ..	15	15	15
Electives <sup>2</sup> at least .....	11	11	11
	<hr/> 47-48	<hr/> 47-48	<hr/> 47-48

<sup>1</sup>For list of Humanities electives see page 219.<sup>2</sup>Elective subjects are to be approved by a member of the Division and must include AM 115 ab if equivalent has not been taken. Electives are to be chosen from advanced subjects.

Students admitted for work toward the M.S. in Chemical Engineering will be required to take the placement examinations in engineering thermodynamics and in elementary fluid flow. Those students who do not propose to register for ChE 166 abc will also be required to take the placement examination in the unit operations of chemical engineering.

## CHEMICAL ENGINEERING

(For 1960-61 and subsequent years)

## 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) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
ChE 167 abc Chemical Engineering Laboratory (0-15-0) ..	15	15	15
Electives <sup>2</sup> at least .....	23	23	23
	<hr/> 47-48	<hr/> 47-48	<hr/> 47-48

<sup>1</sup>For list of Humanities electives see page 219.<sup>2</sup>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.

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.

## CIVIL ENGINEERING

## FIFTH YEAR

(Leading to the degree of Master of Science in Civil Engineering)

		Units per Term		
		1st	2nd	3rd
		9 or 10	9 or 10	9 or 10
	Humanities elective (3-0-6; 4-0-6) <sup>1</sup> .....			
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) <sup>2,3</sup> ....	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).

## STRUCTURAL ENGINEERING

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 112	Reinforced Concrete (3-0-6) .....	.	9	.
CE 120 a	Statically Indeterminate Structures (3-3-6) ....	12	.	.
CE 120 bc	Statically Indeterminate Structures <sup>4</sup> .....	.	.	.
CE 121 abc	Structural Design (0-9-0) .....	9	9	9
CE 122	Earthquake Effects upon Structures <sup>4</sup> .....	.	.	.
CE 126	Masonry Structures (2-3-4) .....	.	.	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 <sup>4</sup> .....	.	.	.
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 103 b	Hydraulic Structures (3-0-6) .....	.	9	.
Hy 104	Advanced Hydraulics Laboratory <sup>4</sup> .....	.	.	.
Hy 134	Flow in Porous Media (3-0-6) .....	.	.	9

## SANITARY 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 (3-0-6) .....	.	9	9
AM 116	Complex Variables & Applications (3-0-6) ....	9	.	.
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	.

<sup>1</sup>For list of Humanities electives, see page 219.<sup>2</sup>Students who have not had AM 15 abc or its equivalent will be required to include AM 115 ab as part of their elective units.<sup>3</sup>Electives must be approved by Civil Engineering faculty.<sup>4</sup>Six or more units as arranged.

## ELECTRICAL ENGINEERING

## FIFTH YEAR

*(Leading to the degree of Master of Science in Electrical Engineering)*

		Units per Term		
		1st	2nd	3rd
Humanities electives (3-0-6; 4-0-6) <sup>1</sup> . . . . .		9 or 10	9 or 10	9 or 10
EE 132 abc	Circuit Analysis (3-0-6) <sup>2</sup> . . . . .	9	9	9
EE 220 abc	Research Seminar in Electrical Engineering . . .	2	2	2
Two or more of the following electives:				
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	Transistor Electronics (3-0-6; 3-0-6; 1-2-6) . . .	9	9	9
Ph 112 abc	Introduction to 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)*

AM 126 abc	Applied Engineering Mathematics (3-0-9) <sup>3</sup> . . .	12	12	12
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The balance of the programs are selected from a comprehensive list of available subjects and are arranged by the student in consultation with members of the Division.

<sup>1</sup>For list of Humanities electives, see page 219.<sup>2</sup>Required unless comparable work done elsewhere.<sup>3</sup>This course is also required for the doctor's degree in electrical engineering.

## 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 Field Theory . . . . .	9	9	9



## GEOLOGICAL SCIENCES

## FIFTH YEAR

*Option leading to degree of Master of Science in Geology*

		Units per Term		
		1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
Ge 100	Geology Club .....	1	1	1
Ge 102	Oral Presentation .....	1	or 1	or 1
Ge 121 abc	Advanced Field Geology <sup>2</sup> .....	14	10	11
Ge 123	Summer Field Geology (30 units, in summer) <sup>2</sup> .	.	.	.
Ch 124 ab	Physical Chemistry for Geologists .....	6	6	.
Elective units from Group A or B below to total 140 units				

*Option leading to degree of Master of Science in Geophysics*

	Humanities electives (3-0-6; 4-0-6) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
Ge 100	Geology Club .....	1	1	1
Ge 102	Oral Presentation .....	1	or 1	or 1
Ge 120 abc	Field Geology .....	10	10	10
Ge 150	The Nature and Evolution of the Earth .....	6	6	.
(any 12 units)				
Ge 175	Introduction to Applied Geophysics .....	.	.	6
Ge 176	Elementary Seismology .....	.	6	.
Ge 282 abc	Geophysics—Geochemistry (Seminar) .....	1	1	1

Elective units to be chosen from advanced courses in the Geological Sciences, physics, mathematics, or electrical engineering to total 140 units.

*Option leading to degree of Master of Science in Geochemistry*

The Candidate for the Master's Degree in Geochemistry must have as a minimum the equivalent of the courses which are required of the Candidate for the Bachelor's Degree in Geochemistry. In addition the Candidate will be expected to take a minimum of 30 units of advanced courses in chemistry and geochemistry and a minimum of 30 units of research in geochemistry. The Institute requirement for the humanities must, of course, be satisfied.

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.

<sup>1</sup>For list of Humanities electives, see page 219.

<sup>2</sup>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 graduate curricula can be 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) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 page 227) ....	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1) ....	2	2	2
	Electives as below. See notes 1, 2, 3 page 227			
	(minimum total for year 18) .....	27	27	27
		47 or 48	47 or 48	47 or 48

## Electives

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 115 abc	Thermodynamics and Heat 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)

		Units per Term		
		1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
	Laboratory elective (See Note 4 page 146) ...	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 227			
	(minimum total for year 18) .....	6	6	6
		50 or 51	50 or 51	50 or 51

## Electives

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 115 abc	Thermodynamics and Heat Transfer (3-0-6) ..	9	9	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6) .....	9	9	9

<sup>1</sup>For list of Humanities electives, see page 219.

**MECHANICAL ENGINEERING  
(NUCLEAR ENERGY OPTION)**

**FIFTH YEAR**

*(Leading to the degree of Master of Science in Mechanical Engineering)*

	1st	Units per Term 2nd	3rd
Humanities electives (3-0-6; 4-0-6) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
Laboratory elective (see Note 4 page 146) ....	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 227			
(minimum) .....	12	12	12
	<u>47 or 48</u>	<u>47 or 48</u>	<u>47 or 48</u>

*Electives*

	1st	Units per Term 2nd	3rd
Ch 127 ab 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 Crystal Structure of Metals and Alloys (3-0-6) ..	.	9	.
PM 116 X-Ray Metallography I (0-6-0) .....	.	.	6

*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)*

	1st	Units per Term 2nd	3rd
Humanities electives (3-0-6; 4-0-6) <sup>1</sup> .....	9 or 10	9 or 10	9 or 10
Laboratory elective (See Note 4 page 227) ....	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 Physical Metallurgy Laboratory (0-9-0) .....	9	.	.
PM 112 ab Advanced Physical Metallurgy (3-0-6) .....	.	9	9
PM 117 X-Ray Metallography II (0-6-3) .....	.	9	.
PM 121 Theory of Alloys (3-0-6) .....	9	.	.
PM 125 Industrial Physical Metallurgy (0-6-3) .....	.	.	9
Electives as below. See notes 1, 2, 3 page 227			
(minimum total for year 24) .....	6	9	9
	<u>50 or 51</u>	<u>47 or 48</u>	<u>47 or 48</u>

*Electives*

AM 110 bc 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 115 abc Thermodynamics and Heat Transfer (3-0-6) ..	9	9	9
Ph 205 abc Principles of Quantum Mechanics (3-0-6) ....	9	9	9

<sup>1</sup>For list of Humanities electives, see page 219.

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 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 160 abc Electronics and Circuits, 6 units each term

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

<sup>1</sup>For list of Humanities electives, see page 219.

## MECHANICAL ENGINEERING

## SIXTH YEAR

*(Leading to the degree of Mechanical Engineer)*

Specific requirements for the degree of Mechanical Engineer are given on page 177. 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 ab	Thermodynamics of Multi-Component Systems
Ph 112 abc	Introduction to Atomic and Nuclear Physics
Ph 205 abc	Principles of Quantum Mechanics
Ph 227 ab	Thermodynamics, Statistical Mechanics, and Kinetic Theory
PM 103	Physical Metallurgy Laboratory
PM 112 ab	Advanced Physical Metallurgy
PM 117	X-Ray Metallography II
PM 121	Theory of Alloys
PM 205	Theory of Mechanical Behavior of Metals
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) <sup>2</sup> .....		9 or 10	9 or 10	9 or 10
Electives as below .....		39	39	39
		<hr/>	<hr/>	<hr/>
		48 or 49	48 or 49	48 or 49
Ph 107 abc	Electricity and Magnetism (3-0-6) <sup>1</sup> .....	9	9	9
Ph 108 abc	Theoretical Mechanics (3-0-6) <sup>1</sup> .....	9	9	9
Ph 110 ab	Kinetic Theory of Matter (3-0-6) .....	.	9	9
Ph 112 abc	Introduction to Atomic and Nuclear Physics <sup>1</sup> ..	8	8	8
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) <sup>3</sup> .....	12	12	12
Ma 118 abc	Functions of Complex Variable (3-0-6) .....	9	9	9

<sup>1</sup>Prerequisite for most other fifth-year courses.<sup>2</sup>For list of Humanities electives, see page 219.<sup>3</sup>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 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) 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. Aircraft Structural Analysis.** 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 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. Texts: *Elasticity in Engineering*, Sechler; *Airplane Structural Analysis and Design*, Sechler and Dunn. 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 105. Wind Tunnel Operation and Techniques.** 6 units (1-3-2); one term. A one-term course covering pressure and velocity measuring instruments, balances, model suspensions, wind tunnel calibration and correction factors, data reduction and presentation, extrapolation of model results to full scale. Experiments on various aerodynamic phenomena are carried out by the students in a special wind tunnel constructed for instruction purposes. Text: *Wind Tunnel Testing*, Pope. Instructor: W. Bowen.



**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:* *Similitude in Engineering*, Murphy, and 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, power plant characteristics, air loads analysis, dynamic stability and control of a flexible aircraft, 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.** 6 units (2-0-4); each term as described below. To be offered in alternate years beginning in 1956-1957. *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: Valluri.

**Ae 202 b. Mechanics of Inelastic Materials.** Ultimate strength of aircraft 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: Valluri.

**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 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 page 278)

## AIR SCIENCE

**AS 1 abc. Air Science 1.** 4 units (2-1-1); each term. *Foundations of Air Power—1.* A general survey of air power designed to provide the student with an understanding of the elements of air power, basic aeronautical science and professional opportunities in the United States Air Force. One hour each week is devoted to Leadership Laboratory. Text: *Foundations of Air Power and Government Manuals* furnished by the Air Force will be issued to the students. Instructor: Air Force ROTC Staff.

**AS 2 abc. Air Science 2.** 4 units (2-1-1); each term. *Foundations of Air Power—2.* A year long survey of the development of aerial warfare, with emphasis on principles of war, concepts of employment of forces, and changing weapon systems. Treatment of aerial warfare covers targets, weapon systems, delivery vehicles, bases and operations. One hour each week is devoted to Leadership Laboratory. Text: *Government Manuals* furnished by the Air Force 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, leadership principles and practices, and the military justice system. One hour each week is devoted to Leadership Laboratory. Text: *Government Manuals* furnished by the Air Force will be issued to the Students. Instructor: Air Force ROTC Staff.

**AS 4 abc. Air Science. 8 units (4-1-3)<sup>1</sup>** A study of a series of short courses including the following: Principles of Leadership and Management, Military Aspects of World Political Geography, and Military Aviation and Evolution of Warfare. One hour each week is devoted to Leadership Laboratory. Text: Government Manuals furnished by the Air Force will be issued to the students. Instructor: Air Force ROTC Staff.

## APPLIED MECHANICS

### UNDERGRADUATE SUBJECTS

**AM 1. Applied Mechanics—Statics. 9 units (2-3-4); first term.** Principles of statics and applications of these principles to engineering problems involving theory of structures, machine design, hydrostatics, and strength of materials. Text: *Applied Mechanics-Statics*, Housner and Hudson. Instructors: Housner and Staff.

**AM 3. Testing Materials Laboratory. 6 units (0-3-3); first, second, or third terms.** Experimental techniques for determining the mechanical behavior of engineering materials. Measurements of elastic limit, yieldpoint, ultimate strength, modulus of elasticity, etc. Experimental verification of theoretical solutions of problems in elastic deformations. Instructors: Vreeland and Assistants.

**AM 4 ab. Applied Mechanics—Strength of Materials. 9 units (3-0-6); second and third terms.** Theory of elasticity applied to engineering problems involving tension and compression, bending of beams, torsion of shafts, buckling of columns, etc.; determination of the stresses, strains, and deformations in typical structures; theory of statically indeterminate structures; properties of materials of construction; determination of safe loads for engineering structures and machines. Text: *Elements of Strength of Materials*, Timoshenko & MacCullough. Instructors: Housner and Staff.

**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 15 abc. Engineering Mathematics. 9 units (3-0-6); first, second, third terms. Prerequisites: Ma 1 abc, Ma 2 abc.** 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 with emphasis on its application to deriving the differential equations of classical field theory in generalized form; the solution of ordinary differential equations by standard techniques and by power series; problems leading to special functions such as Bessel function, and partial differential equations and boundary value problems, with emphasis on techniques applying series of orthogonal functions. Instructors: Knowles, Wayland and Assistants.

### 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.

<sup>1</sup>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.

**AM 101 abc. Nuclear Reactor Theory.** 9 units (3-0-6); each term. *Prerequisite:* AM 15 abc 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 15 abc 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. Instructor: Plesset.

**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 assembly 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. *Prerequisite:* AM 4 ab. 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. *Prerequisite:* AM 4 ab. 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. *Prerequisite:* AM 4 ab. 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. *Prerequisite:* AM 4 ab. 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:* AM 4 ab, 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. 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.** 9 units (3-0-6); second and third terms. *Prerequisites:* Ma 1 abc, Ma 2 abc or equivalent. A course in the mathematical treatment of problems in engineering or physics, primarily for fifth year students who have not had a course in advanced engineering mathematics as undergraduates. The mathematical content is similar to that of AM 15 abc, but less emphasis is placed on ordinary differential equations. Instructors: Miklowitz, Wayland and Assistants.

**AM 116. Complex Variables and Applications.** 9 units (3-0-6); first term. *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 of contour integration. Text: Churchill, *Introduction to Complex Variables and Applications*. Instructors: Miklowitz, Wayland and Assistants.

**AM 125 abc. Engineering Mathematical Principles.** 9 units (3-0-6); each term. *Prerequisites:* AM 15, 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 15, 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. Classical Field Theory I.** 9 units (3-0-6); first, second, and third terms. *Prerequisites:* AM 15 abc, or equivalent. Analytical mechanics of systems of particles, kinetic theory, statistical mechanics and mechanics of continuous media. 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 and solutions governing waves in rods, beams, plates and shells. 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 1958-59. 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. 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. Offered in 1959-60. Instructor: Wu.

**AM 205 abc. Theory of Solids.** 9 units (3-0-6); *first, second, and third terms.* Theory of specific heats. Free electron theory of metals and semi-conductors. Thomas-Fermi and Hartree-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 230 abc. Classical Field Theory II.** 9 units (3-0-6); *first, second, and third terms.* *Prerequisites: AM 130 abc, or equivalent.* Analytical mechanics of fields, electromagnetic field theory, particle transport theory, radiation transport theory, magnetohydrodynamics. Instructors: Plesset and Wu.

**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: Greenstein.

**Ay 2 abc. General Astronomy.** 9 units (3-3-3); *first, second, and third terms.* *Prerequisites: Ay 1, 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. Not given in 1959-60.

**Ay 112 abc. General Astronomy.** 6 units; *first, second, and third terms.* This subject is the same as 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. Given in alternate years. Not given in 1959-60.

**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. Instructor: Oke.

**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 non-thermal emission. The 21-cm hydrogen line and galactic structure. Open to qualified undergraduates. 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 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. Instructor: Munch.

**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. Instructor: Schmidt.

**Ay 213. Selected Topics in Observational Cosmology.** 9 units (2-3-4); *second term.* Calibration of distance indicators. The Hubble constant. World models. Stellar content of galaxies. Classification of galaxies. Instructor: Sandage.

**Ay 214. Theoretical Cosmology.** 9 units (3-0-6); *first term*. The present situation in the interpretation of the large scale structure of the universe. General relativity and recent theories. Relation between data and theory, with special reference to radio astronomy. The expanding universe. Instructor: Hoyle.

**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. Instructor: Munch.

The following courses will be offered from 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 205.** Spectra of Emission-line Stars.

**Ay 207.** Stellar Luminosities and Colors.

**Ay 208.** Photometry.

**Ay 209.** Planetary and Diffuse Emission Nebulae.

**Ay 212.** Extragalactic Nebulae.

**Ay 216.** Advanced Stellar Interiors.

## 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, Beadle, Staff.

**Bi 2. Genetics.** 9 units (3-3-3); *third term*. *Prerequisite:* Bi 1. A course presenting the fundamentals of genetics and their relation to general biological problems. Instructor: Lewis.

**Bi 3. Plant Biology.** 12 units (4-6-2); *first term*. *Prerequisite:* Bi 1. A general survey of the water relations of plants in connection with their morphology. Instructors: Bonner, Staff.

**Bi 4. Invertebrate and Vertebrate Zoology.** 20 units (5-10-5); *summer*. *Prerequisite:* Bi 1. A course dealing with the taxonomy, comparative anatomy, and ecology of the more important animal phyla. (Students taking the Biology option are required to take this course at the Marine Laboratory for six weeks, starting the Monday following the end of their sophomore year. This course is taken without payment of additional tuition. Living quarters are provided at the Laboratory.)

**Bi 5. Advanced Plant Biology.** 12 units (3-6-3); third term. *Prerequisite:* Bi 3. A study of the nutrition, growth, and development of green plants. Emphasis is placed on an understanding of the basic physical and chemical processes regulating the lives of plants. Instructors: Bonner, Staff.

**Bi 18. Review in Botany.** 3 units (1-0-2). No graduate credit. This course is given when convenient for professors and students. A short review of general botany and plant physiology. Required of graduate students who take a minor in plant physiology but have had no previous courses in botany. Instructor: Bonner.

**Bi 20. Mammalian Anatomy and Histology.** 12 units (2-6-4); second term. *Prerequisite:* Bi 4. 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); first term. *Prerequisite:* Bi 4. 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; first 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 2, 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. *Prerequisites:* Bi 2, Ch 41 abc. A course on the principles and methods of immunology and their application to various biological problems. Instructor: Owen.

**Bi 115. Plant Physiology.** 12 units (3-6-3); second term. A study of physiological and biochemical processes in higher plants. Instructor: Bonner.

**Bi 116 ab. Animal Physiology.** 10 units (3-3-4); first and second terms. *Prerequisites:* Bi 4, Bi 20. A survey of comparative and mammalian physiology. Instructors: Sperry, Van Harreveld, Wiersma.

**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 120. Mammalian Anatomy and Histology.** 9 units; second term. *Prerequisite:* Bi 4. 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 125. Topics in Plant Biology.** 12 units (3-3-6); first term. Special topics in plant physiology, plant biochemistry, and plant ecology. Instructors: Bonner, Staff.

**Bi 127. Chemical Genetics Laboratory.** 6 units (0-6-0); by arrangement. A laboratory course dealing with the biochemical genetics of *Neurospora*. The object of the course is to enable the student to verify personally the basic results of *Neurospora* genetics and to acquaint him with some of the special techniques involved in doing genetic work with a microorganism. 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, roughly as follows:

1960 Methods for the analysis of cell structure; tissue ultra-structure.

1961 Applications of nuclear physics, interactions of ionizing radiations with cells and cellular components.

1962 Applications of spectroscopy; action spectra; biological effects of ultraviolet radiation.

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: Anderson, Lewis.

**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, Bi 2, 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 225 ab. Special Topics in Genetics.** *6 units (2-0-4); first and second terms.* Special subjects in genetics will be treated in detail. The material in this course will not ordinarily be duplicated in a period of two to three years, and students majoring in genetics should register for at least four terms. For information regarding the specific topics to be taken up in a given year, see Professor Beadle. Instructors: Staff.

**Bi 230. Psychobiology 1.** *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. Instructor: Bonner.

**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 abc. Advanced Physiology.** *Units to be arranged. First, second, and third terms.* 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 60. Introduction to Chemical Engineering Problems.** *9 units (3-0-6); third term.* An introduction to the problems encountered in the chemical engineering profession. Quantitative discussions on material and energy are presented. Their importance and that of chemical equilibria and chemical kinetics in establishing economical chemical processes are outlined. Industrial processes exemplifying the application of the basic chemical engineering ideas for economic progress are discussed. Typical of the processes considered are those for ammonia, acetylene, hydrogen, sulfuric acid, nitric acid, and caustic. Outside reading and problems are assigned and examinations are given. Text: *Introduction to Chemical Engineering Problems*, Corcoran and Lacey. Instructor: Corcoran.

**ChE 61 ab. Industrial Chemistry.** *9 units (3-0-6); second, third terms. Prerequisite: Ch 21 abc.* A study of the most 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. Instructor: Lacey.

**ChE 66 abc. Chemical Engineering Operations.** *12 units (3-0-9); first, second terms; 9 units (2-0-7); third 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); third 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. Instructors: Richter, Sage.

**ChE 68. Introductory Chemical Engineering Kinetics.** *6 units (2-0-4); first term. Prerequisite: Ch 21 abc.* A quantitative treatment of the engineering design of chemical reactors. Instructor: Corcoran.



**ChE 80. Industrial Chemical Research.** Offered to B.S. candidates in Chemical Engineering.

#### ADVANCED SUBJECTS

**ChE 162 abc. Chemical Engineering Operations.** 9 units (3-0-6); first, second terms; 6 units; third 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 163 abc. Chemical Engineering Thermodynamics.** 6 units (3-0-3); first term (ChE 163 c), second, third terms (ChE 163 ab). *Prerequisite:* Ch 21 abc or Me 15 abc. 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 164. Phase Equilibrium in Applied Chemistry.** 6 units (2-0-4); third term. *Prerequisites:* Ch 21 abc, ChE 61 ab. Problems and discussions on industrial applications involving heterogeneous equilibria, primarily in the quantitative treatment of solid-liquid systems. Instructor: Lacey.

**ChE 166 abc. Chemical Engineering.** 12 units (3-0-9); first, second, third terms. *Prerequisites:* ChE 61 ab, ChE 63 abc, ChE 64 or equivalent. Calculations and discussions designed to bring the student in touch with the quantitative problems involved in carrying out chemical reactions efficiently on a commercial scale. The unit operations of chemical industry (such as materials transfer, heat transfer, evaporation, filtration, distillation, drying) are studied both as to principle and practice. Text: *Unit Operations of Chemical Engineering*, McCabe and Smith. Offered in 1959-60 only. Instructor: Longwell.

**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 experiments and in research encountered by the chemical engineer. Instructors: Richter, Sage.

**ChE 168 abc. Mechanics of Fluid Flow.** 6 units (2-0-4); second, third 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.

**Ch 169. Advanced Industrial Chemistry.** 6 units (2-0-4); first 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 169. Advanced Industrial Chemistry.** 6 units (2-0-4); first term. *Prerequisites:* ChE 61 ab, ChE 63 abc. (Same as 1958-59 catalog Ch 169, pg. 167, except substitute ChE 61 for Ch 61.)

**ChE 170. Chemical Process Dynamics.** 6 units (2-0-4); 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). *Prerequisite:* AM 15 abc. 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. Not offered in 1959-60. Instructor: Longwell.

**ChE 172. Heat Transfer.** 9 units (2-0-7); first term. *Prerequisite:* ChE 66 abc. Detailed consideration of problems in thermal transfer. Not offered in 1959-60.

**ChE 173. Absorption and Extraction.** 9 units (2-0-7); second term. *Prerequisite:* ChE 66 abc. Treatment of absorption and extraction in chemical processing. Not offered in 1959-60.

**ChE 174. Distillation and Drying.** 9 units (2-0-7); third term. *Prerequisite:* ChE 66 abc. Advanced study of distillation and drying. Not offered in 1959-60.

**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 15 abc or taking AM 115 ab). 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 multi-component 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 15 abc. 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 1959-60. Instructor: Sage.

**ChE 266 abc. Applied Chemical Kinetics or Homogeneous and Heterogeneous Reactions.** 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 Chemistry and Quantitative Analysis.** 12 units (3-6-3); first, second, third terms. Lectures, recitations, and laboratory exercises dealing with the general principles of chemistry. In the first and second terms the properties of substances and the fundamental laws and theories of chemistry are treated. The laboratory instruction includes gravimetric and volumetric chemical measurements as well as qualitative analysis for common elements. Texts: *General Chemistry*, Pauling; *Introductory Quantitative Analysis*, 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: *Introductory Quantitative Analysis*, Swift. 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. Conferences and recitations dealing with the general principles of chemistry from an exact, quantitative standpoint, and including studies on the pressure-volume relations of gases; on thermodynamics; on vapor-pressure, boiling point, freezing point, and osmotic pressure of solutions; on the molecular and ionic theories; on electrical transference and conduction; on chemical and phase equilibria; on thermochemistry and the elements of

thermodynamic chemistry and electrochemistry. A large number of problems are assigned to be solved by the student. Text: Mimeographed notes. Instructors: Badger and other staff members.

**Ch 24 ab. Physical Chemistry for Geologists.** 10 units (4-0-6); first, second terms. *Prerequisites:* Ch 1 abc; Ma 2 ab; 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 term; and 8 units (0-6-2) or 4 units (0-3-1), third term. *Prerequisites:* Ch 1 abc; Ch 21 a. Text: Mimeographed notes. Instructors: Badger 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: *Organic Chemistry*, Lucas. 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); third 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. *Prerequisite:* Ch 21 abc. The theory and practice of selected electroanalytical techniques are presented. Topics covered include potentiometric titrations, conductometric titrations, polarography, amperometry, coulometric analysis, 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. *Prerequisite:* Ch 21 abc. Laboratory experiments involving the use of electroanalytical instruments. Instructor: Anson.

**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 proper-

ties of substances. Text: *The Nature of the Chemical Bond*, Pauling. 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. Among the topics included in this course are a review of thermodynamic principles, the elements of statistical mechanics, the relation between statistical mechanics and thermodynamics and the calculation of thermodynamic quantities from information obtained by spectroscopic and diffraction methods of determining the structure of molecules, the elementary principles of quantum theory, the electronic structure of atoms and molecules, paramagnetic resonance and nuclear magnetic resonance, experimental methods of determining the structure of molecules and crystals, and the relation of the properties of substances to their molecular structure. 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 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 1959-60. 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); second term. This course considers the physical chemistry of macromolecules of biological interest. Together with Bi 129 ac it constitutes an integrated program covering the physical and physicochemical approaches to biology. The subject matter to be covered will be repeated approximately in a three-year cycle. A discussion of the principles and methods employed in the determination of size, shape, charge, and thermodynamic properties of biological macromolecules. The methods considered are acid-base titrations, electrophoresis, sedimentation, diffusion, viscosity, osmotic pressure, and light scattering. The use of instruments is demonstrated. This will be covered in two successive years beginning in 1958-59. During the third year the physical chemistry of membrane phenomena will be discussed. Instructors: Vinograd, Davidson.

**Ch 135 abc. 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. Offered in 1959-60. 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. Offered in 1959-60. 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 equilibrium and chemical equilibrium are developed according to the methods of Willard Gibbs. Methods of calculation of the thermodynamic functions of pure chemical substances and of components of real gas mixtures and liquid solutions are treated in a systematic manner. Heterogeneous equilibrium is interpreted analytically by means of the differential equations of the equilibrium lines and surfaces in phase diagram space. Chemical equilibrium in homogeneous real gas reactions, and in reactions in liquid solutions, is treated in detail. Attention is given to the important applications of thermodynamics to electrochemical systems, surface phases, and systems under the influence of external gravitational, electric, and magnetic fields. Problems. Not offered in 1959-60. 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. Offered in 1959-60. Instructor: Mazo.

**Ch 227 abc. The Structure of Crystals.** 9 units (3-0-6); *first, second, third terms.* The following topics are discussed: The nature of crystals and x-rays and their interaction. The various experimental methods of investigation—Bragg, Laue, oscillation, Weissenberg, etc. 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. Offered in 1959-60. Instructor: Sturdivant.

**Ch 228. Electron-Diffraction Method of Determining the Structure of Molecules.** 6 units (2-0-4); *first term.* The topics discussed are the interaction of electrons with atoms, molecules, and crystals, and the techniques of determining the structure of molecules by the electron-diffraction method. Not offered in 1959-60.

**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. Not offered in 1959-60. 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. 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 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 1959-60. 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. Not offered in 1959-60. 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: (1) the fundamental physical and biochemical factors of importance in immunochemistry; (2) the nature of antigens; (3) the nature of antibodies; (4) the physical and biological manifestations of antigen-antibody reactions; (5) the basis of immunological specificity; and (6) 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. Instructor: Campbell.

**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 and gas molecules by the diffraction of X-rays and electrons.

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 immunochemistry and other 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 structure 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. Instructor: Long.

**CE 10 abc. Theory of Structures.** *9 units (2-3-4); first, second terms; 12 units (3-3-6); second term; 9 units (3-0-6); third term. Prerequisites: AM 1, AM 4 ab.* Methods used in the calculation of stresses in beams, girders, and columns; study of the effects of moving load systems; graphic statics applied to roof and bridges. A study of arch, cantilever, and continuous bridges; and deflection of trusses. Texts: *Structural Theory*, Southerland and Bowman; *Structural Design in Metals*, Williams and Harris. Instructors: Martel, McCormick.

**CE 12. Reinforced Concrete.** *12 units (3-3-6); third term. Prerequisites: AM 1, AM 4 ab, CE 10 a.* The theory of reinforced concrete design, with a study of the application of this type of construction to various engineering structures. Text: *Basic Reinforced Concrete Design*, Large. Instructors: Martel, McCormick.

**CE 14 abc. Engineering Conference.** 2 units (1-0-1) first and second terms; (0-2-0) third term. Conferences participated in by faculty and seniors of the Civil Engineering department. The discussions cover current developments and advancements within the field of civil engineering and related sciences. The technique of effective oral presentation of reports is emphasized through criticisms of the reports from the standpoint of public speaking by a member of the department of English. In the third term senior year, students will visit and inspect engineering projects. Instructors: McKee, Ingersoll.

**CE 17. Civil Engineering.** 9 units (3-0-6); third term. Selected comprehensive problems of civil engineering systems involving a wide variety of interrelated factors. Instructor: Staff.

**CE 20. Introduction to Sanitary Engineering.** 6 units (2-0-4); second term. *Prerequisite:* Hy 2 ab. An introduction to the problem of supply, treatment and distribution of water for municipal use and irrigation purpose; and to the problems of collection, treatment, and disposal of municipal sewage and liquid industrial wastes. Instructor: McKee.

#### ADVANCED SUBJECTS

**CE 105. Introduction to Soil Mechanics.** 9 units (2-3-4); first term. *Prerequisites:* AM 1, AM 4 ab. 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 112. Reinforced Concrete.** 9 units (3-0-6). This subject is the same as CE 12 but with reduced credit for graduate students who have had no previous course work in this subject.

**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 a. Statically Indeterminate Structures.** 12 units (3-3-6); first term. *Prerequisites:* CE 10 abc, CE 12. A study of the analysis of rigid frames and indeterminate trusses with particular emphasis on the use of moment distribution in the solution of indeterminate frames. Instructors: Martel, McCormick.

**CE 120 bc. Statically Indeterminate Structures.** 6 or more units as arranged (2-0-4); any term. A continuation of the study of indeterminate structures as begun in CE 120 a with the use of analytical and instrumental methods of solution. Instructor: Martel.

**CE 121 abc. Structural Design.** 9 units (0-9-0); first, second, third terms. *Prerequisites:* CE 10 abc, CE 12. The design of bridges and buildings using steel, reinforced concrete, or timber in accordance with selected specifications. Design office practice is followed as affecting both computations and drawings. Instructors: Martel, McCormick.

**CE 122. Earthquake Effects upon Structures.** *6 or more units as arranged; any term.* A comparison of the analytical study and the experimental effects of vibrations on simple structures with the actual effects of earthquakes upon buildings. Instructor: Martel.

**CE 126. Masonry Structures.** *9 units (2-3-4); third term. Prerequisite: CE 12.* Theory of design and methods of construction of masonry structures; foundations, dams, retaining walls, and arches. Instructors: Martel, McCormick.

**CE 129. Spring Field Trip.** *1 unit (0-1-0); week between second and third terms.* 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 hydroelectric 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. Instructor: Ingersoll.

**CE 137 abc. Water Supply and Waste Water Disposal.** *12 units (3-3-6); first, second terms; 9 units (1-6-2); third term.* 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.* 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.* The application of engineering analysis and scientific phenomena to problems of industrial hygiene; the control of fumes, dusts, and odors; engineering aspects of air pollution; the detection and control of radioactive substances in water and sewage; the sanitary processing of solid wastes; 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. 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. 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 Sanitary 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 18 a. Basic Principles of Computers and Their Applications.** 6 units (2-0-4); third term. Physical principles of instrumentation of analog and digital computers. Theory of feedback amplifiers and electro-mechanical analogies as used for electric analog computers. Boolean algebra and its application to logical design of digital computers. Illustrative applications of computers to problems in science and engineering. Text: *Logical Design of Digital Computers*, Phister, and course notes. Instructor: McCann.

**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, Wilts.

**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 15, 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

The subjects in this group have the twofold purpose of giving the student an insight into fundamental economic principles, and of acquainting him with some of the aspects of the practical operation of business enterprises. They furnish the important connecting link between the technical engineer and the man of affairs.

**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. Instructor: Brockie.

**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. Instructors: Gray, Wermel.

**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: Hayden.

**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

\*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.



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 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, Wermel.

**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 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: MacMillan, Martel, McCann, Middlebrook.

**EE 2 ab.** Basic Electrical Engineering Laboratory. 3 units (0-3-0); second, third terms. *Prerequisites:* Ma 2 abc; Ph 2 abc. This course is the laboratory for EE 1. The experiments are designed to illustrate instrumentation techniques and provide experimental verification of the principles of electronic and electromagnetic devices. Instructors: Electrical Engineering Faculty.

**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. Primarily for science students. Text: To be selected. Instructor: Maxstadt.

**EE 7 abc.** Experimental Techniques in Electrical Engineering. 5 units (0-3-2); first, second, third terms. A general laboratory program developing experimental techniques and verifying the theory of the five senior electrical engineering courses (EE 102, EE 103, EE 15, EE 104 and EE 160). Text: Laboratory notes. Instructors: Electrical Engineering Faculty.

**EE 15 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 15. 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 15 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 18 a.** Basic Principles of Computers and Their Applications. 6 units (2-0-4); third term. Physical principles of instrumentation of analog and digital computers. Theory of feedback amplifiers and electro-mechanical analogies as used for electric analog computers. Boolean algebra and its application to logical design of digital computers. Illustrative applications of computers to problems in science and engineering. Text: *Logical Design of Digital Computers*, and course notes. Instructor: McCann.

**EE 19 a.** Electronic Circuits. 6 units (2-0-4); third term. Detailed treatment of circuit design principles of vacuum tube and solid state devices. Text: Class notes. Instructor: Middlebrook.

**EE 40.** Introduction to Information Theory. 6 units (2-0-4); third term. An introduction to the modern theory of information. Rate of information from a source and channel capacity defined, entropy, equivocation, redundancy, coding theorems, optimum coding, error correcting codes, continuous information and modulation methods considered. As time permits, other facets of modern communication theory will be discussed briefly. Text: Course notes. Instructor: H. Martel.

**EE 70 ab.** Engineering Conference. 2 units (1-0-1); first, second terms. *Prerequisites:* EE 1 abc; EE 2 abc. Presentation and discussion of new developments in the industry. Review of current literature. Instructors: Thomas, McCann.

## ADVANCED SUBJECTS

**EE 102 ab. Electromechanical Devices.** 6 units (2-0-4); first term; 9 units (3-0-6); second term. *Prerequisites:* EE 1 abc, EE 2 ab. A general study of electromechanical energy conversion methods and devices such as transformers, magnetic amplifiers, transducers or sensing devices and rotating machines. Basic principles of automatic control systems and linear feedback theory. Text: Course notes. Instructor: Mullin.

**EE 103 abc. Electric Circuit Theory.** 9 units (3-0-6) first and second terms; 6 units (2-0-4) third term. *Prerequisites:* EE 1 abc; EE 2 ab; 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. Feedback amplifiers and oscillators. Classical transmission-line theory. Instructors: Mason, Wilts.

**EE 104. Electronic Systems.** 9 units (3-0-6); third term. *Prerequisites:* EE 1 abc, EE 2 ab, AM 116. A course of study in large-signal and nonlinear electronics and communication systems. Wave shaping and amplification, oscillators, modulators, mixers, detectors, limiters and discriminators. AM and FM systems. Text: Course notes. Instructor: Mullin.

**EE 120 abc. Advanced Electric Power System Analysis.** 9 units (3-0-6). Three terms. This course is devoted to the study of electric circuit theory as applied to the basic problems encountered in the design and operation of modern power transmission and distribution systems. Theory of symmetrical components and basic circuit theorems for reduction and simplification of power system networks. System fault calculations. Analysis of transformer characteristics. Theory of synchronous and induction motors including transient analysis during system faults. Calculation of transmission line constants and their equivalent sequence circuits. Application of power circle diagrams and other techniques for steady state power flow and regulation problems. Treatment of the steady state and transient stability problem. Texts: *Electrical Transmission and Distribution Reference Book*, and course notes. Instructor: McCann.

**EE 121 abc. Alternating Current Laboratory.** 6 units (0-3-3); first, second, third terms. *Prerequisites:* EE 7 and preceding courses. Detailed tests of the induction motor; the operation of transformers in parallel; study of polyphase connections; photometric measurements; use of oscillograph; calibration of watt-hour meters and relays, electric arc welding. Special emphasis is placed on the report. Text: Advanced laboratory notes. Instructors: Maxstadt and Assistants.

**EE 122. Power Distribution.** 6 units, supervised reading course by assignment. Basic elements of modern distribution system; unit substations, underground distribution, switchgear and protective devices. Application of fireproof equipment in hazardous areas. Instructor: Maxstadt.

**EE 124. Specifications and Design of Electrical Machinery.** Units to be arranged. *Prerequisites:* EE 7, and preceding subjects. Preparation of specifications and design calculations for alternating and direct current machinery. Text: *Electrical Machine Design*, Gray.

**EE 132 abc. Network Synthesis.** 9 units (3-0-6); first, second, third terms. *Prerequisite:* EE 103 ab. Mathematical properties and limitations of network functions, Brune, Darlington, and other synthesis techniques. The approximation problem in time and frequency domains.

**EE 140 abc. Communication Theory.** 9 units (3-0-6); first, second, third terms. *Prerequisites:* EE 103 abc; EE 104. 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 15 or equivalent. 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 160 abc. Electronics and Circuits.** 6 units (2-0-4); first, second, and third terms. *Prerequisite:* EE 1 abc. Principles of physical electronics and electron devices, including vacuum tubes, transistors and special-purpose devices. Theory of noise in electron devices and its application to circuit problems. Use of circuit theory in the design of active systems. Other topics which will be discussed as time permits include switching circuits, large-signal operation modulation and detection, and high energy particle accelerators. Instructor: Dow.

**EE 162 abc. Physical Electronics.** 6 units (2-0-4); first, second, third terms. *Prerequisites:* EE 1 abc. 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: Gould.

**EE 164 abc. Microwave Electronics and Circuits.** 9 units (3-0-6); first, second, third terms. *Prerequisites:* EE 15 ab and EE 160 abc or 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 15; 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 102, EE 103. 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. Instructor: Wilts.

**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 190 abc. Transistor Electronics.**

**EE 190 a.** 9 units (3-0-6); first term. Crystal structure; simplified solution of the wave equation. Insulators, conductors, and semiconductors. Motion of electrons and holes in crystals. Fermi-Dirac distribution function, mobile carrier densities and Fermi level. Drift and diffusion current flow; the continuity equation. Detailed treatment of boundary values.

**EE 190 b.** 9 units (3-0-6); second term. The p-n junction rectifier characteristic. The p-n-p transistor under d-c and a-c applied signals; d-c operating characteristics and simple low-frequency equivalent circuit. Capacitance and feedback effects; Laplace transform solution of the continuity equation; wide-range approximations and equivalent circuits.

**EE 190 c.** 9 units (3-0-6); third term. Transistor bias methods and use in D. C. low-frequency and high-frequency amplifiers; power amplifiers; oscillators, switching circuits; regulators. Associated analysis, synthesis, and problems. Text: *An Introduction to Junction Transistor Theory*, Middlebrook. Instructor: Mead.

**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: Electrical Engineering Faculty.

**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.* 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.** *Prerequisite:* EE 190 ab. Advanced seminar in solid state devices and circuits. A term paper will be required. Instructors: Middlebrook, Mead.

## 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 conven-



tions. 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 vector problems by graphical and algebraic techniques; graphical calculus; nomography. Instructors: Tyson, Welch.

## ENGLISH

English composition is prescribed for all students in the freshman year, and an introduction to literature is prescribed for all students in the junior year. In the senior year the students are offered a number of options in English, American, and European literature.

The instruction in composition is intended to give a thorough training in both writing and speaking. The instruction in literature is intended to provide an appreciate acquaintance with some of the chief works of major authors, past and present, and to foster the habit of self-cultivation in books.

The regular courses in English do not exhaust the attention given at the Institute to the student's use of the language; all writing, in whatever department of study, is subject to correction with regard to English composition.

## 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: Allen, Bowerman, Clark, Eagleson, 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: Allen, Bowerman, Clark, Eagleson, Eaton, Jones, 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.

**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 includes some study of current technical 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.

\*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

**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 in consultation with a member of the staff. Critical essays on reading will be required.

#### 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.

#### 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. 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.

\*The fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

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); *third 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: Kamb.

**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; identification of their constituents by means of the polarizing microscope; interpretation of textures; problems of genesis; qualitative and quantitative classifications. Text: *The Petrology of the Igneous Rocks*, Hatch, Wells, and Wells. 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: Jahns (20 a); Taylor (20 b); Allen (20 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 20 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 20 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: Allen and Silver.

**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 1959-60. 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.** Instructor: Menard.

**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); third term.** The use of gravity and magnetic methods in geological field problems. Theoretical background and field practice. Offered in 1959-60. Instructor: Dix.

**Ge 173 ab. Applied Geophysics, II. 5 units (2-1-2); second and third terms.** The use of seismic methods in geological field problems. Theoretical background and field practice. Not offered in 1959-60. Instructor: Dix.

**Ge 174. Well Logging. 5 units (3-0-2); second term, 1960-61.** Physical principles of various methods of well logging and their applications. Electrical, radioactive, chemical, fluoroscopic and mechanical methods will be studied. 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.** Instructors: Jahns, Wasserburg, Wetherill.

**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.** Not offered in 1959-60. 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. Instructors: Wetherill, 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 Paleocology (Seminar).** 5 units; first term. Critical review of classic and current literature in paleocology, 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. Not offered in 1959-60. 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. Offered in 1959-60. 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. Offered in 1959-60. Instructor: Dix.

**Ge 274 ab. Applied Geophysics, III.** 5 units (2-0-3), first term; 6 units (2-1-3), second term. *Prerequisite:* Ph 107 abc or equivalent. Magnetic and electric methods applied to geological problems. Content of course is altered somewhat from year to year depending mainly upon student needs. Offered 1959-60. Instructor: Potapenko.



**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, Elliot, Fay.

**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 Commonwealth of Nations.\* 9 units (3-0-6). *Senior elective.* A study of imperial relationships. Instructor: Elliot.

**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 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.

\*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

**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.

**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 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.

\*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

**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 English and American civilization. The reading will be chiefly in biographies of great men and women, famous novels, and suggestive essays in historical and political interpretation. Instructor: Paul.

**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 2 ab. Introductory Fluid Mechanics.** *10 units (3-2-5); second and third terms. Prerequisites: Ph 2 abc, Ma 2 abc.* Hydrostatics, kinematics, and dynamics of fluid motion. The continuity equation. Euler equations of motion; Bernoulli and momentum theorems; topics in one-dimensional compressible flow; velocity of sound, the normal shock wave, flow through a DeLaval nozzle. Elements of potential flow; dynamic lift; principles of similarity, and a brief study of boundary layers. Flow in pipes and open channels, surface waves, analysis and characteristics of centrifugal pumps and hydraulic turbines are also included. Instructor: Ingersoll.

\*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

**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.

**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 112 ab. Introductory Fluid Mechanics.** 8 units (3-2-3); second and third terms. This subject is the same as Hy 2 ab, but with reduced credit for graduate students in all fields except Ae, ChE, CE and ME. No graduate credit is given for this subject to students in these fields except by special approval of the department concerned. Instructor: Ingersoll.

**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.* 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.

**Hy 203. Cavitation Phenomena.** *6 units (2-0-4).* 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).* 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 15, ME 15.* 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 powerplants 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); each term. Prerequisites: AM 15, ME 15.* Analysis of ramjet performance; detailed study of subsonic and supersonic ramjet diffuser performance and stability, combustion and flame stabilization in ramjet combustors, off-design performance, transient operation, and starting. Operating principles of pulsejet, ducted rocket, and thrust augmentors. 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; problems of starting and off-design operation. 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 in jet propulsion. Instructor: Zukoski.

**JP 200 abc. Chemistry Problems in Jet Propulsion.** 9 units (3-0-6); each term. 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 1959-60. Instructors: Penner, Marble, Jahn.

**JP 202 abc. Gas Emissivities.** 3 units (3-0-6); one term. 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. Text: *Quantitative Molecular Spectroscopy and Gas Emissivities*. Instructor: Penner.

**JP 210. High Temperature Design Problems.** 6 units (2-0-4); third term. Prerequisite: ME 3, PM 1, 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 coefficients. Ballistic 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 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

The subjects in languages are arranged primarily to meet the needs of science students who find it necessary to read books, treatises, and articles in French, German, and Russian. In the study of these languages correct pronunciation and the elements of grammar are taught, but the emphasis is laid upon the ability to translate from them into English.

## 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 (4-0-6); *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. Instructors: Bowerman, Stern, Wayne.

**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.

\*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

## ADVANCED SUBJECTS

L 105. Same as L 5. For graduate students.

L 140. Same as L 40. For graduate students.

## MATHEMATICS

## UNDERGRADUATE SUBJECTS

*Note:* Students intending to take the Mathematics Option must indicate their choice at the beginning of their sophomore year.

**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: Bohnenblust, Fuller.

**Ma 2 abc. Sophomore Mathematics.** 12 units (4-0-8); first, second, third terms. A continuation of the freshman calculus course to functions of several variables including vector analysis, and differential equations. Professor in charge: Apostol.

**Ma 5 ab. Introduction to Abstract Algebra.** 9 units (3-0-6); first and second terms. This course is intended for mathematicians and those physicists, chemists, and engineers who are interested in the methods and techniques of abstract algebra. The course provides an introduction to the theory of groups, vector spaces, matrix algebra, linear transformations of vector spaces and quadratic forms over the real and complex fields. Characteristic roots, characteristic vectors, similarity and congruence of matrices, orthogonal and unitary transformations are discussed. Text: *A Survey of Modern Algebra*, Birkhoff and MacLane. Instructors: Dean, Hall, Block.

**Ma 31. Introduction to the Constructive Theory of Functions.** 9 units (3-0-6); third 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 approximate integration. Instructor: Erdélyi.

**Ma 32. Introduction to the Theory of Algebraic Fields.** 9 units (3-0-6); third term. *Prerequisites:* Ma 5 ab. Polynomial rings. Factorization. Symmetric functions. Construction of field extensions. Cyclotomic fields. Finite fields. Text: *A Survey of Modern Algebra*, Birkhoff and MacLane. Instructor: Dean.

**Ma 59 ab. Tensor Analysis and Applications.** 9 units (3-0-6); second, third terms. *Prerequisite:* Ma 108 a, Ma 5 or equivalent. Topics: The algebraic theory of tensors. Manifolds. Tensor fields on a manifold. Applications to the geometry of affine and Riemannian manifolds, differential forms on manifolds, analytic dynamics, mechanics of continuous media. Not offered in 1959-60.

\*Graduate students who wish to take any of the courses Ma 59, 61, 62, 63, 68, 91 should register for them under the numbers Ma 159, 161, . . . , 191. These courses carry a credit of 9 units. Graduate students enrolled in Mathematics will be permitted to register for these courses only with the consent of the instructor.

**Ma 61.\* Algebra.** 9 units (3-0-6); first term. *Prerequisites:* Ma 5 ab. This course will present a modern algebraical discussion of quadratic fields, factorization, and ideal theory. Given in 1960-61 and alternate years.

**Ma 62.\* Differential Geometry.** 9 units (3-0-6); second term. Selected topics in metrical differential geometry. Given in 1960-61 and alternate years.

**Ma 63.\* Theory of Sets.** 9 units (3-0-6); second term. The basic concepts of the theory of sets. Cardinal and ordinal numbers. Introduction to point set topology. Discussion of real numbers. Given in 1959-60 and alternate years. Instructor: Ward.

**Ma 64.\* 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 1959-60 and alternate years. Instructor: Hall.

**Ma 68.\* 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 1959-60 and alternate years. Instructor: Erdélyi.

**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 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 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. Todd.

\*Graduate students who wish to take any of the courses Ma 59, 61, 62, 63, 64, 68, 91 should register for them under the numbers Ma 159, 161, . . . , 191. These courses carry a credit of 9 units. Graduate students enrolled in Mathematics will be permitted to register for these courses only with the consent of the instructor.

**Ma 107 abc. Advanced Topics in Numerical Analysis.** 9 units (3-0-6); 3 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, 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. Instructors: J. Todd. (1st term), O. Todd (2nd term), J. N. Franklin (3rd term).

**Ma 108 abc. Introduction to Real and Complex Analysis.** 12 units (4-0-8); three terms. *Prerequisites:* Ma 1, Ma2. This course is an introduction to advanced methods in analysis. Each year the course will include a discussion of functions of a complex variable; line, surface, volume integrals and their inter-relations; applications of the differential calculus of functions of several variables; functions defined by infinite series and integrals. In addition the course will contain topics selected from: Fourier series and integrals; special functions, such as the gamma and beta functions, Bessel functions, error function; Stieltjes integrals. The aim of this course is to provide a thorough understanding of basic principles, a facility in the use of techniques and a familiarity with applications. This course, or its equivalent, is a prerequisite to graduate mathematics courses in analysis. Instructors: Fuller, Knowles, Luxemburg, Ward.

**Ma 112. Elementary Statistics.** 9 units (3-0-6); first and 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 115 abc. Introduction to Probability and Statistics.** 9 units (3-0-6); three terms. *Prerequisite:* Ma 108 (may be taken concurrently). This course is designed to lead up to a mathematical treatment of important probabilistic and statistical models. The basic ideas of probability and of statistical inference are introduced. Limit and ergodic theorems, methods of estimation and of testing hypotheses are treated in some detail. The formulation and development of statistical problems is based on decision theory, and the probability models on the theory of Markov processes. May be offered in the third quarter.

[B] The following courses are intended primarily for graduate students. They count fully towards a major or a minor for the degree of Doctor of Philosophy:

**Ma 117 abc. Set Theory and Theories of Integration.** 9 units (3-0-6); three terms. *Prerequisite:* Ma 108 abc. Beginning with the theory of sets the course consists of a detailed study of the integration and differentiation of functions of one real variable. It includes a modern treatment of Lebesgue and of Lebesgue-Stieltjes integrals, the theory of functions of bounded variation, applications to measure theory. Instructor: Luxemburg.

**Ma 118 abc. Functions of Complex Variable.** 9 units (3-0-6); three terms. *Prerequisite:* Ma 108 abc or equivalent. The basic results in the theory of analytic functions such as Cauchy's theorems, residues, singularities, analytic continuation are reviewed. The

main part of the course is devoted to more advanced topics selected from: entire functions, mapping theorems, algebraic functions, special functions, functions of several complex variables. The subjects are presented from a modern point of view introducing topological and group theoretical considerations. Not given in 1959-60.

**Ma 120 abc. Abstract Algebra.** 9 units (3-0-6); three terms. *Prerequisites:* Ma 5, Ma 61. Abstract treatment of groups, rings and fields including topics chosen from: structure theory of groups and rings, Galois theory, and valuation theory of fields. Text: *Modern Algebra*, Volume 1, Van der Waerden. Instructors: Dilworth (first and second terms), O. Todd (third term).

**Ma 140 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. Not given in 1959-60.

**Ma 160 abc. Theory of Numbers.** 9 units (3-0-6); three terms. *Prerequisites:* Ma 108 and Ma 118 ab for the last two terms. The first term, Ma 160 a, is an introduction to the elementary theory of numbers including divisibility, numerical functions, elementary theory of primes, quadratic residues. The second and third terms, Ma 160 bc, include topics selected from: Dirichlet series, distribution of primes, additive number theory. Not offered in 1959-60.

**Ma 170 abc. Theory of Probability.** 9 units (3-0-6); three terms. *Prerequisites:* Ma 65 and Ma 108 abc. An introduction to the classical theory of probability leading to the limit theorems and the theory of infinitely divisible distributions. The theory of Markoff processes. Not offered in 1959-60.

**Ma 180 abc. Mathematical Methods in Physics.** 9 units (3-0-6); three terms. *Prerequisite:* Ma 108 abc. Topics selected from matrices and bilinear forms, spectral analysis in Hilbert space, Fourier series and integrals, expansions in orthogonal function systems, integral equations, introduction to the calculus of variations, partial differential equations, characteristic value problems, perturbation methods. Instructor: De Prima.

**Ma 182 abc. Ordinary Differential Equations.** 9 units (3-0-6); three terms. *Prerequisites:* *Elements of real and complex variable theory.* Basic existence and uniqueness theorems. Linear systems. Theory of singularities (real and complex variables). Boundary value problems. Geometrical theory. Topics selected from: asymptotic theory; stability; perturbation theory; ergodic theorems; differential equations in abstract spaces. Emphasis will be put on general concepts and methods rather than on the study of particular equations. Not given in 1959-60.

**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: Dean.

[C] The following courses and seminars will be offered according to demand. They are intended for graduate students sufficiently advanced to take an active interest in contemporary fields of research. The courses and seminars to be offered and the topics to be covered will be announced at the beginning of each term:

**Ma 210 abc. Advanced Topics in Analysis.** *9 units; three terms.* Topics selected from: the theories of functions of one and of several complex variables, quasi-analytic functions, asymptotic expansions; transform theories with applications; orthogonal expansions and almost periodic functions; topological methods in analysis; calculus of variations; analytic number theory. Instructor: Erdélyi.

**Ma 211 abc. Topics in Functional Analysis.** *9 units; three terms.* Topics selected from: the theory of topologized algebraic structures (topological groups, normed linear spaces and rings); the abstract differential calculus; applications to analysis and geometry. Not given in 1959-60.

**Ma 215 abc. Seminar in Analysis.** *6 units; three terms.*

**Ma 216 abc. Seminar in Functional Analysis.** *6 units; three terms.*

**Ma 220 ab. Topics in Contemporary Algebra.** *9 units; second and third terms.* Selected topics of current interest in algebra, such as the theory of partially ordered sets, lattice theory, groups and rings. Instructor: Hall.

**Ma 225 abc. Seminar in Algebra.** *6 units; three terms.*

**Ma 230 abc. Advanced Topics in Geometry.** *9 units; three terms.* Topics selected from the theories of modern Riemannian, non-Riemannian geometry, projective differential geometry, infinite dimensional differential geometry, topology and applications to analysis. Not given in 1959-60.

**Ma 235 abc. Seminar in Geometry.** *6 units; three terms.*

**Ma 262 abc. Seminar in Number Theory.** *6 units; three terms.*

**Ma 275 abc. Seminar in Probability and Statistics.** *9 units; three terms.*

**Ma 280 abc. Advanced Topics in Applied Mathematics.** *9 units; three terms.* Topics selected from: non-linear mechanics, mathematical problems in fluid mechanics, mathematical theory of diffraction and scattering; probability methods in analysis with applications; singular integral equations with applications; abstract space methods in applied mathematics. Not given in 1959-60.

**Ma 285 abc. Seminar in Applied Mathematics.** *6 units; three terms.*

**Ma 290. Reading.** Occasionally advanced work is given by a reading course under the direction of an instructor. Hours and units by arrangement.

**Ma 291. Research.** By arrangement with members of the staff, properly qualified graduate students are directed in research. Hours and units by arrangement.

**Ma 292. Research Conference in Mathematics.** *2 units.* Reports on current literature or their own work will be presented at regular intervals by members of the staff, graduate students or visitors.



## APPLIED MATHEMATICS COURSES OFFERED BY OTHER DEPARTMENTS

- AM 15 Engineering Mathematics. *See Applied Mechanics section, for description.*
- 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 175 Non-linear Vibrations. *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 15 abc, AM 4 ab, AM 5 ab (may be taken concurrently), AM 15 abc. 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 15 abc. Thermodynamics and Fluid Mechanics.** 10 units (3-2-5); first, second and third terms. *Prerequisites:* Ph 2 abc, Ma 2 abc. A study of the first and second laws of thermodynamics with applications to flow and non-flow processes. Properties of various fluids and use of standard tables are discussed. Basic power and propulsion cycles employing gases and vapors are studied. Introduction to fluid mechanics, the continuity equation, equations of motion, Bernoulli equation, momentum theorem, etc. Concepts from kinetic theory. Topics in one dimensional compressible flow; velocity of sound, water hammer, normal shock wave flow through a De Laval nozzle. Elements of potential flow. Principles of dynamic similarity and flow of real fluids. Additional topics to include free surface and open channel flow, elements of turbomachine design and a qualitative discussion of heat transfer will be taken up as time permits. Instructor: Acosta.

**ME 16 abc. Thermodynamics.** 9 units (3-0-6); first, second, and third terms. *Prerequisite:* ME 15 abc. Application of thermodynamics to engines and power plants, the study of one dimensional compressible flow, elements of design of turbo machinery. Study of the inter-relations of thermodynamic properties of the elements of combustion and of the thermodynamic equilibrium of mixtures of perfect gases. Discussion of the basic equations of heat transfer by conduction, convection, and radiation and the application of the theory of heat transfer to applied problems. A survey of the thermodynamic characteristics of power producing machinery, including nuclear installations. Text: Notes. Instructors: Sabersky, Marble.

**ME 25. Mechanical Laboratory.** 9 units (0-6-3); third term. *Prerequisite:* ME 15 abc. Principles of engineering measurements. Instructor: Zukoski.

**ME 50 ab. Engineering Conferences.** 2 units (1-0-1); second, third terms. A course in public speaking for engineers, on engineering topics. Instructors: Clark, Thomas.

#### 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 104 abc. Design.** 7 units (2-6-1); first, second, and third terms. *Prerequisites:* Same as for ME 5 abc. This subject is the same as ME 5 abc, but with reduced credit for graduate students in all fields except Ae, CE, and ME. No graduate credit is given for this subject to students in Ae, CE, and ME, except by special approval of the faculty in Mechanical Engineering.

**ME 115 abc. Thermodynamics and Heat Transfer.** 9 units (3-0-6); first, second, and third terms. *Prerequisites:* ME 15 abc, ME 16 abc. Macroscopic thermodynamics and the elements of microscopic thermodynamics with applications to engineering processes; the transport of energy by conduction, convection, and radiation; the thermodynamics of flow systems. Instructor: Sabersky.

**ME 124 abc. Thermodynamics.** 7 units (3-0-4); first, second, and third terms. *Prerequisite:* ME 15 abc. This subject is the same as ME 16 abc, but with reduced credit for graduate students in all fields except Ae, ChE, and ME. No graduate credit is given for this subject to students in Ae, ChE, and ME, except by special approval of the faculty in Mechanical Engineering. Instructor: Sabersky.

**ME 126. Fluid Mechanics and Heat Transfer Laboratory.** 9 units (0-6-3); third term. 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. The course will treat the theory and application of modern instrumentation to dynamic problems in fluid mechanics and elasticity which will be selected to 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 234.

Hydraulics, page 276.

Jet Propulsion, page 278.

Physical Metallurgy, page 290.

**PALEONTOLOGY**

(See under *Geological Sciences*)

**PHILOSOPHY AND PSYCHOLOGY**

**UNDERGRADUATE SUBJECTS**

**PI 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.

**PI 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.

**PI 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.

**PI 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.

**PI 6. General Psychology.\* 9 units (3-0-6). Senior elective.** An introduction to modern psychological theory and practice. The principal topics studied are the response mechanisms and their functions, emotion, motivation; the nature and measurement of intelligence; learning and retention; sensation and perception; personality and personal adjustment. Instructors: Mead, Bures, Weir.

\*The fourth-year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

**PI 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.

**PI 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

**PI 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, causality, probability, induction, space, time, reality. Scientific method and social problems. Instructor: Bures.

**PI 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.

#### PHYSICAL METALLURGY

##### UNDERGRADUATE SUBJECTS

**PM 1. Physical Metallurgy.** 12 units (3-3-6); first term. Prerequisite: ME 3. A study of the properties of ferrous and non-ferrous metals and alloys with respect to their application in engineering; the principles of heat treatment for a proper understanding by engineers for application of alloys for design. The microstructures of ferrous and non-ferrous metals and alloys are studied in the laboratory. Text: *Physical Metallurgy for Engineers*, Clark and Varney. Instructors: Buffington, Clark.

**PM 2. Metallography Laboratory.** 3 units (0-3-0); third term. Prerequisite: PM 1. Technique of metallographic laboratory practice including microscopy, preparation of specimens, etching reagents and their use, photomicrography. Text: *Principles of Metallographic Laboratory Practice*, Kehl. Instructors: Buffington, Clark.

##### ADVANCED SUBJECTS

**PM 101. Physical Metallurgy.** 9 units (3-3-3); first term. Prerequisite: ME 3. This subject is the same as PM 1 but with reduced credit for graduate students who have not had PM 1 or the equivalent.

**PM 102. Pyrometry.** 9 units (1-6-2); third term. 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. Physical Metallurgy Laboratory.** 9 units (0-9-0); first term. Prerequisites: PM 2, PM 110. Experimental studies of heat treatment, grain size, hardenability, and recrystallization. Text: *Principles of Metallographic Laboratory Practice*, Kehl. Instructor: Clark.

**PM 104. Photography.** 9 units (1-6-2); first term. 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 4 ab, PM 1. 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 110. Thermodynamics of Physical Metallurgy.** 9 units (3-0-6); third term. Prerequisites: PM 1, ME 15 abc. General thermodynamic relationships; thermodynamics of equilibrium diagrams; nucleation and growth including basic principles, transformations in steel, precipitation hardening, recrystallization and grain growth; heat transfer. Instructor: Buffington.

**PM 112 ab. Advanced Physical Metallurgy.** 9 units (3-0-6); second and third terms. Prerequisites: PM 110, 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. Crystal Structure of Metals and Alloys.** 9 units (3-0-6); second term. Prerequisite: PM 1. Atomic structure of metals and alloys, physics of X-rays, elementary crystal structure, symmetry operations, symmetry classes, space groups. Typical structures of metals and of intermetallic compounds. Instructor: Duwez.

**PM 116. X-Ray Metallography I.** 6 units (0-6-0); third term. Prerequisite: PM 115. Experimental methods of X-ray diffraction for the study of the structure and texture of metals and alloys. The Laue and Debye-Scherrer methods. Use of the X-ray spectrometer. Interpretation of diffraction patterns and measurement of lattice parameters. Text: *X-ray Metallography*, Taylor. Instructor: Duwez.

**PM 117. X-Ray Metallography II.** 9 units (0-6-3); second term. Prerequisite: PM 116. Methods of X-ray diffraction analysis involving single crystals. Quantitative interpretation of diffraction patterns of metals and alloys. Study of phase diagrams, plastic deformation and grain orientation. Recrystallization texture, precipitation and age hardening. Stress measurement by X-ray diffraction methods. Text: *X-ray Metallography*, Taylor. Instructor: Duwez.

**PM 120. Physics of Metals.** 9 units (3-0-6); second term. *Prerequisite:* AM 15 abc or equivalent. Introduction to wave mechanics. Free electron theory and band theory of solids. Electrical, magnetic, and thermal properties of solids. Instructor: Buffington.

**PM 121. Theory of Alloys.** 9 units (3-0-6); first term. *Prerequisites:* PM 115, PM 120. Atomic structure of alloys. General principles of alloying. Physical properties of solid solutions in relation to their atomic structure. Electron compounds. Relations between crystal structure and physical properties of alloys. Text: *Atomic Theory for Students of Metallurgy*, Hume-Rothery. Instructor: Duwez.

**PM 125. Industrial Physical Metallurgy.** 9 units (0-6-3); third term. *Prerequisites:* PM 103, PM 117. 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 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 dislocation theory. Text: *Dislocations and Plastic Flow in Crystals*, Cottrell. Instructor: Wood.

**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 demon-



stration 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 material is provided for original experiments. Text: *Introduction to Mechanics and Heat*, Frank. Instructors: Sutton, King, Strong, Watson, 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; *Atomic Physics*, Semat. Instructors: Neher, Mercereau, 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, Kavanagh, 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, Barnes, Boehm, Mathews.

**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, Pellam, Robertson.

**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: Leighton.

**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. Not offered in 1959-60. 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: Walker.

**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.** *9 units (3-0-6); first and second 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. Given in alternate years. Not offered in 1959-60. Instructor: Davis.

**Ph 202. Topics in Classical Physics.** *9 units (3-0-6); third term.* The content of this course will vary from year to year. Typical topics: Non-linear vibrations, dynamics of particles in accelerators, elasticity, hydrodynamics, potential theory, mechanical wave motions. Given in alternate years. Not offered in 1959-60. 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 1959-60. 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: Christy.

**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 Sommerfeld 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 optics; special relativity. Instructor: Sands.

**Ph 212 ab. Mechanics of Continuous Media.** 9 units (3-0-6); *second and third terms. Prerequisite: Ph 201 ab.* Hydrodynamics of nonviscous fluids; Euler and Lagrange equations; general integrals and special problems. Hydrodynamics of viscous fluids; application of the Navier-Stokes equations to special problems. Theory of supersonic flow and shock waves. Fundamental equations of the theory of elasticity. Not given in 1959-60. Instructor: Plesset.

**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. Not offered in 1959-60. 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. Offered in 1959-60. 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 orthonormal 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. Offered in 1959-60. Instructor: Davis.

**Ph 231 ab. High Energy Physics.** 9 units (3-0-6); *second and third terms.* A course covering the properties of high-energy particles and radiation, and their interactions. Topics covered include nucleon-nucleon collisions, interactions of pi mesons and nucleons, photoproduction of pi mesons, mesic atoms, "curious" particles and hyperfragments. Given in alternate years. Not offered in 1959-60. 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: Feynman.

**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. Not offered in 1959-60. 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: Christy and Feynman.

**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: Christy.

**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 12, 1959

### DOCTOR OF PHILOSOPHY

- Peter Albersheim (Biochemistry and Chemistry). *B.S., Cornell University, 1956.*  
Thesis: Metabolism of the Pectic Substances.
- Samuel Morris Berman (Physics). *B.S., University of Miami, 1954; M.S., 1955.*  
Thesis: Radiative Corrections to Muon and Neutron Decay.
- Walter Karl Bonsack (Astronomy and Physics). *B.S., Case Institute of Technology, 1954.* Thesis: The Abundance of Lithium in the Atmospheres of Cool Stars.
- Gary Delane Boyd (Electrical Engineering and Physics). *B.S., California Institute of Technology, 1954; M.S., 1955.* Thesis: Experiments on the Interaction of a Modulated Electron Beam with a Plasma.
- Richard Harald Briceland (Mechanical Engineering). *B.S., State University of Iowa, 1954; M.S., 1955.* Thesis: Secondary Flow in a Cascade of Airfoils.
- Howard M. Brody (Physics). *S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute of Technology, 1956.* Thesis: Photoproduction of Positive K Mesons in Hydrogen.
- Gunnar Erik Broman (Mechanical Engineering and Physics). *C.E.(Ae.), Royal Institute of Technology (Stockholm), 1947; M.S., California Institute of Technology, 1955.* Thesis: Experimental Investigation of Flame Stabilization in a Deflected Jet.
- Wilmot Grant Brownlee, Capt., Royal Canadian Artillery (Mechanical Engineering and Physics). *B.Sc., Carleton College (Ontario, Canada), 1951; M.S., California Institute of Technology, 1956.* Thesis: An Experimental Investigation of Unstable Combustion in Solid Propellant Rocket Motors.
- Richard Bradford Campbell (Petrology and Stratigraphy). *B.A.Sc., University of British Columbia, 1948; M.S., California Institute of Technology, 1951.* Thesis: The Texture, Origin, and Emplacement of the Granitic Rocks of Glenlyon Range, Yukon Territory, Canada.
- I-dee Chang (Aeronautics and Mathematics). *B.S., National Central University (Nanking), 1944; M.S., Kansas State College, 1954.* Thesis: Navier-Stokes Solutions at Large Distances from a Finite Object.
- Paul Palmer Craig (Physics and Mathematics). *B.S., Haverford College, 1954.* Thesis: Observations of Perfect Potential Flow and Critical Velocities in Superfluid Helium II.

- Cedric Inglis Davern (Plant Physiology and Genetics). *B.S.Agr., University of Sydney, 1953; M.S.Agr., 1956*. Thesis: I. Chemotherapy of High Temperature Inhibition of Plant Growth. II. Studies of the Relationship between Tobacco Mosaic Virus Infection and the DNA Metabolism of Tobacco Leaves. III. The Conservation of Microsomal RNA in *Escherichia coli*.
- Donald F. DuBois (Physics and Mathematics). *B.A., Cornell University, 1954*. Thesis: Electron Interactions: A Field Theoretic Generalization of the Gell-Mann-Brueckner Method and a Calculation of Exchange Effects.
- David Duncan Elliott (Physics and Mathematics). *B.S., Stanford University, 1951; M.S., California Institute of Technology, 1953*. Thesis: Angular Correlation of Photoproduced Pion Pairs.
- Rolf Engleman, Jr. (Chemistry and Physics). *B.S., University of Oklahoma, 1955*. Thesis: On the Recombination Rate of Iodine Atoms in the Presence of Various Gases.
- Marshall Paul Ernstene (Physics and Electrical Engineering). *A.B., Harvard College, 1952*. Thesis: Counter Telescope Investigations of K Meson Photo-production and Production of Pion Pairs by 1 Bev Photons.
- Nick George (Electrical Engineering and Physics). *B.S., University of California, 1949; M.S., University of Maryland, 1956*. Thesis: Spatial Distribution of Thermal Radiation at Microwave Frequencies.
- Roger Morse Golden (Electrical Engineering and Physics). *B.S., California Institute of Technology, 1954; M.S., 1955*. Thesis: Experiments in Very Low-Frequency Radio Propagation.
- Thomas Pascoe Gordon (Chemistry). *A.B., Princeton University, 1954; M.S., California Institute of Technology, 1956*. Thesis: I. Studies in the Chemistry of Sodium Dithionite. II. A pH Study of the  $\alpha$ -Chymotrypsin Catalysed Hydrolysis of Methyl Hippurate.
- Thomas Neil Irvine (Geology and Geochemistry). *B.Sc., University of Manitoba, 1953; M.Sc., 1954*. Thesis: The Ultramafic Complex and Related Rocks of Duke Island, Southeastern Alaska.
- John Joseph Kalvinskas (Chemical Engineering). *S.B., Massachusetts Institute of Technology, 1951; S.M., 1952*. Thesis: Partial Oxidation of n-Butane.
- Donald Alvin Kohler (Physics and Mathematics). *B.S., University of Oregon, 1951; M.S., 1952*. Thesis: Observations on the Lifetimes of the 3.37-MEV  $2+$  State of  $\text{Be}^{10}$  and of the 6.14-MEV  $3-$  State of  $\text{O}^{16}$ .
- Hans Henry Kuehl (Electrical Engineering and Physics). *B.S.E., Princeton University, 1955; M.S., California Institute of Technology, 1956*. Thesis: Asymmetrically Excited Electromagnetic Radiation from Circular Cylinders of Finite Length and Prolate Spheroids.
- Stanley Lawrence Manatt (Chemistry and Physics). *B.S., California Institute of Technology, 1955*. Thesis: I. 3-Phenylcyclobut-2-enone and 3-Phenylcyclobutanone Derivatives. II. Calculation of the Delocalization Energies of Some Small-ring Systems Employing the Simple Molecular Orbital Treatment.
- Richard Alan McKay (Chemical Engineering and Electrical Engineering). *B.S., California Institute of Technology, 1949; M.S., 1950*. Thesis: I. Measurement of the Latent Heat of Vaporization of Lighter Hydrocarbons—Values for Normal Octane. II. Volumetric and Phase Behavior in the Ethane-Propane System.



- William Geary Melbourne (Astronomy and Physics). *A.B., University of California at Los Angeles, 1954; M.S., California Institute of Technology, 1955.* Thesis: Line Blanketing Effects on Middle-type Main-sequence and Subdwarf Stars.
- James Edgar Mercereau (Physics and Engineering Science). *B.A., Pomona College, 1953; M.S., University of Illinois, 1954.* Thesis: Diffraction of Thermal Waves in Liquid Helium II.
- Joe Hill Mullins (Physics and Mathematics). *B.S., Agricultural and Mechanical College of Texas, 1950; M.S., California Institute of Technology, 1954.* Thesis: I. A  $WF_6$  Bubble Chamber. II. Physics of Bubble Chambers and Applications to Advanced Designs.
- Gordon Cedric Oates (Mechanical Engineering and Physics). *B.A.Sc., University of British Columbia, 1954; M.Sc., University of Birmingham, 1956.* Thesis: Throughflow in Axial Turbomachines with Variable Wall Geometry.
- Paul Pietrokowsky (Engineering Science and Physics). *B.A.S., University of California, 1944; M.S., 1948.* Thesis: A Study of Conformal Phases in Metal Alloy Systems.
- John Rischard Rice (Mathematics). *B.S., Oklahoma Agricultural and Mechanical College, 1954; M.S., 1956.* Thesis: The Characterization of Best Nonlinear Tchebycheff Approximations.
- Robert Gene Rinker (Chemical Engineering and Chemistry). *B.S., Rose Polytechnic Institute, 1951; M.S., California Institute of Technology, 1955.* Thesis: I. Studies in the Chemistry of Sodium Dithionite. II. A Preliminary Study of the Catalyzed Addition of Hydrogen Chloride to Vinyl Chloride in a Stirred Reactor.
- Winston Walker Royce (Aeronautics and Mathematics). *B.S., California Institute of Technology, 1951; M.S., 1952.* Thesis: Transonic Flow about a Non-lifting Slender Body of Revolution.
- Willard Van Tuyl Rusch (Electrical Engineering and Physics). *B.S.E., Princeton University, 1954; M.S., California Institute of Technology, 1955.* Thesis: A New Transmitting Antenna System for Very Low Radio Frequencies.
- Clay Marcus Sharts (Chemistry and Physics). *B.S., University of California, 1952.* Thesis: Some Fluorinated Cyclobutenes and their Derivatives.
- Ronald Lee Shreve (Geology and Physics). *B.S., California Institute of Technology, 1952.* Thesis: Geology and Mechanics of the Blackhawk Rockslide, Lucerne Valley, California.
- Marc Stamm Silver (Chemistry and Physics). *A.B., Harvard College, 1955.* Thesis: Intermediates in Carbonium Ion Reactions of Methyl-substituted Cyclopropylcarbinyll Cyclobutyl and Allylcarbinyll Derivatives.
- Darwin Waldron Smith (Chemistry and Physics). *B.S., University of California at Los Angeles, 1953.* Thesis: Some Electron Diffraction Studies: I. Electron Diffraction Studies of Some Heavy Metal Hexafluorides. II. The Molecular Structure of Gaseous  $N_2O_4$ . III. Applications of the Method of Least Squares in Electron Diffraction Investigations.



- Noboru Sueoka (Genetics and Immunology). *B.Agr., Kyoto University, 1953; M.Agr., 1955*. Thesis: Genetic and Biochemical Studies of Tyrosinase in *Neurospora*.
- Hugh Pettingill Taylor, Jr. (Geochemistry and Geology). *B.S., California Institute of Technology, 1954; A.M., Harvard University, 1955*. Thesis:  $O^{18}/O^{16}$  Ratios in Coexisting Minerals of Igneous and Metamorphic Rocks.
- Guy Allen Thompson, Jr. (Biochemistry and Chemistry). *B.S., Mississippi State College, 1953*. Thesis: The Biosynthesis of Carotenes in the Tomato.
- Frank Lee Vernon, Jr. (Electrical Engineering and Physics). *B.S., Southern Methodist University, 1949; M.S., University of California, 1952*. Thesis: The Theory of a General Quantum System Interacting with a Linear Dissipative System.
- Willard Henry Wells (Physics and Mathematics). *B.S., University of Texas, 1952*. Thesis: Quantum Theory of Coupled Systems Having Applications to Masers.
- Paul Frederick Robert Weyers (Aeronautics and Physics). *B.Sc., University of Sydney, 1950; B.E.(Ae.), 1952; M.S., California Institute of Technology, 1954*. Thesis: The Vibration and Acoustic Radiation of Thin-Walled Cylinders Caused by Internal Turbulent Flow.
- John Peter Wolf, III (Chemistry and Animal Physiology). *B.A., University of California at Riverside, 1956*. Thesis: I. The *Alpha*-Chymotrypsin-Catalyzed and Base-Catalyzed Hydrolysis of Some Substituted Glycine Esters and Related Compounds. II. The Nature and Properties of the Enzyme-Substrate Complex Produced under Conditions of Very High Substrate Concentrations. III. A Hypothesis Concerning *Alpha*-Chymotrypsin-Substrate Complexes.
- Norman Julius Zabusky (Physics). *B.E.E., The City College of New York, 1951; S.M., Massachusetts Institute of Technology, 1953*. Thesis: Hydromagnetic Stability of a Streaming Cylindrical Plasma.

# ENGINEER'S DEGREE

## AERONAUTICAL ENGINEER

- Andrew Burkhard Bauer. *B.Aero.E., Ohio State University, 1951; M.Sc., 1951.*
- Robert Lynn Chapkis. *B.S., California Institute of Technology, 1956; M.S., 1957.*
- Thomas Emmett Dawson, Major, U.S.M.C. *B.S., United States Naval Academy, 1947; B.S., United States Naval Postgraduate School, 1958.*
- Eugene Richard Doering, Lt., U.S.N. *B.S., United States Naval Academy, 1951; B.S., United States Naval Postgraduate School, 1958.*
- Richard Earl Hemmingway, Capt., U.S.M.C. *B.S.I.E., Georgia Institute of Technology, 1948; B.S., United States Naval Postgraduate School, 1958.*
- Louis L. Monroe. *B.S., Newark College of Engineering, 1936; M.S., Case Institute of Technology, 1953.*
- Jerry Clifford Peck. *B.S., California Institute of Technology, 1957; M.S., 1958.*
- Robert Scott Satre, Lt., U.S.N. *B.S., United States Naval Academy, 1950; B.S., United States Naval Postgraduate School, 1958.*
- Homer Leroy Smith, Lt., U.S.N. *B.S., United States Naval Academy, 1949; B.S., United States Naval Postgraduate School, 1958.*
- Wilfried Erhard Stockmair. *Cand.Eng., Technische Hochschule (München), 1958.*
- Richard Donald Wood. *B.M.E., University of Minnesota, 1950; M.S., 1954.*

## MECHANICAL ENGINEER

- Boris Auksmann. *B.A.Sc., University of British Columbia, 1955; M.S., California Institute of Technology, 1958.*
- Victor Charles Douglas Dawson. *S.B., Massachusetts Institute of Technology, 1948; M.S., Harvard University, 1950.*

## MASTER OF SCIENCE IN SCIENCE

## ASTRONOMY

Harvey Harold Bird. *A.B.*, *The Johns Hopkins University*, 1956.

## CHEMISTRY

J. Philip Bromberg. *S.B.*, *Massachusetts Institute of Technology*, 1956.

Richard Bernard McGriff. *B.S.*, *Florida A. & M. University*, 1955.

## CHEMICAL ENGINEERING

Louis Najib Bathish. *B.A.*, *Pomona College*, 1957.

Ernest Russell Boller. *B.S.*, *Purdue University*, 1958.

Alan S. Emanuel. *B.S.*, *California Institute of Technology*, 1958.

Charles Ronald Penquite. *B.S.*, *California Institute of Technology*, 1958.

Philip Lee Reynolds. *B.S.*, *California Institute of Technology*, 1958.

James Steven Rode. *B.S.*, *California Institute of Technology*, 1958.

Clayton Sutherland Smith. *B.S.*, *Purdue University*, 1958.

Jon René Valbert. *B.S.*, *California Institute of Technology*, 1958.

Emilio Cesare Venezian. *B.E.*, *McGill University*, 1958.

John Walden. *B.Ch.E.*, *Polytechnic Institute of Brooklyn*, 1955.

## GEOLOGY

Meredith Grant Gross, Jr. *A.B.*, *Princeton University*, 1954.

Lewis Brigham Gustafson. *B.S.E.*, *Princeton University*, 1955.

Harvey John Meyer. *B.A.*, *University of Minnesota*, 1957.

Dean Carl Presnall. *B.S.*, *The Pennsylvania State University*, 1957.

Robert Victor Shull. *B.S.*, *New Mexico Institute of Mining and Technology*, 1957.

John C. Vinje. *B.A.*, *University of Minnesota*, 1957.

Robert Eugene Zartman. *B.S.*, *The Pennsylvania State University*, 1957.

## GEOCHEMISTRY

Robert Lawrence Wershaw. *B.S.*, *Texas Western College*, 1956.

## GEOPHYSICS

Shelton Setzer Alexander. *B.S.*, *The University of North Carolina*, 1956.

Don Lynn Anderson. *B.S.*, *Rensselaer Polytechnic Institute*, 1955.

Ritchie Brooke Coryell. *S.B.*, *Massachusetts Institute of Technology*, 1958.

Francis Clay McMichael. *B.S.*, *Lehigh University*, 1958.

Kenneth Watson. *B.A.*, *University of Toronto*, 1957.

## PHYSICS

Raymond Wallace Allard, Jr. *B.A.*, *University of Minnesota*, 1958.

Alan George Bodine. *B.S.*, *University of Illinois*, 1957.

William Davis Burnett. *B.S.*, *Texas Western College*, 1955.

Donald Delbert Clayton. *B.S.*, *Southern Methodist University*, 1956.

Richard Lewis Cohen. *B.A.*, *Haverford College*, 1957.

James L. C. Ford. *B.A.*, *Montana State University*, 1955.

Murlin Fern Gillis. *B.S.*, *University of Washington*, 1956.

Richard O'Neil Hundley. *B.S.*, *California Institute of Technology*, 1957.

James Daniel Larson. *S.B.*, *Massachusetts Institute of Technology*, 1957.

Norton Leonard Moise. *B.S.*, *University of Illinois*, 1948; *M.A.*, *University of California*, 1954.

Martin Emery Nordberg, Jr. *B.S.*, *The University of Rochester*, 1957.

Theodore Wesley Speiser. *B.S.*, *Colorado Agricultural and Mechanical College*, 1956.

John Richard Stevens. *B.A.*, *Pomona College*, 1956.

Joseph Louis Vogl. *A.B.*, *Columbia University*, 1957.

## MASTER OF SCIENCE IN ENGINEERING

### AERONAUTICS

Stanley Walter Augustyniewicz, Jr. *B.S.*, *Parks College of Aeronautical Technology*, 1956.

Michael Eugene Fournery. *B.S.A.E.*, *West Virginia University*, 1958.

Donald James Ketter. *B.S.*, *Parks College of Aeronautical Technology*, 1958.

Wolfgang Gustav Knauss. *B.S.*, *California Institute of Technology*, 1958.

William Ko. *B.S.*, *National Taiwan University*, 1950.

Akira Kobayashi. *B.E.*, *University of Tokyo*, 1954.

Gary Lynn Marlotte. *B.S.*, *Purdue University*, 1958.

Roy Donald Maxwell. *B.S.*, *Louisiana State University*, 1958.

Robert James McElvain, IV. *B.S.*, *Purdue University*, 1958.

Burton Walters Melcher, II. *B.C.E.*, *Cornell University*, 1957.

Harry Moerjono. *B.S.*, *Feati Institute of Technology*, 1956.

Robert Reid Parmeter. *B.S.*, *California Institute of Technology*, 1958.

Françoise Renée Pioline. *Dipl.d'Ing.*, *École Nationale Supérieure de L'Aéronautique*, 1958.

Charles P. Ranunkel. *Dipl.d'Ing.*, *École Centrale des Arts et Manufactures*, 1958.

Xavier Marc Rouvillois. *Dipl.d'Ing.*, *École Nationale Supérieure de L'Aéronautique*, 1958.

Patrick J. Rygh. *B.Aero.E.*, *University of Minnesota*, 1955.

Mitchell Harvey Seidman. *B.S.*, *California Institute of Technology*, 1958.

Frank Clark Thomas. *B.S.*, *University of California*, 1957.

George Charpentier Vlases. *B.E.S.*, *The Johns Hopkins University*, 1958.

Walter Victor Weber, Jr. *B.S.*, *University of Kansas*, 1955.

Jain-Ming Wu. *B.S.*, *National Taiwan University*, 1955.

### CIVIL ENGINEERING

William Thomas Alt. *B.C.E.*, *Rensselaer Polytechnic Institute*, 1958.

Victor Baekelandt. *C.E.* *University of Ghent*, 1958.

Armando Hamel. *C. E.*, *Escuela de Ingeniería de la Universidad de Chile*, 1954.

Izzat Muhammad Idriss. *B.C.E.*, *Rensselaer Polytechnic Institute*, 1958.

Young Chun Kim. *B.E.*, *University of Southern California*, 1958.

Andrew Richard Nasser. *B.Ar.E.*, *University of Detroit*, 1958.

## ELECTRICAL ENGINEERING

- David Anthony Ackley. *B.S., California Institute of Technology, 1958.*  
 John Fredrich Asmus. *B.S., California Institute of Technology, 1958.*  
 Richard Lee Baron. *B.S., California Institute of Technology, 1958.*  
 Robert Harold Bond. *B.S., Colorado State University, 1958.*  
 Carl James Buczek. *B.E.E., Rensselaer Polytechnic Institute, 1956.*  
 George M. Canova. *B.S., California Institute of Technology, 1958.*  
 William Kent Clarkson. *B.S.E., Princeton University, 1958.*  
 Richard Kent Cooper. *B.S., California Institute of Technology, 1958.*  
 Harvey Emanuel Fiala. *B.S., The North Dakota Agricultural College, 1958.*  
 David Edward Fisher. *B.A.Sc., University of Toronto, 1957.*  
 Harold Kay Forsen. *B.S., California Institute of Technology, 1958.*  
 André Jean Pierre Fossard. *Dipl.d'Ing., École Supérieure de L'Aéronautique, 1958.*  
 Stuart Goff. *B.S., California Institute of Technology, 1958.*  
 Richard M. Goldstein. *B.S., Purdue University, 1947.*  
 Michel Pierre Guillemet. *Dipl.d'Ing., École Nationale d'Ingénieurs Arts et Métiers, 1958.*  
 Jay Howard Harris. *B.E.E., Brooklyn Polytechnic Institute, 1958.*  
 Richard F. Herlein. *B.S., California Institute of Technology, 1958.*  
 Robert Henry Hertel. *S.B., Massachusetts Institute of Technology, 1958.*  
 Donivan Richard Howard. *B.S., Purdue University, 1958.*  
 Edgar Towar Irons. *B.S.E., Princeton University, 1958.*  
 Donald Melvin Kisner. *B.E.E., The Cooper Union, 1958.*  
 Norman Bruce Kramer. *B.S., Oklahoma State University of Agriculture and Applied Science, 1958.*  
 Raymond Walter Latham. *B.E., McGill University, 1958.*  
 Joseph Louis LeMay. *B.E.E., University of Detroit, 1957.*  
 Alfred George Lieberman. *B.E.E., Polytechnic Institute of Brooklyn, 1958.*  
 Bruce Timoney McKeever. *B.S., California Institute of Technology, 1958.*  
 Rémi-Noël Menegaux. *Dipl.d'Ing., École Centrale des Arts et Manufactures, 1958.*  
 Kenneth Martin Mitzner. *S.B., Massachusetts Institute of Technology, 1958.*  
 Warren Darold Moon. *S.B., Massachusetts Institute of Technology, 1958.*  
 Xavier F. Namy. *Dipl.d'Ing. École Supérieure D'Électricité, 1958.*  
 Henri Lucien Neuville. *Dipl.d'Ing., École Supérieure D'Électricité, 1958.*  
 Richard Coulston Neville. *B.S., California Institute of Technology, 1958.*  
 Patrick Gerard O'Regan. *B.E., University College, Cork, Ireland, 1957.*  
 Max Bruno Peltier. *Dipl.d'Ing. École Supérieure D'Électricité, 1958.*  
 Andrew Louis Perga. *B.S., California Institute of Technology, 1958.*  
 Bernard Charles Reardon. *B.E., University College, Cork, Ireland, 1957.*  
 Donald Wesley Rice. *B.S., University of Pennsylvania, 1958.*  
 Robert Finley Ringland, II. *B.S.E., Princeton University, 1958.*  
 Lee Rosenthal. *B.E.E., Polytechnic Institute of Brooklyn, 1958.*  
 Lee Otis Schmidt. *B.S., California Institute of Technology, 1958.*  
 Danver Schuster. *B.S., California Institute of Technology, 1957.*  
 Donald R. Sessler. *B.S., California Institute of Technology, 1958.*

- Joe Nelson Smith, Jr., *B.S., California Institute of Technology, 1958.*  
 Lawrence Shepard Smith. *B.S., California Institute of Technology, 1958.*  
 Peter Raymond Smith. *B.S., California Institute of Technology, 1958.*  
 Robert Edward Tokheim. *B.S., California Institute of Technology, 1958.*  
 James Norman Weaver. *B.S., California Institute of Technology, 1958.*  
 John S. Winslow. *B.S., California Institute of Technology, 1953.*  
 Jonas Stasys Zmuidzin. *B.S., Indiana Technical College, 1958.*

## MECHANICAL ENGINEERING

- Frank A. Albin. *B.S., California Institute of Technology, 1958.*  
 Charles Albert Bodeen. *B.S., California Institute of Technology, 1956.*  
 Ray Morris Bowen. *B.S., Agricultural and Mechanical College of Texas, 1958.*  
 Ronald Arlie Christensen. *B.S., Iowa State College, 1958.*  
 Thomas Francis Clancy. *B.S., University of Pennsylvania, 1958.*  
 Joseph Michael Colucci. *B.S., Michigan State College, 1958.*  
 Martin Leo Conneally. *B.S., California Institute of Technology, 1958.*  
 Glenn Leland Converse. *B.S., California Institute of Technology, 1958.*  
 Richard Truman Cowley. *B.S., California Institute of Technology, 1958.*  
 Brinton Stanley Deighton, Jr. *B.Ch.E., Cornell University, 1958.*  
 John Irvine Dick-Peddie. *B.S., Iowa State College, 1953.*  
 George Frederick Engelke. *B.S., California Institute of Technology, 1958.*  
 Roger Keith Farrar. *B.S., Stanford University, 1958.*  
 Alan K. Forsythe. *B.S., California Institute of Technology, 1958.*  
 Walter Robert Haddad. *B.S.M.E., West Virginia University, 1958.*  
 Lance Gregory Hays. *B.S., California Institute of Technology, 1958.*  
 Kalman I. Krakow. *B.E., McGill University, 1958.*  
 Daniel Julius Krause. *B.Met. E., The Ohio State University, 1958.*  
 Robert Julius Kwik. *M.E., Stevens Institute of Technology, 1958.*  
 Robert Georges Lallement. *Dipl.d'Ing., École Nationale Supérieure des Mines de Paris, 1958.*  
 Kaye Don Lathrop. *B.S., United States Military Academy, 1955.*  
 Didier Vincent Morane. *Dipl.d'Ing., École Nationale Supérieure du Génie Maritime, 1958.*  
 Robert Max Schmidt. *S.B., Massachusetts Institute of Technology, 1958.*  
 Andrew Charles Sergi. *B.Ch.E., Pratt Institute, 1958.*  
 Alan Soler. *B.S., University of Pennsylvania, 1958.*  
 John William Wesner, Jr. *B.S., Carnegie Institute of Technology, 1958.*  
 Charlie Lee Yates. *B.S., Virginia Polytechnic Institute, 1958.*

## BACHELOR OF SCIENCE IN SCIENCE

- Gerald Jack Arenson, Los Angeles, California. *Applied Chemistry; Academic Honor, Honor Key.*
- Allen Miller Ashley, North Hollywood, California. *Physics.*
- Walter S. Baer, Glencoe, Illinois. *Physics; Academic Honor, Honor Key.*
- Luis Báez-Duarte, Caracas, Venezuela. *Mathematics; Academic Honor.*
- John Stanton Bailey, Memphis, Tennessee. *Mathematics.*
- Gordon E. Baird, Dallas, Texas. *Physics.*
- Jack Bass, Los Angeles, California. *Physics; Academic Honor.*
- Robert Roy Blandford, Ghost Hollow, Pennsylvania. *Physics.*
- Michael Barry Bogost, Honolulu, Hawaii. *Chemistry.*
- Keith Spalding Brown, Jr., Amado, Arizona. *Chemistry; Academic Honor, Honor Key.*
- Richard Nelson Byrne, Columbus, Ohio. *Physics; Academic Honor.*
- Alan Philip Carlin, Birmingham, Michigan. *Physics; Academic Honor.*
- Clark Edward Carroll, Pittsburgh, Pennsylvania. *Physics; Academic Honor.*
- Hung Cheng, Canton, China. *Physics; Academic Honor.*
- Melvyn David Cheslow, Pasadena, California. *Physics.*
- Barry Gillespie Clark, Canyon, Texas. *Astronomy; Academic Honor.*
- Alexis Neal de Gaston, Los Angeles, California. *Physics.*
- Solomon DePicciotto, Los Angeles, California. *Physics.*
- Richard Darby Dietz, Mountainside, New Jersey. *Astronomy.*
- Robert John Doyle, New Albany, Indiana. *Physics; Academic Honor.*
- Lawrence W. Elmore, Sebastopol, California. *Physics.*
- John C. Everitt, Hallowell, Kansas. *Physics; Honor Key.*
- Clinton Frasier, Greenlawn, New York. *Geophysics.*
- Arnold Irl Goldford, University City, Missouri. *Applied Chemistry.*
- William Robert Graham, Jr., Fairborne, Ohio. *Physics; Academic Honor.*
- Michael Thomas Gray, Marysville, California. *Physics.*
- Herold Richard Gustafson, Portland, Oregon. *Physics.*
- David Handel, Brooklyn, New York. *Mathematics; Academic Honor.*
- Robert Philip Hangebrauck, Waukegan, Illinois. *Applied Chemistry.*
- Michael David Hanley, Greenlawn, New York. *Physics.*
- Robert Earl Harmon, Pasadena, California. *Applied Chemistry; Academic Honor.*
- Philip Darling Harriman, Larkspur, California. *Physics.*
- Timothy Merrill Harrington, Carmel, California. *Physics.*
- James Halbert Havey, Jr., Montgomery, Alabama. *Physics.*
- David Kirk Himrod, Pasadena, California. *Physics.*
- Roger Louis Hoelter, Menlo Park, California. *Physics.*
- Gordon Frierson Hughes, Cheviot Hills, California. *Physics; Academic Honor.*
- Robert Isreal Jewett, Providence, Rhode Island. *Mathematics.*
- Charles Richard Johnson, Lewiston, Idaho. *Applied Chemistry; Academic Honor, Honor Key.*
- Richard Michael Jones, South Gate, California. *Physics.*
- Robert Douglas Junge, Jr., Tracy, California. *Physics.*
- Lloyd Philip Kamins, Milwaukee, Wisconsin. *Biology; Academic Honor.*
- H. Jerome Keisler, Seattle, Washington. *Mathematics; Academic Honor.*



- Mike Edward Kiefer, Van Nuys, California. *Chemistry*.  
 E. David Kipping, Whittier, California. *Physics*.  
 Karl Kent Knapp, La Mesa, California. *Physics*.  
 Murray Arnold Koerner, Santa Barbara, California. *Physics*.  
 DeWitt Landis, Jr., Dallas, Texas. *Physics*.  
 Robert Victor Lange, Phoenix, Arizona. *Physics; Academic Honor, Honor Key*.  
 Ronald Baldwin Leonard, North Hollywood, California. *Applied Chemistry*.  
 Lewis Martell Linson, Berkeley, California. *Physics; Academic Honor*.  
 George Wahl Logemann, Milwaukee, Wisconsin. *Mathematics; Academic Honor*.  
 Bernard Miles Malofsky, Valley Stream, New York. *Chemistry*.  
 Carl Maltz, Pasadena, California. *Physics*.  
 Robert Maltz, Pasadena, California. *Physics*.  
 William Owen McClure, Yakima, Washington. *Biology*.  
 John D. Mihalov, Pasadena, California. *Physics*.  
 David Michael Milder, North Hollywood, California. *Physics; Academic Honor, Honor Key*.  
 Richard C. Montgomery, Frankfort, Kentucky. *Physics*.  
 Eldridge Morton Moores, III, Globe, Arizona. *Geology; Academic Honor*.  
 Thomas Ernest Morton, Great Falls, Montana. *Mathematics; Academic Honor*.  
 Martin G. Olsson, Pasadena, California. *Physics*.  
 David Vincent Owens, San Fernando, California. *Chemistry*.  
 Donald Boyd Owings, Rolling Hills, California. *Applied Chemistry*.  
 Michael Wood Peters, Santa Barbara, California. *Physics*.  
 Russell Mosher Pitzer, Berkeley, California. *Chemistry; Academic Honor*.  
 James Emerson Potter, Rockford, Illinois. *Mathematics; Academic Honor*.  
 John Charles Price, Deerfield, Illinois. *Physics; Academic Honor*.  
 Eugene Elliot Robkin, Los Angeles, California. *Mathematics*.  
 Arthur Rosenthal, Pasadena, California. *Chemistry*.  
 Stanley Roth, Los Angeles, California. *Mathematics; Academic Honor*.  
 Michael Henry Rusin, Chicago, Illinois. *Physics*.  
 Steven Emanuel Schwarz, Oxnard, California. *Physics; Academic Honor*.  
 Edwin Charles Seltzer, Encino, California. *Applied Chemistry; Academic Honor*.  
 James Seymour Somberg, Berkeley, California. *Physics*.  
 John D. Stack, Van Nuys, California. *Physics; Academic Honor*.  
 Byron Edwin Swartz, Kansas City, Missouri. *Physics*.  
 Ivo Tammaru, Los Angeles, California. *Physics; Academic Honor*.  
 John David Teal, Seattle, Washington. *Physics; Academic Honor*.  
 Robert Melvin Thornton, Auburn, California. *Biology; Academic Honor*.  
 Jon Alan Wright, Tacoma, Washington. *Physics; Academic Honor*.  
 Harold Thomas Yura, Los Angeles, California. *Physics*.

## BACHELOR OF SCIENCE IN ENGINEERING

- Kenneth Hoyt Adams, San Francisco, California. *Mechanical Engineering.*
- Steven Martin Ahrens, Los Angeles, California. *Mechanical Engineering.*
- Gustave Akselrod, New York, New York. *Mechanical Engineering; Honor Key.*
- DeLoyce Alcorn, Jr., Pasadena, California. *Electrical Engineering.*
- Bruce Allesina, Oswego, Oregon. *Mechanical Engineering.*
- Vladimir Vadim Baicher, Altadena, California. *Mechanical Engineering; Academic Honor.*
- Edward Raymond Bate, Jr., San Francisco, California. *Mechanical Engineering.*
- Richard Alan Baugh, Port Townsend, Washington. *Electrical Engineering.*
- Chai Bong Byun, Seoul, Korea. *Electrical Engineering.*
- Robert Eugene Chandos, Garden Grove, California. *Electrical Engineering; Academic Honor.*
- Frank Wesley Childs, III, Omaha, Nebraska. *Mechanical Engineering.*
- Douglas Ronald Christman, San Francisco, California. *Mechanical Engineering.*
- Philip Luis Clar, Los Angeles, California. *Electrical Engineering.*
- John Allan Conover, Laguna Beach, California. *Mechanical Engineering.*
- Mert Cramer, Los Angeles, California. *Electrical Engineering.*
- Walter James Cribbs, Torrance, California. *Electrical Engineering.*
- Charles Kenneth Daniels, Santa Ana, California. *Mechanical Engineering.*
- Ronald Alvin Forbess, Nyssa, Oregon. *Electrical Engineering; Academic Honor.*
- Michael DeWitt Godfrey, Eugene, Oregon. *Electrical Engineering; Honor Key.*
- L. Dale Green, Pasadena, California. *Electrical Engineering; Academic Honor.*
- Joel David Greenberg, Los Angeles, California. *Electrical Engineering.*
- Francis Wayne Groesbeck, Altadena, California. *Electrical Engineering; Academic Honor.*
- Gary Deane Hachtel, North Hollywood, California. *Electrical Engineering.*
- Harvey Jerome Hansen, Carlsbad, New Mexico. *Civil Engineering; Honor Key.*
- Hubert Kenneth Hopkins, Los Angeles, California. *Electrical Engineering.*
- William Norris Huse, Cos Cob, Connecticut. *Electrical Engineering.*
- Anthony Joseph Iorillo, Southington, Connecticut. *Mechanical Engineering.*
- Joseph Michael Jenkins, Abilene, Texas. *Electrical Engineering.*
- Walter Adrian Johnson, Jr., Covina, California. *Mechanical Engineering; Academic Honor.*
- Joseph Adamec Jurca, Phoenix, Arizona. *Electrical Engineering.*
- Carl C. Kesler, Jr., Cedar Rapids, Iowa. *Electrical Engineering.*
- Gerhard Joachim Klose, Hagerstown, Maryland. *Mechanical Engineering; Academic Honor.*
- Wayne Charles Kreger, Toledo, Ohio. *Mechanical Engineering.*
- Dennis Wayne Kuli, Lancaster, California. *Electrical Engineering; Honor Key.*
- Robert Mark Lebovitz, Scranton, Pennsylvania. *Electrical Engineering.*
- Anthony Leonard, Ventura, California. *Mechanical Engineering; Academic Honor, Honor Key.*
- Lanny Louis Lewyn, Los Angeles, California. *Electrical Engineering; Academic Honor.*
- Richard Frederick Long, Hanford, California. *Mechanical Engineering.*
- James Nelson Lovelady, Colorado Springs, Colorado. *Electrical Engineering.*

### 310 *Degrees Conferred*

David Gilbert Luenberger, Los Angeles, California. *Electrical Engineering; Academic Honor.*

Richard Bruce MacAnally, Omaha, Nebraska. *Electrical Engineering.*

Raymond Edward Magdaleno, Los Angeles, California. *Electrical Engineering.*

Gail Austin Massey, Glendale, California. *Electrical Engineering; Academic Honor.*

James Michael Moore, Hollydale, California. *Electrical Engineering.*

Kenneth Akira Muraoka, Honolulu, Hawaii. *Mechanical Engineering.*

Frank A. Nowak, Santa Paula, California. *Mechanical Engineering.*

Ralph Bailey Owen, White Swan, Washington. *Mechanical Engineering.*

Robert Marshall Pailthorp, Portland, Oregon. *Electrical Engineering.*

Dennis Lorin Paull, Los Angeles, California. *Electrical Engineering.*

John Charles Petersen, Los Angeles, California. *Electrical Engineering; Academic Honor.*

James Sibley Petty, Guthrie, Oklahoma. *Mechanical Engineering.*

Kirk Alexander Polson, Kansas City, Missouri. *Mechanical Engineering; Honor Key.*

Allan Ray Porush, Pasadena, California. *Civil Engineering.*

Donald Orville Rasmussen, Pasadena, California. *Mechanical Engineering.*

John Joseph Schuster, Peoria, Illinois. *Electrical Engineering; Academic Honor.*

David Crosthwaite Spencer, Los Angeles, California. *Mechanical Engineering; Honor Key.*

John Iver Stene, Los Angeles, California. *Electrical Engineering; Academic Honor.*

John Michael Stevens, San Diego, California. *Electrical Engineering.*

Terry Olin Teigen, Orange, California. *Electrical Engineering; Academic Honor.*

Lawrence Finlayter Tenn, Bog Walk, Jamaica, B. W. I. *Mechanical Engineering.*

William Louis Waggoner, South Gate, California. *Electrical Engineering.*

Evan Otto Weiner, Eagle Rock, California. *Mechanical Engineering.*

Donald Martin Wiberg, Highland Park, Illinois. *Mechanical Engineering.*

William Y. Wong, Shanghai, China. *Electrical Engineering.*

Pai Cheng Young, Weng Tung, China. *Electrical Engineering.*

CANDIDATES FOR COMMISSIONS  
UNITED STATES AIR FORCE  
RESERVE OFFICERS' TRAINING CORPS

Steven Martin Ahrens\*

John Allan Conover\*

Philip Darling Harriman

David Vincent Owens

James Sibley Petty

Arthur Rosenthal

*\*Distinguished Air Force Reserve Officers' Training Corps Graduates*

## 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 1958-59.

## CLASS OF 1960

Adelberger, E. G.	Efron, B.	Munson, J. H.
Anderson, D. W.	Hales, A. W.	Neville, M. K.
Black, N. A.	Hood, L. E.	Rix, J. R.
Bowman, T. E.	Jantscher, G. R.	Rony, P. R.
Campbell, J. H.	Jovin, T. M.	Sinoff, W. A.
Cassel, D. G.	Koh, R. C.	Stephens, S. V.
Cauley, J. M.	Lawler, R. G.	Toth, L. E.
Clark, L. E.	Lee, K. S. H.	Trafton, L. M.
Cooper, J. N.		Weisberg, H. L.

## CLASS OF 1961

Bauer, W. R.	Kasper, J. V.	Seely, O.
Benson, C. T.	Leibovich, S.	Shampine, L. F.
Bickel, P. J.	Lindsey, J. J.	Smith, T. B.
Brown, L. D.	Lortz, D. R.	Stark, H. M.
Chernow, E. I.	Poe, R. F.	Thompson, R. S.
Hechler, S. H.	Ruecker, M. R.	Todoroff, J. A.
Hriber, J. R.	Schwab, M.	Vogt, P. R.
Huld, B.		Wersel, O. A.

## CLASS OF 1962

Armstrong, J. T.	Gordon, B. A.	Moore, R. F.
Baum, C. E.	Hardy, L. M.	Prince, J. F.
Bocklage, J. T.	Hess, R. I.	Ruddick, R. C.
Brandt, R. C.	Hughes, E. E.	Russ, John C.
Bruenn, S. W.	Kabakow, H. A.	Sallee, G. T.
Chang, D. M.	Kugler, L. D.	Schultz, M. H.
Crow, S. C.	Lin, R. P.	Teitelman, W.
Emerson, W. R.	Lorden, G. A.	Thorne, K. S.
Flatte, S. M.	Manning, R. J.	Weihs, W. H.
Fraleigh, G. S.	Mead, C. A.	Zacher, A. R.
Gerber, P. D.	Metcalf, P. L.	Zame, A.
	Miller, E. S.	

## 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."

KEITH BROWN, JR.

## DON BAXTER, INC. PRIZES IN CHEMISTRY

Awarded to the two undergraduate students who during the year have carried out the best original researches in chemistry.

*First Prize:* DONALD H. VOET

*Second Prize:* DAVID V. OWENS

CONGER PEACE PRIZE ORATION

Established in 1912 by the late Everett D. Conger, D.D.

*First Prize:* THOMAS M. JOVIN

*Second Prize:* KEITH BROWN, JR.

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.

GEORGE C. VLASES

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.

BRENT BANTA

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:* ROBERT LEROY WAX

*Second Prize:* DAVID BERNARD BENSON

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.

BRADLEY EFRON

THOMAS M. JOVIN

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