CALIFORNIA INSTITUTE OF TECHNOLOGY

CATALOGUE 1950-1951

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CALIFORNIA INSTITUTE OF TECHNOLOGY

A College, Graduate School, and Institute of Research in Science Engineering, and the Humanities

CATALOGUE
1950 - 1951

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PASADENA, CALIFORNIA

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THE CAMPUS OF THE CALIFORNIA INSTITUTE

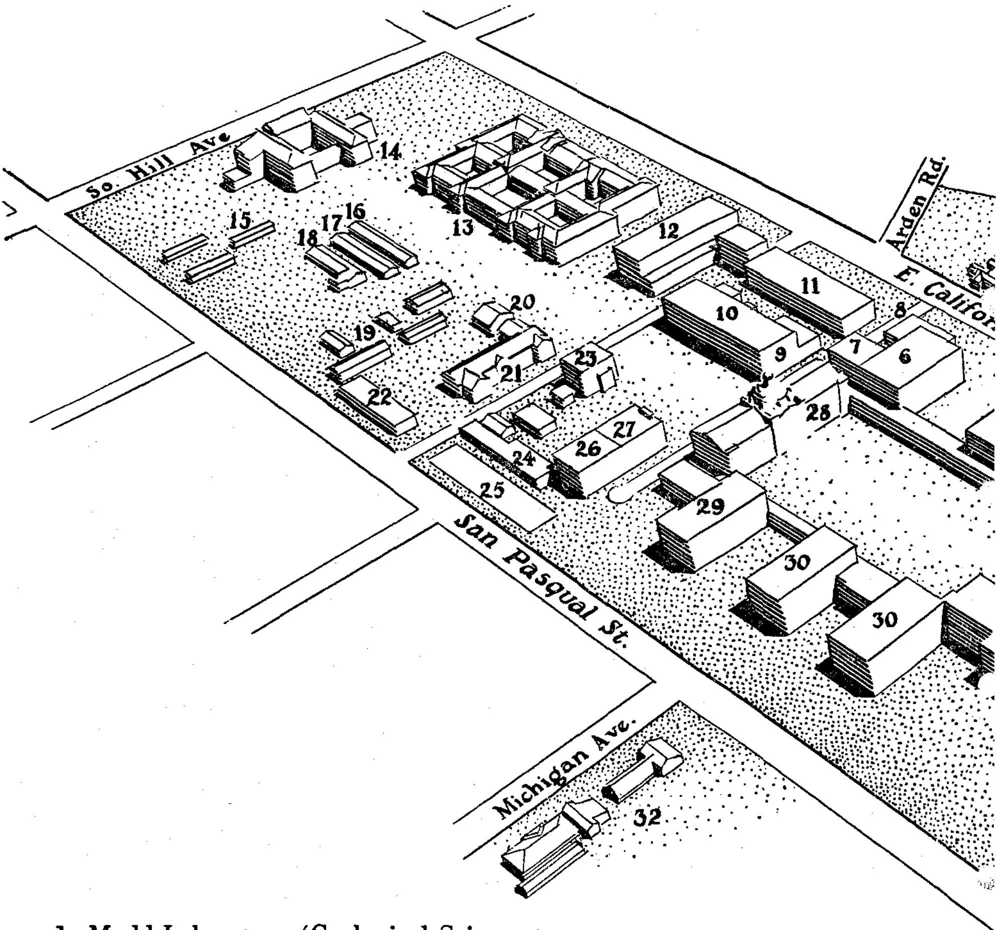
The following two pages present a schematic view of the campus of the California Institute. The campus is in a residential section of Pasadena, about a mile from the central business district. The area bounded by East California Street, South Hill Avenue, San Pasqual Street, and South Wilson Avenue is 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 club for faculty, graduate students, and the staffs of the Mount Wilson Observatory and the Huntington Library.

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 much-needed parking space for students and staff, Tournament Park has the following facilities for athletics and recreation: tennis and badminton courts; three outdoor basketball and three 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 training quarters with locker and shower rooms.

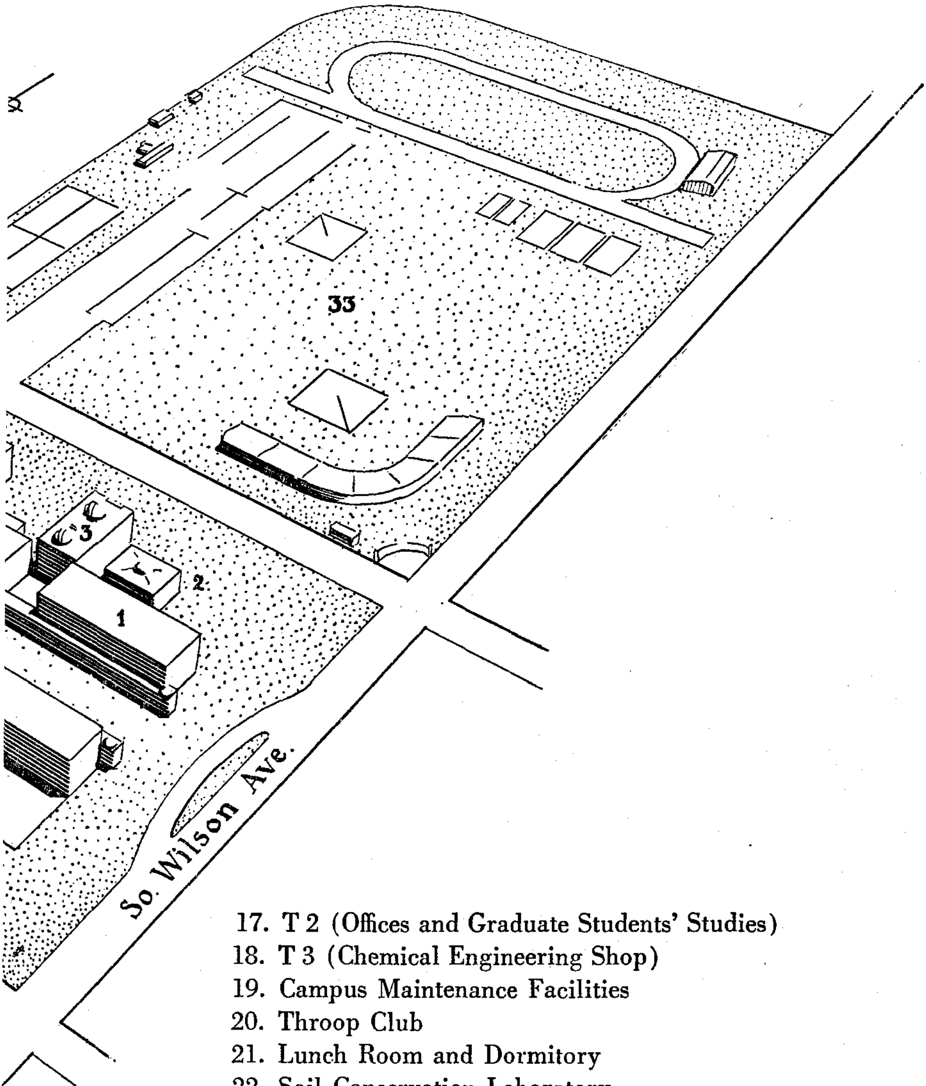
Plans for the future development of Tournament Park call for the construction of a student union building and a gymnasium and swimming pool.

CAMPUS MAP · CALIFORNIA



1. Mudd Laboratory (Geological Sciences)
2. Culbertson Hall (Auditorium; Industrial Relations)
3. Robinson Laboratory (Astrophysics)
4. Arms Laboratory (Geological Sciences)
5. Bridge Laboratory (Physics)
6. High Potential Research Laboratory
7. Kellogg Laboratory (Electrical Engineering; Physics)
8. Buildings and Grounds Office; Receiving Room
9. Fluid Mechanics Laboratory
10. Guggenheim Laboratory (Aeronautics)
11. Central Machine Shop
12. Optical Shop (Astrophysics)
13. Student Houses
14. Athenaeum
15. T 4 (Health Center)
16. T 1 (Physical Education Office; Sanitary Engineering and Soil Mechanics Laboratories; Earthquake Research)

INSTITUTE OF TECHNOLOGY



17. T 2 (Offices and Graduate Students' Studies)
18. T 3 (Chemical Engineering Shop)
19. Campus Maintenance Facilities
20. Throop Club
21. Lunch Room and Dormitory
22. Soil Conservation Laboratory
23. Mechanical Engineering Laboratory
24. Mechanical Engineering Laboratory and Shop
25. Hydraulic Structures Laboratory
26. Research Laboratory (Chemical Engineering)
27. Heating Plant
28. Throop Hall (Administration; Civil Engineering)
29. Dabney Hall (Humanities)
30. Gates and Crellin Laboratories (Chemistry)
31. Kerckhoff Laboratories (Biological Sciences)
32. Dolk, Clark, and Earhart Laboratories (Plant Research)
33. Tournament Park (Physical Education Facilities)

CALENDAR

1950

SEPTEMBER

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CALENDAR 1950-51

FIRST TERM

1950	
September 21	Registration of entering freshmen—9:00 A.M. to 3:30 P.M.
September 21	Registration of students transferring from other colleges—8:30 A.M.
September 25	General registration—8:30 A.M. to 3:30 P.M.
September 26	Beginning of instruction—8:00 A.M.
October 14	Last day for adding courses.
October 14	Examinations for the removal of conditions and incompletes.
October 30–November 4	Mid-term week.
November 4	MID-TERM.
November 6	Mid-term deficiency notices due—9:00 A.M.
November 10	Last day for dropping courses.
November 17	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
November 20–24	Pre-registration for 2nd term 1950–51.
November 23–26	Thanksgiving recess.
December 11-16	Final examinations—1st term 1950–51.
December 16	Last day for filing application for candidacy for the degree of Doctor of Philosophy in June 1951.
December 16	End of 1st term 1950–51, 12M.
December 17–January 2	Christmas vacation.
December 27	Meeting of Freshman Registration Committee—9:00 A.M.
December 27	Meeting of Upperclass Registration Committee—1:00 P.M.

SECOND TERM

1951	
January 2	General registration—8:30 A.M. to 3:30 P.M.
January 3	Beginning of instruction—8:00 A.M.
January 19	Last day for adding courses.
January 20	Examinations for the removal of conditions and incompletes.
January 29–February 3	Mid-term week.
February 3	MID-TERM.
February 5	Mid-term deficiency notices due—9:00 A.M.
February 9	Last day for dropping courses.
February 16	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
February 19–23	Pre-Registration for 3rd term 1950–51.
March 10	College Entrance Board examinations for admission to the freshman class, September 1951.
March 12–17	Final examinations—2nd term 1950–51.
March 17	End of 2nd term 1950–51, 12M.
March 23	Meeting of Freshman Registration Committee—9:00 A.M.
March 23	Meeting of Upperclass Registration Committee—1:00 P.M.

THIRD TERM

1951	
March 26	General registration—8:30 A.M. to 3:30 P.M.
March 27	Beginning of instruction—8:00 A.M.
April 13	Last day for adding courses.
April 14	Examinations for the removal of conditions and incompletes.
April 23-28	Mid-term week.
April 28	MID-TERM.
April 30	Mid-term deficiency notices due—9:00 A.M.
May 4	Last day for dropping courses.
May 11	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
May 14–18	Pre-Registration for 1st term of 1951–52.
May 25	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy and theses for Engineer's degree.
May 30	Memorial Day Holiday.
May 28–June 2	Final examinations for senior and graduate students—3rd term 1950–51.
June 1 & 2	Examinations for admission to upper classes, September 1951.
June 4–9	Final examinations for undergraduate students—3rd term 1950–51.
June 6	Meeting of Committees on Course in Science and Engineering—10:00 A.M.
June 6	Faculty meeting—2:00 P.M.
June 7	Class Day.
June 8	Commencement.
June 9	End of 3rd term 1950–51, 12M.
June 15	Meeting of Freshman Registration Committee—9:00 A.M.
June 15	Meeting of Upperclass Registration Committee—1:00 P.M.

FIRST TERM 1951–52

September 20	Registration of entering freshmen—9:00 A.M.
September 20	Registration of students transferring from other colleges, 8:30 A.M.
September 21–23	Student Camp.
September 24	General registration—8:30 to 3:30 P.M.
September 25	Beginning of instruction—8:00 A.M.

PART ONE

General Information

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CIVIL, ELECTRICAL AND MECHANICAL ENGINEERING AND AERONAUTICS............
............FREDERICK C. LINDVALL
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HUMANITIES............HALLETT D. SMITH
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DEAN OF ADMISSIONS AND REGISTRAR............L. WINCHESTER JONES
ASSOCIATE DEAN FOR UPPER CLASSMEN............PAUL C. EATON
ASSOCIATE DEAN FOR FRESHMEN............FOSTER STRONG

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DIRECTOR OF PUBLIC RELATIONS............GEORGE H. HALL
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1950-51

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SECRETARY—R. R. MARTEL

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LECTURES AND ASSEMBLIES—*Strong,* Buwalda, Eagleson, Mead, McCrery, Newton, Noble, Smith.

LIBRARY—*Stanton,* Bell, Converse, Dunn, Epstein, Gray, Hughes, P. Kyropoulos, Liepmann, P. W. Merrill, Nichols, Schutz, Stock, Tyler, Zwicky.

MUSICAL ACTIVITIES—*Mead,* J. S. Campbell, DuMond, Duwez, Erdélyi, Gilbert, Hudson, Lagerstrom, Thomas, Wayland.

See page 16.

PATENTS—*D. S. Clark,* Beadle, Fowler, P. Kyropoulus, Lindvall, Martel, Niemann.

PHYSICAL EDUCATION—*Eaton,* Gevurtz, Jahns, Jones, LaBrucherie, Musselman, Nerrie, Paul, Preisler, Sorensen, Tanham.

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[1]Carnegie Institution of Washington, Division of Plant Biology, Stanford.
[2]University of Cambridge.

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RENATO DULBECCO, PH.D.	Biology
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GEOFFREY L. KEIGHLEY, PH.D.	Biology
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[1]U.S. Department of Agriculture, Bureau of Agricultural and Industrial Chemistry.
[2]On leave of absence.

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Katerina I. Zarudnaya, Ph.D.	Biology

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1949-50

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ERNEST H. SWIFT, PH.D.	Analytical Chemistry
DON M. YOST, PH.D.	Inorganic Chemistry
LÁSZLÓ ZECHMEISTER, DR.ING.	Organic Chemistry

VISITING PROFESSORS

BRYCE L. CRAWFORD, JR.,[2] PH.D.	Chemistry
J. B. CULBERTSON, PH.D.	Chemistry
R. M. KEEFER, PH.D.	Chemistry
MASSIMO SIMONETTA, PH.D.	Chemistry

RESEARCH ASSOCIATES

EDWIN R. BUCHMAN, D.PHIL.	Organic Chemistry
EDWARD W. HUGHES, PH.D.	Physical Chemistry
JOSEPH B. KOEPFLI, D.PHIL.	Chemistry
SEELEY G. MUDD, M.D.	Medical Chemistry
OLIVER R. WULF, PH.D.	Physical Chemistry

ASSISTANT PROFESSOR

NORMAN DAVIDSON, PH.D.	Chemistry

SENIOR RESEARCH FELLOWS

G. VICTOR BEARD,* PH.D.	Chemistry
JOHN R. CANN, PH.D.	Chemistry
JERRY DONOHUE,[3] PH.D.	Chemistry
FRED J. EWING, PH.D.	Structural Chemistry
WALTER A. SCHROEDER,[3] PH.D.	Chemistry
DAVID P. SHOEMAKER, PH.D.	Chemistry
S. J. SINGER, PH.D.	Chemistry

INSTRUCTOR

DAVID M. MASON, JR., PH.D.	Chemical Engineering

[1]Arthur A. Noyes Professor.
[2]John Simon Guggenheim Memorial Foundation Fellow.
[3]Arthur A. Noyes Senior Research Fellow.
*In residence during 1949–50.

RESEARCH FELLOWS

Robert A. Alberty,[1] Ph.D.
Robert E. Barieau,* Ph.D.
O. Bastiansen, Dr. Phil.
Raymond A. Brown,[2] Ph.D.
Christoph H. Burckhardt, Ph.D.
Stanley C. Burket, Ph.D.
Richard E. Cline, M.A.
Sheldon C. Crane, Ph.D.
David L. Douglas, Ph.D.
Jack D. Dunitz,[3] Ph.D.
F. Charlotte Green, Ph.D.
Kenneth W. Hedberg, Ph.D.
Edgar Heilbronner, Dr. tech. sc.
Hsing-Tsung Huang, Ph.D.
Miyoshi Ikawa, Ph.D.
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Victor A. Lewinson, Ph.D.
Ernst F. Luescher, Ph.D.
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Roger Newman, Ph.D.
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J. Howard Pinckard, Ph.D.
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Heinrich Rinderknecht, Ph.D.
Warren G. Schlinger, Ph.D.
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Robert G. Shulman,* Ph.D.
Robert C. C. St. George,[6] Ph.D.
Charles Sutherland,* M.D.
You-Chi Tang,[7] Ph.D.
Dudley W. Thomas, Ph.D.
B. S. J. Wöstmann, Ph.D.
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[2]U.S. Public Health Service Fellow.
[3]Parke, Davis and Company Fellow.
[4]U.S. Public Health Service Senior Assistant Surgeon.
[5]National Research Fellow.
[6]Merck Fellow.
[7]George Ellery Hale Fellow.
*In residence during 1949-50.

RESEARCH ASSISTANTS
1949-50

Jay B. Banovitz, B.S.
Darlton K. Breaux, M.S.
David A. Downing, B.S.
Ruth V. Dunham, B.S.
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SIMON RAMO, PH.D. .... Electrical Engineering
RAYMUND SÄNGER, PH.D. .... Engineering
DEAN E. WOOLDRIDGE, PH.D. .... Electrical Engineering

[1]Emeritus

ASSOCIATE PROFESSORS

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Robert F. Tangren, A.E.	Jet Propulsion

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Chang-Pen Hsu, Ph.D.	Electrical Engineering
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Max L. Williams, Ph.D.	Aeronautics

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Nathaniel W. Wilcox, A.B.	Engineering Drafting

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1949-50

Allan J. Acosta, M.S.
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Peilin Luo, B.S.
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Robert V. Meghreblian, B.Ae.E.
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Clement J. Savant, B.S.
Glenn A. Schurman, M.S.
David E. Shonerd, Ae.E.
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George E. Solomon, B.S.
Robert R. Solverson, M.S.
Ezra Spevak, B.E.
Leo Stoolman, B.S.
Jay W. Stuart, Jr., M.S.
Wilber M. Swanson, M.S.
Paul G. Thiene, B.S.
Harry N. Upthegrove, B.S.
Thomas Vrebalovich, M.S.
Hugh R. Wahlin, B.S.
William W. Ward, M.S.
Robert R. Waters, B.S.
Joseph W. Wechsler, M.S.
Hans E. Wohlwill, B.S.

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IAN CAMPBELL, *Associate Chairman*
BENO GUTENBERG, *Director of the Seismological Laboratory*

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IAN CAMPBELL, PH.D. .... Petrology
BENO GUTENBERG, PH.D. .... Geophysics
RICHARD H. JAHNS, PH.D. .... Geology
JAMES A. NOBLE, PH.D. .... Economic Geology
ROBERT P. SHARP, PH.D. .... Geomorphology
CHESTER STOCK, PH.D. .... Paleontology

VISITING PROFESSOR

R. DANA RUSSELL, PH.D. .... Sedimentation

RESEARCH ASSOCIATES

D. FOSTER HEWETT, PH.D. .... Geology
CLINTON R. STAUFFER, PH.D. .... Invertebrate Paleontology
HARRY O. WOOD, A.M. .... Seismology

ASSOCIATE PROFESSORS

HUGO BENIOFF, PH.D. .... Seismology
CHARLES HEWITT DIX, PH.D.[1] .... Geophysics
ALBERT E. J. ENGEL, PH.D. .... Mineralogy
CHARLES W. MERRIAM, PH.D.[1] .... Invertebrate Paleontology
GENNADY W. POTAPENKO, PH.D.[2] .... Geophysics
CHARLES F. RICHTER, PH.D. .... Seismology

LECTURERS

WILFRID H. GEIS, B.S. .... Petroleum Geology
MERLE C. ISRAELSKY, B.S. .... Micropaleontology

[1]On leave until January 1, 1951
[2]Member of the Division of Physics, Mathematics and Astronomy

VISITING RESEARCH FELLOW

Marcus Båth, Ph.D. .... Seismology
P. G. Gane, Ph.D. .... Geology

INSTRUCTOR

Lloyd C. Pray, M.S. .... Geology

RESEARCH FELLOW

Kazim Ergin, Ph.D. .... Geology

RESEARCH ASSISTANTS

Rudolf von Huene, E.M.
William J. P. Otto
David P. Willoughby

GRADUATE FELLOWS AND ASSISTANTS

1949-50

Manuel Bass, B.S.
Richard B. Campbell, B.A.Sc.
Peter Dehlinger, M.S.
M. Elner Denson, Jr., M.S.
Royal S. Foote, A.B.
James P. Heppner, B.Ph.
William P. Irwin, B.S.
Harold M. Mooney, M.S.
Joseph R. Moran, B.A.
William R. Muehlberger, M.S.
John F. Murphy, M.A.
Robert L. Nelson, B.A.
Donald K. Norris, M.A.
Donald B. Potter, M.S.
John R. Reese, B.S.
George P. Rigsby, B.S.
James A. Roddick, B.A.Sc.
Allen M. Rugg, Jr., G.E.
Leon T. Silver, M.S.

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HORACE N. GILBERT, M.B.A.	Business Economics
ROBERT D. GRAY, B.S.	Economics and Industrial Relations
WILLIAM HUSE, M.A.	English
CLINTON K. JUDY,[1] M.A.	English
JOHN R. MACARTHUR,[1] M.A.	Languages
GEORGE R. MACMINN, A.B.	English
HUNTER MEAD, PH.D.	Philosophy and Psychology
WILLIAM B. MUNRO,[1] PH.D., LL.D., LITT.D.	History and Government
HALLETT D. SMITH, PH.D.	English
ALAN R. SWEEZY, PH.D.	Economics
RAY E. UNTEREINER, PH.D.	Economics

ASSOCIATES

GODFREY DAVIES, M.A.	History

ASSOCIATE PROFESSORS

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L. WINCHESTER JONES, A.B.	English
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ARTHUR H. YOUNG	Industrial Relations

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MELVIN D. BROCKIE, PH.D.	Economics
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J. KENT CLARK, PH.D.	English
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RICHARD D. SENSOR, M.A.	Industrial Relations
ALFRED STERN, PH.D.	Languages and Philosophy

INSTRUCTORS

JACOB CHAITKIN, LL.B.	Russian
HEINZ ELLERSIECK, M.A.	History
GEORGE K. TANHAM, M.A.	History

[1]Emeritus

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PAUL S. EPSTEIN, PH.D.	Theoretical Physics
A. ERDÉLYI, D.SC.	Mathematics
RICHARD P. FEYNMAN, PH.D.	Theoretical Physics
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CHARLES C. LAURITSEN, PH.D.	Physics
ARISTOTLE D. MICHAEL, PH.D.	Mathematics
ROBERT A. MILLIKAN[1], PH.D., LL.D., SC.D.	Physics
H. VICTOR NEHER, PH.D.	Physics
H. P. ROBERTSON[2], PH.D.	Mathematical Physics
WILLIAM R. SMYTHE, PH.D.	Physics
H. C. VAN BUSKIRK[1], PH.B.	Mathematics
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FRITZ ZWICKY, PH.D.	Astrophysics

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J. R. OPPENHEIMER, PH.D., D.SC., LL.D.	Physics
I. I. RABI, PH.D.	Physics

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SAMUEL J. BARNETT, PH.D.	Physics
WALTER G. CADY, PH.D., SC.D.	Physics
SPIRO KYROPOULOS, PH.D.	Physics
FRITZ OBERHETTINGER, DR. PHIL.	Mathematics
F. TRICOMI, DR. MATH.	Mathematics

Various members of the staff of the Mount Wilson and Palomar Observatories will participate from time to time in the instructional work of the Division.

[1]Emeritus
[2]On leave of absence

ASSOCIATE PROFESSORS

Leverett Davis, Jr., Ph.D.	Theoretical Physics
Robert P. Dilworth, Ph.D.	Mathematics
Alexander Goetz, Ph.D.	Physics
Robert B. King, Ph.D.	Physics
Thomas Lauritsen, Ph.D.	Physics
Gennady W. Potapenko, Ph.D.	Geophysics
Luther E. Wear, Ph.D.	Mathematics

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T. M. Apostol, Ph.D.	Mathematics
William N. Birchby, M.A.	Mathematics
Eugene Cowan, Ph.D.	Physics
Samuel Karlin[1], Ph.D.	Mathematics
Robert V. Langmuir, Ph.D.	Physics
Robert B. Leighton, Ph.D.	Physics
Foster Strong, M.S.	Physics
Robert L. Walker, Ph.D.	Physics

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David A. Lind[1], Ph.D.	Physics
Matthew L. Sands, Ph.D.	Physics

RESEARCH FELLOWS

Henry A. Dye, Ph.D.	Mathematics
Harley Flanders, Ph.D.	Mathematics
Vincent Peterson, Ph.D.	Physics
John Teasdale, Ph.D.	Physics
Donald L. Thomsen, Jr., Ph.D.	Mathematics
Alvin V. Tollestrup, Ph.D.	Physics
Maria Weber, Ph.D.	Mathematics
Ward Whaling, Ph.D.	Physics

[1]On leave of absence

GRADUATE ASSISTANTS AND FELLOWS

1949-1950

Helmut Abt, M.S.
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E. Leonard Arnoff, M.S.
Halton C. Arp, A.B.
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Mrs. James G. Newcomb
Mrs. Arthur Noble
K. T. Norris
George J. O'Brien
Mrs. Henry W. O'Melveny
John O'Melveny
Stuart O'Melveny
Mrs. Charles W. Paddock
Mrs. Benjamin E. Page
James R. Page
Mrs. James R. Page
I. Graham Pattinson
Mrs. June Braun Pike
Clarence B. Piper
Mrs. William M. Prindle
Mrs. Charles H. Prisk
W. F. Prisk
Mrs. Louis D. Ricketts
Alden G. Roach
Mrs. Harry W. Robinson
Mrs. Frederick Roeser
Albert B. Ruddock

Mrs. Albert B. Ruddock
Robert O. Schad
Howard J. Schoder
Mrs. Richard J. Schweppe
Frank R. Seaver
Charles P. Skouras
Dana C. Smith
Keith Spalding
Mrs. Keith Spalding
Mrs. Silsby M. Spalding
Charles F. Stern
Dillon Stevens
Ron Stever
W. L. Stewart, Jr.
Leonard G. Strater
Charles H. Strub
Reese H. Taylor
Mrs. Joseph E. Tilt
Mrs. John Treanor
Fred R. Tuerk
Mrs. John K. Urmston
Edward R. Valentine
Mrs. W. L. Valentine
William W. Valentine
J. Benton Van Nuys
Victor von Borosini
Richard R. von Hagen
Charles B. Voorhis
Mrs. Thomas W. Warner
Mrs. Gurdon W. Wattles
A. L. Weil
Leland K. Whittier
R. J. Wig
P. G. Winnett
Thomas Wolfe
Mrs. Casey A. Wood
Archibald B. Young
Gerald C. Young

HISTORICAL SKETCH

The California Institute of Technology had its origin in 1891, with the founding of Throop University. At that time the opportunities for obtaining systematic vocational training on the west coast were meager, if they existed at all. It was primarily to meet this need that the Hon. Amos G. Throop founded the institution to which he gave his name and to which he later left the bulk of his estate. Throop Polytechnic Institute—the name was changed in 1892—while it offered work of college grade, concentrated most of its energies on instruction in manual training, domestic science, and kindred subjects, preparing its graduates mainly for teaching positions which were opened by the addition of manual arts to the curricula of the public schools. And to round out its general educational program, Throop Polytechnic also maintained an academy and an elementary school.

Thus it continued for nearly two decades, with no change in its principal aims, and housed in three buildings on a small campus in the present business section of Pasadena. The impulse toward change originated with Dr. George E. Hale, who had come to Pasadena to direct the building of the Mount Wilson Observatory of the Carnegie Institute of Washington. The need which had been met by the founding of Throop Polytechnic Institute was now being met by other institutions; Dr. Hale perceived a new and greater need, growing out of changed conditions; and he became enthusiastic over the possibility of developing an institution which would give sound engineering training, but which might in time, with the friendly association of the Mount Wilson Observatory, make Southern California a center for distinguished scientific work.

The possibility which he envisaged fired the enthusiasm and enlisted the support of a number of outstanding citizens of the community, notably Messrs. Arthur H. Fleming, Norman Bridge, Henry M. Robinson, James A. Culbertson, Charles W. Gates, and Hiram and John Wadsworth. Mr. Fleming and his daughter, Marjorie, presented the institution with twenty-two acres of land which, with the addition of eight acres later, comprise the present campus. The Flemings were also largely instrumental in providing the first building to be erected on the new site, the present Throop Hall. In 1910, under the presidency of Dr. James A. B. Scherer, the institute moved to its new quarters. A few years earlier the elementary school had been set up as a separate institution, the present Polytechnic Elementary School; and by 1911 the normal school and the academy had been discontinued.

For the first few years in its new location, Throop Polytechnic Institute—or Throop College of Technology as it was called after 1913—gave degrees only in electrical, civil, and mechanical engineering. Gradually, however, it was able to add to its objectives. In 1913, Dr. A. A. Noyes, who was founder and director of the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology and who had also served as president of that institution, became associated on part-time with the College. In 1916 a chemical laboratory was assured. It was completed in 1917, and instruction and research in chemistry and chemical engineering was inaugurated under Dr. Noyes' direction. In that same year, Dr. Robert A. Millikan, then professor of physics at the University of Chicago, arranged to spend a part of each year at Throop, where as Director of Physical Research, he was to develop a program of graduate work in physics.

The War necessitated a temporary diversion of energies. Numerous members of the faculty went into service, and undergraduate instruction was radically revised to meet the immediate needs of the national emergency. With the close of the war, however, normal activities were resumed, and in the next few years the institution entered on the most rapid and consistently sustained phase of its development. In 1919 Dr. Noyes resigned from the faculty of the Massachusetts Institute of Technology to give his whole time to Throop College. In 1920 the name was changed to the California Institute of Technology. In that same year, Dr. Scherer resigned because of ill health.

Nineteen hundred and twenty-one was marked by developments which made it one of the most important years in the history of the Institute. When a laboratory of physics was assured by Dr. Norman Bridge, Dr. Millikan severed his connection with the University of Chicago to become director of the laboratory and Chairman of the Executive Council of the Institute.

In the same year, 1921, financial stability was assured by Mr. Arthur H. Fleming's agreement to give the California Institute his personal fortune as permanent endowment. In November of that year, the Board of Trustees formulated in the "Educational Policies of the Institute" an explicit statement of the principles which were to govern the present conduct of the Institute and its future development. Recognition by the Southern California community of the value of these aims has resulted in a steady growth of the physical facilities and has made possible the addition of work in geology, paleontology, geophysics, biology, biophysics, biochemistry, aeronautics, astrophysics, meteorology and industrial relations. In 1928 the Institute was chosen to undertake the responsibility for the design and construction of the 200-inch telescope, funds for which were supplied by the General Education Board.

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 and 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 non-profit contracts with the Federal 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.

With the end of the war, all these emergency activities were terminated as quickly as possible, so that the Institute could get back to its primary job of undergraduate and graduate instruction and fundamental research.

In 1945 Dr. Robert A. Millikan, having guided the Institute through its formative years to maturity, retired as Chairman of the Executive Council, to become a Vice-President of the Board of Trustees. He was succeeded by Dr. Lee A. DuBridge, who assumed the office of President of the California Institute on September 1, 1946.

EDUCATIONAL POLICIES

The educational policies which the Trustees adopted in 1921 have been followed without essential modification ever since. Hence, a description of current practices will also constitute a summary of these policies.

The primary purpose of the undergraduate school, 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 commonly included in undergraduate engineering courses. Such a curriculum, it is hoped, will provide a combination of a 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 on one hand the narrowness often observed among students in technical schools and on the other hand the superficiality and lack of purpose noticeable in many of those taking academic college courses.

The course in Science affords, even more fully than is possible in the Engineering course, an intensive training in physics, chemistry, and mathematics. In the third and fourth years groups of optional studies are included which permit some measure of specialization in a chosen field of science. Instruction is also provided in French and German, with the object of giving the student a sufficient reading knowledge to follow the scientific and technical literature in those languages. This 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, ideals, 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 geophysics, 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 proportion (about forty per cent) 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 instruction 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, at present, 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 select body of students of more than ordinary ability. A standard of scholarship is also maintained which rapidly eliminates from the Institute those who from lack of industry or competence demonstrate that they are not fitted to pursue the work of the Institute to the best advantage.

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 the 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, trustee of the Institute and Vice-President of the Board 1908-1915.

NORMAN BRIDGE LABORATORY OF PHYSICS: first unit, 1922; second unit, 1924; third unit, 1925.

The gift of the late Dr. Norman Bridge.

HIGH-POTENTIAL RESEARCH LABORATORY, 1923.

Erected with funds provided by the Southern California Edison Company. Ltd.

CHEMICAL ENGINEERING LABORATORY AND 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.

SEISMOLOGICAL RESEARCH LABORATORY (of the Division of the Geological Sciences), 1928.

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, 1929; second unit, 1938. An annex was erected in 1948.

The gift of the late Mr. William G. Kerckhoff and Mrs. Kerckhoff, of Los Angeles.

EXPERIMENTAL STATION (of the Division of Biology), Arcadia, California. 1929.

PLANT PHYSIOLOGY LABORATORY (of the Division of Biology), 1930.

WILLIAM G. KERCKHOFF MARINE BIOLOGICAL LABORATORY (of the Division of Biology), *Corona del Mar, California*, 1930.

ATHENAEUM, 1930.
The gift of the late Mr. and Mrs. Allan C. Balch, of Los Angeles.
A clubhouse for the use of the Staffs of the California Institute, the Huntington Library, and the Mt. Wilson Observatory; and the California Institute Associates.

STUDENT HOUSES, 1931.
Blacker House.
The gift of the late Mr. and Mrs. R. R. Blacker, of Pasadena.
Dabney House.
The gift of the late Mr. and Mrs. Joseph B. Dabney, of Los Angeles.
Fleming House.
Erected with funds provided by some twenty donors, and named in honor of the late Mr. Arthur H. Fleming, of Pasadena, President of the Board of Trustees of the Institute 1918-1932.
Ricketts House.
The gift of the late Dr. L. D. Ricketts and Mrs. Ricketts, of Pasadena.

CENTRAL SHOP FACILITIES, 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 OF RADIATION, 1932.
The gift of 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.

HYDRAULIC STRUCTURES LABORATORY, 1932.

ASTROPHYSICAL OPTICAL SHOP, 1933.
Erected with funds provided by the International Education Board and the General Education Board. Following the completion of the Palomar Observatory, this building is being converted into a Nuclear Physics Laboratory.

SOIL CONSERVATION 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.

BUILDINGS AND GROUNDS BUILDING, 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.

TEMPORARY BUILDINGS

The Internal Combustion Engine, and Hydraulic Laboratories for undergraduate work in the fields of thermodynamics and hydraulics are housed in a building of temporary construction.

Another such building contains living quarters for graduate students, a restaurant for non-resident students, and a club-room for the Throop Club.

In 1947 the Institute obtained from the government four temporary buildings, one of which provides quarters for the Division of Physical Education and for civil engineering laboratories; a second affords space for studies for graduate students; and a third is used for a chemical engineering shop. The fourth of these buildings constitutes a health center and infirmary.

LIBRARIES

The libraries of the Institute offer students and staff members a comprehensive and well selected collection of books, periodicals, and other printed materials for study and research. The General Library, in the Norman Bridge Laboratory of Physics, contains a general reference collection and also covers the fields of mathematics and of civil, mechanical, and electrical engineering. The Humanities Library, in Dabney Hall of the Humanities, provides materials in literature, history, and the other non-technical fields, and offers additional books for general cultural and recreational reading. The separate libraries for physics, chemistry, biology, geology, aeronautics, and industrial relations provide books and periodicals in their respective fields.

OFF CAMPUS FACILITIES

JET PROPULSION LABORATORY.
Owned and sponsored by the Armed Services and operated by the California Institute.

SOUTHERN CALIFORNIA COOPERATIVE WIND TUNNEL, 1945.
Owned by five cooperating aircraft companies and operated under a management agreement by the Aeronautics department of the Institute.

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

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

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, an optical shop and a machine shop 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 will permit further studies of the size, structure and motion of the galactic system; of the distance, motion, radiation and evolution of the stars; 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 will make possible a systematic 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, nebulae as gravitational lenses, supernovae, and the stellar content of the milky way. These two unique instruments will supplement each other as well as the telescopes on Mount Wilson; the one will reach still further into space in a given direction, while the other will photograph upon a single plate an entire cluster of nebulae in its full geometrical and large scale material content.

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 fields of physics, mathematics, and chemistry. For some time 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 will function as a single scientific organization under the direction of Dr. I. S. Bowen, has been 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 the Mount Wilson Observatory will join with the Institute Faculty.

As a result of this cooperative arrangement unusual opportunities exist at the California Institute for advanced study and research in astronomy and astrophysics. The instructional program is superimposed upon an especially thorough preparation in mathematics, physics and chemistry made possible by the strong work given at the Institute in these fields. It should be remembered, however, that the number of positions open to men trained in astronomy and its related subjects is small. For this reason only those exceptionally well-qualified for such work should undertake graduate study and research.

BIOLOGICAL SCIENCES

The William G. Kerckhoff Laboratories of the Biological Sciences consist of two adjacent units, erected in 1928 and 1938. These provide classrooms and undergraduate laboratories, a lecture room seating 174 persons, and several smaller seminar rooms. The large library is a memorial to Mr. William G. Kerckhoff for his generous gift to the Institute. The major portion of the buildings is devoted to research laboratories and related facilities. Laboratories designed for biological, biochemical and physiological research are available, together with darkrooms, animal rooms, aquarium rooms, an autoclave room, wood-working and machine shops, and a stockroom. A number of coldrooms are provided for the carrying out of operations requiring low temperature and for the storage of perishable materials. In addition, constant temperature workrooms which operate at temperatures at or above room temperature are available. The constant temperature equipment includes rooms for the culturing of the Institute's valuable collection of mutant types of *Drosophila* and *Neurospora.* Other research facilities include a modern microanalytical laboratory equipped for the determination of carbon, hydrogen, and nitrogen, and for various special analyses.

Adjacent to the campus there are the Plant Physiology Laboratories, with several air-conditioned greenhouses, and the newly completed 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. The old and the new research laboratories offer the opportunity to study plants under different synthetic climatic conditions, yet with complete reproducibility of experimental results.

At 870 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.

At Arcadia, about five miles from the campus, is the Institute farm. Equipped with a laboratory and greenhouse, the Arcadia farm is devoted to research in corn genetics.

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 materials for research and teaching. The fauna at Corona del Mar and at Laguna Beach, which is near-by, is exceptionally rich and varied, and is easily accessible.

UNDERGRADUATE AND GRADUATE WORK

At the present time biology is one of the most rapidly expanding fields of modern science. In recent years theoretical and practical advances of the most spectacular kind have been made in our knowledge of living matter. This is especially true of those branches of biology in which it has been found possible to utilize physical, chemical, and mathematical methods in the investigation of biological phenomena. A strong demand for physico-chemical biologists now exists, and qualified men will find excellent opportunities for careers in biology and its applied fields—e.g., medicine and medical research, agriculture, food technology, industrial fermentations, etc.

Because of the pre-eminent position of the California Institute in both the physical and biological sciences, students at the Institute have an unusual opportunity to receive training in modern biology. The undergraduate option is designed to give the student an understanding of the basic facts, theories, and techniques of biology. In building on the foundation in the physical sciences received by all students at the Institute, emphasis is placed on the physicochemical viewpoint in the study of living systems. Through this viewpoint it is possible to unify the traditionally separate fields of zoology and botany and to stress the general and fundamental properties common to plants and animals. The course serves as a basis for graduate study leading to an advanced degree (M.S. or Ph.D.), or for admission to medical school.

Graduate work leading to the Ph.D. degree is chiefly in the following fields: animal biochemistry, plant biochemistry, bio-organic chemistry, animal and plant genetics, chemical genetics, immunology, biophysics, mammalian physiology, comparative physiology, plant physiology, virology, and experimental embryology. 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.

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 which affords new space approximately equal to that of the first two units, is the gift of the late Mr. and Mrs. E. W. Crellin.

These three units include laboratories used for undergraduate instruction in inorganic, analytical, physical, and organic chemistry, and instrumental analysis; they also include class-rooms, demonstration 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, organic, and immunological chemical research, providing space for about one hundred research fellows and advanced students.

With the Gates and Crellin Laboratories is associated the Chemical Engineering Laboratory, which is located in another 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 transfers of matter and energy in systems involving fluids.

The undergraduate instruction is so arranged that in the last two years of the undergraduate course in science there are offered to students an option in chemistry and an option in applied chemistry. These options, especially when followed by the fifth-year courses 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 in charge of the operation and control of manufacturing processes, and, in the case of the fifth- and sixth-year chemical engineering, in positions involving the management and development of chemical industries on the chemical engineering side. 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 more specialized 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 chemical engineering.

First-year chemistry, which is taken by all freshman students of the Institute, puts special emphasis on the fundamental principles of chemistry and their use in systematizing descriptive chemistry. Provision is made for the execution in the laboratory of interesting and fruitful experiments closely coordinated with the lectures and classroom discussions. The laboratory work of the third term is devoted to elementary qualitative analysis.

The second-year work in chemistry consists in the laboratory of gravimetric and volumetric, advanced qualitative, and electrometric analysis; in the class work emphasis is placed on the principles relating to mass-action, the ionic theory, oxidation, and the periodic law. In the second and third terms, and also in the subjects of physical and organic chemistry taken in the later years, the abler students, after a few weeks of introductory work, may undertake minor researches in place of the regular laboratory work.

The chemical subjects of the junior and senior year consist of courses in physical, advanced inorganic, organic, colloid and surface, and applied chemistry. The junior and senior courses in physical chemistry are not descriptive courses of the usual type, but from beginning to end are presented as a series of problems to be solved by the student. Problems are a feature in the subjects of organic and applied chemistry also.

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 page 206.

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 either in chemical engineering or in applied chemistry, 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 chemistry or in mechanical 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, and combustion.

GEOLOGICAL SCIENCES

The Division is housed in the Charles Arms Laboratory and in the Seeley W. Mudd Laboratory, designed especially for instruction and research in the geological sciences. Office space for graduate students is provided in these buildings.

Exceptional opportunities for research in the geological sciences exist at the Institute. An almost unrivaled variety of rock types, geologic structures, and physiographic forms occurs within convenient reach of Pasadena. The relatively mild climate permits field studies throughout practically the entire year, and consequently field training is an unusually important part of the department program. The scant vegetation of much of southeastern California permits study of rock types and delineation of structure to a degree not often available to the geologist.

Stratigraphic and faunal studies may be pursued in the Cenozoic and Mesozoic sedimentary rocks of the Southern Coast Range, and in the Mojave Desert region. Thick sections of Paleozoic sediments in southeastern California remain only partly explored. Structural and physiographic problems in the Coast and Basin Ranges await critical investigation and frequently involve an interpretation of folding and faulting on a large scale. Field trips and research work pertaining to features of arid region geomorphology are carried on in the nearby Mojave and Colorado deserts. Studies of geomorphology and glaciation in various western mountain ranges and investigations of existing glaciers in Alaska constitute an integral part of the current program in geomorphology. The many productive oil fields in southern California afford opportunity to students interested in petroleum geology. Many of the actively worked metallic and nonmetallic deposits of California and Arizona are within reach of week-end field parties. The world famous mineral localities of Crestmore and Pala are within a few hours' driving time from the Institute. Suites of ores, minerals and rocks from these localities are available for study in the Institute's collections, in addition to suites from many other parts of the world.

Collections available from many invertebrate and vertebrate faunal horizons in the sedimentary record of western North America permit the student interested in paleontology to secure an intimate knowledge of the history of life. Attractive field and laboratory problems are presented by the sequence, correlation, and ecologic relationships of western faunas, and their significance in an interpretation of geologic history, and by the structure, relationships and evolution of specific groups of fossil organisms.

A wide range of graduate courses is offered in both theoretical geophysics and in geophysics as applied to prospecting for oil and other mineral substances. The geophysical staff comprises five members, devoting themselves to different phases of the subject. Instruction is given in seismic, gravity, electrical, magnetic and other methods of prospecting. The design and construction of geophysical instruments in the shop of the sesimological laboratory receive attention.

The Seismological Laboratory of the California Institute is located about three miles west of the campus on a granite ridge affording firm bed-rock foundation for the instrument piers. There are now eleven branch stations, built and maintained with the aid of cooperating agencies in Southern California. While devoted mainly to research, the laboratory is open to qualified students registered at the California Institute who desire advanced training in seismology.

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 there are comparatively few teaching or industrial positions open to mathematicians having only a Bachelor's degree, the man who expects to make mathematics his profession must normally plan to continue with graduate work leading to the degree of Doctor of Philosophy either here or elsewhere.

Courses. The undergraduate option described on page 172 contains many electives. Their purpose is to enable the student to adapt his program to his needs and mathematical interests and to give him the opportunity to become familiar with creative mathematics early in his career. These electives may be chosen on consultation with the department either from the current graduate courses in mathematics which are open to undergraduates, or else from predominantly mathematical courses in allied fields such as physics or astronomy. Depending on the demand, elective courses in mathematics in addition to those listed explicitly in the catalogue will be offered.

Requirements. Unless a student has done exceptionally well in his freshman and sophomore years, he should not contemplate specializing in mathematics. Ordinarily, an average of at least "B" in his mathematics courses is expected of a student intending to major in mathematics.

Library facilities. The mathematics department has an excellent 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 a 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 100 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 pp. 143-146; additional requirements for mathematics are found on p. 146. The special prerequisites for the course requirements in the minor subject are listed under the separate departments. In particular those for physics are listed on pp. 251-253. A candidacy course requirement may be passed by examination if the student is sufficiently prepared.

As stated on p. 147, the student must submit his thesis before May first of the year in which his degree is to be granted. In addition, he must be prepared to present the work of his thesis in person to the staff in one of the research seminars before April 15 of the same year.

To be allowed to present himself for the doctoral examination, the candidate must submit a list of topics offered for examination. This list must be approved by the department. It must include the equivalent of a full year's work in each of the fields of the candidacy courses and in addition two more advanced topics.

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 degrees. Students initially planning to take only a Master's degree are accepted only under special circumstances. In the exceptional cases when the complete Ph.D. requirements cannot be met, a Master's degree will be awarded upon completion of all candidacy courses 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 rather elaborate demonstration lecture each week throughout the freshman and sophomore years. All the members of the staff participate in these lectures and almost all give at least one undergraduate course. The entering freshman thus makes some contact in his first year with practically all of the 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, senior and fifth years intensive problem type courses that provide a more than usually thorough preparation for graduate work. However, electives are provided during the third and fourth years that permit those who do not expect to go into graduate work to replace some of the mathematics and problem courses by 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 in the Norman Bridge Laboratory of Physics, and the graduate seminars are open to undergraduates at all times.

GRADUATE WORK

Graduate students should complete as soon as possible the courses required for admission to candidacy for the doctor's degree. (See page 146.) These provide an unusually thorough grounding in the fundamentals of physics, and the student learns to use these principles in the solution of problems of all kinds. In general, also, graduate students should begin research during their first year and continue it through their whole graduate period.

The Norman Bridge Laboratory of Physics is equipped to carry on research in all of the principal fields of physics. Special facilities for research in nuclear physics are also provided in the W. K. Kellogg Laboratory of Radiation. This laboratory is equipped with three electrostatic generators and auxiliary equipment which makes the facilities especially good for precision work in the field of light nuclei. An electron synchrotron is now under contruction as the central equipment for a new laboratory of high energy physics. This accelerator is designed to accelerate electrons to an energy of one billion electron volts. The work in high energy physics will bridge 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 high energy x-rays and gamma rays and the study of beta ray spectra.

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 all graduate students. In addition, there is a weekly theoretical seminar conducted for the benefit of those interested primarily in mathematical physics and several seminars on special fields of work such as x-radiation, nuclear physics, metals, physics of solids, and ultra-short electromagnetic waves.

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.

2. ENGINEERING

UNDERGRADUATE WORK

"The four-year Undergraduate Course in Engineering," as prescribed in the Educational Policies of the Institute, "shall be of a 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. The civil, electrical and mechanical engineering groups are not separated until the third year, all students following the same program of the fundamental subjects—mathematics, physics and chemistry—supplemented by their general applications in surveying, mechanism, mechanics, strength of materials, direct and alternating currents, heat engines and hydraulics. The divergence between the different branches occurs in the third and fourth years, when the study of the professional subjects of specialized nature is introduced. Subjects in the humanities—English, history, and economics—are included in each year of the curriculum.

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, which represents additional professional subjects and work in both design and research. While the work of the fifth year is prescribed to a considerable extent, it offers time and encouragement for the student to 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.

GRADUATE STUDY AND RESEARCH IN ENGINEERING

Graduate study and research opportunities in Engineering are available in the fields of aeronautical, civil, mechanical, electrical, and chemical engineering, with courses quite definitely 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, and Mechanical Engineering 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 in which degrees designated with these options are given. In addition, the Division includes courses of study 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, and Metallurgy. Some of the specialized laboratory facilities available for instruction and research are the various wind tunnnels, the Analysis Laboratory which includes the Analog Computer, the Dynamics Laboratory, the High Voltage Laboratory, and the several facilities for work in Hydraulic Structures and Hydrodynamics.

AERONAUTICS

The graduate School of Aeronautics and 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. Since their inception the department and laboratory have been actively engaged in the fields of Aeronautics and the allied sciences. The following program of instruction at the post-graduate 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 and compressibility.

   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.

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 aerodynamical 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. 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 can be made 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 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 600 persons, of whom about 150 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, including a 20-inch tunnel capable of speeds of 4.8 times the velocity of sound, as well as 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 or who are registered for the JP laboratory course, JP 170.

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 has approximately 15,000 installed horsepower, an 8½ by 12 foot working section, and develops speeds up to the velocity of sound. It can be operated both above and below atmospheric pressure and is used for studying the aerodynamic problems of modern aircraft and guided missiles.

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 older departments of physics, chemistry, and mathematics, emphasis is placed primarily upon the development of graduate study and research; but provision has also been made in the four-year undergraduate course in engineering for work leading to such graduate study and research. This affords a broad and thorough preparation in the basic science and engineering upon which aeronautics rests.

The graduate courses may be taken either by students who have completed a four-year course at the Institute, or by students from other colleges who have had substantially the same preparation. The field of aeronautics is so many-sided that a student who has completed the undergraduate course either in engineering or in applied science will be admitted to the fifth-year course. The sixth-year work, however, may be taken only by students who have completed the fifth-year course at the Institute or who have had substantially the same preparation elsewhere.

Still more advanced study and research are offered for the degree of Doctor of Philosophy. This degree is given under the same general conditions as those that obtain in the other courses offered at the Institute.

CHEMICAL ENGINEERING AND APPLIED CHEMISTRY

(See pp. 89-91)

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 branches of civil engineering in which advanced work is offered include the control, development and conservation and treatment of water; the analysis of structures with particular reference to those types achieving economy through continuity of arrangement; the study of earthquake effects and means of resisting them; investigation of stresses in dams and the design of different types of dams; the study of the increasingly important problems of sanitation, sewage treatment and disposal work; the location, design, construction and operation of railroads and highways; the study of properties and economical utilization of construction materials; and the study of soil mechanics as related to foundations, earth dams, stability of slopes, and other earthwork problems.

In addition to research facilities in the above subjects, special instruction and research facilities are available in the subjects of hydraulic structures, open and closed hydraulic channels, sediment transport, hydraulic machinery, experimental stress analysis, elasticity, and 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.

Students desiring to become research men, college teachers, or professional experts in the highly mathematical and scientific phases of electrical engineering may continue their work for the degree of Doctor of Philosophy; those preparing for work relating to the application, development and manufacture of electrical equipment may continue their work for the degree of Electrical Engineer.

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, two, the High Voltage Research Laboratory and the Analysis Laboratory, are outstanding.

The High Voltage Building and the million-volt power frequency transformer were provided by the Southern California Edison Company. The million-volt transformer, which was designed by Professor R. W. Sorensen, has a normal rating of 1,000 kilovolt amperes but is capable of supplying several times the rated load at the above potential, with one end of the winding grounded. A 2,000,000 volt surge generator which can be conveniently used as two

1,000,000 volt surge generators and a high current surge generator supplemented by cathode-ray oscillographs and other apparatus used in the study of electric surges (artificial lightning) and its effect upon electrical apparatus provides ample facility for the study of high voltage transients.

The *Analysis Laboratory* recently established at the Institute provides means for the development of large scale computer techniques and their application to the solution of the more complex mathematical equations that must be solved in connection with engineering and scientific investigations. At present the main activity of this laboratory is centered around a unique electric analog computer developed by Professor G. D. McCann.

This computer is available not only as an aid to the research of members of the Institute staff but also as an instrument of general service to the engineering staffs of the Southern California industrial area and to the armed forces research groups.

Equipment and laboratories for research work in electronics, radio, and microwaves are available. Research projects now in progress or planned for the immediate future include basic studies of wave guide phenomena, propagation of microwaves through the various meteorological conditions encountered in Southern California, studies of the behavior of electric and electronic equipment at very high altitudes. Facilities for research in dynamo-electric machinery and in servo mechanisms are also available.

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. The fifth year, therefore, is somewhat more specialized, but yet basic in the field of mechanical engineering. A set schedule of subjects is specified for the fifth year covering the more specialized and advanced phases of mechanical engineering.

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 the Mechanical Engineering Department provides facilities 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 catalogue. 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 the 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, heat transfer apparatus, and refrigeration equipment. 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. (See page 100.) 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 a field of 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 technology, to promote research and advanced thinking on rocket and jet propulsion problems, and to be a center for peacetime 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 that in general 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 will have 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 the 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 of the department of Aeronautics and the department of Mechanical Engineering, are available to students working towards advanced degrees. The laboratory work of students in the Jet Propulsion Center is carried on at the off-campus Jet Propulsion Laboratory. Under the present regulations, students who wish to use the facilities of the Jet Propulsion Laboratory must, however, first obtain clearance fom 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, 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.

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 above 70 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 precision instrument shop are part of the laboratory facilities.

HYDRAULIC STRUCTURES LABORATORY. This laboratory is equipped to study problems of open channel flow that ordinarily occur in water and flood control work, and problems of wave action that arise in connection with beach and harbor development. The equipment includes (a) a model basin of about 2400 square feet equipped with a water supply, wave, surge, and tide apparatus required for studying river, harbor, beach, and reservoir spillway problems; (b) a tilting channel platform 100 feet long for studying high velocity flow; (c) a concrete flume for use in weir, spillway, and allied problems requiring a deep basin; (d) a complete laboratory unit with a large model basin 120 feet by 120 feet, located about 12 miles east of Pasadena, together with office space, shops, and auxiliary apparatus such as wave and tide machines, automatic wave recording gauges, special flash lamp and other photographic and electronic apparatus. It was built for the Navy Bureau of Yards and Docks to study the development of Apra Harbor at Guam, and is especially suitable for wave and surge problems.

Soil Conservation 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) the closed circuit suspended load flume with an adjustable gradient, (b) a special flume for the study of rate of reduction of bed load, (c) an outdoor model basin for studying field problems requiring either clear or silt laden flows, and (d) sediment analysis laboratory. Facilities of this installation are also available to qualified graduate students.

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 grounding 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 room for the exhibition of pictures and other works of art, 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.

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 is guided by the Committee of the Industrial Relations Section consisting of Trustees appointed by the Board and faculty members appointed by the President.

Regular senior and graduate students may take an introductory course in industrial relations which is counted as part of the Humanities requirements for seniors and for candidates for the Master's Degree. The Section also has available the Clarence J. Hicks Fellowship in Industrial Relations. (See p. 155.) The Section does not offer a special curriculum in industrial relations at either the undergraduate or graduate level.

For a description of the services offered by the section to industry, labor unions and the general public, see pages 129-130.

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 Athenæum, 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 seventy-five 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. Most of the rooms are single, but there is a limited number of rooms for two. All the rooms 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.

The completion of this group of four residence halls marks the initial step in a plan to meet the housing and living problems of undergraduate students. The plan calls eventually for eight residence halls. Each of the four present houses 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 houses are under the general supervision and control of a member of the Faculty known as the Master of the Student Houses.

By action of the Board of Trustees, all undergraduate students are expected to live in the Student Houses unless permission is given by one of the Deans to live elsewhere. This permission will be given only when there are reasons of emergency or when there are no longer any vacancies in the Houses. Since the demand for rooms may exceed the supply, newly entering students are advised to file room applications immediately upon being notified by the Registrar of admission to the Institute.

Throop Club. The Throop Club is designed to provide for non-resident students the same sort of focus for undergraduate life that the Student Houses provide for resident students. The 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 the 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 football, softball, cross-country, swimming, water polo, skiing, basketball, and handball.

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.

Associated Student Body. The undergraduate students are organized as the "Associated Students of the California Institute of Technology, Incorporated." All students who pay their student body fees 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 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 faculty.

Faculty-Student Relations. Faculty-student coördination and coöperation with regard to campus affairs is secured through periodic joint meetings of the Faculty Committee on Student Relations, and the Board of Directors and the Board of Control of the Student Body. These conferences serve as a clearing house for suggestions as to policy, organization, etc., originating with either students or faculty.

Departmental Advisers. Each member of the three undergraduate upper classes is assigned to a Departmental 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.

Athletics. The California Institute maintains a well-rounded program of athletics and schedules inter-collegiate events with various neighboring institutions.

The California Institute, having acquired the right to purchase a portion of Tournament Park through a recent city election, plans to expand its athletic facilities available to the student. A baseball stadium, championship tennis courts, a football field, and a standard outdoor track are now available, and as time and construction permit, other facilities will be offered.

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 varsity and freshman 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 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. The Musicale is an organization which encourages interest in 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.

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.

Special interests and hobbies are provided for by the Chem Club, the Radio Club, and the Ski Club. The Christian Fellowship Group, Christian Science Group, Episcopal Group, and the Newman Club are organized on the basis of religious interests. The Walrus Club comprises a group interested in the discussion of questions of current national and international importance.

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 solely as a place where qualified students may work on private projects that require machinery.

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.

Forensics. Institute debaters engage in an annual schedule of debates with other Southern California colleges, and take part annually in oratorical and extempore speaking contests. To encourage undergraduate forensics the English department offers a course in debate. During the second and third terms a special debating class for freshmen gives first-year men an opportunity to prepare for freshman debates. A number of intramural practice debates, and the annual oratorical contest for the Conger Peace Prize afford all men interested in public speaking an opportunity to develop their abilities.

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, forums and lectures, student-faculty firesides, inter-collegiate conferences and work with local church groups. It also sponsors an annual freshman tea dance and cooperates in planning the New Student Camp. The "Y" services to the student body include a used textbook exchange, a tutoring service, a loan fund, an all-year calendar of student events and the use of the lounge and offices. The executive secretary of the Y.M.C.A., Wesley L. Hershey, is always available to help students with their personal problems.

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.

PART TWO

Detailed Information for Present and Prospective Undergraduate and Graduate 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.

I. 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) a personal interview. The specific requirements in each of these groups are described below.

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. 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 and high school records including courses that may be in progress must reach the Registrar's Office by February 1, 1951 if the applicant wishes to be sure that his record is satisfactory before he arranges to take the College Board tests. Admission applications may reach the Registrar's Office as late as March 1, 1951 from those who have already arranged to take the tests. The Institute cannot, however, be responsible in the event that an applicant who has paid his fee to the College Board must later be informed that his record is not acceptable.

Applicants living outside the continental limits of the United States must submit their credentials by November 1, 1950.

Records submitted by February 1 will ordinarily show the grades for only the first three years of high school. The applicant should make sure that a supplementary transcript showing the grades for the first semester of the senior year is sent as soon as these grades are available. He should likewise be sure to list in the space provided on the application blank the subjects he 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 and one-half units in Group B.

Group A:	English	3
	Algebra	2
	Plane Geometry	1
	Trigonometry	½
	Physics	1
	Chemistry	1
	United States History and Government	1
Group B:	Foreign Languages, Shop, additional English, Mathematics, Geology, Biology or other Laboratory Science, History, Drawing, Commercial subjects, etc.	5½

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, algebra 1½ units, geometry 1 unit, trigonometry ½ unit, 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, preferably Latin, 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.

Each applicant is expected to show that he has satisfactorily completed the above-stated required preparation, by presenting a complete scholastic record from an approved school. This record must contain a list of courses in progress—if any—at the time the record is submitted.

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, Physics, and either Chemistry or English. Note that while an applicant may choose between the tests in Chemistry and English, no substitution of other tests for those in physics and advanced mathematics can be permitted.

In 1951 these tests may be taken either on Saturday, January 13, or on Saturday, March 10. Most applicants will find themselves better prepared if they wait until the latter date. *It is important to note, however, that no applicant can be considered for admission in 1951 who has not completed the tests by the March 10 date.* 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 9896, Terminal Annex, Los Feliz Station, Los Angeles 27, California:

Arizona	New Mexico	Territory of Hawaii
California	Oregon	Province of Alberta
Colorado	Utah	Province of British Columbia
Idaho	Washington	Republic of Mexico
Montana	Wyoming	Australia
Nevada	Territory of Alaska	Pacific Islands, including 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.

Applicants should be sure to state whether they will take the tests in January or March.

Each examination application submitted for registration must be accompanied by the examination fee of $12 which covers the Scholastic Aptitude Test and three Achievement Tests.

All examination applications and fees should reach the appropriate office of the Board not later than the dates specified below:

	For examination centers located	
Date of Tests	In the United States, Canada, the Canal Zone, Mexico, or the West Indies	Outside the United States, Canada, the Canal Zone, Mexico, or the West Indies
January 13, 1951	December 23, 1950	November 25, 1950
March 10, 1951	February 17, 1951	January 20, 1951

Examination applications received after these closing dates will be subject to a penalty fee of three dollars in addition to the regular fee.

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 the 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 INTERVIEW. A personal interview will, wherever possible, be arranged with each applicant unless the results of the entrance examinations show very definitely that he has not had sufficient preparation. These interviews will be held in the locality in which the applicant lives or is attending school. In some cases, applicants may be asked to travel short distances to a central point. Notices of interview appointments will be sent, and the applicant has no responsibility with regard to the interview until such notice is received.

NOTIFICATION OF ADMISSION. Final selections are ordinarily made and the applicants notified of their admission or rejection by May 20. Upon receipt of a notice of admission an applicant should immediately send in the registration fee of $10.00, which covers the cost of the New Student Camp. (See below.) 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 for more than ten days from the time an applicant could reasonably be expected to have received notice of acceptance. 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.

PHYSICAL EXAMINATION. Prior to 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 124.) Admission is tentative pending such examination, and is subject to cancellation if the results of the examinations 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.

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. The expenses of the camp are met in part by the $10 registration fee from new students and in part by a contribution of funds from the Institute.

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.

II. 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 111-114 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, physics and chemistry, will be classified as freshmen and must be admitted as such. (See freshman admission requirements on pages 111-114.) They may, however, receive credit for the subjects which have been completed in a satisfactory manner.

A minimum residence at the Institute of one scholastic year is required of all candidates for the degree of Bachelor of Science. (See page 122.)

An applicant for admission 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. In addition, he should file an application for admission; the necessary blanks for this will be forwarded from the Registrar's office upon request, but only after transcripts are on file. Transcripts and applications must be on file by April 1. If the applicant is attending another college, a list of subjects in progress, to be completed by June, must accompany the transcript. A supplementary transcript, showing the grades of this work, must be filed as soon as possible after the grades are available.

Before their admission to the upper classes of the Institute all students are required to take entrance examinations in mathematics, physics, chemistry and English composition covering the work for which they desire credit, except that the examination in chemistry is required only of those desiring to pursue the course in science. Students must offer courses, both professional and general, substantially the same as those required in the various years at the Institute (see pages 162-175) or make up their deficiences as soon as possible after admission. In case there is a question regarding either the quality or the extent of the previous work, examinations in the subjects concerned may be arranged.

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 our work. 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 certain topics in differential and integral calculus. It is possible, however, for an able student to cover outside of class, the necessary work in integral calculus and thus prepare himself for the entrance examination and the sophomore course in mathematics.

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 on the basis of their previous record and of the results of the examinations.

Applications will not be considered unless the applicant has had the substantial equivalent of all four of the following courses—mathematics, physics, chemistry and English—given at the California Institute at the first year level for sophomore standing, and at the first and second year levels for junior standing in the option of the applicant's choice.

No fee is charged for the entrance examinations, but only those whose records are good will be permitted to write upon them.

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 three-hour examinations for admission to upper classes September 20, 1951, is as follows:

Mathematics	9:00 a.m.	June 1, 1951
English	1:00 p.m.	June 1, 1951
Physics	9:00 a.m.	June 2, 1951
Chemistry	1:00 p.m.	June 2, 1951

No other examinations for admission to upper classes will be given in 1951.

Applicants who have completed the substantial equivalent of the first three years, and wish to transfer to the senior class at the Institute, take the same examinations as are given to junior transfers. After they have been admitted, further examinations may be required if any doubt exists with regard to their previous preparation in any subject.

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 Registrar from the person directing the tests stating that the required supervision will be given.

The attention of students planning to transfer to junior or senior 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 119-123.) 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 pages 121-122.)

Physical examinations and vaccination are required as in the case of students entering the freshman class. (See page 124.) 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 114.) In the event of subsequent cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute.

REGISTRATION REGULATIONS

Registration Dates		Fees Payable	Instruction Begins
Freshmen and Transfer Students	Sept. 20, 1951	Sept. 20, 1951	Sept. 25, 1951
Upperclassmen and Graduate Students	Sept. 24, 1951	Sept. 24, 1951	Sept. 25, 1951

Fees for Late Registration

Registration is not complete until the student has 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.

Change of Registration

All changes in registration must be reported to the Registrar's Office by the student. A fee of one dollar is assessed for any registration change made after the first week of classes, unless such change is made at the suggestion of an officer of the Institute. Registration changes are governed by the last dates for adding or dropping courses as shown on the Institute calendar.

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 or wilful destruction or waste, and at the close of the year, or upon the severance of their connection with any part of the work of the Institute, 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 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 $10 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 the 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 giving the grade *incomplete* the "inc" must be followed by a letter indicating the grade of work and by a number in parenthesis indicating approximately the percentage of the work completed. When so reported the grade of 'inc" may, in summing grades, be provisionally considered to correspond to such a number of credits as the Registrar shall determine; but if reported without these specifications it shall not be counted. The instructor's reason for giving the grade and the manner by which the incomplete may be removed must be entered in the space provided for that purpose.

It is recommended that the grade incomplete be given only in the case of ickness or other emergency which justifies the non-completion of the work at he usual time.

Conditioned indicates deficiencies other than incomplete that may be made p without actually repeating the subject. A grade of "D" is given when the ork is completed.

An incomplete or a condition in any term's work must be removed during e next term in residence by the date fixed for the removal of conditions and completes. 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 ecommended in writing to the Registrar by the instructor prior to the date r removal of conditions and incompletes.

Failed means that credit may be secured only by repeating the subject, except that in special cases the Registration Committee may, with the instructor's proval, authorize a removal of an "F" by three 3-hour examinations. When grade of "F" is removed either by repeating the work or by three 3-hour aminations, the instructor may award whatever grade he believes the student s earned. The new units, grade and credits appear on the record and are lded to the total to obtain grade-point average. (See page 120.) However, e original grade of "F" also remains on the record, and the original units e likewise included in computing 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 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 or in assembly.

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.)

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 1.30.

(b) If he fails to obtain a grade-point average of at least 1.90 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 average of at least 1.90 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 1.30 each term to be eligible for subsequent registration. (Special note should be made of the graduation requirement described on page 122.)

(c) 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 Registrar 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. A reinstated student who again fails to fulfill the scholastic requirements for registration will be granted a second reinstatement only under very exceptional conditions.

Deficiency. Any freshman, sophomore, or new transfer student who fails to receive at least 72 credits 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.

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 work of that option. (See note at head of each option in schedules of undergraduate

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*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 designators see the following table.

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

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 grade point average of 1.9.

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 Honors and Awards awards *Honor Standing* to fifteen or twenty students in each of the three classes remaining in residence. These awards are based on the scholastic records of the students. Any holder of such an award who in any subsequent term fails to maintain a scholastic standard set by the Committee loses his honor standing for the remainder of the academic year.

Honor Standing entitles the student to such special privileges and opportunities as excuse from some of the more routine work, instruction in "honor sections," and admittance to more advanced subjects and to research work, but a student in Honor Standing may not be admitted to an honor section in a particular subject unless he has obtained a grade of "B" or better in the work prerequisite to that subject.

A student will be *graduated with honor* 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 department and the Committee on Honors and Awards, and approval of the Faculty.

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*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 the Geological Sciences.

Division of Biology.

Division of the Humanities.

Term examinations will be held in all subjects unless the instructor in charge of any subject shall arrange otherwise. No students 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. Applications for registration in excess of the prescribed number of units, or for fewer than 33 units, must be approved by the Registration Committee.

Leave of absence. Leave of absence involving non-registration for one or more terms must be sought by written petition 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.

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.

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 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 training classes.

Men over 24 years of age by the opening date of the academic year may be excused from the requirement of physical education by action of the Physical Education Committee. 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.

HEALTH SERVICE

A. PHYSICAL EXAMINATION AND VACCINATION

All admissions to the California Institute, whether graduate or undergraduate, are conditional until a report of physical examination has been approved by the Director of Student Health. A form on which the report is to be made is mailed to applicants at the time they are notified of acceptance. This form is to be filled out and signed by a licensed Doctor of Medicine (M.D.) of the applicant's own choosing. Payment for this service is the applicant's responsibility. Vaccination against smallpox is required at the time of the examination. Applicants who refuse to be vaccinated will be denied admission.

B. HEALTH FEE

Each undergraduate and graduate student will pay a health fee of sixteen dollars ($16.00) per academic year, $5.00 of which is paid toward the Emergency Hospitalization Fund.

C. EMERGENCY HOSPITALIZATION FUND

The following regulations have been established with respect to the Emergency Hospitalization Fund:

1. The funds derived from the Emergency Hospitalization fee will be deposited at interest in a special account known as the Emergency Hospitalization Fund. The Institute will be the custodian of the fund. Money in this fund shall not be used for any other purpose than for the payment of hospital, surgical and medical expenses, including Institute infirmary charges. Whether a case is one within the scope of the Emergency Hospitalization Fund will be decided by the Director of Student Health.

The Emergency Hospitalization Fund is not applicable to accidents away from the grounds of the Institute, unless these occur in authorized activities of the Institute.

2. In cases falling within the scope of the Emergency Hospitalization Fund, necessary care will be allowed for a period not to exceed one week. Other necessary hospital expenses during this period of one week, such as the use of operating-room, surgical supplies and

dressings, laboratory service, etc., will be allowed. The total allowance for hospital care and other necessary hospital expenses shall not exceed one hundred and twenty-five dollars. Payment of surgical fees, anesthetic fees and necessary special nursing fees will also be allowed whenever possible, provided that the total amount of payments inclusive of hospital care and hospital expenses shall not exceed one hundred and twenty-five dollars. The amount to be contributed from the Fund in any particular case shall be decided by the Faculty Committee on Student Health.

3. The Fund is not available for those students who require, after leaving the hospital, further attention or special equipment. No distinction will be made between injuries incurred in athletics or otherwise, in judging whether the case is an emergency or not, or the extent to which expenses will be paid out of the Fund.

4. Whenever the expenses for emergency care in any one fiscal year are less than the total collected in fees for that year, the balance of money remaining shall be kept in the Emergency Hospitalization Fund, and shall remain deposited at interest to increase for the benefit of the Fund. A balance kept over from one year will be used to render emergency medical and surgical aid to the students in later years. It is hoped that the plan can be liberalized by the building up of the Fund in this manner.

5. The Emergency Hospitalization Fund does not provide for the families of graduate or undergraduate students.

6. Donations to the Emergency Hospitalization Fund will be gratefully received.

7. The Faculty Committee on Student Health supervises, and authorizes, expenditures by the Fund. All questions regarding the administration of this Fund are to be referred to this Committee. The Committee will review the facts of every emergency case, and may, if it feels it desirable, recommend an extension of payments in excess of the maximum amounts prescribed in Section 2 above for specific purposes cited by the Committee.

D. RESPONSIBILITY OF THE PATIENT

The responsibility for securing adequate medical attention in any contingency, whether an emergency or not, is solely that of the patient. This is the case whether the student is residing on or off the campus. Apart from providing the opportunity for free consultation with the Institute Physician at his office on the Institute grounds, during his office hours, and for free service from the registered nurse during her office hours, the Institute bears no responsibility for providing medical attention in case of illness.

Any expenses incurred in securing medical advice and attention in any case are entirely the responsibility of the patient. Six beds are available for cases not requiring extensive Hospital care.

EXPENSES

The following is a list of student expenses at the California Institute of Technology for the academic year 1950-51, together with the dates on which the various fees are due. These charges are subject to change at the discretion of the Institute. In addition to the total amount given, a student must purchase his books and supplies, which will amount to approximately $65 for the year.

Date Due	*Fee*		*Amount*
Upon notification of admission	Registration Fee		$ 10.00[1]
At time contract for Student House reservation is signed or at time of registration for off-campus students	General Deposit		25.00[2]
Sept. 21, 1950: Freshmen and transfer students; Sept. 25, 1950: All others	Tuition, 1st term		200.00
	1st installment of Board and Room		
	21 meals per week		108.22[3]
	15 meals per week		104.10[3]
	First Term Incidental Fees for undergraduates:		
	Associated Student Body Dues	4.50[4]	
	Subscription to California Tech for 1950-51	1.50	
	Health and Hospitalization Fee	16.00[5]	
	Total		22.00
	Locker Rent, 1st Term		1.00[6]
	Packing Fee, 1st Term		1.50[6]
	Student House Dues, 1st Term		4.00
	First Term Incidental Fees for graduates:		
	Health and Hospitalization Fee		16.00[5]
November 6, 1950	2nd installment of Board and Room		
	21 meals per week		114.76[3]
	15 meals per week		111.40[3]
January 2, 1951	Tuition, 2nd Term		200.00
	3rd installment of Board and Room		
	21 meals per week		105.60[3]
	15 meals per week		100.95[3]
	Second Term Incidental Fees for undergraduates:		
	Associated Student Body Dues		5.75[4]
	Locker Rent, 2nd Term		1.00[6]
	Parking Fee, 2nd Term		1.50[6]
	Student House Dues, 2nd Term		4.00
February 12, 1951	4th installment of Board and Room		
	21 meals per week		97.30[3]
	15 meals per week		92.35[3]

March 26, 1951	Tuition, 3rd Term	200.00
	5th installment of Board and Room	
	21 meals per week	89.88[3]
	15 meals per week	86.75[3]
	Third Term Incidental Fees for undergraduates:	
	Associated Student Body Dues	5.75[4]
	Locker Rent, 3rd Term	1.00[6]
	Parking Fee, 3rd Term	1.50[6]
	Student House Dues, 3rd Term	4.00
April 30, 1951	6th installment of Board and Room	
	21 meals per week	110.04[3]
	15 meals per week	104.10[3]

TOTAL FOR ACADEMIC YEAR (less deposits, optional items and Registration Fee)

A. Without Board and Room	Tuition	600.00	
	Health Fee	16.00	
	Student House Dues	17.50	633.50
B. With Board and Room 21-meal plan	As under (A)	633.50	
	Board and Room	625.80	
	Student House Dues	12.00	1271.30
15-meal plan	As under (A)	633.50	
	Board and Room	599.65	
	Student House Dues	12.00	1245.15

Tuition Fees for fewer than normal number of units:

Over 32 units	Full Tuition[7]
32 to 25 units	$150 per term
24 to 10 units	$6 per unit per term
Minimum per term	$60.00

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.[8] No portion of the Health Fee, Student Body Dues, or Subscription to California Tech, is refundable upon withdrawal at any time.

[1]Paid by all freshmen and transfer students (veteran and non-veteran); constitutes fee to cover expense of New Student Camp. Not refundable if admission cancelled by applicant.

[2]$15 required from veterans inasmuch as laboratory breakage is reimbursed under Public Laws 16 and 346.

[3]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 students.

[4]If applicable, 20c Federal Tax on admissions is added to Student Body dues per term. Not chargable under Public Laws 16 or 346.

[5]Required of all students (veteran and non-veteran). However, if student's first registration in any school year occurs at beginning of second or third terms, charges are $10.67 and $5.33, respectively to cover balance of school year.

[6]Optional.

[7]Although the Institute charges full tuition for over 32 units, the Veterans Administration allows the following subsistence percentages: 25% for 10 through 17 units per term; 50% for 18 through 26; 75% for 27 through 35; and 100% for 36 and over. See footnote page 161.

[8]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.

EMERGENCY HOSPITALIZATION FEE

The emergency hospitalization fee, payable by each student at the beginning of each year, provides a certain amount of hospitalization and medical and surgical care in accordance with regulations prescribed by the Board of Trustees and administered by the Institute Physician and the Faculty Committee on Student Health (see pages 124-125).

ASSOCIATED STUDENT BODY FEE

The Associated Student Body Fee of $16.00 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 each year, is collected from every undergraduate.

TELEPHONE FEE

Those living in the Student Houses will be charged a fee of $1.50 per term to cover cost of House telephones.

GENERAL DEPOSIT

Each student is required to make a general deposit of $25, to cover possible loss and/or damage of Institute property used in connection with his work in regular courses of study. 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 118) is $10 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 by the date of graduation will be refused graduation.

THE INDUSTRIAL RELATIONS SECTION*

The Industrial Relations Section has developed a five-fold program of activities and services for companies, unions, associations, and individuals: (1) a reference library of books, pamphlets, magazines, and other materials related to industrial relations, including a complete index to all provisions of many union contracts; (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 the other activities.

The specific services of the Section are listed below and may be secured by the payment of the specified fees. Further information may be secured directly from the Industrial Relations Section.

SCHEDULE OF FEES AND SERVICES

REGULAR FEE—$100 A YEAR

Any company, union, association, or individual may, on payment of the general fee of $100 a year, become a Subscriber to the Section and receive the following privileges:

1. Discussion of special individual problems with members of the staff. Such discussions are not of a consulting nature because the members of the staff cannot undertake to install any part of a personnel program nor engage in arbitration.

2. Use of Industrial Relations Library and reference facilities.

3. Use of union contract index.

4. Borrowing of duplicate copies of reference materials from the Industrial Relations Library.

5. Waiving of Tuition fee for one representative in one series of evening meetings or a credit of $30 for one special summer conference arranged by the Industrial Relations Section.

6. Priority in admission to all events sponsored by the Section.

7. Two copies of each publication issued by the Section during the year, mailed to same or different addresses.

Note: Any company, union, or association may purchase multiple subscriptions and receive multiple privileges. Various departments, branches, or plants may thus have ready access to the services of the Section and may send their own representatives to conferences, evening meetings, and other activities of the Section.

RESEARCH FEE—$1,000 A YEAR

Any company, union, association, or individual may, on payment of the research fee of $1,000 a year, become a Sponsor of the Section and receive the following privileges:

1. The equivalent of five subscriptions to the Section as outlined above under Regular fee.

2. Two special half-day conferences will be scheduled each year at a time and place mutually convenient to the Section and the Sponsor. Such conferences will be open only to the representatives of a specific Sponsor and will be focused on significant problems selected by that Sponsor. At such conferences, the Section will bring to the representatives of the Sponsor significant findings of research which may help in the solution of some of the personnel and industrial relations problems of the Sponsor.

SPECIAL FEE—OUTSIDE OF CALIFORNIA—$10 A YEAR

Individuals, associations, unions, companies, or their branches, may, if located outside of California, pay a fee of $10 a year and receive the following limited privileges:

1. One copy of each publication issued by the Section during the year.

2. Borrowing of duplicate copies of reference materials from the Industrial Relations Library, by mail.

TUITION FEES FOR SPECIAL EVENING MEETINGS AND SUMMER CONFERENCES

These fees will be determined from time to time by the Section, taking into consideration the length of each series of meetings or conferences. For each regular fee of $100 paid during any year, the tuition in one series of evening meetings will be waived, or a credit of $30 for one special summer conference will be granted, to one representative of the Subscriber. The cost of books, meals, rooms, and other expenses arising from the meetings or conferences will be charged in addition to the tuition fee.

SCHOLARSHIPS, STUDENT AID, AND PRIZES*

FRESHMAN SCHOLARSHIPS

A number of freshman scholarships covering all tuition or part tuition are awarded each year to members of the incoming freshman class. A few scholarships in excess of tuition, notably the J. N. Kelman Scholarships listed below, are awarded to outstanding applicants. The recipients of scholarships are selected by the Committee on Honors and Awards from the candidates who have stood sufficiently high on the entrance examinations and have otherwise satisfied the entrance requirements of the Institute.

The scholarships 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. Applications for scholarships should be made on a form which may be obtained by writing to the Registrar or calling at the office. Scholarship forms should be submitted at the same time as is the entrance application. Funds for these scholarships are provided in large part by the income from the various scholarship funds described below and by other gifts for scholarships.

Recipients of these scholarships are expected to maintain a reasonably good 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, the recipient in any other way has failed to justify the confidence placed in him, the Committee on Honors and Awards may cancel the scholarship for the balance of the academic year.

UPPER CLASS SCHOLARSHIPS

Sophomores, Juniors, and Seniors are considered for scholarships if need is demonstrated and if they have attained a certain academic rank—usually the top quarter of their respective classes—which is set each year by the Committee on Honors and Awards. The rank is determined in the light of the probable demand and of the funds available. Scholarships are for full tuition or part tuition. Students who are academically qualified to make application will be notified and may obtain an application form from the Registrar's Office. The completed forms must be submitted during the first week of the fall term.

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.

Funds for these scholarships, as well as for Freshman Scholarships, are provided in large part from the special scholarship funds named below.

*For further information on Graduate Scholarships and Fellowships see page 154.

NAMED SCHOLARSHIPS

The following named scholarships are available to either freshmen or upperclassmen with the exception of the Seeley W. Mudd Scholarship which is awarded to juniors and seniors only.

Meridan Hunt Bennett Scholarships and Fellowships: Mrs. Russell M. Bennett of Minneapolis, in January, 1946, made a gift of approximately $50,000 to the Institute to constitute the Meridan Hunt Bennett Fund, as a memorial to her son, Meridan Hunt Bennett, a former student at the Institute. The income of this fund is to be used to maintain scholarships and fellowships which shall be awarded to undergraduate and graduate students of the Institute, the holders of such scholarships and fellowships to be known as Meridan Hunt Bennett Scholars, in the case of undergraduates, and Meridan Hunt Bennett Fellows, in the case of graduates.

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.

Blumenthal Scholarship in Physics: Mr. and Mrs. H. A. Blumenthal of Los Angeles, have recently made provision for a scholarship in Physics in memory of their son, William David Blumenthal, a member of the class of 1942, who served as a member of the armed forces and lost his life in the European Theater of Operations. Preference in the awarding of this scholarship is to be given to a deserving applicant from the Los Angeles High School.

Dabney Scholarships: Mrs. Joseph B. Dabney has made provision for an annual scholarship or scholarships to be awarded at the discretion of the Institute to some member or members of the undergraduate student body. The recipients are designated Dabney Scholars.

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.

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.

Kelman Scholarships: Mr. J. N. Kelman of Los Angeles has made possible the award, for the academic year 1950-51, of several scholarships of one thousand dollars each for entering freshmen. Recipients of these scholarships can expect to receive this amount each year for four years provided that their conduct and grades continue to be satisfactory.

Amie S. Kennedy Scholarship: Mrs. Amie S. Kennedy of Los Angeles, in December, 1945, made possible a scholarship for a worthy student, or for two or more students, as the Institute may determine.

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 selected by the Faculty Committee On Honors and Awards.

Seeley W. Mudd Scholarship: Mr. Seeley G. Mudd has established at the Institute a tuition scholarship of $600 a year available on a competitive basis to all third and fourth year undergraduates in the Biology Option who plan to enter medical school or to work toward a Ph.D. degree in a field of biological science related to medicine. This scholarship will be awarded on the basis of: (1) the scholastic achievements of candidates during their first two years at the Institute (2) reports and recommendations of faculty members under whom the candidates have studied and (3) a competitive examination given by the Division of Biology (on May 19, 1951). Applications for the academic year 1951-52 should be submitted by May 14, 1951 to the Chairman, Division of Biology.

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.

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

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.

STUDENT AID

LOAN FUNDS

The Institute has the following loan funds, from the income, and in certain cases the principal, of which it makes loans to students for the purpose of aiding them to pursue their education:

The Olive Cleveland Loan Fund—established by Miss Olive Cleveland.

The Howard R. Hughes Loan Fund—established by the gift of Mr. Howard R. Hughes.

The Raphael Herman Loan Fund—established by the gift of Mrs. Raphael Herman.

The Noble Loan and Scholarship Fund—given by Mr. and Mrs. Arthur Noble of Pasadena.

The Thomas Jackson Memorial Loan Fund—established in 1932 by Mr. and Mrs. Willard C. Jackson in memory of their son Thomas Jackson, a member of the sophomore class of that year who died during the fall, at the beginning of a very promising career.

The Roy W. Gray Fund.

The James R. Page Loan Fund.

The David Joseph Macpherson Fund, given by Miss Margaret V. Macpherson in memory of her father, David J. Macpherson.

The John McMorris Loan Fund—established by the gift of an anonymous donor as a memorial to John McMorris, a graduate of the Institute and a member of the Institute Staff, who lost his life while engaged in defense research work conducted by the Institute for the Armed Forces.

The Scholarship and Loan Fund which has been constituted by gifts from a number of donors.

The Albert H. Stone Education Fund in Los Angeles has made available to the Institute from time to time funds for loans to students of the Institute.

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, in cooperation with the Alumni Association, maintains a Placement Office, under the direction of a member of the Faculty. With the services of a full-time secretary, this office assists graduates and undergraduates to find employment. 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. Graduates who are unemployed or desire improvement in their positions should register at the Placement Office.

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 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 a 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 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 MARY A. EARL MCKINNEY PRIZE IN ENGLISH

The Mary A. Earl McKinney Prize in English was established in 1946 by 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 department of 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.

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 men students of superior ability*, and application should be made as early as possible. 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 need not make separate application for admission to graduate standing. (See page 154.) For requirements in regard to physical examination, see page 124.

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 the student 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 139, 140, 144 for special requirements for residence.

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 fulfilment of the residence requirements, the student must file a registration card for such summer work in the office of the Registrar. Students who are registered for summer research will not in general be required to pay tuition therefor.

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. Registration is required for the term in which a degree is conferred, unless all requirements for the degree, including approval of the thesis, have been met earlier.

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 $600 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. 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 $150 a term for 32 to 25 units, and at the rate of $6 a unit for fewer than 25 units, with a minimum of $60 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.

There is a fee of $16.00 per academic year to assist in defraying expenses for medical care and emergency hospitalization. (See page 124.) 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 pages 154-156 of this catalogue. In addition, to students with 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 176-186) 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 representatives of the department 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 in biology, chemistry, chemical engineering, geology, geophysics, mathematics, paleontology, or physics), or of the Committee on the Course in Engineering (in case the work is to be in civil, mechanical or electrical engineering, or 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 and recommendation 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 (together with his previous record if he tranfers from another institution), 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 page 118 of the catalogue 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 Registration Committee.

5. In the case of a student registered for the degree of Master of Science and holding a position as 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 120) also apply to students working toward the master's degree. In meeting the graduation requirements as stated on page 122, 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. 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 catalogue.

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 page 120.

4. Candidates for the degree of Master of Science who have completed their undergraduate work at other institutions are subject to the scholastic regulations applying to new transfers students as listed on pages 121-122.

5. Candidates for the master's degree in the Division of the Geological Sciences should familiarize themselves with, and are expected to meet, certain special requirements: foreign language, basic sciences, field geology, thesis. Detailed information 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 178-179.

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. In the Department of Mathematics, a complete first draft of a thesis presented in partial fulfilment of the requirements for the degree of Master of Science must be submitted to the supervising instructor not later than six weeks before the date on which 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 143. Regulations governing registration will be found on page 142.

2. *Residence.* At least six terms of graduate residence (as defined on pages 136, 137) 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.

Work for which a grade lower than C is received will not be accepted toward the final three terms of graduate residence for an engineer's degree. Work upon research and the preparation of a thesis must constitute in no case fewer than 45 units, and in most cases at least 70 units.

In the case of a student registered for work toward an Engineer's degree, and holding a position as 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.

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 his 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 catalogue.

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 can probably 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 two copies 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 145.)

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 Electrical Engineer

To be recommended for the degree of Electrical Engineer the applicant must pass with a grade of C or better (with the exception of Ph 131) the same subject requirements as listed for the doctor's degree on page 149.

Special Requirements for the Degree of Mechanical Engineer

Each candidate shall be required to take an oral placement examination given by the department before his registration. The results will be used as a guide in planning the student's work.

The candidate must take on the average at least 48 units of advanced work per term for two years subsequent to the bachelor's degree. Not less than a total of 45 units and in most cases at least 70 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:

ME 125 abc	Engineering Laboratory
and one of the following:	
EE 226 abc	Engineering Mathematical Physics
Ph 102 abc	Introduction to Mathematical Physics and Differential Equations
AM 257 abc	Engineering Mathematical Principles
Ma 114 abc	Mathematical Analysis

A list of possible courses from which a program of study may be organized will be found on page 185.

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 French and German*.

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 THE 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 degree first. The master's degree, however, is not a general prerequisite for the doctor's degree. Students who have received the master's degree and wish to pursue further studies leading towards the doctor's degree must file a new application for admission to graduate standing to work toward that degree.

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.

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*With the permission of the Department concerned and the Dean of Graduate Studies, another modern language may be substituted for French.

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. 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. When admitted for work leading to the doctor's degree, Graduate Assistants with duties in either teaching or research will be allowed to register for not more than 45 units.

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 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. In addition to these grades, which are to be interpreted as having the same significance as for undergraduate courses, (See page 119) the grade "P", which denotes passed, may be used at the discretion of the instructor, in the case of seminar, research, or other work which does not lend itself to more specific grading.

V. GENERAL REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

1. *Major and Minor Subjects:* The work for the doctor's degree must consist of scientific research and advanced studies in some branch of science or engineering, which will be termed the "major subject" of the candidate. In addition, as "minor subject" (or subjects), studies which will give a fundamental knowledge and research point of view must be pursued in at least one other branch of science or engineering.

The choice and scope of the minor subject must be approved by the departments in charge both of the major and of minor subjects, and must involve not less than 45 units of advanced study in each minor subject. Such advanced study must consist of subjects which are listed as graduate subjects.

Advanced studies include courses with numbers of 100 or over. However, no graduate residence credit is 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 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 five years of graduate residence, or more than 18 terms of full- or part-time academic work, except by special action of the Committee on Graduate Study.

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 fulfilment of the residence requirements, the student must comply with the above regulations and file in advance a registration card for such summer work in the office of the Registrar. Students who are registered for summer research will not in general be required to pay tuition therefor.

A graduate student who, by special arrangement, is permitted to conduct a portion of his research in the field, in government laboratories, or elsewhere off the campus, must file a registration card for this work in the office of the Registrar, in order that it may count in fulfilment of residence requirements. 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 Business Manager.

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:* Any student admitted to work for the doctor's degree who has been in residence one term* or more, who has satisfied the several departments concerned by written or oral examination or otherwise that he has a comprehensive grasp of his major and minor subjects as well as of subjects fundamental to them, who has satisfied the department of modern languages that he can read with reasonable facility scientific literature in German and one other approved language (see page 142), who has shown ability in carrying on research and whose research subject has been approved by the Chairman of the Division concerned, and whose program of study has been approved by both his major and minor departments may, on recommendation of the Chairman of the Division in which he is working, be admitted by the Committee on Graduate Study to candidacy for the degree of Doctor of Philosophy. Members of the permanent Institute staff of rank higher than that of Assistant Professor are not admitted to candidacy for a higher degree. For special departmental regulations concerning admission to candidacy, see Section VI.

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

*One year's residence required prior to application for admission to candidacy in the Division of the Geological Sciences. See Section VI D.

which the degree is to be conferred, and must be followed by two terms of further residence (45 units per term; see pp. 136, 137) 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 examinations, prerequisite to admission to candidacy for the degree of Doctor of Philosophy, will be given three times in the year, these times to be announced by the Registrar's Office. In place of these examinations, students may take the advanced undergraduate examinations offered at the end of each term. Students who have credit for courses in languages taken at the Institute and who have a grade above average may be exempted from further requirements after consultation with the language department.

Graduate students are permitted to audit all courses in the department of languages. In general, however, it is desirable for students without previous study in required languages to take these subjects in class for at least the first term rather than to depend upon studying them by themselves. Students are advised to take examinations as long as possible before they expect to file application for candidacy, so that, if their preparation is inadequate, they may enroll in one of the language courses. No graduate credit is given for language courses.

(b) Final examinations in their major and minor subjects are required of all candidates for the doctor's degree. 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 or oral, or both, and may be divided 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.

5. *Thesis:* Two weeks before the degree is to be conferred, the candidate is required to submit to the Dean of Graduate Studies two copies 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 141.

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.*

6. *Grades on Degree:* The doctor's degree is awarded with the designations *"summa cum laude," "magna cum laude," "cum laude,"* or without designation, in aeronautics, in physics, and in civil, electrical, and mechanical engineering. It is awarded without designation in the biological sciences, chemistry, chemical engineering, the geological sciences, and mathematics.

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 143), the various divisions and departments of the Institute have adopted the following supplementary regulations.

A. DIVISION OF PHYSICS, ASTRONOMY, AND MATHEMATICS

1a. *Physics.* To be recommended for candidacy for the doctor's degree in physics the applicant must pass the following subjects with a grade C or better:

Ph 131 abc	Electricity and Magnetism
Ph 133 abc	Analytical Mechanics
Ph 135 ab	Optics
Ph 137	Spectroscopy
Ph 139 abc	Nuclear Physics

1b. *Astronomy.* To be recommended for candidacy for the doctor's degree in astronomy the applicant must pass 130 units of the following subjects with a grade of C or better:

Ay 131 abc	Astroyphysics I
and/or	
Ay 132 abc	Astrophysics II
with the balance from:	
Ph 130 abc	Methods of Mathematical Physics
Ph 133 abc	Analytical Mechanics
Ph 135 ab	Optics
Ph 137	Spectroscopy
Ph 139 abc	Nuclear Physics
Ph 143 abc	Principles of Quantum Mechanics

1c. *Mathematics.* To be recommended for candidacy for the doctor's degree in mathematics the applicant must pass with a grade of C or better, at least 27 units of his minor subject and the following courses:

Ma 101 ab	Modern Algebra
Ma 114 ab	Mathematical Analysis
Ma 256 ab	Modern Differential Geometry
Ma 102 ab	Introduction to Higher Geometry

The courses in his minor subject must be approved by the department. The attention of graduate students in Mathematics is called to the fact that Geometry courses are given generally only in alternate years.

2. 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. These so-called candidacy examinations will be

given early in the first term of each academic year and the student must apply for permission to take them before the end of the second week of the term. Such application must be in writing and, if approved, will be regarded as one of the two permitted trials, whether or not the student actually takes the examination. (Note: The above regulations are not to be interpreted as preventing the student, with the permission of the instructor in charge, from satisfying the candidacy requirements by taking the examinations in a course without actual class attendance.)

No course which has been taken more than twice will be counted towards the fulfilment of the above candidacy requirements, nor will the student be permitted a total of more than three trials at the removal of any part of the candidacy requirements. A trial consists in registration for the course and class attendance for a sufficient period to appear in the instructor's records regardless of subsequent withdrawal.

Students are advised to satisfy the conditions for admission to candidacy in their respective departments as rapidly as possible.

Students registered for the Ph.D. degree who fail to meet at least two-thirds of the candidacy requirements by the end of their first academic year of graduate study will not be allowed to register for further work without special permission from the department.

3. In general a student will find it necessary to continue his graduate study and research for two years after admission to candidacy, and the final doctoral examination will be based upon this work rather than upon the candidacy courses.

4. Candidates for the degree of Doctor of Philosophy with a major in physics or mathematics must take the final examination some time before the beginning of the term in which they expect the degree to be conferred.

5. A candidate for the degree of Doctor of Philosophy with a major in mathematics must be ready to present the results of his thesis in one of the seminars by April 15. He must deliver a typewritten or printed copy of his completed thesis, in final form, to the professor in charge on or before May 1 of the year in which the degree is to be conferred.*

B. DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

1a. *Chemistry*. During the week preceding 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.

*It is requested that he deposit in the Graduate Office an additional copy of his thesis in final form, for transmission to the Library of the American Mathematical Society.

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 undergaduate 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 present a written research 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.

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 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 the same as those in chemistry except that the placement examinations will be required in the fields of physical chemistry, either inorganic or organic chemistry, engineering thermodynamics of one-component systems, and the unit operations of chemical engineering.

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 cases where 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 45 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 23 units to consist of appropriate research.

4. The candidate must submit to the Division of Chemistry and Chemical Engineering two copies of his thesis, in final form, at least two weeks before the date of his final examination. These 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 subject.

The propositions should be about ten in number, of which about four should relate to the minor subject 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 subject, 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 fields. 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.

Two copies of the set of propositions in final form must be submitted to the Division of Chemistry and Chemical Engineering at least two weeks before the date set for the examination. A copy of the set of propositions must be submitted to the Dean of Graduate Studies as a part of each of the two copies of the thesis.

C. 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 elected 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 C or better:

Ph 131 abc	Electricity and Magnetism
EE 120 abc	Advanced Electric Power System Analysis
EE 121 abc	Alternating Current Laboratory
EE 158 abc	Circuit Analysis.

and one of the following subjects:

Ph 102 abc	Introduction to Mathematical Physics and Differential Equations
AM 115 abc	Engineering Mathematics
Ma 108 abc	Advanced Calculus

Before completing the requirements for the doctorate in electrical engineering the applicant must pass with a grade of C or better:

EE 226 abc	Engineering Mathematical Physics

The final examination will be designed to test the candiate's knowledge of the fields of engineering, mathematics, and science relating to his program of graduate study.

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.* To be recommended for candidacy for the doctor's degree in mechanical engineering, the applicant must pass the following subjects with a grade of C or better:

ME 125 abc	Engineering Laboratory

and one of the following:

EE 226 abc	Engineering Mathematical Physics
Ph 102 abc	Introduction to Mathematical Physics and Differential Equations
AM 257 abc	Engineering Mathematical Principles
Ma 114 abc	Mathematical Analysis

and, in addition, not fewer than 50 units of advanced courses arranged by the student in conference with his department advisor 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.

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 15 units of research in his chosen field. Thus, upon completion of his 5th year's work, he will be admitted to work towards the engineer's degree and, at the end of the first term of the 6th year he should apply for permission to work towards the doctorate in aeronautics. If his course work and research show that he is capable of carrying on work at the doctorate level he will then be admitted to work towards the doctor's degree. In general, notification of the department's action will be given to the applicant by the middle of the second term. Upon being admitted to work towards the doctor's degree, he is expected to withdraw any request for the engineer's degree and to proceed directly to the doctorate.

To be recommended for candidacy for the doctor's degree in aeronautics the applicant must pass the following subjects with a grade of C or better:

	AM 257 abc	Engineering Mathematical Principles
or		
	Ma 114 abc	Mathematical Analysis
or		
	Ph 102 abc	Introduction to Mathematical Physics and Differential Equations

and two of the following subjects:

AE 252 abc	Airplane Design	
AE 261 abc	Hydrodynamics of Compressible Fluids	
AE 266 abc	Theoretical Aerodynamics of Real and Perfect Fluids	
(JP 121	Rocket)	considered as one subject.
(JP 130 ab	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.

D. DIVISION OF THE GEOLOGICAL SCIENCES

1. A student cannot become eligible for admission to candidacy for the doctorate in the Division of the Geological Sciences until after completion at the Institute of 3 terms of graduate residence. The applicant will be given a qualifying examination before admission to candidacy.

2. Doctorate research may be initiated prior to admission to candidacy provided Division approval is obtained.

3. The Division will accept as major subjects any of those subjects listed under the following groups, providing the number of students working under the staff member in charge of the field does not exceed the limit of efficient supervision:

GROUP I—GEOLOGY	GROUP II—PALEONTOLOGY	GROUP III—GEOPHYSICS AND GEOCHEMISTRY
Engineering Geology	Invertebrate Paleontology	Applied Geophysics
Geomorphology	Micropaleontology	General Geophysics
Glaciology	Stratigraphy	Geochemistry
Mineralogy	Vertebrate Paleontology	Seismology
Ore deposits		
Petroleum Geology		
Petrology		
Structural Geology		

The candidate must also undertake research in a minor subject, which in general must be given in another Division of the Institute or in one of the above groups different from that of the major subject. Requests for approval of major and minor subjects in the same group will be considered by the Division but will be approved only if it can be shown that they are widely separated in subject matter and in methods of study. Applications for approval of minor subjects in other Divisions must be approved by the Division of the Geological Sciences and by the Division concerned. A minor subject in the Division of the Geological Sciences shall consist of a minimum of 45 units at the graduate level, comprising courses, research, and a thesis.

4. Although the requirements for the degree of Doctor of Philosophy may in exceptional cases be fulfilled in three years of graduate work, a total of four years will normally be needed.

5. Special training in California geology and in field technique will be required, and the amount will be determined in each case by review of the candidate's record and experience. All candidates will take the Spring Field Trip. Ge 122, every year they are in residence. All candidates from other institutions will attend the Summer Field Geology Camp, Ge 123, at least once during their period of residence.

6. The candidate must prepare a paper for publication embodying the results of his major or minor thesis work in whole or in part. Approval of the Division on the choice of subject (particularly as between major and minor) and on the scope of the paper must be obtained prior to preparation. This paper must either be accepted by an agency of publication or be in form

such that the examining committee believes that it will be published. This paper, the major thesis, and the minor thesis must be completed and in final form for submission to the Division Secretary by April 20.

E. 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). 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. Students admitted on the basis of preparation in chemistry or physics will be required to make up deficiencies in biological training early in the course of graduate study.

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. *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 consist at present of:—

Animal Physiology	Biophysics	Immunology
Biochemistry	Embryology	Invertebrate Zoology
Bio-organic Chemistry	Genetics	Plant Physiology

4. *Minor Subjects.* A student majoring in one of these fields may select a minor either (a) in another field of biology which in the opinion of his Advisory Committee is not too closely related to his major study, or (b) in another Division of the Institute. In general the minor subject should make use of material and techniques different from those of the major field.

A student majoring in another Division of the Institute may, with the approval of the Division of Biology, select as a minor subject any one of those listed in paragraph 3, or he may select a minor in General Biology, which will consist of at least 45 units of approved course work.

5. *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 both major and minor studies in the Division of Biology is required to take four candidacy examinations including one in either general botany or general zoology, one in the field of the major, one in the field of the minor, and one in one other of the subjects listed above in section 3.

b. A student taking a major subject in the Division of Biology and having a minor subject in another Division is required to take three candidacy examinations including one in either general botany or general zoology, one in the field of his major subject, and one other.

c. A student majoring in another Division 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 the field of his minor.

d. A student taking the General Biology minor is required to take the candidacy examination in either general botany or general zoology. Before being recommended for admission to candidacy he should have passed at least half of his minor courses satisfactorily.

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.

6. *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. Three copies of the candidate's thesis, one of which will be retained by the Division, must be submitted at least two weeks before the date of the final examination. 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.

F. OPPORTUNITIES FOR GRADUATE AND SCIENTIFIC WORK AT THE INSTITUTE

I. 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 or stipends.

Provision is made so that appointees may secure for themselves board in the Athenaeum (see page 85), and when space is available lodging as well. This 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 from any university or college who have completed their undergraduate work satisfactorily (see page 136) are eligible to apply for graduate assistantships, scholarships, and fellowships. In the award of such appointments preferred consideration will be given to students who have been accepted as candidates for the degree of Doctor of Philosophy.

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.

(A). 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. Of the remaining time at least one-half must be devoted to research, unless otherwise arranged by the division or department concerned; and the obligation to prosecute the research earnestly is regarded as no less binding than that of showing proper interest in the teaching and in the advanced study, which is also pursued so far as time permits. The usual assistantship assignment calls for twelve hours per week and permits the holder to carry a full graduate residence schedule as well.

(B). Graduate Scholarships and Fellowships

1. Institute Scholarships: The Institute offers a number of tuition scholarships to graduate students of exceptional ability who wish to pursue advanced study and research.

2. Cole Scholarships: 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 scholarships annually, one in each of the following fields: electrical engineering, mechanical engineering, and physics. The recipients are designated as Cole Scholars.

3. Drake Fellowships and Scholarships: The income from the Drake Fund, provided by the late Mr. and Mrs. Alexander M. Drake, is used to maintain fellowships and scholarships in such numbers and amounts as the Board of Trustees determines. Graduate students who are recipients from this fund are designated as Drake Fellows or Scholars.

4. Blacker Fellowships and 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 Fellows or Scholars.

5. Henry Laws Fellowships: The income from a fund given by the late Mr. Henry Laws is used to provide fellowships for research in pure science, preferably in physics, chemistry, and mathematics. The recipients are designated as Henry Laws Fellows.

6. Caroline W. Dobbins Fellowships and Scholarships: The income from the Caroline W. Dobbins Fellowships and Scholarships Fund, provided by the late Mrs. Caroline W. Dobbins, is used to maintain fellowships and scholarships at the Institute. Graduate student recipients are designated as Caroline W. Dobbins Fellows or Scholars.

7. Meriden Hunt Bennett Fellowships: These fellowships for graduate students are granted from the Meriden Hunt Bennett Fund as stated on page 131.

8. 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.

9. Frederick Roeser Scholarship: This scholarship is granted from the Frederick Roeser Loan, Scholarship and Research Fund. The recipient is designated as the Roeser Scholar.

10. David Lindley Murray Scholarships: The income from the David Lindley Murray Educational Fund is used in part to provide scholarships for graduate students. The recipients are designated as Murray Scholars.

11. 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 in engineering who undertakes some studies in industrial relations.

12. Sigma Xi Fellowships: The California Institute of Technology Chapter of the Society of the Sigma Xi has contributed funds for the support of several fellowships to assist graduate students during their last year of work toward the doctorate.

(C). Special Fellowship and Research Funds

1. A considerable group of governmental units, industrial organizations, and private individuals have contributed funds for the support of Fellows and Assistants engaged in fundamental researches related to their interests and activities. These include Abbot Laboratories, Allied Chemical and Dye Corporation, American Cancer Society, American Petroleum Institute, James G. Boswell Foundation, California Research Corporation, California Ship Building Corporation, Carbide and Carbon Chemicals Corporation, Lucy Mason Clark, Climax Molybdenum Company, Consolidated Vultee Aircraft Corporation, Department of Water and Power of City of Los Angeles, Douglas Aircraft Company, E. I. de Pont de Nemours and Company, Ethyl Corporation, Peter E. Fluor, Herman Frasch Foundation, General Petroleum Corporation, Howard Hughes, John B. Keating, Kelman Electric and Manufacturing Company, Eli Lilly and Company, John and Mary L. Markel Foundation, McCallum Foundation, Merck and Company, Charles E. Merrill, Molybdenum Corporation of America, National Advisory Committee for Aeronautics, Nutrition Foundation, Inc., O'Keefe and Merritt Company, Phi Beta Kappa Alumni Association Fellowship Fund, Pioneer Hi-Bred Corn Company, Purdue University Corn Research Fund, Research Corporation, Shell Fellowship Committee, A. O. Smith Corporation, Socony-Vacuum Oil Company, Southern California Edison Company, Standard Oil Company of California, Stanolind Oil and Gas Company, State of California, Elbridge and Mary Stuart Foundation, Sugar Research Foundation, Times-Mirror Company, United States Army (Army Air Forces, Engineer Corps, Ordnance Department), United States Navy (Bureau of Yards and Docks, Bureau of Ordnance, Office of Naval Research), United States Public Health Service, United States Rubber Company, Westinghouse Educational Foundation.

2. 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.

3. The National Foundation for Infantile Paralysis Fund: This fund, contributed by the National Foundation for Infantile Paralysis, is for support of studies of fundamental molecular biology, including the physical, chemical, and biological properties of proteins, nucleic acids, and nucleo-proteins and the relation of these substances to self-duplicating bodies, such as genes and viruses, including the poliomyelitis virus. The work is being carried on in the Division of Biology and in the Division of Chemistry and Chemical Engineering.

4. 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. Each year there will be a total of six Guggenheim Fellows. The value of each Fellowship is normally $2,000 annually. In addition a tuition scholarship is granted.

II. POST-DOCTORAL FELLOWSHIPS

1. 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, Lalor Foundation, 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 and other government agencies, as well as various foreign governments. Applications for such fellowships should in general be directed to the agency concerned.

2. *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.

3. 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.

4. 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 upper class course in mathematics. The stipend is $3600 for the academic year, and appointment is normally made for one year, but may be renewed for a second year.

5. 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 molecule structure by the methods of modern physics). These fellowships are to carry stipends, obligations and privileges similar to those of the National Research Fellowships.

6. 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 the 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 of 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."

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. 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, Research Associates, or Visiting Professors and thus have faculty status during their stay at the Institute.

PART THREE

Course Schedules and Subjects of Instruction

SCHEDULES OF THE UNDERGRADUATE COURSES

SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

SUBJECTS OF INSTRUCTION

SCHEDULES OF THE UNDERGRADUATE 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 parenthesis denote hours in class (first figure), hours in laboratory (second figure), and hours of outside preparation (third figure).*

Besides the subjects shown in the course schedules, students are required to take assembly and physical education** in each term of each of the four school years. Students who continue their undergraduate work beyond four years continue to take physical education throughout their undergraduate course. Freshmen attend six orientation assemblies in addition to the general assemblies.

KEY TO ABBREVIATIONS

Aeronautics	AE	Geology	Ge
Applied Chemistry	ACh	History and Government	H
Applied Mechanics	AM	Hydraulics	Hy
Astronomy	Ay	Jet Propulsion	JP
Biology	Bi	Languages	L
Chemistry	Ch	Mathematics	Ma
Civil Engineering	CE	Mechanical Engineering	ME
Drafting and Drawing	D	Philosophy	Pl
Economics	Ec	Physical Education	PE
Electrical Engineering	EE	Physics	Ph
English	En		

*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.

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 1/3. See footnote 7 on page 127.

***See page 124 for rule regarding excuse from physical education.*

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.

		Units per Term 1st	2nd	3rd
Ma 1 abc	Plane Analytical Geometry, Differential and some Principles of Integral Calculus (4-0-8)	12	12	12
Ph 1 abc	Mechanics, Molecular Physics, Heat, Sound (3-3-6)	12	12	12
Ch 1 abc	Inorganic Chemistry, Qualitative Analysis (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
D 1 abc	Freehand and Engineering Drafting (0-3-0)	3	3	3
		50	50	50

ASTRONOMY OPTION

(For First Year see page 162)

(For Second Year see Physics Option, page 174)

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 116.

THIRD YEAR

		Units per Term 1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	15
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 b	Basic Electrical Engineering Laboratory	....	3	....
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
L 32 abc	Elementary German (4-0-6)	10	10	10
		48	51	48

FOURTH YEAR

		1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	....
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
Ma 108 abc	Advanced Calculus (4-0-5)	9	9	9
Ph 112 abc	Introduction to Atomic & Nuclear Physics (3-0-6)	9	9	9
	Electives (See list below) to make	11-18	11-18	17-24
		46-53	46-53	46-53

ELECTIVES

		1st	2nd	3rd
Ay 131 or Ay 132 abc	Astrophysics (3-0-6)**	9	9	9
Ay 141 abc	Astronomy Research Conference	2	2	2
Ma 112	Elementary Statistics (3-0-6)** (1st or 3rd Term)	(9)	....	(9)
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10
EE 60 abc	Electronics and Circuits (3-0-6, 2-3-4, 2-3-4)	9	9	9
Ph 135 ab	Optics (3-0-6)**	9	9	....
Ph 136 ab	Optics Laboratory (0-3-0)**	3	3	....
Ph 137	Spectroscopy (3-0-6)**	....	....	9
Ph 138	Spectroscopy Laboratory (0-3-0)**	....	....	3

*Fourth year Humanities Electives (the courses to be offered in any one term will be announced before the close of the previous term):

Pl 1	Philosophy	Ec 48	Introduction to Industrial Relations
Pl 2	Logic	H 4	The British Empire
Pl 3	Current European Philosophies	H 7	Modern and Contemporary Germany
Pl 4	Ethics	H 8	The History of Russia
Pl 5	Sociology	H 15	The World Since 1914
Pl 6	Psychology	H 16	American Foreign Relations Since 1789
En 8	Contemporary English and European Literature	H 17	The Far West and the Great Plains
En 9	American Literature	H 18	The South: A Study in Persistence
En 10	Modern Drama	H 19	Modern America
En 11	Literature of the Bible	H 21	British-American History
En 17	Technical Report Writing	H 22	Modern England
En 18	Modern Poetry		
L 5	French Literature		
L 40	German Literature		

**Students who plan to do graduate work in astronomy at the California Institute should elect one of these courses.

BIOLOGY OPTION

(For First Year see page 162)

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 121.

SECOND YEAR*

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (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
Ch 12 ab	Analytical Chemistry (2-6-2)	10	10	....
Ge 1 a	Physical Geology (4-2-3)	9	....	....
Bi 1	Elementary Biology (3-3-3)	....	9	....
Bi 2	Genetics (2-4-3)	....	....	9
Bi 3	Plant Biology (2-6-2)	....	....	10
		49	49	49

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
L 32 abc	Elementary German (4-0-6)	10	10	10
Ch 41 abc	Organic Chemistry (3-0-5)	8	8	8
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10
Bi 5 abc	Advanced Plant Biology (3-8-2; 3-8-2; 2-4-1)	13	13	7
Bi 13	Mammalian Anatomy (1-3-1)	....	....	5
		49	49	48

FOURTH YEAR

		1st	2nd	3rd
	Humanities Electives (3-0-6)**	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
Ch 47	Organic Chemistry Laboratory (0-6-0)	6	....	....
Bi 114	Immunology (2-4-4)	....	....	10
Bi 107 ab	Biochemistry (3-4-5)	....	12	12
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	....
Bi 11	Histological Technique (1-3-0)	4	....	....
Bi 12	Histology (1-3-2)	6	....	....
Bi 116 abc	Animal Physiology (2-3-3)	8	8	8
Bi 106	Embryology (2-6-4)	....	12	....
Bi 108	Advanced Genetics (2-0-4)	6	....	....
	Biology Electives†	....	....	9
		47	49	50

*Students taking the Biology option are required to take Bi 4 (20 units), Invertebrate and Vertebrate Zoology, 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, and living quarters are provided at the Laboratory.

**For the list of Humanities electives, see footnote, page 163.

†The following subjects are contemplated as Biology electives of which one or two will be offered each year:

Bio-organic Chemistry Laboratory
Entomology
Biophysics
Chemical Genetics (Bi 126)
Chemical Genetics Laboratory (Bi 127)
General Microbiology (Bi 110)
Invertebrate and Experimental Embryology
Marine Ecology
Paleontology (Ge 1 b)
Special Problems (Bi 22)

CHEMISTRY OR APPLIED CHEMISTRY OPTIONS

(For First Year see page 162)

Any student of the Chemistry or Applied Chemistry Option whose grade point average (credits divided by units) in the required chemistry subjects of any year is less that 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	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics and Electrodynamics (3-3-6)	12	12	12
Ch 12 abc	*Analytical Chemistry (2-6-2)*	10	10	10
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1 a	Physical Geology (4-2-3)	9	....	....
Bi 1	Elementary Biology (3-3-3)	....	9	....
Bi 2	Genetics (2-4-3)	....	....	9
	or			
Ay 1	Introduction to Astronomy (3-1-5)	....	....	9
		49	49	49

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 21 abc	*Physical Chemistry (4-0-6)*	10	10	10
Ch 41 abc	Organic Chemistry (3-0-5)	8	8	8
Ch 46 abc	Organic Chemistry Lab. (0-6-0; 1-9-0)	6	6	10
L 32 abc	Elementary German (4-0-6)	10	10	10
		48	48	46

CHEMISTRY OPTION

FOURTH YEAR

	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H 10	Constitution of the United States (1-0-1)	....	....	2
Ch 13 ab	Inorganic Chemistry (2-0-4)	6	6	....
Ch 123	Thermodynamic Chemistry (2-0-4)	....	6	....
Ch 129	Surface and Colloid Chemistry (3-0-5)	....	....	8
Ch 16	Instrumental Analysis (0-6-2)	8	....	....
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	....	8	8
L 35	Scientific German (4-0-6)	10	....	....
	Elective Subjects**	13	17	21
		48	48	48

*For list of Humanities electives, see footnote, page 163.

**Professional elective subjects include the following: Chemical Research Ch 80-86, Inorganic Chemistry Ch 13 c, Radioactivity and Isotopes Ch 27 ab, Photochemistry Ch 130, Advanced Organic Chemistry Ch 148 abc, Advanced Organic Chemistry Laboratory Ch 149 abc, Industrial Chemistry Ch 61, Introduction to Mathematical Physics and Differential Equations Ph 6 abc, Biochemistry Bi 107 ab.

APPLIED CHEMISTRY OPTION

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
Ch 16	Instrumental Analysis (0-6-2)	8	....	....
Ch 26 ab	Physical Chemistry Lab. (0-6-2; 0-3-1)	....	8	4
Ch 129	Surface and Colloid Chemistry (3-0-5)	....	....	8
Ch 61	Industrial Chemistry (4-0-8)	12	....	....
Ch 63 ab	Chemical Engineering Thermodynamics (4-0-8)	....	12	12
AM 2 abc	Applied Mechanics (3-0-5)	8	8	8
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0)	3	3	....
		48	48	49

*For list of Humanities electives, see footnote, page 163.

CIVIL ENGINEERING OPTION

(For First Year see page 162)

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 121.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (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
CE 1	Surveying (2-4-3)	9 or	9	....
ME 3	Materials and Processes (3-3-3)	9 or	9	....
Ge 1 a	Physical Geology (4-2-3)	9	....	....
AM 1 a	Applied Mechanics (Statics) (3-3-6)*	....	....	12
D 2	Descriptive Geometry (0-6-0)	....	6	....
ME 1 ab	Empirical Design (0-3-0; 0-6-0)	....	3	6
		48	48	48

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 1 abc	General Economics & Economic Problems (3-0-3)	6	6	6
AM 1 bcd	Applied Mechanics (Strength of Materials, Dynamics) (3-3-6)	12	12	12
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
Hy 2 ab	Hydraulics (3-0-6)	9	9	....
CE 20	Introduction to Sanitary Engineering (2-0-4)	....	....	6

Option A:

		1st	2nd	3rd
EE 2 ab	Basic Electrical Engineering Lab (0-3-0)	3	3	....
CE 2	Advanced Surveying (1-7-2)	....	....	10
CE 6	Transportation Engineering (2-0-4)	6	....	....
CE 7	Curves and Earthwork (2-0-4)	....	6	....
		50	50	48

Option B:

		1st	2nd	3rd
AM 15 abc	Engineering Mathematics (3-0-6)	9	9	9
		50	50	47

FOURTH YEAR

		1st	2nd	3rd
	Humanities Elective (3-0-6)**	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H ~~10~~ 5c	The Constitution of the United States (1-0-1)	....	....	2
CE 4	Highways and Airports (2-4-4)	....	10	....
Hy 11	Hydraulics Laboratory (0-6-0)	....	6	....
CE 10 abc	Theory of Structures (3-3-6; 3-0-6)	12	12	9
CE 12	Reinforced Concrete (3-3-6)	....	....	12
AM 3	Testing Materials Laboratory (1-6-1)	....	....	8
AM 105 a	Soil Mechanics (2-0-4)	6	....	....
ME 20	Heat Engineering (3-0-6)	9	....	....
CE 14 abc	Engineering Conference (1-0-1; 1-0-1; 1-0-0)	2	2	1

*Transfer students who have not completed the requirements of Applied Mechanics, AM 1 a, may be excused from this requirement provided they satisfy the Applied Mechanics department by examination that they have a satisfactory knowledge of the subject.

**For list of Humanities electives, see footnote, page 163.

OPTION A:

CE 8	Route Surveying (0-7-0)	7	....	....
Ge 110	Engineering Geology (2-3-4)	....	....	9
Ec 25	Engineering Law (3-0-4)	....	7	....
		47	48	50

OPTION B:

CE 6	Transportation Engineering (2-0-4)	6	....	....
CE 9 ab	Route Surveying Problems (1-3-2)	....	6	6
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0)	3	3	....
		49	50	47

ELECTRICAL ENGINEERING OPTION

(For First Year see page 162)

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 121.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (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
CE 1	Surveying (2-4-3)	9 or	9	....
ME 3	Materials and Processes (3-3-3)	9 or	9	....
Ge 1 a	Physical Geology (4-2-3)	9	....	....
AM 1 a	Applied Mechanics (Statics) (3-3-6) *	....	....	12
D 2	Descriptive Geometry (0-6-0)	....	6	....
ME 1 ab	Empirical Design (0-3-0; 0-6-0)	....	3	6
		48	48	48

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
AM 1 bcd	Applied Mechanics (Strength of Materials, Dynamics) (3-3-6)	12	12	12
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 abc	Basic Electrical Engineering Laboratory (0-3-0)	3	3	3
AM 15 abc	Engineering Mathematics (3-0-6) **	9	9	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-3-5)	11	11	11
		49	49	49

*Transfer students who have not completed the requirements of Applied Mechanics, AM 1 a, may be excused from this requirement provided they satisfy the Applied Mechanics department by examination that they have a satisfactory knowledge of the subject.

**Electrical and mechanical engineering students with scholastic records that warrant the excess load may take Ph 6 abc, Introduction to Mathematical Physics and Differential Equations (5-0-10) as an alternate for Engineering Mathematics.

FOURTH YEAR

		1st	2nd	3rd
	Humanities Elective (3-0-6) *	9	9	9
Ec 1 abc	General Economics and Economic Problems (3-0-3)	6	6	6
Ec 25	Engineering Law (3-0-4)	....	7	....
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
AM 3	Materials Testing Laboratory (1-6-1)	8	....	....
Ph 7 abc	Electricity and Magnetism (2-0-4) **	6	6	6
EE 6 ab	Electrical Machinery (2-0-4; 3-0-6)	....	6	9
EE 7	Electrical Engineering Laboratory (0-3-4)	....	....	7
EE 12	Electrical Circuits (4-0-8)	12	....	....
EE 16	Electrical Measurements (0-3-3)	6	....	....
EE 70 ab	Engineering Conference (1-0-1)	2	2	....
EE 62 ab	Electron Tubes (2-3-5)	....	10	10
		51	48	49

*For list of Humanities electives, see footnote, page 163.

**Electrical engineering students who have completed Ph 6 abc will, as an alternate for Ph 7 abc, take the *following:*

Ph 8	Electricity and Magnetism (3-0-6)	9	....	....
EE 15 ab	High Frequency Circuits (2-0-4; 0-3-3)	....	6	6
		54	48	49

GEOLOGICAL SCIENCES OPTION

(For First Year see page 162)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in freshman and sophomore physics and chemistry may, at the discretion of the Division of the Geological Sciences, be refused permission to register for the third-year course in the Geological Sciences Option. Students whose grade point average is less than 1.9 in the required geology subjects of the third year will be admitted to the required geology subjects of the fourth year only with the special permission of the Division of the Geological Sciences.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 ab	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)	12	12	....
Ph 2 abc	Optics, Electrostatics and Electrodynamics (3-3-6)	12	12	12
Ch 12 a	Analytical Chemistry (2-6-2)	10	....	....
H 2 abc	History of the United States (2-0-4)	6	6	6
CE 1	Surveying (2-4-3)	....	....	9
Ge 1 a	Physical Geology (4-2-3)	9	....	....
Bi 1	Elementary Biology (3-3-3)	....	9	....
Ge 3 ab	Mineralogy (3-3-2; 3-4-3)	....	8	10
	Geology Option			
Ge 1 b	Elementary Paleontology (4-1-4)	....	....	9
		49	47	46
	Geophysics Option			
Ma 2 c	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)	....	....	12
		49	47	49

All majors in the Division of the Geological Sciences may attend the Summer Field Camp, Ge 123, without registration for credit.

THIRD YEAR*

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	....
CE 3	Plane Table Surveying (1-6-1)	....	....	8
Ge 4 ab	Petrology (2-3-1; 2-4-2)	6	8	...
Ge 1 c	Historical Geology (3-2-5)	....	....	10
Ge 9	Structural Geology (4-0-6)	10	....	....
Ge 14	Geologic Illustration (0-3-2)	....	....	5
Ge 21 abc	Introduction to Field Geology (4-5-1; 0-8-2; 0-6-4)	10	10	10
Ge 176	Elementary Seismology (3-0-3)	....	6	....
Ge 102	Oral Presentation (1-0-0)	1 or	1 or	1
	Geology Option			
Ch 24 ab	Physical Chemistry (4-0-6)	10	10	....
D 5	Descriptive Geometry (0-6-0)	....	....	6
		50 or 51	48 or 49	47 or 48
	Geophysics Option			
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 ac	Basic Electrical Engineering Laboratory (0-3-0)	3	3	....
		49 or 50	47 or 48	47 or 48

*Spring Field Trip, Ge 122, 1 unit, required in third and fourth years.
Summer Field Geology, Ge 123, 20 units, required after third year.

GEOLOGICAL SCIENCES OPTION

FOURTH YEAR*

		Units per Term 1st	2nd	3rd
	Humanities Elective (3-0-6)**	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
L 32 abc	Elementary German (4-0-6)	10	10	10
Ge 100	Geology Club (1-0-0)	1	1	1
Ge 128	Introduction to Economic Geology (4-0-3)	....	....	7
Ge 175	Introduction to Applied Geophysics (3-0-3)	6	....	....
	Geology Option			
Ge 105	Optical Mineralogy (2-6-2)	10	....	....
Ge 106 ab	Petrography (2-6-2)	....	10	10
Ge 111 ab	Invertebrate Paleontology (2-6-2)	10	10	....
Ge 121 abc	Field Geology (1-1-0; 0-8-0; 0-7-3)	2	8	10
		50	50	49
	Geophysics Option			
Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	15
Ph 9	Electrical Measurements (0-3-3)	....	6	....
Ma 112	Elementary Statistics (3-0-6)	9	....	....
D 5	Descriptive Geometry (0-6-0)	....	....	6
Ge 165	Introduction to General Geophysics I (2-0-4)	....	6	....
		52	49	50

*Spring Field Trip, Ge 122, 1 unit, required in third and fourth years.
**For list of Humanities electives, see page 163.

MATHEMATICS OPTION

(For First Year see page 162)

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 121.

SECOND YEAR

		Units per term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1 a	Physical Geology (4-2-3)	9	....	....
Bi 1	Elementary Biology (3-3-3)	....	9	....
Ay 1	Introduction to Astronomy (3-1-5)	....	....	9
Ma 3	Theory of Equations (4-0-6)	10	....	....
Ma 16	Matrices and Quadratic Forms (4-0-6)	....	10	....
	Schedule A (1950-51, and alternate years thereafter)			
Ma 10	Differential Equations (4-0-6)	....	....	10
	Schedule B (1951-52, and alternate years thereafter)			
Ma 4	Geometry (4-0-6)	....	....	10
		49	49	49

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	....
Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	15
L 32 abc	Elementary German (4-0-6)	10	10	10
Ma 108 abc	Advanced Calculus (4-0-5)	9	9	9
	Schedule A (1951-52, and alternate years thereafter)			
Ma 4	Geometry (4-0-6)	....	....	10
	Schedule B (1950-51, and alternate years thereafter)			
Ma 10	Differential Equations (4-0-6)	....	....	10
		48	48	52

FOURTH YEAR

		1st	2nd	3rd
	Humanities Elective (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
L 35	Scientific German (4-0-6)	10	....	....
L 1 ab	Elementary French (4-0-6)	....	10	10
Ma 112	Elementary Statistics (3-0-6)	9	....	....
	Approved Mathematics Electives	18	27	27
		48	48	48

*For list of Humanities electives, see footnote, page 163.

MECHANICAL ENGINEERING OPTION

(For First Year see page 162)

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 121.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (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
CE 1	Surveying (2-4-3)	9 or	9	....
ME 3	Materials and Processes (3-3-3)	9 or	9	....
Ge 1 a	Physical Geology (4-2-3)	9	....	....
AM 1 a	Applied Mechanics (Statics) (3-3-6)*	....	....	12
D 2	Descriptive Geometry (0-6-0)	....	6	....
ME 1 ab	Empirical Design (0-3-0; 0-6-0)	....	3	6
		48	48	48

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
AM 1 bcd	Applied Mechanics (Strength of Materials, Dynamics) (3-3-6)	12	12	12
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 abc	Basic Electrical Engineering Laboratory (0-3-0)	3	3	3
AM 15 abc	Engineering Mathematics (3-0-6)**	9	9	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-3-5)	11	11	11
		49	49	49

FOURTH YEAR

		1st	2nd	3rd
	Humanities Elective (3-0-6)†	9	9	9
H 5 ab	Current History (1-0-1)	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
Ec 1 abc	General Economics and Economic Problems (3-0-3)	6	6	6
Ec 18	Industrial Organization (3-0-4)	7	....	....
ME 5 abc	Machine Design (2-6-1)	9	9	9
ME 10	Metallurgy (3-3-6)	....	....	12
AM 3	Testing Materials Laboratory (1-6-1)	....	8	....
ME 16 ab	Thermodynamics (3-0-6; 2-0-4)	9	6	....
ME 25	Mechanical Laboratory (0-6-3)	....	....	9
Hy 1	Hydraulics (3-0-6)	9	....	....
Hy 11	Hydraulics Laboratory (0-6-0)	....	6	....
ME 50 ab	Engineering Conference (1-0-1)	....	2	2
		51	48	49

*Transfer students who have not completed the requirements of Applied Mechanics, AM 1 a, may be excused from this requirement provided they satisfy the Applied Mechanics department by examination that they have a satisfactory knowledge of the subject.

**Electrical and mechanical engineering students with scholastic records that warrant the excess load may take Ph 6 abc, Introduction to Mathematical Physics and Differential Equations (5-0-10), as alternate for Engineering Mathematics.

†For list of Humanities electives, see footnote, page 163.

PHYSICS OR ASTRONOMY OPTION

(For First Year see page 162)

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 work of that option. A fuller statement of this regulation will be found on page 121.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1 a	Physical Geology (4-2-3)	9	....	....
Bi 1	Elementary Biology (3-3-3)	....	9	....
Ay 1	Introduction to Astronomy (3-1-5)	....	....	9
ME 3	Materials and Processes (3-3-3)	9	....	....
Ch 43	Organic Chemistry (2-6-2)	....	....	10
Ch 11	Quantitative Chemical Analysis (2-6-2)	....	10	....
		48	49	49

PHYSICS OPTION

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	15
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 b	Basic Electrical Engineering Laboratory (0-3-0)	....	3	....
Ma 108 abc	Advanced Calculus (4-0-5)	9	9	9
	Electives	10	10	10
		48	51	48

Electives

L 32 abc	Elementary German (4-0-6) *	10	10	10
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10

FOURTH YEAR

		1st	2nd	3rd
	Humanities Electives (3-0-6) **	9	9	9
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	....	6
H 5 ab	Current History	2	2	....
H 10	The Constitution of the United States (1-0-1)	....	....	2
Ph 9	Electrical Measurements (0-3-3)	....	6	....
Ph 112 abc	Introduction to Atomic and Nuclear Physics (3-0-6)	9	9	9
	Electives per term, 22 to 24 units	22	to	24
	Total per term	48	to	50

Electives†, ‡

L 35	Scientific German (4-0-6)*	10	....	....
L 1 ab	Elementary French (4-0-6)	....	10	10
Ph 131 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 135 ab	Optics (3-0-6)	9	9	....
Ph 137	Spectroscopy (3-0-6)	....	....	9
Ph 136 ab	Optics Laboratory (0-3-0)	3	3	....
Ph 138	Spectroscopy Laboratory (0-3-0)	....	....	3
Ph 8	Electricity and Magnetism (3-0-6)	9	....	....
EE 60 abc	Electronics and Circuits (3-0-6, 2-3-4, 2-3-4)	9	9	9
EE 15 ab	High Frequency Circuits (2-0-4, 0-3-3)	....	6	6
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10
Ph 14 abc	Physics Conferences (1-0-2)	3	3	3
Ph 172	Research§	9	9	9
Ma 112	Elementary Statistics (3-0-6) (First or third term)	9	....	(9)

*Students who elect L 32 abc must also elect L 35.

**For list of Humanities electives see page 162.

†Students who expect employment at the B.S. level should elect one of the Electricity and Magnetism courses and EE 60 abc.

‡Students who plan to do graduate work at the California Institute should elect one of the sequences in the Ph 131 to Ph 138 group.

§Students may not register for Research until *after* making arrangements with the supervising instructor.

SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

AERONAUTICS

FIFTH YEAR

(Leading to the degree of Master of Science in Aeronautics)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
†AE 251 abc	Aerodynamics of the Airplane (3-0-6)	9	9	9
†AE 252 abc	Airplane Design (2-1-6)	9	9	9
AE 253 abc	Design of Aircraft Components (2-0-2)	4	4	4
AM 257 abc	Engineering Mathematical Principles (3-0-6)**	9	9	9
AE 258 abc	Introductory Mechanics and Thermodynamics of Fluids (3-0-6)	9	9	9
AE 290 abc	Aeronautical Seminar (1-0-0)	1	1	1
		50 or 51	50 or 51	50 or 51

*Graduate humanities electives to the extent of 9 or 10 units per term for a total of 27 or 30 units are required of all candidates for the Master's Degree in any option.

Humanities Electives: (The subjects to be offered in any one term will be announced before the close of the previous term.)

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 115 abc	Industrial Administration
Ec 120 abc	Money, Income, and Employment

**AM 257 abc will be taken by all students who have previously had Advanced Calculus and Differential Equations or AM 15 (or AM 115) Engineering Mathematics. Otherwise they will take AM 115 abc.

†For those students who have previously had the equivalent of these courses, courses in Jet Propulsion (page 177) or advanced courses in Aeronautics (pages 187-189) may be substituted.

AERONAUTICS

SIXTH YEAR

(Leading to the degree of Aeronautical Engineer)

		Units per Term 1st	2nd	3rd
AE 260 abc	Aeronautics Research	20	20	20
AE 272 abc	Precision Measurements (2-0-1)	3	3	3
AE 290 abc	Aeronautical Seminar (1-0-0)	1	1	1
	Electives (not less than)	21	21	21
		45	45	45

Elective subjects are to be selected from Aeronautics courses (pages 187-189) or advanced courses in other departments, as approved by the Aeronautics Department.

AERONAUTICS (JET PROPULSION OPTION)

SIXTH YEAR

(Leading to the degree of Aeronautical Engineer)

AE 261 abc	Hydrodynamics of Compressible Fluids (3-0-6)	9	9	9
AE 290 abc	Aeronautical Seminar (1-0-0)	1	1	1
JP 280 abc	Jet Propulsion Research	17	17	17
	Electives (not less than)*	18	18	18
		45	45	45

*The electives are to be chosen from the list of Jet Propulsion subjects on page 177 with the approval of the Goddard Professor of Jet Propulsion.

ASTRONOMY

FIFTH YEAR

(Leading to the degree of Master of Science in Astronomy)

	Units per Term 1st	2nd	3rd
Humanities Elective (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
Ay 131 abc or Ay 132 abc, Astrophysics (3-0-6)	9	9	9
Electives, as below, to total	48 to 50	48 to 50	48 to 50

ELECTIVES:

		1st	2nd	3rd
Ay 112 abc	General Astronomy (3-3-3)**	6	6	6
Ay 135	Internal Constitution of the Stars (3-0-6)	....	9	....
Ay 136	Magnetic Fields in the Sun and Similar Bodies (3-0-6)	....	9	....
Ay 141 abc	Research Conference in Astronomy	2	2	2
Ma 108 abc	Advanced Calculus (4-0-5)	9	9	9
Ph 133 abc	Analytical Mechanics (4-0-8)	12	12	12
Ph 135 ab	Optics (3-0-6)	9	9	....
Ph 136 ab	Optics Laboratory (0-3-0)	3	3	....
Ph 137	Spectroscopy (3-0-6)	....	....	9
Ph 138	Spectroscopy Laboratory (0-3-0)	....	....	3
Ph 139 abc	Nuclear Physics (3-0-6)	9	9	9
Ch 130	Photochemistry (2-0-4)	....	....	6

*For list of Humanities electives, see footnote, page 176.

**These courses, with reduced credit, may be required of students whose previous training seems insufficient.

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)

During the week preceding 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 Undergraduate and Fifth-Year Study of the Division.

The Humanities requirement for a master's degree will be found on page 176. Candidates who have not had courses substantially equivalent to Inorganic Chemistry Ch 113ab, Thermodynamic Chemistry Ch 123, and Surface and Colloid Chemistry Ch 129, must take these courses. In addition not fewer than 30 units of courses of science subjects chosen from fifth-year and 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 Committee at least ten days before the degree is to be conferred.

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

CHEMICAL ENGINEERING

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
Ch 166 abc	Chemical Engineering (3-0-9)	12	12	12
Ch 167 abc	Chemical Engineering Laboratory (0-15-0)	15	15	15
	Electives—at least	14	14	14
		50 or 51	50 or 51	50 or 51

Elective subjects approved by a member of the Division to be chosen from advanced subjects in Chemistry, Chemical Engineering, Physics, Mathematics and Mechanical Engineering, or Ma 10 Differential Equations.

Students admitted for work toward the M.S. in Chemical Engineering will be required to take the placement examination in engineering thermodynamics (see pp. 147 and 148). Those students who do not propose to register for Ch 166 abc will also be required to take the placement examination 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.

*For list of Humanities electives, see footnote, page 176.

CIVIL ENGINEERING

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
Ec 100 abc	Business Economics (4-0-6)	10	10	10
CE 120 a	Statically Indeterminate Structures (4-3-5)	12	....	....
CE 121 abc	Civil Engineering Design (0-12-0; 0-9-0)	12	9	9
CE 125	~~Irrigation and Water Supply~~ (4-0-8)	....	12	....
CE 126	Masonry Structures (2-3-4)	....	....	9
CE 127	Sewerage and Sewage Treatment (2-3-4)	....	....	9
AM 115 abc	Engineering Mathematics (3-0-6)	9	9	9
AM 105 b	Soil Mechanics (2-0-4)	....	6	....
Hy 100	Hydraulics Problems (2-0-4)*	6	....	....
CE 130 ab	Engineering Seminar (1-0-1; 1-0-3)	2	....	4
	Approved Elective	....	5	....
		51	51	50

SUPPLEMENTARY SUBJECTS**

		1st	2nd	3rd
CE 120 bc	Statically Indeterminate Structures (2-0-4)	....	6	6
CE 122	Earthquake Effects upon Structures	....	....	....
CE 131	Sewage Treatment Plant Design	....	....	....
CE 132	Water Power Plant Design	....	....	....
CE 133	Water Treatment Plant Design	....	....	....
CE 134	Ground Water Investigations	....	....	....
CE 135	Geodesy and Precise Surveying	....	....	....
CE 136	Irrigation Investigations	....	....	....
CE 141	Structural Engineering Research	....	....	....
CE 142	Sanitation Research	....	....	....
CE 143	Highway Research	....	....	....
CE 144	Airport Design	....	....	....
CE 150	Foundations (3-0-6)	....	....	6
CE 155	Advanced Hydrology	....	....	....
CE 156	Industrial Wastes	....	....	....
Ge 110	Engineering Geology (2-3-4)	....	....	9
~~AM 106~~	Soil Mechanics Laboratory (0-3-3)	....	6	....
AM 110 a	Introduction to the Theory of Elasticity (2-0-4)	6	....	....
AM 110 b	Theory of Plates and Shells (2-0-4)	....	6	....
AM 110 c	Mechanics of Materials (2-0-4)	....	....	6
AE 270 abc	Elasticity Applied to Aeronautics (2-0-4)	6	6	6
Hy 100	Hydraulics Problems	....	....	....
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9

SIXTH YEAR

(Leading to the degree of Civil Engineer)

Programs are arranged by the student in consultation with members of the Department. Note: No deviation from the prescribed 5th-year work will be permitted unless the student has had equivalent work in one or more of the subjects listed under the above 5th-year curriculum, in which case courses may be elected from the supplementary subjects.

*For students who have credit for AM 105 a.

**Where no hours are shown, units are to be arranged based upon work done.

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)*	9 or 10	9 or 10	9 or 10
EE 120 abc	Advanced Electric Power System Analysis (4-0-8)	12	12	12
EE 121 abc	Alternating Current Laboratory (0-3-3)**	6	6	6
EE 158 abc	Circuit Analysis (3-0-6)	9	9	9
		36 or 37	36 or 37	36 or 37
	Electives	12	12	12

SIXTH YEAR

(Leading to the degree of Electrical Engineer)

EE 226 abc	Engineering Mathematical Physics (3-0-12)***	15	15	15

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.

*For list of Humanities electives, see footnote, page 176.
**Required unless comparable work done elsewhere.
***This course is also required for the doctor's degree in electrical engineering.

GEOLOGICAL SCIENCES

FIFTH YEAR

(Leading to the degree of Master of Science in Geology)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	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 165	Introduction to General Geophysics, I	....	6	....
Ge 295	Master's Thesis Research (units and subjects by arangement)			
	Elective units from groups A and B below to total	50	50	50

(Leading to the degree of Master of Science in Geophysics)

		1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	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 165	Introduction to General Geophysics, I	....	6	....
	For additional requirements, consult Division circular: required and optional courses to total	50	50	50

A. Geology and Paleontology

FIFTH AND SIXTH YEARS

(Leading to the degree of Geological Engineer)

		1st	2nd	3rd
Ge 105	Optical Mineralogy	10	....	....
Ge 106 ab	Petrography	....	10	10
Ge 107	Stratigraphy**	....	....	10
Ge 109	Structural Geology	6	....	....
Ge 110	Engineering Geology	....	....	9
Ge 111 ab	Invertebrate Paleontology	10	10	....
Ge 112 ab	Vertebrate Paleontology	....	10	10
Ge 115	Micropaleontology	....	8	....
Ge 121 abc	Field Geology	2	8	10
Ge 122	Spring Field Trip	....	....	1
Ge 123	Summer Field Geology	....	....	20
Ge 125	Geology of Western America	....	....	5
Ge 126	Geomorphology	10	....	....
Ge 128	Introduction to Economic Geology	....	....	7
Ge 200	Mineragraphy	10	....	....
Ge 202	Ore Deposits	....	10	....
Ge 209	Sedimentary Petrology**	....	10	....
Ge 210	Metamorphic Petrology†	....	10	....
Ge 212	Nonmetalliferous Deposits	....	....	10
Ge 213	Mineralogy (Seminar)	5	....	....
Ge 214	Petrology (Seminar)	....	5	....
Ge 215	Ore Deposits (Seminar)	....	....	5
Ge 220	History of the Geological Sciences (Summer reading)	....	....	5
Ge 226	Advanced Geomorphology**	....	10	....
Ge 228	Geomorphology of Arid Regions**	....	10	....
Ge 229	Glacial Geology†	....	10	....
Ge 230	Geomorphology (Seminar)	....	5	....
Ge 232	Petroleum Geology	10	....	....
Ge 233	Petroleum Geology Practices	....	10	....
Ge 235	Petroleum Geology (Seminar)	....	....	5
Ge 237	Tectonics	....	....	8
Ge 238	Structural Geology (Seminar)	5	....	....
Ge 245 ab	Vertebrate Paleontology (Seminar)	....	5	5
Ge 248	Fossils of the California Tertiary	....	5	....
Ge 249	Stratigraphy of the Coast Ranges	....	....	5
Ge 250	Invertebrate Paleontology (Seminar)	5	....	....
Ge 295	Master's Thesis Research (units by arrangement)	....	....	....
Ge 297	Advanced Study (units and subject by arrangement)	....	....	....
Ge 299	Research (units and subject by arrangement)	....	....	....

*For list of Humanities electives, see footnote, page 176.
**1951–52
†1950-51

B. GEOPHYSICS

FIFTH AND SIXTH YEARS

(Leading to the degree of Geophysical Engineer)

		Units per Term 1st	2nd	3rd
Ge 165	Introducton to General Geophysics I	....	6	....
Ge 166	Introduction to General Geophysics II*	6	....	....
Ge 174	Well Logging	....	5	....
Ge 175	Introduction to Applied Geophysics	6	....	....
Ge 176	Elementary Seismology	....	6	....
Ge 261	Theoretical Seismology**	6	....	....
Ge 262	Interpretations of Seismograms of Teleseisms**	....	4	....
Ge 263	Field Work in Earthquakes and Interpretation of Seismograms of Local Earthquakes**	....	....	4
Ge 268 ab	Selected Topics in Theoretical Geophysics*	....	6	6
Ge 270	Geophysical Instruments***	....	....	7
Ge 273 ab	Applied Geophysics I*	....	5	5
Ge 274 abc	Applied Geophysics II**	5	5	7
Ge 275 abc	Applied Geophysics III**	6	8	4
Ge 282 abc	Geophysics (Seminar)	1	1	1
Ge 297	Advanced Study (units and subject by arrangement)	....	....	....
Ge 299	Research (units and subject by arrangement)	....	....	....
CE 122	Earthquake Effects Upon Structures (units by arrangement)	....	....	....
EE 156	Electrical Communication	6	....	....
Ph 102 abc	Introduction to Mathematical Physics and Differential Equations	10	10	10
Ph 130 abc	Methods of Mathematical Physics	12	12	12
Ph 131 abc	Electricity and Magnetism	9	9	9
Ph 133 abc	Analytical Mechanics	12	12	12

Graduate students who have not had the equivalent of the following undergraduate subjects may have to take one or more of these subjects without graduate credit.

EE 1 abc	Basic Electrical Engineering	6	6	6
EE 2 abc	Basic Electrical Engineering Laboratory	3	3	3
EE 62 ab	Electron Tubes	....	10	10
Ma 112	Elementary Statistics	9 or	....	9
EE 16	Electrical Measurements	6	....	....
or				
Ph 9	Electrical Measurements	....	6	....

*1950–51
**1949–50
***Not offered in 1950–51

MATHEMATICS

As nearly all mathematics majors are working for the doctor's degree and following programs arranged by the student in consultation with members of the Division, no specific graduate curricula can be outlined.

MECHANICAL ENGINEERING

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)*	9 or 10	9 or 10	9 or 10
ME 125 abc	Engineering Laboratory (1-6-2)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
	Electives as below (minimum)	27	27	27
		47 or 48	47 or 48	47 or 48

ELECTIVES

ME 101 abc	Advanced Machine Design (1-6-2)	9	9	9
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 110 abc	Physical Metallurgy and Metallography (3-0-6; 1-6-2; 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
AM 110 abc	Elasticity (2-0-4)	6	6	6

JET PROPULSION, MECHANICAL ENGINEERING OPTION

FIFTH YEAR

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

	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
JP 121	Rocket (4-0-8)	12	....	....
JP 130 ab	Thermal Jets (4-0-8)	....	12	12
JP 170 abc	Jet Propulsion Laboratory (0-3-0)	3	3	3
JP 200 abc	*Chemistry Problems in Jet Propulsion* (2-0-4)	*6*	*6*	*6*
ME 125 abc	Engineering Laboratory (1-6-2)	9	9	9
	Electives	15	15	15
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
		50 or 51	50 or 51	50 or 51

ELECTIVES

ME 101 abc	Advanced Machine Design (1-6-2)	9	9	9
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 110 abc	Physical Metallurgy and Metallography (3-0-6; 1-6-2; 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
AM 110 abc	Elasticity (2-0-4)	6	6	6

NOTE: Students who desire to do so may substitute Elementary Statistics Ma 112 for one term of Engineering Laboratory ME 125.

NOTE: 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 abc among the elective units.

NOTE: Students who plan advanced study past the fifth year, and who have had AM 115 abc 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 Mechanical Engineering Department:

EE 226 abc *Engineering Mathematical Physics*
AM 257 abc Engineering Mathematical Principles
Ph 102 abc Introduction to Mathematical Physics and Differential Equations

*For list of Humanities electives, see footnote, page 176.

MECHANICAL ENGINEERING

SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

Specific requirements for the degree of Mechanical Engineer are given on page 141. The following list will suggest possible subjects from which a program of study may be organized:

ME 200	Advanced Work in Mechanical Engineering
ME 210 abc	Science of Metals
ME 211 abc	Metallography Laboratory
ME 212 ab	X-ray Metallography
ME 215	Internal Combustion Engines
ME 216 ab	Refrigeration and Air Conditioning
ME 217 abc	Turbomachines
ME 218 ab	Aircraft Power Plants
ME 219	Experimental Background of Engine Research
ME 220	Lubrication
ME 300	Thesis—Research
Hy 200	Advanced Work in Hydraulic Engineering
Hy 201 abc	Hydraulic Machinery
Hy 202 ab	Hydraulics of Free Surface Phenomena
Hy 203	Cavitation Phenomena
Hy 210 ab	Hydrodynamics of Sediment Transportation
Hy 300	Thesis
AE 261 abc	Hydrodynamics of Compressible Fluids
AE 266 abc	Theoretical Aerodynamics of Real and Perfect Fluids
AE 267 abc	Statistical Problems in Gas Dynamics
AE 270 abc	Elasticity Applied to Aeronautics
Ch 63 ab	Chemical Engineering Thermodynamics
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 211	Thermodynamics

JET PROPULSION, MECHANICAL ENGINEERING OPTION

SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

		Units per Term 1st	2nd	3rd
JP 200 ab	Chemistry Problems in Jet Propulsion (2-0-4)	6	6	....
JP 210	High Temperature Design Problems (2-0-4)	....	....	6
JP 220 ab	Applications of Jet Propulsion Power Plants (2-0-4)	6	6	....
JP 280 abc	Jet Propulsion Research (Thesis)	18	18	18
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
	Electives	18	18	18
		50	50	50

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)*	9 or 10	9 or 10	9 or 10
Ph 133 abc	Analytical Mechanics (4-0-8)	12	12	12
or	or	or	or	or
Ph 131 abc	Electricity and Magnetism (3-0-6)	9	9	9
	Electives as below	27 to 30	27 to 30	27 to 30
		48 to 49	48 to 49	48 to 49

Ph 102 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)**	10	10	10
Ph 131 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 133 abc	Analytical Mechanics (4-0-8)	12	12	12
Ph 135 ab	Optics (3-0-6)	9	9	....
Ph 136 ab	Optics Laboratory (0-3-0)	3	3	....
Ph 137	Spectroscopy (3-0-6)	....	....	9
Ph 138	Spectroscopy Laboratory (0-3-0)	....	....	3
Ph 139 abc	Nuclear Physics (3-0-6)	9	9	9
Ph 140 ab	Kinetic Theory of Matter (3-0-6)	9	9	....
Ph 143 a	Principles of Quantum Mechanics (3-0-6)	9	....	....
Ph 147 ab	X-Rays (3-0-6)	9	9	....
Ph 149	History of Modern Physics (3-0-6)	9	....	....
Ma 108 abc	Advanced Calculus (4-0-5)†	9	9	9
Ma 114 abc	Mathematical Analysis (4-0-8)	12	12	12

*For list of Humanities electives, see footnote, page 176.

**Prerequisite for most other fifth-year courses. Two-thirds credit allowed graduate students. (Note: with the department's approval, students who have the proper preparation may substitute other graduate courses in Electrical Engineering, Mathematics or Physics for some of those listed above. Students who have received credit for Ph 131 abc, Ph 133 abc or Ph 135 ab and Ph 137 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.

†Prerequisite for Ma 114.

SUBJECTS OF INSTRUCTION

AERONAUTICS

FIFTH YEAR AND ADVANCED SUBJECTS

AE 251 abc. Aerodynamics of the Airplane. 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 stability. Dynamic stability. Maneuverability.

Texts: *Aerodynamics of the Airplane,* Millikan; *Technical Aerodynamics,* Wood; *Theory of Flight,* von Mises.

Instructor: Felberg.

AE 252 abc. Airplane Design. 9 units (2-1-6); each term.

Prerequisites: Applied Mechanics, Strength of Materials, and Machine Design.

The solution of problems connected with the structural design and analysis of airplane structural components. Special emphasis is placed on the problems dealing with monocoque construction. A modern airplane is considered and the key structural elements are designed and analysed.

Texts: *Airplane Structural Analysis and Design,* Sechler and Dunn; *Airplane Structures,* Niles and Newell.

Instructor: Solverson.

AE 253 abc. Design of Aircraft Components. 4 units (2-0-2); each term.

A study of the non-structural components of airplane including control and flap systems, landing gears, power plants, electrical, radio, and instrument installations, heating and ventilating problems, hydraulic systems and acoustics.

Instructor: Klein, assisted by engineers from aircraft companies.

AE 254 abc. Advanced Problems in Airplane Design. 4 units (2-0-2); each term.

Prerequisites: AE 252, AE 253.

The application of basic mathematical methods to structural problems. A study of advanced design methods for airplane structural components.

Instructor: Williams.

AE 255. Wind Tunnel Operation and Technique. 6 units (1-3-2); one term.

A one-term course covering pressure and velocity measuring instruments, balances, model suspensions, wind tunnel calibrations 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: Bowen.

AE 256. Flight Test Techniques. 6 units (2-0-4); one term.

Prerequisite: AE 251.

The methods of obtaining aerodynamic data by means of flight testing. Instrumentation, types of flight testing, and flight tests procedures. The reduction of flight test data and their correlation with wind tunnel data and airplane performance.

Instructor: Williams.

AE 257 abc. Engineering Mathematical Principles. 9 units (3-0-6); each term.

Note: This course now designated AM 257abc.

AE 258 abc. Introductory Mechanics and Thermodynamics of Fluids. 9 units (3-0-6) ; each term.

Dimensional analysis, thermodynamics, kinetic theory of gases, dynamical principles, circulation and vorticity, velocity potentials, stream functions, perfect fluid flows, one dimensional gas dynamics, viscosity, turbulence, Reynolds stresses, heat transfer, diffusion.

Reference texts: *Airfoil and Airscrew Theory*, Glauert; *Aerodynamic Theory*, Vol. I, Durand.

Instructor: Liepmann.

AE 260 abc. Research in Aeronautics. Units to be arranged.

Theoretical and experimental investigations in the following fields: aerodynamics; fluid mechanics; compressibility; supersonics; structures, including photoelasticity; and flutter.

AE 261 abc. Hydrodynamics of Compressible Fluids. 9 units (3-0-6) ; each term.

Prerequisites: AE 251, AE 258.

One dimensional gasdynamics; subsonic and supersonic channel flow; normal and oblique shockwaves; condensation phenomena. Experimental methods employed in compressible fluid mechanics research using Schlieren, shadowgraph, interferometers, and other high speed instruments. Two- and three-dimensional vortices; Linearized theory of subsonic and supersonic flow fields; Hodograph methods. Boundary layer and interactive phenomena between boundary layers and shockwaves.

Text: *Introduction to the Aerodynamics of a Compressible Fluid*, Liepmann and Puckett.

Instructor: Millikan.

AE 265 abc. Advanced Problems in Aerodynamics. 6 units (2-0-4) ; each term.

Prerequisites: AE 251, AM 257, AE 258.

Aerodynamics of propeller design. Flow in ducts and cooling problems. Aerodynamics of high speed flight including the effects of compressibility on stability and control.

Instructor: Bell.

AE 266 abc. Theoretical Aerodynamics of Real and Perfect Fluids. 9 units (3-0-6) ; each term.

Prerequisites: AE 251, AM 257, AE 258.

Hydrodynamics of perfect fluids, potential motion, circulation, laws of vortex motion, elements of conformal transformation, streamline bodies, two-dimensional airfoil theory, three-dimensional wing theory, monoplanes, biplanes, interference, propellers, theory of airfoils in non-uniform motion, hydrodynamics of viscous fluids, laminar motion in pipes and channels, turbulence and Reynolds' criterion, similarity laws, theory of drag, discontinuous flow, and vortex streets, theory of skin-friction, boundary layer, general theory of turbulence.

Text: *Aerodynamic Theory*, Vols. I and II, Durand.

Instructor: Stewart.

AE 267 abc. Statistical Problems in Gas Dynamics. 6 units (2-0-4) each term.

Prerequisites: AE 258; AE 261; AM 257, or Ma 114.

Fundamental concepts: concept of probability, random variables, averaging procedures, distributions, random walk, relation to parabolic equations, use of Fourier analysis, correlations, stochastic processes. Statistical foundation of continuum hydrodynamics: review of statistical theory of gases, transport phenomena, Boltzmann equation, motion of rarefied gases, interaction of gas and solid surface, nucleation. Turbulence: experimental methods and phenomenological turbulence, stability of laminar motion, statistical theories of turbulence.

Instructors: Lagerstrom, Liepmann.

AE 268 abc. Advanced Problems in Fluid Mechanics. 9 units (3-0-6); each term.

Prerequisite: AE 258; AE 261; AE 266, or consent of instructor.

Waves of finite amplitude, both stationary and non-stationary. Theory of characteristics of linear and quasi-linear hyperbolic equations. Transonic flow. Mixed elliptic-hyperbolic equations. Influence of viscosity. Parabolic equations and the connection with statistical concepts.

Instructor: Lagerstrom.

AE 269 abc. Seminar in Fluid and Solid Mechanics. 3 units (2-0-1); each term.

A seminar course in the applications of theoretical aerodynamics to aeronautical problems for students who have had AE 266 and AE 267.

Instructor: Liepmann.

AE 270 abc. Elasticity Applied to Aeronautics. 6 units (2-0-4); each term,

Prerequisites: Applied Mechanics, AM 257.

Fundamental stress and strain relationships in elastic bodies. Theories of bending and torsion. Elastic stability problems including those of thin plates and shells.

Texts: *Elasticity in Engineering*, Sechler; *Theory of Elasticity*, *Elastic Stability*, and *Plates and Shells*, by Timoshenko.

Instructor: Sechler.

AE 272 abc. Precision Measurements. 3 units (1-0-2); each term.

Prerequisites: Applied Mechanics, Mechanisms.

A study of the fundamental principles involved in making precision measurements. Determination of limits of error. Primary and secondary references. Problems in the design of precision instrumentation.

Instructor: Klein.

AE 273 abc. Photoelasticity and Structural Testing Methods. 6 units (2-0-4); each term.

Prerequisites: AE 270. (May be taken simultaneously)

The basic principles of photoelasticity used as a method of stress distribution determination. Types of photoelastic procedure, the equipment involved, and the results obtained. Discussions of newer types of testing instruments and machines, their advantages and disadvantages. Demonstrations and laboratory problems as required.

AE 274 abc. Problems in Aero-elasticity. 6 units (2-0-4); each term.

Prerequisites: AE 251, AE 265, AE 270.

A survey of the developments in aero-elasticity and associated fields. The dynamics of a deformable body subjected to aerodynamic, elastic, and inertia forces. Effect of deformations on stability, control, and flutter. Gust frequency and landing impact as they effect airplane design.

Instructor: Fung.

AE 290 abc. Aeronautical Seminar. 1 unit (1-0-0); each term.

Study and critical discussion of current work in aeronautics and allied fields.

JET PROPULSION

For Jet Propulsion see page 236.

APPLIED MECHANICS

UNDERGRADUATE SUBJECTS

AM 1 a. Applied Mechanics—Statics. 12 units (3-3-6); third term.

Prerequisites: Ma 1 abc, 2 ab; Ph 1 abc.

Principles of statics; composition and resolution of forces and force systems; equilibrium of force systems; 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, Hudson and Assistants.

AM 1 bcd. Applied Mechanics—Strength of Materials and Dynamics. 12 units (3-3-6); first, second, third terms.

Prerequisite: AM 1 a.

The first term (AM 1 b) and half of the second term (AM 1 c) are devoted to Strength of Materials. The remainder of the second term and the third term (AM 1 d) are devoted to Dynamics. Thus, approximately 18 units of work are done in each of these subjects. The following topics will be included: Theory of elasticity applied to engineering problems involving tension and compression, bending of beams, torsion of shafts, buckling, etc.; determination of the stresses, strains, and deformations in typical structures; theory of statically indeterminate structures; properties of the materials of construction; determination of safe loads for engineering structures and machines; principles of dynamics; dynamics of a particle, including equations of motion, impulse and momentum, work and energy; dynamics of rigid bodies; applications to engineering problems involving dynamic characteristics of machine parts, mechanical and structural vibrations, impact, fluid dynamics, etc.

Texts: *Elements of Strength of Materials,* Timoshenko and MacCullough; *Applied Mechanics-Dynamics,* Housner and Hudson.

Instructors: Housner, Hudson and Assistants.

AM 2 abc. Applied Mechanics. 8 units (3-0-5); first, second, third terms.

Prerequisites: Ma 1 abc, 2 ab; Ph 1 abc.

An abridgement of AM 1 abcd designed particularly to meet the needs of students of Applied Chemistry.

AM 3. Testing Materials Laboratory. 8 units (1-6-1); first second, or third terms.

Prerequisite: AM 1 c.

Tests of the ordinary materials of construction in tension, compression, torsion, and flexure; determination of elastic limit; yield point; ultimate strength, and modules of elasticity; experimental verification of formulas derived in the theory of strength of materials.

Instructors: Converse and Assistants.

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. The topics studied include: solution of ordinary differential equations by standard techniques, power series and Fourier series; problems leading to special functions such as Bessel functions and Legendre functions; partial differential equations and boundary value problems; complex variables, conformal mapping and vector analysis as applied to fluid flow, electrostatics, etc.

Instructors: Wayland and Assistants.

ADVANCED SUBJECTS

AM 105 a. Soil Mechanics. 6 units (2-0-4); first term.

Prerequisite: AM 1 abcd.

A study of the physical characteristics of soil, including origin, methods of classification and identification; elasticity, plasticity, the effects of soil moisture on physical properties. permeability, seepage, capillary action, and the effects of frost.

Instructor: Converse.

AM 105 b. Soil Mechanics. 6 units (2-0-4); second term.

Prerequisite: AM 105 a.

A study of the mechanics of soil masses subjected to loads, including the distribution of stress within the soil mass, active and passive pressures on retaining walls, bearing capacity and settlement of footings, piles, stability of slopes, earth dams, highway and airport runways.

Instructor: Converse.

AM 106. Soil Mechanics Laboratory. 6 units (0-3-3); second term.

Prerequisite: AM 105a.

Tests to determine the basic physical and mechanical properties of soil, including classification, plasticity, specific gravity, volumetric changes, shearing strength, consolidation characteristics, and the standard tests for controlling and checking the compaction of earth fills.

Instructor: Converse.

AM 110 a. Introduction to the Theory of Elasticity. 6 units (2-0-4); first term.

Prerequisite: AM 1 bcd.

Fundamental concepts of elasticity theory. Equations of stress equilibrium and strain compatibility. Solution of two-dimensional problems. Photo-elastic method of stress measurements. Analysis of stress and strain in three dimensions. Solution of torsion problems. Wave propagation in elastic solids.

Instructor: Housner.

AM 110 b. Theory of Plates and Shells. 6 units (2-0-4); second term.

Prerequisite: AM 1 bcd.

Simplifications introduced in elasticity theory. Laterally loaded plates with various boundary conditions. Elastic stability of plates. Membrane theory of shells. General theory of shells.

Instructor: Housner.

AM 110 c. Mechanics of Materials. 6 units (2-0-4); third term.

Prerequisites: AM 1 bcd, AM 110 a.

Use of tensors in elasticity theory. Non-linear stress-strain relations. Theory of plasticity. Theories of failures of stressed materials.

Instructor: Housner.

AM 115 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 for fifth year graduate students who have not had a course in advanced engineering mathematics or advanced calculus in their undergraduate work. The mathematical content is similar to that of AM 15, but greater emphasis is placed on applications to the specific field of engineering in which the student is specializing.

Instructors: DePrima, Wayland and Assistants.

AM 150 abc. Mechanical Vibrations. 6 units (2-0-4); first, second, and third terms.

Prerequisites: AM 1 bcd, AM 115 abc.

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; self-excited vibrations and instability in mechanical systems, including aircraft flutter problems; non-linear vibration theory.

Texts: *Mathematical Methods in Engineering*, Kármán and Biot; *Mechanical Vibrations*, Den Hartog.

Instructor: 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 measurement of strains, accelerations, frequencies, etc., in vibrating systems, and the interpretaion 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.

Instructor: Hudson.

AM 175 abc. Non-linear Vibrations. 6 units (2-0-4).

Prerequisites: AM 257 (formerly AE 257), or EE 226, or Ma 114. AM 150 may be taken concurrently.

Review of stability and resonance properties of linear oscillatory systems described by time dependent as well as constant parameters. Discussion of analytical and geometric properties of solutions of systems of non-linear ordinary differential equations. Phase trajectories, limit cycles. Stability and resonance properties of certain autonomous and non-autonomous systems will be investigated. Perturbation and numerical methods. Relaxation oscillations. Other topics will be selected as time permits. Applications will be made to non-linear mechanical and electrical systems.

Instructor: DePrima.

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. Theory of Cavitating Flow. Units in accordance with work done.

Theory of free streamline flow. Applications of kinetic theory and statistical mechanics to liquid-vapor systems.

Instructor: Plesset.

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.

AM 257 abc. Engineering Mathematical Principles. 9 units (3-0-6); each term.

Prerequisites: AM 15, AM 115, Ma 108, or equivalent.

Elementary theory and applications of ordinary and partial differential equations in applied mechanics and related fields.

Calculus of residues and conformal transformations. Laplace and Fourier transforms, characteristic value problems, special functions. Second order partial differential equations, method of Green's functions, Riemann's method and theory of characteristics. Direct variational methods and numerical solutions.

Note: Other subjects in the general field of Applied Mechanics will be found listed under the departments of Aeronautics, Mechanical Engineering, and Physics.

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.

Text: *Astronomy*, Baker.

Instructor: Deutsch.

Ay 2 abc. General Astronomy. 9 units (3-3-3); first, second, 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.

Instructor: Joy.

ADVANCED SUBJECTS

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.

Instructor: Joy.

Ay 131 abc. Astrophysics I. 9 units (3-0-6); first, second and third terms.
Prerequisites: Ay 2 abc, Ph 112 abc, Ma 10, or their equivalents.

The masses, luminosities and radii of the stars. The sun. Stellar spectra. The theory of radiative equilibrium in steller atmospheres. The continuous absorption by atoms and the production of the continuous spectrum of the star; the line absorption coefficient and the formation of spectral lines. Determination of the abundances of the elements.

Instructor: Greenstein.

Ay 132 abc. Astrophysics II. 9 units (3-0-6); first, second, third term.
Prerequisites: Ay 2abc, Ph 112 abc or their equivalents.

An introduction to the study of stellar interiors. Polytropic gas spheres; white dwarfs. Atomic processes in diffuse nebulae. Properties of interstellar space. Structure of the Galaxy and of extragalactic nebulae.

Offered in alternate years with Ay 131. Not given in 1950-51.

Instructor: Greenstein.

Ay 135. Internal Constitution of the Star. 9 units (3-0-6); second term.
Prerequisites: Ph 6 abc, Ph 112 abc, Ma 108 abc or their equivalents.

Properties of matter at the pressure and temperature in stellar interiors. Stellar models. Chemical composition and the mass-luminosity relation. Energy generation. Degenerate matter and white dwarfs.

Not given in 1950-51.

Ay 136. Magnetic Fields in the Sun and Similar Bodies. 9 units (3-0-6); second term.

Admission to qualified students.

Conductivity of an ionized gas; times of generation and decay of sunspot and general solar magnetic fields; the origin of the magnetic fields; motions near a sunspot; electric discharges on the sun.

Instructor: Cowling.

Ay 140 abc. Seminar in Astrophysics. 4-12 units; first, second, third terms.

Discussions on the large scale distribution of mattter in the Universe, statistics of the distribution of nebulae and of 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 and Astrophysics. Units in accordance with the work accomplished.

The student should consult the division and have a definite program of research outlined before registering.

Ay 203. Stellar Magnetic Fields. Units to be arranged; second term.

Admission to qualified students.

Measurement of magnetic fields in the sun and stars by the Zeeman effect. Polarizing analyzers; practical measurement of spectra. Problems of pecular A-type stars and of magnetically variable stars.

Instructor: H. W. Babcock.

Ay 208. Photometry. Units to be arranged; first term.

Admission to qualified students.

A practical course in the techniques and applications of photographic and photoelectric photometry.

Instructor: Baum.

Ay 209. Wolf-Rayet Stars and Planetary Nebulae. Units to be arranged; third term.

Admission to qualified students.

General study of Wolf-Rayet spectra and their interpretation with emphasis on binary systems. Recent developments in the study of planetary nebulae. Internal motions and dynamics.

Instructor: O. C. Wilson.

The following special seminars will be offered from time to time by members of the Mount Wilson Observatory and Institute staffs:

Ay 201. The Sun and Planetary System
Ay 202. Sunspots and the Solar Atmosphere
Ay 204. Classification of Stellar Spectra
Ay 205. Spectra of Emission-line Stars
Ay 206. Stellar Radial Velocities
Ay 207. Stellar Absolute Magnitudes
Ay 210. Interstellar Matter
Ay 211. Structure of the Galaxy.
Ay 212. Extragalactic Nebulae
Ay 213. Observational Cosmology
Ay 214. Theoretical Cosmology

BIOLOGY

UNDERGRADUATE SUBJECTS

Bi 1. Elementary Biology. 9 units (3-3-3); second term.

An introductory subject intended to give the student of general science some information about the fundamental properties of living organisms.

Instructors: ————, Beadle.

Bi 2. Genetics. 9 units (2-4-3); third term.

Prerequisite: Bi 1.

An introductory subject presenting the fundamentals of genetics in connection with some general biological problems, such as variation and evolution.

Instructor: Lewis.

Bi 3. Plant Biology. 10 units (2-6-2), third term.

Prerequisite: Bi 1.

A general survey of the water relations of plants in connection with their morphology.

Instructor: Went.

Bi 4. Invertebrate and Vertebrate Zoology. 20 units, (5-10-5).

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, and living quarters are provided at the Laboratory.)

Bi 5 abc. Advanced Plant Biology. 13 units (3-8-2), first term; 13 units (3-8-2), second term; 7 units (2-4-1), third term.

Prerequisite: Bi 3.

A general survey of growth and the chemical processes taking place in the living plant (Bi 5 ab), followed by a survey of the plant kingdom (Bi 5 c).

Instructors: Bonner, Went.

Bi 11. Histological Technique. 4 units (1-3-0); first term.

A course in the preparation of biological material for microscopic examination; includes electron microscopy.

Instructor: Tyler.

Bi 12. Histology. 6 units (1-3-2); second term.

Prerequisite: Bi. 4

A course in the microscopic anatomy of vertebrates.

Instructor: Tyler.

Bi 13. Mammalian Anatomy. 5 units (1-3-1); third term.

Prerequisite: Bi. 4

The dissection of a mammal.

Instructors: Van Harreveld, Keighley.

Bi 18. Review in Botany. 3 units (1-0-2). No graduate credit.

A short review course 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: Went.

Bi 22. Special Problems. 9 units. (0-0-9); third term.

Special problems in one of the fields represented in the undergraduate biology curriculum to be arranged with instructor 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 102 abc. Biological Assays. 8 units (1-6-1); first, second, third terms.

A course with lectures and laboratory practice, on certain biological tests for physiologically active substances.

Instructors: Went, Haagen-Smit, Bonner.

Bi 106. Embryology. 12 units (2-6-4); second term.

Prerequisite: Bi. 4

A subject in vertebrate embryology, including some experimental and cytological material.

Instructor: Tyler.

Bi 107 ab. Biochemistry. 12 units (3-4-5); second, third terms.

Prerequisites: Bi 116 a, 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.

Instructors: Borsook, Mitchell.

Bi 108. Advanced Genetics. 6 units (2-0-4); first term.

Prerequisite: Bi 2.

A course dealing with advanced general genetics for seniors and graduate students. Required of graduate students majoring and minoring in Genetics. Graduate students majoring or minoring in Genetics who have not had a course in Genetics with laboratory, are required to take Bi 109, a laboratory course, simultaneously with Bi 108.

Instructor: Sturtevant.

Bi 109. Advanced Genetics Laboratory. Units to be arranged; first term.

Prerequisite: Bi 2.

A laboratory course in general genetics designed to accompany Bi 108.

Bi 110. General Microbiology. 9 units (2-4-3).

Prerequisites: Bi 2; Bi 107a.

A course dealing with 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 111. Histological Technique. 3 units; first term.

This subject is the same as Bi 11, but with reduced credit for graduate students. Graduate students majoring in Biology receive no credit for this subject.

Instructor: Tyler.

Bi 112. Histology. 4 units; second term.

Prerequisite: Bi 4.

This subject is the same as Bi 12, but with reduced credit for graduate students. Graduate students majoring in Biology receive no credit for this subject.

Instructor: Tyler.

Bi 113. Mammalian Anatomy. 3 units; first term.

Prerequisite: Bi 4.

This subject is the same as Bi 13, but with reduced credit for graduate students. Graduate students majoring in Biology receive no credit for this subject.

Instructors: Van Harreveld, Keighley.

Bi 114. Immunology. 10 units (2-4-4); third term.

Prerequisites: Bi 2, Ch 41 abc.

A course on the principles and methods of immunology and their application to various biological problems. Some previous knowledge of biochemistry and embryology is desirable.

Instructors: Emerson, Owen.

Bi 116 abc. Animal Physiology. 8 units (2-3-3); first, second, third terms.

Prerequisites: Bi 4, Bi 13, Ch 41 to be taken simultaneously or previously.

A survey of comparative and mammalian physiology.

Instructors: Wiersma, Van Harreveld.

Bi 126. Chemical Genetics. 6 units (2-0-4); third term.

Prerequisites: Bi 107 and Bi 108.

A course dealing with chemical genetics, especially in Neurospora. Required of all graduate students majoring or minoring in Genetics. May be taken by seniors as a Biology elective.

Instructors: Horowitz, Beadle.

Bi 127. Chemical Genetics Laboratory. 3 or 6 units (0-3-0) or (0-6-0); third term.

A laboratory course dealing especially with Neurospora, to be taken concurrently with Bi 126. May be taken by seniors as a Biology elective.

Instructors: Horowitz, Beadle.

B. Subjects primarily for graduate students:

Bi 201. Biology Seminar. 1 unit.

Meets weekly for reports on current research of general biological interest by members of the Institute Staff and visiting scientists.

In charge: Bonner, Van Harreveld.

Bi 202. Biochemistry Seminar. 1 unit.

A seminar throughout the academic year on special selected topics and on recent advances.

In charge: Bonner, Horowitz.

Bi 204. Genetics Seminar. 1 unit.

Reports and discussion on special topics.

In charge: Anderson.

Bi 205. Experimental Embryology Seminar. 1 unit.

Reports on special topics in the field; meets twice monthly.

In charge: Tyler.

Bi 206. Immunology Seminar. 1 unit.

Reports and discussions; meets twice monthly.

In charge: Tyler, Owen.

Bi 207. Biophysics Seminar. 1 unit.

A seminar throughout the academic year 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.

In charge: 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 which have special interest from a biological viewpoint.

Instructor: Haagen-Smit.

Bi 217. Quantitative Organic Microanalysis. Units based on work done (0-20-0); 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 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 alternat› years.

Instructor: Tyler.

Bi 221. Experimental Embryology Laboratory. Units to be decided by student and instructor: Given any term.

The work will include certain classical experiments and instruction in the methods of studying embryonic metabolism, in transplantation, vital staining, cytochemistry, etc.

Instructor: Tyler.

Bi 225. Special Topics in Genetics. 6 units (2-0-4); second term.

Special subjects in genetics will be treated in detail. The material in this course will not ordinarily be duplicated in a period of three years, and students majoring in Genetics will be expected to register for at least five terms.

Instructors: Beadle, Sturtevant, Anderson, Emerson, Delbrück, Horowitz, Lewis, Owen, Novitski.

Bi 240 abc. Plant Physiology. 6 units (2-0-4); first, second and third terms.

Reading and discussion of the problems of plant physiology.

Instructors: Went, Bonner, Galston.

Bi 241 abc. Plant Chemistry. 6 units (2-3-1); first, second and thirds terms.

A survey of the biochemistry of higher plants with selected laboratory exercises.

Instructor: Bonner.

Bi 242 abc. Physical Factors and Plant Growth. 6 units (2-0-4); first, second and third terms.

Prerequisite: Bi 5 abc.

Discussion of the physical factors such as temperature, light and humidity on growth and development of plants. This course is intended as an introduction to work in the Earhart Plant Research Laboratory.

Instructor: Went.

Bi 260 abc. Advanced Physiology. Units to be arranged. First, second and third terms.

A subject in the methods of physiology, with special reference to nerve and muscle, with opportunity for research.

Instructors: Wiersma, Van Harreveld.

Bi 280-288. Biological Research.

Students may register for research in the following fields, the number of units to be determined by 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).

CHEMISTRY AND CHEMICAL ENGINEERING

UNDERGRADUATE SUBJECTS

Ch 1 abc. Inorganic Chemistry, Qualitative Analysis. 12 units (3-6-3); first, second, third terms.

Lectures, recitations, and laboratory exercises dealing with the general principles of chemistry. The first and second terms are devoted to the preparation and properties of subtances and to the fundamental laws and theories of chemistry. The subject matter for the third term is qualitative analysis of the common metals.

Text: *General Chemistry*, Pauling.

Instructors: Pauling, Davidson and Assistants.

Ch 11. Quantitative Chemical Analysis. 10 units (2-6-2); second term.

Prerequisite: Ch 1 c.

Laboratory practice in typical methods of gravimetric and volumetric analysis, supplemented by lectures and problems emphasizing the principles involved.

Text: *Introductory Quantitative Analysis*, Swift.

Instructor: Swift.

Ch 12 ab. Analytical Chemistry. 10 units (2-6-2); first, second terms.

Prerequisite: Ch 1 c.

Laboratory practice in the methods of gravimetric and volumetric, and advanced qualitative analysis, supplemented by lectures and problems in which the principles involved in the laboratory work are emphasized.

Text: *Introductory Quantitative Analysis*, Swift.

Instructor: Swift.

Ch 12 c. Analytical Chemistry and Chemistry Review. 10 units (2-6-2); third term.

Prerequisite: Ch 12 b.

Advanced qualitative analysis and a study of special methods of chemical analysis, including electrometric methods. Analysis of selected alloys, minerals, and other materials will be made. Students may be assigned individual problems for investigation. The class exercises are devoted to a discussion and review of the general principles of analytical and inorganic chemistry. The examination in this subject covers the chemistry work of the whole sophomore year.

Text: *A System of Chemical Analysis*, Swift.

Instructor: Swift.

Ch 13 abc. Inorganic Chemistry. 6 units (2-0-4); first, second, third terms.

Prerequisites: Ch 12 b, 21 ab.

The chemical and physical properties of the elements are discussed with reference to the periodic system and from the view-points 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 16. Instrumental Analysis. 8 units (0-6-2); first term.

Prerequisite: Ch 12 c.

Laboratory practice designed to familiarize the student with special analytical apparatus and methods, used both for process control and for research.

Instructor: Sturdivant.

Ch 21 abc. Physical Chemistry. 10 units (4-0-6); first, second, third terms.

Prerequisites: Ch 12 ab or Ch 11; 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 electro-chemistry. A large number of problems are assigned to be solved by the student.

Text: Mimeographed notes.

Instructors: Bates, Badger.

Ch 24 ab. Physical Chemistry. 10 units (4-0-6); first, second terms.

Prerequisites: Ch 12 ab; 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 12 ab, Ch 21 a.

Text: Mimeographed Notes.

Instructor: Badger.

Ch 27 ab. Radioactivity and Isotopes. 6 units (2-0-4); first and second terms.

The fundamental particles and isotopes. Natural and artificial radioactivity. The applications of natural and artificial radioactive substances and isotopes to the study of chemical and biochemical reactions.

Instructors: Yost, Davidson.

Ch 41 abc. Organic Chemistry. 8 units (3-0-5); first, second, third terms.

Prerequisite: Ch 12.

Lectures and recitations treating of the classification of carbon compounds, the development of the fundamental theories, and the characteristic properties of the principal classes of carbon compounds.

Text: *Organic Chemistry*, Lucas.

Instructor: Lucas.

Ch 43. Organic Chemistry. 10 units (2-6-2); third term.

Prerequisite: Ch 1.

A discussion of selected topics in organic chemistry, adapted to the needs of Science Course students in the Physics Option.

Ch 46 abc. Organic Chemistry Laboratory. 6 units (0-6-0) first, second terms; 10 units (1-9-0) third term.

Prerequisite: Ch 12.

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: Lucas and Assistants.

Ch 47. Organic Chemistry Laboratory. 6 units (0-6-0); first term.

Prerequisite: Ch 12.

Similar to 46. Selected experiments for students of biology.

Text: *Principles and Practice in Organic Chemistry*, Lucas and Pressman.

Instructors: Lucas and Assistants.

Ch 61. Industrial Chemistry. 12 units (4-0-8) first term.

Prerequisite: Ch 21 a.

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.

Text: *Chemical Process Industries*, Shreve.

Instructor: Mason.

Ch 63 ab. Chemical Engineering Thermodynamics. 12 units (4-0-8); second and third 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.

Ch 80-86. Chemical Research.

Opportunities for research in analytical and inorganic chemistry (80), physical chemistry (82), and organic chemistry (84) are offered to candidates for the degree of Bachelor of Science.

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 view-points; 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 122. Thermodynamic Chemistry. 6 units (2-0-4); first term.

Prerequisites: Ch 12 ab or Ch 11; Ph 2 abc; Ma 2 abc or the equivalent; a year's course in Physical Chemistry.

This subject is for students who have studied physical chemistry but wish to review the elements of thermodynamics. It covers substantially the same topics as does Ch 21 a. This course is not open for credit to students who already have credit for Ch 21 a or Ch 24 a.

Text: Mimeographed notes.

Instructor: Bates.

Ch 123. Thermodynamic Chemistry. 6 units (2-0-4); second term.

Prerequisities: Ch 21 abc, or Ch 122 or the equivalent.

This course deals chiefly with applications of thermodynamic principles. Practice is given in the computation of free energies, entropies, and activities of typical chemical substances, and in the relations of these to various physical and chemical phenomena.

Instructor: Bates.

Ch 127 ab. Radioactivity and Isotopes. 4 units (2-0-2); first and second terms.

This course is the same as Ch 27.

Instructors: Yost, Davidson.

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 to the general principles relating to disperse systems with particular reference to the colloidal state.

Instructor: Badger.

Ch 130. Photochemistry. 6 units (2-0-4); third term.

Prerequisite: Ch 21.

Lectures and discussions on photochemical processes, especially in their relation to quantum phenomena. The following topics will be 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 148 abc. Advanced Organic Chemistry. 4 units (2-0-2); first, second, third terms.

Prerequisites: Ch 41, Ch 46.

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. Advanced Organic Chemistry Laboratory. 6 units (0-6-0); first, second and third terms.

Prerequisites: Ch 41, Ch 46, 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 163 ab. Chemical Engineering Thermodynamics. 8 units second and third terms.

Prerequisites: Ch 21 or ME 15.

This subject is the same as Ch 63 ab, but with reduced credit for graduate students. No graduate credit is given for this subject to students in chemistry or chemical engineering.

Ch 166 abc. Chemical Engineering. 12 units (3-0-9); first, second, third terms.

Prerequisites: Ch 61, Ch 63 ab.

Calculations and discussions designed to bring the student in touch with the problems involved in carrying out chemical reactions efficiently on a commercial scale. The unit operations of chemical industry (such as materials transfer, heat transfer, mixing, filtration, distillation) are studied both as to principle and practice.

Text: *Principles of Chemical Engineering*, Walker, Lewis, McAdams, and Gilliland.

Instructor: Lacey.

Ch 167 abc. Chemical Engineering Laboratory. 15 units (0-15-0); first, second, third terms.

Prerequisites: Ch 21, Ch 61, Ch 63.

A course in laboratory work to give training in the methods and technique fundamental to engineering measurements and to research encountered by the chemical engineer.

Instructors: Sage and Schlinger.

Ch 168 ab. Mechanics of Fluid Flow. 8 units (2-0-6); second, third terms.

Prerequisite: Ch 166 a.

Consideration is given to the flow of compressible and incompressible fluids in conduits from the standpoint of the more recent theories of fluid mechanics. Emphasis is placed upon the estimation of velocity and pressure distributions and the friction associated with the flow of fluids under conditions of known geometric restraint.

Instructor: Sage.

Ch 180-186. Chemical Research.

Opportunities for research in analytical and inorganic chemistry (180), physical chemistry (182), organic chemistry (184), and applied chemistry and chemical engineering (186) are offered to candidates for the degree of Master of Science. The main lines of research in progress are tabulated under Ch 280-286.

Ch 221 abc. The Nature of the Chemical Bond (Seminar). 6 units (2-0-4); first, second, third terms.

This subject comprises the detailed non-mathematical discussion of the electronic structure of molecules and its correlation with the chemical and physical properties of substances.

Given every third year. Offered in 1950-51.

Text: *The Nature of the Chemical Bond,* Pauling.

In Charge: Pauling, Schomaker.

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. The interpretation of phase transitions as cooperative phenomena in aggregates of molecules is presented. In the third term the statistical mechanics of systems departing from equilibrium is developed, and the transport process, diffusion, heat transfer, and viscous fluid flow are analyzed in the light of current theories.

Given every other year. Offered in 1949-50.

Instructor: Kirkwood.

Ch 225 abc. Advanced Chemical Thermodynamics. 9 units (3-0-6); first, second, third terms.

Prerequisite: Ch 21 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 to systems under the influence of external gravitational, electric, and magnetic fields. Problems.

Given in alternate years. Offered in 1950-51.

Instructor: Kirkwood.

Ch 226 abc. Introduction to Quantum Mechanics, with Chemical Applications. 9 units (3-0-6); first, second, third terms.

A review of 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 equations, 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 every third year. Offered in 1949-50.

Text: *Introduction to Quantum Mechanics, with Applications to Chemistry,* Pauling and Wilson.

Instructors: Pauling, Kirkwood.

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 every third year. Offered in 1949-50.

Instructor: Sturdivant.

Ch 229. Diffraction Methods of Determining the Structure of Molecules. 6 units (2-0-4).

A discussion of the diffraction of X-rays and electrons by gases, liquids, glasses, and crystals.

Given every third year. Offered in 1948-49.

Instructors: Schomaker, Hughes, Sturdivant.

Ch 233 ab. The Metallic State. 6 units (2-0-4); first and 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; first term.

The theory of the structure of the spectra of both the diatomic and the 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 1949-50.

Instructor: Badger.

Ch 243. Quantitative Organic Microanalysis. Units based on work done; any term by arrangement.

Prerequisite: Consent of instructor.

Laboratory practice in the methods of quantitative organic microanalysis required for the structure determinations of organic compounds.

Instructor: Haagen-Smit.

Ch 244 abc. The Reactions of Organic Compounds. 4 units (2-0-2); first, second, third terms.

Prerequisites: Ch 41, Ch 46.

A consideration of the typical reactions exhibited by certain classes of organic compounds with particular reference to reaction mechanisms.

Given every third year. Offered in 1948-49.

Instructors: Lucas, Niemann.

Ch 250 abc. Selected Chapters of Organic Chemistry. 2 units (2-0-0); first, second, third terms.

Prerequisite: Ch 41.

Topics considered have included chromatography, fats, steroids, sex hormones, simple heterocyclic compounds and alkaloids, chlorophyll, carotenoids, anthocyanins, flavones, pterins, bile pigments; structure and physiological action; chemistry of the chemotherapeutics and of the insecticides; detoxification processes, nitrogen metabolism, carbohydrate metabolism, nucleic acids, and history of organic chemistry.

Instructor: Zechmeister.

Ch 252 abc. The Chemistry of the Carbohydrates. 3 units (1-0-2); first, second, third terms.

Prerequisites: Ch 41, Ch 46.

Lectures and discussions on the chemistry of the mono-, di-, and polysaccharides.

Given every third year. Offered 1950-51.

Instructor: Niemann.

Ch 254 abc. The Chemistry of the Amino Acids and Proteins. 3 units (1-0-2); first, second, third terms.

Prerequisite: Ch 41, Ch 46.

A consideration of the physical and chemical properties of the amino acids, peptides, and proteins.

Given every third year. Offered in 1949-50.

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 (3-3-2); second term.

Prerequisite: Consent of instructor.

After a discussion of the techniques of immunology, a detailed presentation is given of the properties of antisera, serological reactions, hypersensitivity, and immunity and resistance to disease. The laboratory work covers techniques and methods involved in the study of antigen-antibody reactions with emphasis on the quantitative aspects of serological reactions.

Instructor: Campbell.

Ch 260. Volumetric and Phase Behavior in Fluid Systems. 6 units (2-0-4); first term.

Prerequisite: Ch 21.

A discussion of pure substances and of binary, ternary, and multicomponent systems restricted primarily to liquid and gas phases. Problem work relating to the prediction of behavior in relation to pressure, temperature, and composition is included.

Text: *Volumetric and Phase Behavior of Hydrocarbons*, Sage and Lacey.

Instructor: Sage.

Ch 261. Phase Equilibria in Applied Chemistry. 6 units (2-0-4); first term.

Prerequisites: Ch 21, Ch 61.

Problems and discussions relating to industrial applications involving heterogeneous equilibria, primarily in the quantitative treatment of solid-liquid systems.

Instructor: Lacey.

Ch 262 ab. Thermodynamics of Multi-Component Systems. 8 units (2-0-6); second and third terms.

Prerequisite: Ch 166, AM 15 ab or equivalent.

A presentation of the background necessary for a working knowledge of the thermodynamics of multicomponent systems from the engineering viewpoint. The work includes numerous problems relating to the application of these principles to industrial practice.

Instructor: Sage.

Ch 263 abc. Thermal Transfer in Fluid Systems. 8 units (2-0-6); first, second, third terms.

Given in alternate years. Offered in 1949-50.

Prerequisites: Ch 166, AM 15 ab or equivalent.

A consideration of thermal transfer in fluid systems under conditions encountered in practice. Emphasis is placed upon the analogy between momentum and thermal transfers. The greater part of the effort of the course is devoted to the solution of thermal transfer problems many of which require the use of graphical or numerical methods of solution of the differential equations involved.

Instructor: Sage.

Ch 264 abc. Material Transfer in Fluid Systems. 8 units (2-0-6); first, second, third terms.

Given in alternate years. Offered in 1948-49.

Prerequisites: Ch 166, AM 15 ab or equivalent.

Treatment of diffusion processes under conditions of industrial interest followed by consideration of material transfer in fluid systems under both laminar and turbulent flow conditions. Emphasis is placed upon the analogy between momentum and material transfer in such systems.

Instructor: Sage.

Ch 265 ab. Combustion in Homogeneous Systems. 8 units (2-0-6); second and third terms.

Given in alternate years. Offered in 1949-50.

Prerequisites: Ch 166, Ch 262.

The problems of thermodynamic equilibrium and the influence of reaction kinetics in combustion processes is first considered. This is followed by a treatment of the influence of the physical environment upon the combustion process.

Instructors: Mason and Sage.

Ch 280-286. Chemical Research.

Opportunities for research are offered to graduate students in all the main branches of chemistry; namely, in analytical and inorganic chemistry (280), physical chemistry (282). organic chemistry (284), immunochemistry (285), and applied chemistry and chemical engineering (286).

The main lines of research now in progress are:

(In physical and inorganic chemistry)

The free energies, equilibria, and electrode-potentials of reactions.
Distribution of chemical compounds between immiscible phases.
Studies of analytical methods.
The crystal structure of amino acids, peptides, and proteins.
The kinetics of chemical reactions including photochemical reactions.
The study of crystal structure and molecular structure by diffraction of X-rays and electrons.
The application of quantum mechanics to chemical problems.
The study of molecular structure and of chemical problems by spectroscopic methods.
The diamagnetic anisotropy of crystals.
The nature of the metallic bond and the structure of metals and intermetallic compounds.
Studies of radioactivity.
Studies of the transuranic elements.
The application of physical methods to the study of proteins and other high molecular weight substances.

(In organic chemistry and immunochemistry)

Chemotherapy of parasitic diseases.
Isolation and structure of alkaloids.
The synthesis of cyclobutadiene and related substances.
The chemistry of carotenoids and other plant pigments.
The use of chromatographic methods of analysis and separation of stereoisomers.
Diphenylpolyenes.
Configuration and vitamin A potency.
Fluorescing compounds in the vegetable kingdom including micro organisms.
The Walden inversion.
Kinetics and equilibria involving addition to unsaturated compounds.
Coordination reactions of unsaturated compounds.
Sulfinyl and phosphinyl chlorides.
The chemistry of protozoa.
The study of plant hormones and related substances of physiological importance.
Studies on the constitution of the phosphatides and cerebrosides.
The chemistry of amino acids and peptides.
Studies on mammalian and bacterial polysaccharides including the blood group specific substances.
Studies on the enzymatic cleavage and formation of amide bonds.
The mechanism of antigen-antibody reactions and the structure of antibodies.
The isolation and characterization of cellular antigens.
The functional significance of antibodies.
The chemical and physical properties of blood.
The nature of sickle cell anemia and some other diseases.

(In applied chemistry and chemical engineering)

The influence of turbulence upon heat transfer in fluids.
The influence of turbulence on the transfer of material through fluids.
Phase and thermodynamic behavior of hydrocarbons and other fluids.
Gas phase combustion.

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, inorganic chemistry, crystal structure, organic chemistry) are also held.

CIVIL ENGINEERING

UNDERGRADUATE SUBJECTS

CE 1. Surveying. 9 units (2-4-3); first or second terms.
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 surveys, calculation and balancing of traverses, use of calculating machines, topographic mapping and field methods.

Text: *Elementary Plane Surveying,* Davis.

Instructor: Michael.

CE 2. Advanced Surveying. 10 units (1-7-2); third term.

Prerequisite: CE 1.

A continuation of CE 1, covering topographic surveys, plane table surveys, base line measurements, triangulation, determination of latitude and a true meredian by sun and circumpolar star observations, curves, cross-section surveys and earthwork estimates, stream gauging, draughting room methods and mapping, and the solution of problems.
Instructor: Michael.

CE 3. Plane Table Surveying. 8 units (1-6-1); third term.
A subject offered primarily for students in geology but may be elected by arrangement with the department. Theory and use of the plane table as applied to geological surveys. The class devotes one entire day a week to field surveys over typical terrain completing a topographic and geological map of the region covered.

Text: *Elementary Plane Surveying,* Davis.
Instructor: Michael.

CE 4 Highways and Airports. 10 units (2-4-4); second term.
A comparison of various types of highway construction; the design, construction and maintenance of roads and pavements. An introduction to airport design.
Text: *Highway Design and Construction,* Bruce and Clarkeson.
Instructor: Michael.

CE 6. Transportation Engineering. 6 units (2-0-4); first term.
Prerequisite: CE 1.

A study of economic railway location and operation; waterways and motor traffic; railway plant and equipment; signaling; the solution of grade problems.

Text: *Elements of Railroad Engineering,* Raymond, Riggs, Sadler.
Instructor: Thomas.

CE 7. Curves and Earthwork. 6 units (2-0-4); second term.
Prerequisite: CE 1.

The theory of railway, highway and ditch location and surveys; problems relating to curves, grades, earthwork and track layout, including a study of the mass diagram as applied to railway and highway earthwork.

Text: *Route Surveys,* Skelton.
Instructor: Michael.

CE 8. Route Surveying. 7 units (0-7-0); first term.
Prerequisite: CE 7

The class devotes one entire day a week to field surveys of a route location, applying the principles as outlined under course CE 7.

Text: *Route Surveys,* Skelton.
Instructor: Michael.

(1-4-1)

CE 9 ab. Route Eurveying Problems. 6 units (2-0-4); 2nd and 3rd term senior year.
Selected problems in advanced surveying, curves and earthwork and route surveying.
Instructor: Michael.

CE 10 abc. Theory of Structures. 12 units (3-3-6) first, second terms; 9 units (3-0-6) third term.

Prerequisite: AM 1 c.

Methods used in the calculation of stresses in beams, girders, and columns; study of the effects of moving load systems; graphic statics applied to roofs 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.

Instructor: Martel.

CE 12. Reinforced Concrete. 12 units (3-3-6); third term.

Prerequisites: AM 1 c, 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; 1 unit (1-0-0) 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: McCrery, Michael.

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 purposes; and to the problems of collection, treatment, and disposal of municipal sewage and liquid industrial wastes.

Instructor: McKee.

FIFTH-YEAR AND ADVANCED SUBJECTS

CE 120 a. Statically Indeterminate Structures. 12 units (4-3-5); first term.

Prerequisites: CE 10 abc, 12.

A study of such structures as continuous spans, rigid frames and arches by the methods of least work or slope-deflections; analysis of secondary stresses.

Text: *Continuous Frames of Reinforced Concrete,* Cross and Morgan.

Instructor: Martel.

CE 120 bc. Statically Indeterminate Structures. Units to be based upon work done; 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 a. Structural Design. 12 units (0-12-0); one term.

Prerequisites: CE 10 abc, 12.

The design of a plate girder bridge and a truss bridge or a steel frame building; stress sheets and general drawings are made. Designing office practice is followed as affecting both computations and drawings.

Instructor: McCormick.

CE 121 b. Structural Design. 9 units (0-9-0); one term.

Prerequisites: CE 10 abc, 12.

The design of a reinforced concrete building in accordance with a selected building ordinance, with computations and drawings.

Instructors: Martel, McCormick.

CE 121 c. Civil Engineering Design. 9 units (0-9-0); one term.

Prerequisite: CE 125.

Special problems including preliminary investigations of irrigation or water power projects; study of stream flow data, the effect of reservoir storage upon distributed flow, determination of size and type of economic development.

Instructors: McCormick, McKee.

CE 122. Earthquake Effects upon Structures. Units to be based upon work done; 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 125. ~~Irrigation and Water Supply~~. ~~12~~ units (4-0-8); second term.

Prerequisites: Hy 2 ab; Hy 11.

A study of the modern practice of the collection, storage, purification and distribution of water for municipal, domestic and irrigation uses; design, construction and operation of systems; consideration of the conditions adapted to irrigation developments, dams, reservoirs, canals; laws pertaining to irrigation; the economic aspects of projects.

Instructor: McKee.

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.

Text: ~~*Design of Masonry Structures*, Williams.~~

Instructors: Martel, McCormick.

CE 127. Sewerage and Sewage Treatment. ~~9~~ units (2-3-4); second or third terms.

Prerequisite: CE 125.

A study of systems for the collection and treatment of sewage, the design of sewers and storm drains; characteristics of various treatment processes; factors affecting treatment plant design; inspection of local plants.

Instructor: McKee.

CE 130 ab. Engineering Seminar. ~~2~~ units ~~(1-0-1)~~; ~~first~~ term; ~~4~~ units ~~(1-0-3)~~, 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 131 ab. Advanced Study in Sewerage and Sewage Treatment. Units to be based upon work done; any term.

Prerequisite: CE 127.

A study of the mechanisms of sewage treatment processes with particular reference to the effects of pollution on the receiving water course or other body of water.

Instructor: McKee.

CE 131 c. Sewage Treatment Plant Design. Units to be based upon work done; any term.

A design of treatment works for a selected community and site involving special conditions of location, volume, and requirements for disposal. Includes selection of type of treatment, arrangement of tanks and equipment, and general design of structures.

Instructor: McKee.

CE 132. Water Power Plant Design. Units to be based upon work done; any term.

A design of a power plant in conformity with the conditions of head, flow, and load fluctuations at a particular site. Includes selection of number and type of units, design of water passages and general structural features.

Instructor: Thomas.

CE 133 ab. Advanced Study in Water Supply and Treatment. Units to be based upon work done; any term.

Prerequisite: CE 125.

A more detailed study of methods of hydrology, water supply, treatment, and control of water quality.

Instructor: McKee.

CE 133 c. Water Treatment Plant Design. Units to be based upon work done; any term.

Preparation of a layout and design of the general features of a plant to effect the purification and softening of water as may be required in specific circumstances. Includes design of typical structural features of the plant.

Instructor: McKee.

CE 134. Ground Water Investigations. Units to be based upon work done; any term.

A study of the relation between rainfall, runoff, percolation, and accumulations of ground water. Investigation of the location, extent, and yield of underground reservoirs.

Instructor: Thomas.

CE 135. Geodesy and Precise Surveying. Units to be based upon work done; any term.

Methods of triangulation and surveying over extended areas. The adjustment of triangulation systems, the adjustment of observations by the method of least squares. Map projections, precise leveling determination of a true meridian.

Instructor: Michael.

CE 136. Irrigation Investigations. Units to be arranged.

Prerequisite: CE 125.

Investigation of irrigation methods and practices and the presentation of reports.

Instructor: Thomas.

CE 141. Structural Engineering Research. Units to be based upon work done; any term.

Selected problems and investigations to meet the needs of advanced students.

Instructor: Martel.

CE 142. Sanitation Research. Units to be based upon work done; any term.

Exceptional opportunities for advanced study in the fields of water and sewage treatment are available at the numerous plants located in this locality.

Instructor: McKee.

CE 143. Highway Research. Units to be based upon work done; any term.

Cooperating with the Highway Research Board of the National Research Council, opportunities are offered for advanced studies in highway engineering. Arrangements may be made for special studies on subgrade materials, wearing surfaces, economics of vehicle operation, and allied subjects.

Instructor: Michael.

CE 144. Airport Design. Units to be based upon work done; any term.
Prerequisite: CE 4.

Preparation of a layout and design of an airport, including studies of a proposed site, surface and subsurface drainage; runway, and taxiway. Design of base courses and runways surfaces. Accessory structures and lighting.

Instructor: Michael.

CE 150. Foundations. 6 or more units as arranged ;(3-0-6) third term.
Prerequisite: AM 105 ab.

Types and methods of construction of foundations for buildings, bridges, and other major structures. Spread footings and foundation slabs, piles and pile driving equipment, open and pnuematic caissons, cofferdams, underpinning, methods of exploration.

Instructor: Converse.

CE 155. Advanced Hydrology. 6 or more units as arranged; any term.
Prerequisite: CE 125.

Detailed studies of climatology, precipitation, run-off, evaporation, transpiration, flood flows, flood forecasting and flood routing, with special emphasis on statistical analysis.

Instructor: McKee.

CE 156. Industrial Wastes. 6 or more units as arranged; any term.
Prerequisite: CE 127.

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.

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 1 abc. General Economics and Economic Problems. 6 units (3-0-3); first, second, third terms.

A course in economic life and institutions, the principles underlying them, and the major problems they present. Subjects studied include production, exchange, distribution, money and banking, the economic activities and policies of government, and international trade.

Instructors: Brockie, Untereiner, Sweezy.

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 1 ab, with such difference in emphasis as is necessary to make this shorter course complete in itself. Students who have satisfactorily completed the two terms of Ec 4 may register for the third term of Ec 1 as an elective.

Instructors: Brockie, Untereiner, Sweezy.

Ec 18. Industrial Organization. 7 units (3-0-4); first 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: Brockie, Gray.

Ec 25. Engineering Law. 7 units (3-0-4); second term.

The law of business, with particular emphasis on the legal rights and obligations pertaining most directly to the engineering profession. Contracts and specifications, agency, property, mechanics liens, workmen's compensation, and the principles of legal liability are studied.

Instructor: Untereiner.

Ec 48. Introduction to Industrial Relations* 9 units (3-0-6).

Senior Elective.

This course stresses the personnel and industrial relations functions and responsibilities of supervisors and executives. The history, organization, and activities of unions and the provisions of current labor legislation are included. The relationships of a supervisor or executive with his employees, his associates, and his superiors are analyzed, and the services which he may receive from the personnel department are examined. The course also discusses the use of basic tools of supervision.

Instructor: Gray.

FIFTH YEAR AND 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 fourth year Humanities electives to be offered in any given term will be scheduled before the close of the preceding term.

The broad assumptions in the course are that technical training is an excellent approach to positions of general responsibility in business and industry, and that technically trained men going into industry can make significant contributions to the improved functioning of the economy.

The principal divisions of the subject matter of the 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.

Instructors: Gilbert, Kinard.

Ec 106 abc. Business Economics (Seminar). Units by arrangement; first, second, third terms.

Open to graduate students.

This seminar is intended to assist the occasional graduate student who wishes to do special work in some part of the field of business economics or industrial relations. Special permission to register for this course must be secured from the instructors.

Instructors: Gilbert, Gray.

Ec 110. Industrial Relations. 9 units (3-0-6); first term.

Not open to students who have taken Ec 48, Introduction to Industrial Relations.

An introductory course dealing with the 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.

Instructors: Gray, Arthur H. Young.

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 economic equilibrium.

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: Untereiner.

Ec 115 abc. Industrial Administration. 9 units (3-0-6); first, second, third terms.

Emphasis in this course is on the discussion and working out of administrative problems in all areas and at all levels of management. Extensive use is made of the case method, which may be briefly described as analysis and determination of appropriate action for actual business situations as they confront those who must make managerial decisions.

Cases will be the basis of both numerous written reports and examinations.

Instructor: Kinard.

Ec 120 abc. Money, Income, and Employment. 9 units (3-0-6); first second, third terms.

Brief introduction to accounting; analysis of money in the modern economy and the relation of the banking system to the money supply; the determinants of national income: consumption, savings, investment, government spending, and the tax structure; analysis of the flow of money against goods and the behavior of prices and wages with fluctuations in economic activity; the problem of maintaining full employment; international trade and finance and their impact on the domestic economy.

Instructor: Sweezy.

ELECTRICAL ENGINEERING

UNDERGRADUATE SUBJECTS

EE 1 abc. Basic Electrical Engineering. 6 units (2-0-4); EE 1a first term only, EE 1 bc second or third terms.

Prerequisites: Ma 2 abc; Ph 2 abc.

An introductory study of electric and magnetic fields and circuits, electromagnets, direct and alternating current machinery and electronic devices.

Instructors: Maxstadt, Pickering and Assistants.

EE 2 abc. Basic Electrical Engineering Laboratory. 3 units (0-3-0); first, second, third terms.

Prerequisites: Ma 2 abc; Ph 2 abc.

This course is the laboratory for the corresponding EE 1 course. Use of measuring instruments, operation of direct and alternating current machinery and determination of their characteristics and instrumentation of electronic circuits.

Text: *Laboratory Notes.*

Instructors: Maxstadt, Pickering and Assistants.

EE 6 ab. Electrical Machinery. 6 units (2-0-4) second term; 9 units (3-0-6) third term.

Prerequisites: EE 1 abc; EE 2 abc; and EE 12.

Windings, special characteristics, graphical methods, commutation, machine reactances, and short circuit currents. System stability; short transmission lines.

Instructor: Sorensen.

EE 7. Electrical Engineering Laboratory. 7 units (0-3-4); third term.

Prerequisites: EE 1 abc; EE 2 abc; and enrollment in EE 6.

A continuation of EE 2 abc. Efficiency tests of alternating current machinery. Graphic analysis of alternator performance; operation of tranformers and alternators in parallel; communication circuit testing; use of electronic devices; writing of engineering test reports.

Text: *Laboratory Notes.*

Instructors: Maxstadt and Assistants.

EE 12. Electric Circuits. 12 units (4-0-8); first term.

Prerequisites: EE 1 abc; EE 2 abc.

A course of study relating to the calculation of voltage, current, and power in electrical power and electronic circuits, including an introductory study of filter circuits. In all of these studies free use is made of the symbolic or complex method of solving problems using Kirchoff's laws, Thevenin's theorem and other special methods of calculation.

Text: *Alternating Current Circuits,* Kerchner and Corcoran.

Instructors: McCann and Assistants.

EE 15 ab. High Frequency Circuits. 6 units (2-0-4) second term; (0-3-3) third term.

Prerequisites: Ph 7 or Ph 8; EE 62 to be taken concurrently.

Maxwell's equations, electromagnetic fields, generation and propagation of microwaves. Laboratory experiments illustrating microwave phenomena.

Instructors: Pickering and Assistants.

EE 16. Electrical Measurements. 6 units (0-3-3); first term.

Prerequisites: Ph 2 abc; EE 1 abc; EE 12 (which may be taken simultaneously).

Advanced course in precision electrical measurements, measurements of impedance, voltage, current, etc. Estimation of experimental accuracy.

Text: *Laboratory Notes.*

Instructors: Pickering and Assistants.

EE 60 abc. Electronics and Circuits. 9 units (3-0-6; 2-3-4; 2-3-4); first, second, third terms.

Prerequisite: EE 1 abc.

Basic physics of vacuum tubes, electron ballistics, thermionic emmission, space charge effects, etc. Application of tubes and circuits to physical measurements.

Instructor: Nichols.

EE 62 ab. Electron Tubes. 10 units (2-3-5); second, third terms.

Prerequisites: EE 1 abc; EE 12.

Fundamental theory of electron tubes in radio, communication and control circuits.

Instructors: Pickering and Assistants.

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: McCrery, Sorensen.

FIFTH-YEAR SUBJECTS

EE 120 abc. Advanced Electric Power System Analysis. 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.

Texts: *Electrical Transmission and Distribution Reference Book* and *Course Notes.*

Instructors: McCann, Lindvall, and Sorensen.

EE 120 a. 12 units (4-0-8); first term.

Prerequisites: EE 6 ab; EE 7; EE 12.

Theory of symmetrical components and basic circuit theorems for reduction and simplification of power system networks. System fault calculations supplemented by a comprehensive power system fault study with the Electric Analog-Computer used as an AC-Network Analyzer.

EE 120 b. 12 units (4-0-8); second term.

Prerequisite: EE 120 a.

Analysis of transformer characteristics including development of sequence circuits for two and three winding transformer banks. Theory of synchronous and induction motors including transient analysis during system faults. Calculation of transmission line constants and their equivalent sequence circuits. General principles of circuit breaker and relay application.

EE 120 c. 12 units (4-0-8); third term.

Prerequisite: EE 120 b.

Development of generalized circuit constants for transmission lines and integrated systems. 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. Transient circuit analysis as applied to switching surge calculations. General discussion of the effects of system grounding on switching surge voltages. Basic principles of overvoltage protection against switching surges and lightning. AC-Network Analyzer techniques will be applied to actual calculations of transient stability and switching surge problems.

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 the 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 128. Electric Transportation. 9 units supervised reading course by assignment.

Prerequisites: EE 1 abc, EE 6 ab.

Modern electric and oil-electric railways, studies of the motive power, train requirements, frictional and other resistances, schedules, acceleration and braking; the portable power plant vs. substations and contact conductor. Safe speeds and riding qualities are studied.

Text: *Electric Transportation,* Thompson.
Instructor: Maxstadt.

EE 130. Electric Lighting and Power Distribution. 6 units supervised reading course by assignment.

Prerequisites: EE 1 abc, EE 6 ab.

Comparison of hydro with other forms of motive power for central power stations; bus layouts; protective circuit breakers, reactors and lightning arrestors. Distribution circuits; network transformers and protective devices; underground distribution. Economics of power and substation location. Costs.

Text: *Generating Stations,* Lovell; *Current Literature.*
Instructor: Maxstadt.

EE 148. Specifications and Design of Electrical Machinery. 6 units (3-0-3); first term.

Prerequisites: EE 7, and preceding subjects.

Preparation of specifications and design calculations for alternating and direct current machinery.

Text: *Electrical Machine Design,* Gray.
Instructor: Sorensen.

EE 152. Dielectrics. 6 units (2-0-4); third term.

Prerequisites: EE 120 ab, and preceding subjects.

A study of electric fields in insulations, particularly air, and the effects on sparking voltage of the sparking distance, atmospheric pressure and humidity; corona phenomena; high frequency voltages, characteristics of commercial insulations.

Instructor: Sorensen.

EE 156. Electric Communication. 6 units (2-0-4); first term.

Prerequisites: EE 12, EE 62 ab.

A study of selected topics in communication with special emphasis on recent developments.

Instructor: Pickering.

EE 157. Communications Laboratory. 6 units (0-3-3); first term.

Prerequisite: Must be taking or have taken EE 156.

Laboratory assignments in advanced communication problems.

Instructors: Pickering and Assistants.

EE 158 abc. Circuit Analysis. 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 12, EE 62 ab.

Transient analysis of linear networks; Laplace transform methods; generalized network analysis.

Instructor: Pickering.

EE 162 ab. Electron Tubes. 7 units; second and third terms.
Same as EE 62 ab with reduced units for chemical engineers.

EE 170 a. Servemechanisms. 9 units (3-0-6); second term.
Covers the theory and analysis of electrical, mechanical and hydraulic feedback and servomechanism systems.

EE 170 b. Servomechanisms. 12 units (2-3-7); third term.
A continuation of EE 170a with more advanced theoretical analysis of servomechanisms and the inclusion of a laboratory program with servo systems and computations of servo performances with the electric analog computer.
Instructors: McCann, Vazsonyi, Wilts.

EE 190 abc. Electromagnetic Fields. 9 units (3-0-6); first, second, third terms.
Prerequisites: EE 62, Ph 7 or Ph 8, EE 15.
Applications of Maxwell's equations to the generation and radiation of microwaves. Includes antenna problems, wave guides, cavity resonators, etc.
Instructor: Begovich.

EE 191. Ultra High Frequency Laboratory. 6 units (0-3-3); third term.
Prerequisite: EE 190, or be enrolled for it.
Laboratory measurements and use of ultra-high frequency equipment.
Instructors: Pickering and Assistants.

ADVANCED SUBJECTS

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 in the field of electricity. The Institute is equipped to an unusual degree for the following lines of work: Theory of Electrical Machine Design, Electrical Transients, and High Voltage Engineering Problems, under the direction of Professors R. W. Sorensen, F. C. Lindvall, and G. D. McCann; Electrical Engineering Problems relating to physical electronics, electronic devices and their application under the direction of Professors S. S. Mackeown, W. H. Pickering and M. H. Nichols; Engineering Analysis problems requiring large scale computer techniques, A.C. network techniques, Analog and Transient studies, etc., under the direction of Professor G. D. McCann. Problems relating to the distribution and uses of electric power for lighting and industrial uses; studies of light sources and illumination under the direction of Professor F. W. Maxstadt.

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: Maxstadt, Mackeown, Nichols, Pickering, Sorensen.

EE 223 abc. Electric Strength and Dielectrics. Units by arrangement; first, second, third terms. Not given every year.
A study of the effect of high potentials applied to dielectrics.
Instructor: Sorensen.

EE 224 abc. Vacuum Tube and Radio Frequency Circuits. Units to be based on work dane; first, second, third terms.
A study of the literature on vacuum tubes and associated circuits. Experimental work with oscillators, transmitters, and receivers.
Instructor: Mackeown.

EE 226 abc. Engineering Mathematical Physics. 15 units (3-0-12); first, second, third terms.
Prerequisites: Differential Equations or AM 15 or 115.
This subject is designed to develop the correlation of mathematics and physics with problems in engineering design and application. The following subjects will be treated in detail: mechanical vibrations, oscillations in electro-mechanical systems, short circuit forces, power system transients, electric motors aapplied to variable or pulsating loads, heat transfer and transient heat flow. The principle of constant flux linkage in electrical transient analysis; solution of mechanical problems by electrical methods; application of Heaviside operational calculus to mechanical and thermal problems.
Instructors: Lindvall, MacNeal.

EE 228 abc. Conduction of Electricity in Gases and Solids. Units to be arranged; first, second, third terms. Not given every year.

Fundamental physical processes underlying electrical conduction, with examples from flow, arc, and spark discharges, rectifiers (gaseous and solid), conductors, insulators, and semi-conductors.

Instructor: Wooldridge.

EE 230. Microwave Electronics. 9 units (3-0-6); third term.

The behavior of vacuum tubes at ultra-high frequencies, electron transit time effects, microwave oscillators.

Instructor: Pickering.

EE 232 abc. Advanced Problems in Modern Radio Engineering. 8 units (2-0-6); first, second, third terms. Given in alternate years.

Prerequisites: EE 15 ab, EE 62 ab, Ph 7, Ph 8, or Ph 131 abc.

A case-problem course treating frontier problems in antennas, electron tubes, random phenomena and signal-noise ratio, and complex radio systems. Order-of-magnitude estimates are emphasized for many important phenomena not yet susceptible to complete analytical solution.

Instructor: Ramo.

EE 234 abc. Radio Engineering. 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 15 ab, EE 60 abc, EE 62 ab, or EE 190.

An advanced lecture and problem course covering most important aspects of modern radio engineering for students who have completed a first course.

Instructor: Ramo.

ENGINEERING DRAFTING

D 1 a. Freehand Drawing. 3 units (0-3-0); first term.

The study of geometrical forms and their representation by means of freehand orthographic and perspective drawings. Training in pencil rendering is given and the fundamental principles of perspecttve are illustrated by simple engineering studies and the use of machine parts. Emphasis is placed on careful observation and accurate drawing.

Instructors: Wilcox and Assistants.

D 1 b. Engineering Drafting. 3 units (0-3-0); second term.

Prerequisite: D 1 a.

This course is designed to give the student a general knowledge of the most important types of engineering drawings and to develop his ability to visualize in three dimensions. Instruction is given in the proper use of drafting equipment and lettering and in the fundamental principles of orthographic projection.

Text: *Engineering Drawing,* French.

Instructors: Campbell, Welch, Wilcox.

D 1 c. Engineering Drafting. 3 units (0-3-0); third term.

Prerequisite: D 1 ab.

A continuation of D 1 b. Emphasis is placed on the application of the techniques of engineering drawing. Elementary principles of design and shop precedure are discussed and the accepted standards of machine drafting are applied in the making of simple working drawing. The use of graphics in the solution of simple equations is introduced in the form of nomograms.

Text: *Engineering Drawing,* French.

Instructors: Campbell, Welch, Wilcox.

D 2. Descriptive Geometry. 6 units (0-6-0); second term.

Prerequisite: D 1 abc.

The course is designed to supplement the study of shape description as given in D 1 abc, and to present a graphical means of solving the more difficult three-dimensional problems. Special emphasis is placed on the ability to visualize and analyze three-dimensional structures. Methods of combining the analytical solution of the simpler problems with the graphical solution are discussed and applied. Problems include the geometrical relationship of straight lines and planes, curved lines, curved surfaces, warped surfaces, intersections, developments, graphical integration and the graphical representation of more complex engineering equations. The course stresses the practical application of graphics in the various fields of engineering.

Text: *Descriptive Geometry,* Watts and Rule.

Instructors: Tyson, Welch, Wilcox.

D 5. Descriptive Geometry. 6 units (0-6-0); third term.

Prerequisite: D 1 abc.

This course is planned primarily for geology students and is designed to cover the fundamentals of descriptive geometry as given in the first part of D 2. Emphasis is placed, throughout the course, on practical problems in mining and earth structures.

Text: *Geometry of Engineering Drawing,* Hood.

Instructors: Tyson, Welch.

D 7. Advanced Graphics. Maximum of 6 units. Elective; any term.

Prerequisites: D 1 abc; D 2; ME 1 ab.

Further study in the application of graphics to the solution of engineering problems and in the basic elements of design for production. Emphasis will be 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; Graphical solution of vector problems, graphical integration, graphic differentials; Nomography.

Instructors: Tyson, Campbell, 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 appreciative 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. English: Reading, Writing, and Speaking. 6 units (3-0-3); first, second, third terms.

A thorough review of the principles of composition; constant practice in writing and speaking; and an introduction to the critical reading of essays, biographies, short stories, novels, plays, and poems.

Instructors: Bowerman, Clark, Eagleson, Huse, Langston, Stanton.

En 7 abc. Introduction to Literature. 8 units (3-0-5); first, second, third terms.

Prerequisite: En 1 abc.

This course is designed to give the student a discriminating acquaintance with a selected group of principal literary works. The reading for the first term is concentrated on Shakespeare; for the second and third terms, on representative English authors.

Instructors: Bowerman, Clark, Eagleson, Eaton, Huse, Jones, Langston, MacMinn, 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.

Instructors: Langston, MacMinn.

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 the twentieth centuries.

Instructors: Huse, Stanton.

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

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: MacMinn.

En 12 abc. Debating. 4 units (2-0-2).
Elective, with the approval of the Registration Committee.

A study of the principles of argumentation; systematic practice in debating; preparation for intercollegiate debates.

Instructor: McCrery.

En 13. Reading in English and History. Units to be determined for the individual by the department.
Elective, with the approval of the Registration Committee, in any term.

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.
Elective, with the approval of the Registration Committee.

A study of the elementary principles of newspaper writing and editing, with special attention to student publications at the Institute.

Instructors: MacMinn, McCrery.

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: MacMinn.

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: Smith.

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. A brief written report will be required.

FIFTH YEAR AND 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: Smith.

FRENCH

(See under Modern Languages)

GEOLOGICAL SCIENCES

UNDERGRADUATE SUBJECTS

Ge 1 a. Physical Geology. 9 units (4-2-3); first term.

Prerequisites: Ch 1 abc, Ph 1 abc.

Rocks and minerals; deformation and structure of the earth's crust; earthquakes; work of weathering, wind, running water, oceans, glaciers and volcanism; economic aspects and principles of ground water; ore deposits and petroleum. Occasional field trips.

Text: *Textbook of Geology*, Part I, Longwell, Knopf, and Flint.

Instructors: Sharp and Teaching Fellows.

Ge 1 b. Elementary Paleontology. 9 units (4-1-4); third term.

Prerequisite: Ge 1 a.

A discussion of the principles on which the history of life is based. Illustrations of evolution taken from certain groups of animals for which the fossil record is essentially complete. Occasional field trips.

Text: *Organic Evolution*, Lull.

Instructor: Stock.

Ge 1 c. Historical Geology. 10 units (3-2-5); third term.

Prerequisite: Ge 1 a.

A consideration of the geologic history of the Earth, as shown by the changing patterns of land and sea and by the succession of faunas and floras. Conferences, lectures, and occasional field trips.

Text: *Introduction to Historical Geology*, Moore.

Instructor: Merriam.

Ge 3 ab. Mineralogy. 8 units (3-3-2), second term; 10 units (3-4-3), third term.

Prerequisites: Ge 1 a, Ch 1 abc.

A study of the physical and chemical properties of minerals, of their associations and modes of occurrence; of their industrial applications; with training in their identification.

Text: *Manual of Mineralogy*, Dana-Hurlbut.

Instructor: Engel.

Ge 4 a. Petrology. 6 units (2-3-1); first term.

Prerequisites: Ge 1 a, Ge 3 ab.

A study of the origin and occurrence of the igneous rocks, with training in the megascopic identification, description, and interpretation of these rocks and their constituent minerals.

Text: *Principles of Petrology*, Tyrrell.

Instructor: Jahns.

Ge 4 b. Petrology. 8 units (2-4-2); second term.

Prerequisites: Ge 1 a, Ge 3 ab.

A study of the origin, identification and classification of the principal sedimentary and metamorphic rocks.

Text: *Principles of Petrology*, Tyrrell.

Instructor: Pray.

Ge 9. Structural Geology. 10 units (4-0-6); first term.

Prerequisite: Ge 1 a.

A consideration of the structural features of the Earth's crust: folds, faults, joints, foliation.

Text: *Principles of Structural Geology*, Nevin.

Instructor: Buwalda.

Ge 14. Geologic Illustration. 5 units (0-3-2); third term.

Classroom training in the drawing of block diagrams. Problems in perspective, projection, and the rendering of topographical features and stratigraphy. Exercises, using various mediums, in freehand and mechanical drawing as applied to geologic illustration. Freehand sketching of landscape forms and visible geologic structures in the field.

Text: *Block Diagrams*, Lobeck.

Instructor: Willoughby.

Ge 21 abc. Introduction to 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 ab, Ge 3 ab.

An introduction to 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 simple field problems in structure and stratigraphy, geologic computations, and an introduction to the use of aerial photographs and of the plane table for field mapping. To these ends, small areas are mapped in great detail and reports are prepared in professional form.

Text: *Field Geology*, Lahee.

Instructor: Jahns, (21a); Engel and Pray (21bc).

UNDERGRADUATE OR GRADUATE SUBJECTS

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.

Required of all senior and graduate students in the Division; optional for sophomores and juniors.

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, McCrery.

Ge 105. Optical Mineralogy. 10 units (2-6-2); first term.

Prerequisite: Ge 3 ab.

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.

Texts: *Optical Crystallography*, Wahlstrom, and *Notes on Optical Mineralogy*, Tunell.

Instructor: Jahns.

Ge 106 ab. Petrography. 10 units (2-6-2); second and third terms.

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: *Igneos Minerals and Rocks*, Wahlstrom.

Instructor: Campbell.

Ge 107. Stratigraphy. 10 units (3-2-5); third term, 1951-52.

Prerequisite: Ge 111 ab.

General principles of stratigraphy. Correlation and description of sedimentary formations. Standard sections and index fossils, with emphasis on the California and Great Basin columns. The course is given in alternate years.

Text: *Historical Geology*, Moore.

Instructor: Merriam.

Ge 109. Structural Geology. 6 units; first term.

This subject is the same as Ge 9 but with reduced credit for graduate students.

Text: *Principles of Structural Geology*, Nevin.

Instructor: Buwalda.

Ge 110. Engineering Geology. 9 units (2-3-4); third term.

Prerequisite: Ge 1 a.

A discussion of those conditions that affect particular engineering operations, such as tunnelling, the building of dams, the retention of water in reservoirs, foundation excavation, harbor work, control of erosion and landslides, materials of construction, etc. Lectures, assigned reading, weekly field trips.

The course is planned primarily for civil engineers.

Text: *Geology for Engineers*, Trefethen.

Instructor: Buwalda.

Ge 111 ab. Invertebrate Paleontology. 10 units (2-6-2); first, second terms.

Prerequisite: Ge 1 ab.

Morphology and geologic history of the common groups of fossil invertebrates, with emphasis on their evolution and adaptive modifications. Second term: identification, classification, and preparation of invertebrate fossils, with emphasis on characteristic forms of the California section. Occasional field trips.

Instructor: Merriam.

Ge 112 ab. Vertebrate Paleontology. 10 units (2-6-2); second, third terms.

Prerequisite: Ge 1 b.

Osteology, affinities, and history of the principal groups of fossil mammals and reptiles. History of vertebrate life with special reference to the region of western North America.

Instructor: Stock.

Ge 115. Micropaleontology. 8 units (1-3-4); second term.

Prerequisite: Ge 111 ab.

Introduction to the morphology and classification of the foraminifera.

Text: *Principles of Micropaleontology*, Glaessner.

Instructor: Israelsky.

Ge 121 abc. Field Geology. 2 units (1-1-0), first term; 8 units (0-8-0), second term; 10 units (0-7-3), third term.

Prerequisites: Ge 3 ab, Ge 21 ab.

The student investigates a limited geologic problem in the field. Individual initiative is developed, principles of research are acquired, and practice is gained in technical methods, including those of plane-table and underground mapping. The student prepares a report setting forth the results of the research and their meaning.

Instructors: Engel, Jahns, Pray.

Ge 122. Spring Field Trip. 1 unit (0-1-0); week between second and third terms.

Brief studies of various localities in the Southwest representative of important geologic provinces. Trips are conducted in successive years to such regions as Owens and Death Valleys where excellent Paleozoic sections are exposed, and Basin Range structure and morphology may be observed; to the Salton Basin and Lower California where the San Andreas fault and the Peninsular Range may be studied; to the San Joaquin Valley and the mountains to the west where important Tertiary formations are exposed and typical Coast range structure may be seen; and to the Grand Canyon of the Colorado River where a fascinating record of Archean, Algonkian and Paleozoic geologic history may be investigated.

Required of junior, senior, and graduate students in the Division of the Geological Sciences.

Instructors: Engel, Jahns, Merriam, Pray, Sharp.

Ge 123. Summer Field Geology. 20 units (0-17-3).

Prerequisites: Ge 3 ab, Ge 21 ab.

Intensive field mapping of a selected area from a centrally located field camp. Determination of the rock types, fossil content, stratigraphy, structure and geologic history of this area. Preparation of a map, structure sections, and a report in professional form. Both field and office work are done under close supervision.

The area chosen will probably lie in the Great Basin or other parts of the southwestern states, inasmuch as the regular school-year courses, Ge 21 and Ge 121, provide training in the geology of the California Coast Ranges. As an occasional alternative an expedition will be conducted to localities important in western geology. The interpretations of classical localities afforded in the literature will be studied in the field.

The course begins immediately after Commencement (about June 12), and lasts for approximately 6 weeks. Required at the end of the junior year for the bachelor's degree. Required also 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 the Geological Sciences.

Text: *Field Geology*, Lahee; *Suggestions to Authors*, Wood and Lane.

Instructors: Pray and other members of the Staff.

Ge 125. Geology of Western America. 5 units (3-0-2); third term.

Presents an organized concept of the geologic history of western North America. Lectures, mainly by staff members personally familiar with the regions discussed, and assigned reading.

Text: *Geologic History at a Glance*, Richards and Richards.

Instructors: Buwalda, (in charge), and Campbell, Hewett, Jahns, Noble, Sharp.

Ge 126. Geomorphology. 10 units (4-0-6); first term.

Prerequisites: Ge 9, Ge 121 ab.

Origin and evolution of land features produced by weathering, mass movements, wind, running water, glaciers, shore processes, vulcanism, and diastrophism.

Text: *Geomorphology*, 4th edition, revised, Cotton.

Instructor: Sharp.

Ge 128. Introduction to Economic Geology. 7 units (4-0-3); third term.

A survey course of geology applied to coal, oil and gas, industrial minerals, metalliferous deposits, water resources, and engineering.

Text: *Economic Mineral Deposits*, Bateman.

Instructors: Noble (in charge), and Buwalda, Campbell, Geis, Jahns.

Ge 165. Introduction to General Geophysics, I. 6 units (2-0-4); second term.

Prerequisite: Ph 1 abc.

Structure of the Earth; gravity and isostasy; tides; movement of the poles; elastic properties; temperature; density.

Instructor: Gutenberg.

Ge 166. Introduction to General Geophysics, II. 6 units (2-0-4); first term, 1950-51.

Prerequisites: Ma 2 ab, Ph 2 abc.

Structure of the ocean and the atmosphere, tides, propagation of sound waves, temperature, density.

Instructor: Gutenberg.

Ge 174. Well Logging. 5 units (3-0-2); second term.

Physical principles of various methods of well logging and their applications. Electrical. radioactive, chemical, fluoroscopic and mechanical methods will be studied.

Instructor: Potapenko.

Ge 175. Introduction to Applied Geophysics. 6 units (3-0-3); first 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: *Geophysical Prospecting for Oil*, Nettleton.

Instructor: Potapenko.

Ge 176. Elementary Seismology. 6 units (3-0-3); second term.

Prerequisites: Ge 1 a, Ma 2 ab.

A survey of the geology and physics of earthquakes.

Instructor: Richter.

GRADUATE 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.

GEOLOGY

Ge 200. Mineragraphy. 10 units (1-9-0); first term.

Prerequisites: Ge 106 ab, Ge 128.

Techniques of the study of the minerals of ore deposits in polished and in thin sections.

Texts: *Microscopic Determination of Ore Minerals*, M. N. Short; U.S.G.S. Bull. 914.

Instructor: Noble.

Ge 202. Ore Deposits. 10 units (2-6-2); second term.

Prerequisites: Ge 106 ab, Ge 128, Ge 200.

A study of the mode of occurrence and theory of origin of the main types of ore deposits of the world. The laboratory work will use the technique of Ge 200 and the materials of the Frederick Leslie Ransome memorial collection. Reading will be assigned in the literature of ore deposits; there will be no required textbook.

Instructor: Noble.

Ge 209. Sedimentary Petrology. 10 units (2-4-4); second term, 1951-52.

Prerequisite: Ge 105.

Lectures, reports and discussions on recent and ancient sediments, particularly from the petrographic viewpoint. The work in the laboratory affords an introduction to the various quantitative methods for detailed analysis of sediments.

Instructor: Pray.

Ge 210. Metamorphic Petrology. 10 units (2-4-4); second term, 1950-51.

Prerequisite: Ge 106 ab.

A study of metamorphic processes.

Text: *Metamorphism*, Harker.

Instructor: Campbell.

Ge 212. Nonmetalliferous Deposits. 10 units (2-3-5); third term.

Prerequisite: Ge 106 ab.

A study of the industrial minerals; their occurrence, exploitation, beneficiation. In the laboratory the petrographic microscope is applied not only to problems of identification and paragenesis of the minerals, but also to problems involving processed and fabricated materials. Occasional field trips.

Text: *Industrial Minerals and Rocks,* Dolbear (editor).

Instructor: Campbell.

Ge 213. Mineralogy (Seminar). 5 units; first term.

Discussion of special problems and current literature related to the general province of mineralogy. Topics in such broad fields as the geology of mineral deposits, crystallography, geochemistry, techniques of mineral identification, and optical mineralogy are selected for attention during the term, largely on the basis of trends of interest among members of the group.

In charge: Jahns.

Ge 214. Petrology (Seminar). 5 units; second term.

Discussion of classic and current literature with consideration of recent advances in the field of petrology. Occasional conferences on research problems are included.

In charge: Campbell.

Ge 215. Ore Deposits (Seminar). 5 units; third term.

Discussion of problems and current literature concerning ore deposits.

In charge: Noble.

Ge 220. History of the Geological Sciences. 5 units, summer reading course.

Development of basic concepts and specialized fields by great geologists of the past. Intended to provide historical background and understanding of growth of the science.

Assigned reading during summer, examination second week of fall term.

Instructor: Stock.

Ge 226. Advanced Geomorphology. 10 units (3-0-7); second term, 1951-52.

Prerequisites: Ge 9, Ge 121 ab, Ge 126.

Detailed analysis of geological processes acting on the earth's crust, and of the land forms they produce, with emphasis on humid regions. Lectures, assigned reading, field trips to the San Gabriel Mountains, the Coast Ranges, and the coast of California.

Instructor: Sharp.

Ge 228. Geomorphology of Arid Regions. 10 units (3-0-7); second term 1951-52.

Prerequisite: Ge 126.

A study of the geological processes of arid regions and their products. Origin of pediments and evolution of other land forms. Reading, discussion, and field trips to the Mojave Desert.

Text: *Climatic Accidents,* Cotton.

Instructor: Sharp.

Ge 229. Glacial Geology. 10 units (3-0-7); second term, 1950-51.

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 Geology and the Pleistocene Epoch,* Flint.

Instructor: Sharp.

Ge 230. Geomorphology (Seminar). 5 units; second term.

Discussion of research and current literature in geomorphology.

In charge: Sharp.

Ge 232. Petroleum Geology. 10 units (2-0-8); first term.
Prerequisites: Ge 9, Ge 21 ab, Ge 174.

History of oil and gas development; physical and chemical properties of oil, characteristics of source and reservoir rocks; theories of origin, migration and accumulation. Occasional field trips.

Text: *Bulletins, AAPG and AIME.*
Instructor: Geis.

Ge 233. Petroleum Geology Practices. 10 units (2-4-4); second term.
Prerequisites: Ge 9, Ge 21 ab, Ge 174.

Type cases of structural and stratigraphic traps; oil shale; oil field exploration and exploitation methods; general drilling and completion practices; core analysis; reservoir characteristics; evaluation of fields and properties. Occasional field trips.

Text: *Bulletins, AAPG and AIME.*
Instructor: Geis.

Ge 235. Petroleum Geology (Seminar). 5 units; third term.
Problems of petroleum geology; geology and engineering of typical American and foreign oil fields; current literature and study of new discoveries.
In charge: Geis.

Ge 237. Tectonics. 8 units (3-0-5); third term.
Prerequisites: Ge 9, or equivalent, and Ge 121 ab, 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: Buwalda.

Ge 238. Structural Geology (Seminar). 5 units; first term.
Critical review of literature dealing with some part of the field of structural geology.
In charge: Buwalda.

GRADUATE SUBJECTS—PALEONTOLOGY

Ge 245 ab. Vertebrate Paleontology (Seminar). 5 units; second and third terms.
Discussion of progress and results of research in vertebrate paleontology.
Critical review of current literature.
In charge: Stock.

Ge 248. Fossils of the California Tertiary. 5 units; second term.
Study of some of the more important invertebrate fossils of the California Tertiary with especial emphasis on their use as horizon markers in field geology.
Instructor: Merriam.

Ge 249. Stratigraphy of the Coast Ranges (Seminar). 5 units; first term.
Review, discussion and criticism of literature of the California Coast Ranges, with especial emphasis on correlation and fauna.
In charge: Merriam.

Ge 250. Invertebrate Paleontology (Seminar). 5 units; first term.
Critical review of classic and current literature in invertebrate paleontology. Study of paleontologic principles and methods.
In charge: Merriam.

GRADUATE SUBJECTS—GEOPHYSICS

Ge 261. Theoretical Seismology. 6 units (2-0-4); first term, 1951-52.
Prerequisites: Ma 108, or Ma 10, or Ph 102 abc.

Studies and conferences on the principles of physical seismology.
Instructor: Gutenberg.

Ge 262. Interpretation of Seismograms of Teleseisms. 4 units (0-3-1); second term, 1951-52.
Prerequisite: Ge 261.
Instructor: Gutenberg.

Ge 263. Field Work in Earthquakes and Interpretation of Seismograms of Local Earthquakes. 4 units (0-3-1); third term, 1951-52.

Prerequisite: Ge 261.

Instructor: Richter.

Ge 268 ab. Selected Topics in Theoretical Geophysics. 6 units (3-0-3); second and third terms, 1950-51.*

Prerequisite: Ph 102 abc or equivalent.

Discussion of seismic wave propagation, gravitational and magnetic fields, stress systems and general thermodynamics as applied to earth processes. Content of course is altered somewhat from year to year depending mainly upon student needs.

Instructor: Dix.

Ge 270. Geophysical Instruments. 7 units (3-2-2). Not offered in 1950-51.

Prerequisite: Ph 102 abc or equivalent.

Discussion of instruments used in seismology and geophysical exploration.

Instructor: Dix.

Ge 273 ab. Applied Geophysics, I. 5 units (2-0-3); second and third terms, 1950-51.

Prerequisite: Ph 102 abc or equivalent.

Methods of seismology applied to geological problems and prospecting. Theory and practice.

Instructor: Dix.

Ge 274 abc. Applied Geophysics, II. 5 units (2-0-3), first and second terms; 7 units (0-4-3), third term; 1951-52.

Prerequisite: Ph 102 abc or equivalent.

Theory of electrical methods of prospecting, laboratory and field work.

Text: *Geophysical Exploration*, Heiland.

Instructor: Potapenko.

Ge 275 abc. Applied Geophysics, III. 6 units (3-0-3), first term; 8 units (3-2-3), second term; 4 units (1-2-1), third term; 1951-52.

Prerequisite: Ph 102 abc or equivalent.

Theory of potential useful in making interpretations of gravity and magnetic field data. Brief discussion of gravity and magnetic fields of the earth. Interpretation of field data. Practice in making field observations.

Instructor: Dix.

Ge 282 abc. Geophysics (Seminar). 1 unit; first, second, third terms.

Prerequisite: At least two subjects in geophysics.

Discussion of papers in both general and applied geophysics.

In charge: Gutenberg, Buwalda, Dix, Potapenko.

GRADUATE SUBJECTS—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.

Special requirement in Field Geology for graduate students in the Division of the Geological Sciences.

If, in the judgment of the Division, additional technical training in geologic mapping is desirable, a graduate student may be required to take Ge 21 or Ge 121 and/or Ge 123.

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*To be offered in alternate years beginning with 1950-51.

GERMAN

(See under Modern Languages)

HISTORY AND GOVERNMENT

UNDERGRADUATE SUBJECTS

H 1 abc. History of European Civilization. 5 units (2-0-3); first, second, third terms.

Lectures and discussions dealing with European civilization. Emphasis will be on the more recent past. The course will begin with a brief survey of the medieval background and the Renaissance and Reformation, and will then turn to a study of the development of the modern state system.

Instructors: Ellersieck, Elliot, Tanham.

H 2 abc. History of the United States. 6 units (2-0-4); first, second, third terms.

Lectures and discussions on the United States since 1763. Particular attention will be given to the rise of the great questions of domestic and foreign policy which have dominated the United States in recent decades. This course will include a study of the development of the Federal Constitution.

Instructors: Ellersieck, Paul, Schutz.

H 4. The British Empire Since 1783.* 9 units (3-0-6).

Senior elective.

A study in the evolution of empire. Discussion of the changing political philosophies and methods by which Britain has adjusted her imperial policy to new conditions created by such factors as modern industrialism, humanitarianism, and shifts in the international balance of power.

Instructor: Schutz.

H 5 ab. Current History. 2 units (1-0-1); first, second terms.

This course, required of all seniors, focuses attention on major problems of international and national affairs. It is given as a series of weekly lectures, accompanied by appropriate reading. The course will include a study of contemporary constitutional problems.

Instructors: Elliot, Schutz, Sweezy, Tanham.

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.

A study of the rise of Russia as a national state. Attention will be directed particularly to the revolutionary movement, with its economic and political implications, which culminated in the Bolshevik Revolution of 1917. Due emphasis will be placed on the organization and character of the Soviet Regime.

H 5c ~~10~~. The Constitution of the United States. 2 units (1-0-1); third term.

A study of the principles and provisions of the national constitution in the light of interpretation by the courts. Required of all seniors.

Instructor: Schutz.

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

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 problems and international organization.

H 16. American Foreign Relations Since 1889.* 9 units (3-0-6).

Senior elective.

A study of the foreign relations of the United States. Attention will be directed to problems concerning the Monroe Doctrine, neutrality, freedom of the seas, manifest destiny, acquisition of overseas possessions, and isolationism vs. world leadership.

Instructor: Schutz.

H 17. The Far West and the Great Plains.* 9 units (3-0-6).

Senior elective.

A study of the development of the great regions that compose the western half of the United States. Especial attention will be paid to the influence of the natural environment on the men who settled the West, from pioneer days to the present time, and the exploitation of natural resources, through such industries as mining, ranching, oil, and farming.

Instructor: Paul.

H 18. The South: A Study in Persistence.* 9 units (3-0-6).

Senior elective.

A study of life in the Old South, of the sectional crisis, Civil War, and Reconstruction, and of the problems which persist today in the modern South.

Instructor: Paul.

H 19. Modern America.* 9 units (3-0-6).

Senior elective.

An experimental course in which the main theme will be the conflict between government regulation and private enterprise in Twentieth-Century America. Classes will be conducted as discussions under the joint leadership of an historian and an economist.

Instructors: Paul, Sweezy.

H 21. British-American History.* 9 units (3-0-6).

A study of English expansion, 1558-1783. Attention will be devoted to the development of British-American social and political institutions, with special emphasis upon the philosophy, literature, and travel accounts of the period.

Instructor: Schutz.

H 22. Modern England* 9 units (3-0-6).

A study of England's recent development, with particular emphasis upon the factors which have led to the present experiments in Socialism.

Instructor: Elliot.

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 consulation with members of the department. A brief written report will usually be required.

FIFTH YEAR AND ADVANCED SUBJECTS

H 100 abc. Seminar in History and Government. 9 units (2-0-7).

A study of recent developments in national and international history.

First and second terms: English and American foreign policy considered in its political, social and economic aspects.

Third term: world problems from an Anglo-American point of view. Initial enrollment in the second or third term is allowed only upon approval of the instructor.

Instructor: Davies.

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

HYDRAULICS

UNDERGRADUATE SUBJECTS

Hy 1. Hydraulics. 9 units (3-0-6); first term.

Prerequisites: AM 1 abcd, ME 15 abc.

Application of basic principles of fluid mechanics to engineering problems in laminar and turbulent flow, flow in closed conduits, flow in open channels, flow around immersed bodies; analysis and study of hydraulic turbines and centrifugal pumps.

Hy 2 ab. Hydraulics. 9 units (3-0-6); first and second terms. (For Civil Engineers).

Prerequisite: AM 1 ab.

Kinematics and dynamics of fluid motion with particular emphasis on the properties of liquids. Hydrostatics, flow of water in pipes, nozzles, channels; hydraulic turbines; centrifugal pumps and other hydraulic equipment.

Hy 11. Hydraulic Laboratory. 6 units (0-6-0); second term.

Prerequisite: AM 1 abcd.

Experiments on the characteristics of fluid flow and tests of hydraulic machines. Principles of engineering measurements.

Instructor: Kyropoulos.

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. Advanced Fluid Mechanics. 9 units (3-0-6); first, second, and third terms.

Prerequisites: Hy 1 or Hy 2 ab and Hy 11.

Dimensional analysis; hydraulic similitude, theory and use of hydraulic models; elementary principles of flow; principles of energy, continuity and momentum; theory and use of the flow net; development of generalized equations of flow; circulation and vorticity; velocity and force potentials; stream function; conformal transformation; cavitation; equations of viscous motion; laminar flow; lubrication; percolation.

Fluid turbulance; boundary layer; separation; resistance of immersed bodies; flow in closed conduits; resistance and roughness; flow in open channels; hydraulic jump; sub- and super-critical flow phenomena; weirs and spillways; erosion; wave phenomena; and miscellaneous topics.

Instructor: Levy.

Hy 110. Hydraulics. 7 units (3-0-4); first term.

Prerequisites: AM 1 abcd, ME 15 abc.

This subject is the same as Hy 1, but with reduced credit for graduate students in all departments except AE, ChE, CE, and ME. No graduate credit is given for this subject to students in AE, ChE, CE, and ME, except by special approval of the Mechanical Engineering department.

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 Hydrodynamic and Mechanical Engineering staffs.

Hy 202 ab. Hydraulics of Free Surface Phenomena. 6 units (2-0-4).

A study of the hydrodynamics of a fluid having a free surface with special reference to gravity wave phenomena. Fields studied will include low and high velocity in open channels and wave phenomena in enclosed bodies of fluid.

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 from the field of hydraulic machinery and also for bodies moving in a stationary fluid.

Instructors: Knapp, Plesset.

Hy 210 ab. Hydrodynamics of Sediment Transportation. 6 units (2-0-4).

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 300. Thesis.

JET PROPULSION

FIFTH YEAR AND ADVANCED SUBJECTS

JP 121. Rocket. 12 units (4-0-8); first term.

Prerequisite: AM 15.

Fundamentals of rockets, solid propellant rocket, liquid propellant rocket.

Instructors: Tsien, Marble.

JP 130 ab. Thermal Jets. 12 units (4-0-8); second and third terms.

Prerequisite: AM 15.

Performance analysis of ramjet, pulsejet, turbojet, turbofan, and turboprop. Combustion chamber design. Design principles of centrifugal and axial compressors.

Instructors: Marble, Rannie.

JP 170 abc. Jet Propulsion Laboratory. 3 units (0-3-0); each term.

Laboratory demonstrations of the operation of jet propulsion systems and the reduction and interpretation of observed data.

Instructors: Marble, Penner and JPL staff members.

JP 200 abc. Chemistry Problems in Jet Propulsion. 6 units (2-0-4); each term.

Chemistry of propellants. Chemical kinetics and equilibrium. Thermodynamics of combustion.

Instructor: Penner.

JP 201 abc. Applied Physical Chemistry. 6 units (2-0-4); each term.

Calculation of thermodynamic functions from spectroscopic data. Equations of state. Radiant heat transfer. Theory of reaction rates, combustion, and flame propagation.

Instructor: Penner.

JP 210 High Temperature Design Problems. 6 units (2-0-4); third term.

Prerequisites: ME 3, ME 10 and AE 270 a or AM 110 a.

Temperature distribution and thermal stress under non-uniform and nonsteady conditions. Design principles for high temperature operations. Heat resistant alloys and ceramic materials.

Instructors: Duwez, Tsien.

JP 220 ab. Applications of Jet Propulsion Power Plants. 6 units (2-0-4); first and second terms.

Prerequisites: AM 257 or EE 226.

Jet propelled vehicles; rockets applied to assisted take-off and superperformance; dispersion of rockets.

Instructor: Tsien.

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: Tsien and JPL staff members.

JP 290 abc. Advanced Seminar in Jet Propulsion. 3 units (1-0-2); each term.

Seminars on current research problems in jet propulsion to be held in conjunction with the JPL staff, for students working on special projects with the JPL.

Instructors: Staff members.

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 differential and integral calculus and the fundamentals of plane analytic geometry.

Text: *Analytic Geometry and Calculus,* Phillips.

Professor in charge: Bohnenblust.

Ma 2 abc. Sophomore Mathematics. 12 units (4-0-8); first, second, third terms.

A continuation of the freshman calculus, through partial differentiation, multiple integration and the use of series. The course includes as well topics in solid analytic geometry and vector analysis.

Text: *Analytic Geometry and Calculus,* Phillips.

Professor in charge: Ward.

Ma 3. Theory of Equations. 10 units (4-0-6); first term.

Includes topics of algebra of interest primarily to prospective mathematicians.

Topics Treated: the fundamental algebraic operations, the field concept, properties of number fields and polynomials, symmetric functions, elimination and resultants.

Text: *Introduction to Theory of Equations,* Weisner,

Instructor: Karlin.

Ma 4. Geometry. 10 units (4-0-6); third term.

A treatment of the classical metric, affine, and projective geometries of two and three dimensions.

Text: *Higher Geometry,* Graustein.

Instructor: Wear.

Ma 10. Differential Equations. 10 units (4-0-6); third term.

Prerequisites: Ma 1, 2.

This course will stress the rigorous development of the subject rather than formal methods of solution. Topics treated will include the general existence theorems, systems of differential equations, solutions of equations by means of operators, series, and iteration methods, treatment of non-linear differential equations and perturbation methods.

Text: *Differential Equations,* Agnew.

Instructor: Bohnenblust.

Ma 16. Matrices and Quadratic Forms. 10 units (4-0-6); second term.

This course is intended for mathematicians and those physicists and engineers who must use the methods and techniques of modern linear algebra. It will cover the more frequently used parts of matrix algebra, linear transformations, quadratic forms and linear spaces.

Instructors: Bell, Dilworth.

Ma 43. Cardinal Numbers. 9 units (3-0-6); second term.

The basic concepts of set theory. Ordinal sets. Elementary properties of ordinal and cardinal numbers. Transfinite induction and the Maximum Principle. Applications.

Instructor: Dilworth.

Ma 44. Diophantine Analysis 9 units (3-0-6); third term.

A selection of classical indeterminate equations will be discussed by both old and new methods.

Instructor: Bell.

UNDERGRADUATE OR GRADUATE SUBJECTS

Ma 101 abc. Modern Algebra. 9 units; three terms.

Prerequisite: Ma 108 abc.

Abstract algebra as developed since about 1910.

Instructors: Bell, Dilworth, Ward.

Ma 102 abc. Introduction to Higher Geometry. 12 units; three terms.

Prerequisites: Ma 1 ab, 2 abc, 4.

The course covers selected topics in metrical differential geometry and in algebraic geometry.

Instructor: Wear.

Ma 103. Fourier Analysis. 9 units (3-0-6); third term.

Prerequisites: Ma 108 abc. A working knowledge of Lebesgue and Stieljes integration will be assumed.

This course is intended for pure mathematicians and those applied mathematicians, physicists and engineers who must use Fourier Series and Integrals extensively. The topics treated will include complete orthonormal systems, Fourier Integral theorem, Plancherel theorem, Fourier-Stieltjes transforms and other unitary transforms, Féjer-Lebesgue kernels with application to various fields of analysis and number theory.

Instructor: DePrima.

Ma 106 abc. Introduction to Theory of Functions of Real Variables. 9 units; three terms.

Prerequisite: Ma 108 ab.

Postulational treatment of real number system, descriptive properties of point sets, continuous and discontinuous functions, derivatives and differentials. Riemann integration, functions of several real variables, implicit functions. Modern integration theory. Topological spaces, metric spaces and normed spaces with special emphasis on function spaces, Hilbert spaces and Banach spaces. Existence theorems for differential equations. Theory of functionals and functional transformations. Polynomials and power series in normed linear spaces. Differentials in normed linear spaces. Integral equations and other functional equations.

Instructor: Michal.

Ma 108 abc. Advanced Calculus. 9 units (4-0-5); three terms.

Prerequisites: Ma 1, Ma 2.

This course will deepen and extend the student's knowledge of the technique and methods of the calculus. The course will include elementary functions of a complex variable, line integrals, gamma functions, and functions of several variables. This course or its equivalent is a prerequisite to graduate mathematics courses in analysis. Graduate students in Mathematics receive no credit for taking this subject.

Text: *Differential and Integral Calculus*, Courant, McShane.

Instructors: Erdélyi, Dye.

Ma 111 ab. Elementary Theory of Tensors. 9 units; two terms.

Prerequisites: Ma 108 abc, 10.

Fundamental properties of tensors, differential forms, covariant differentiation, geodesic coordinates, Riemannian differential geometries. Applications to dynamics, fluid mechanics, elasticity theory and other physical and engineering subjects.

Text: *Matrix and Tensor Calculus with Applications to Mechanics, Elasticity, and Aeronautics,* Michal.

Instructor: Michal.

Ma 112. Elementary Statistics. 9 units (3-0-6).

Prerequisites: Ma 1, 2

This course is intended for anyone interested in the applications 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. No graduate credit will be given to mathematics majors for this course.

Text: Selected references.

Instructors: Dilworth, Ward.

Ma 113 abc. Geometry. 12 units; three terms.

Prerequisite: Ma 2 abc.

Algebraic geometry; projective geometry; differential geometry; tensor analysis and its applications to numerous geometrical problems; non-Euclidean geometry; Riemannian differential geometry; geometry of dynamics; hyperspace; elementary group theory and its geometrical applications.

Texts: *Application of the Absolute Differential Calculus,* McConnell; *Riemannian Geometry,* Eisenhart; collateral reading.

Instructor: Michal.

Ma 114 abc. Mathematical Analysis. 12 units; three terms.

Prerequisites: Ma 108 abc; Ma 10 or its equivalent.

Theory of convergence, integration and residues, expansions of functions in infinite series. asymptotic and divergent series. Fourier series. Differential equations and function theory, integral equations, the gamma function and the zeta function, the hyper-geometric function and related functions of mathematical physics, elliptic functions, ellipsoidal harmonics.

Text: *Functions of a Complex Variable,* Copson.

Instructors: Bohnenblust, Erdélyi, Roberston, Ward.

Ma 119 abc. Introduction to Theory of Numbers. 9 units; three terms.

Prerequisites: Ma 1 abc, 2 abc.

The fundamental theorem of arithmetic, continued fractions, congruences, Bernoulli numbers, quadratic residuces, quadratic forms and other topics in elementary number theory.

Instructor: Ward.

Ma 137 abc. Real Variables. 9 units; three terms.

Prerequisite: Ma 108 abc or its equivalent.

The real number system; the fundamental concepts of topology and point-set theory; types of abstract spaces and mappings of spaces, set functions, functionals and sequences, continuous and discontinuous functions, series and summability methods, measure of sets, Lebesgue and Stieltjes integration, differentiability, functions spaces and Hilbert space, linear operators.

Instructors: Bohnenblust, Dilworth, Ward.

Ma 138 abc. Applied Mathematics. 12 units; three terms.

Prerequisite: Ma 108 abc or Ma 10.

Matrix calculus, tensor calculus and operational calculus—including Laplace transform theory and numerical methods. Most of the course will be devoted to applications of the subjects to vibrations, circuit theory, flutter theory in aeronautics, fluid mechanics, elasticity theory, classical dynamics of particles and rigid bodies, and to modern physics. A brief but adequate introduction to analytic functions of a complex variable and conformal mapping will be given. The applications will include airfoil theory and the more advanced portions of Laplace transform theory.

Instructor: Michal.

Ma 270 abc. Seminar in Applied Mathematics. 6 units; three terms.
Prerequisite: Graduate standing.

Subjects selected according to the interest of the members of the seminar.

In charge: Michal.

Ma 271 abc. Seminar in Mathematical Analysis. 3 or 6 units; three terms.
A fortnightly seminar open to anyone who has taken or is taking a course in analysis or functional theory.

In charge: Michal.

Ma 272 abc. Seminar in Differential Equations. 3 or 6 units; three terms.
Selected topics.

In charge: Bohnenblust.

Ma 273 abc. Seminar in Structure of Abstract Algebras. 6 units; three terms.
Prerequisite: Graduate standing.

This seminar is a continuation of Ma 253 with emphasis upon the structure theorems of groups, rings, and fields.

In charge: Dilworth.

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 257 Engineering Mathematical Principles—See Applied Mechanics section, for description.

Ph 6 (Ph 102) Introduction to Mathematical Physics and Differential Equations—See Physics section, for description.

Ph 130 Methods of Mathematical Physics—See Physics section, for description.

MECHANICAL ENGINEERING

UNDERGRADUATE SUBJECTS

ME 1 a. Empirical Design. 3 units (0-3-0); second term.

Prerequisite: D 1 abc.

This course is designed to supplement first year graphics with more advanced techniques involving the kinematics of machines. Studies are made and problems given in machine mechanisms, the transfer of velocities and accelerations through linkages by graphical means, gearing applications, gear trains, and cams.

Instructors: Tyson, Welch, Campbell.

ME 1 b. Empirical Design. 6 units (0-6-0); third term.

Prerequisites: D 1 abc, D 2, ME 1 a.

This is a continuation of ME 1a. Machine mechanisms involving linkages, gears, bearings and fastenings are studied in relation to layout and design procedure. Drafting room problems are formulated to introduce elementary principles of machine design with emphasis on materials and manufacturing processes as they affect design and to stress the use of engineering reference data.

Instructors: Tyson, Welch, Campbell.

ME 3. Materials and Processes. 9 units (3-3-3); first or second term.

Prerequisites: Ph 1 abc, 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 class work is combined with inspection trips to many industrial plants. 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,* Clapp and Clark.

Instructors: Clark, Varney.

ME 5 abc. Machine Design. 9 units (2-6-1); first, second, third terms.

Prerequisites: ME 1 ab, AM 1 abcd.

Application of the mechanics of machinery and strength of materials, which are reviewed and extended, to practical design and construction. Fastenings: riveting, welding, screws, bolts and keys. Power transmission: shafting, sleeve and rolling bearings, belts, chains, gears, couplings, and clutches. Elements of power machinery: cylinders, cylinder heads, piping and valves, springs, crankshafts, flywheels, packing and seals. Variety in design is explained by pointing out the different requirements of every application.

Text: *Design of Machine Elements,* Spotts; *Prevention of Fatigue of Metals,* Battelle.

Instructor: Morelli.

ME 10. Metallurgy. 12 units (3-3-6); third 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 in specification of alloys for design. The microstructures of ferrous and non-ferrous metals and alloys are studied in the laboratory.

Text: *Modern Metallurgy for Engineers,* Sisco.

Instructors: Clark, Varney.

ME 15 abc. Thermodynamics and Fluid Mechanics. 11 units (3-3-5); first, second, third terms.

Prerequisites: Ph 2 abc, Ma 2 abc.

A study of the first and second laws of thermodynamics and their application to flow and non-flow processes both with and without friction. Emphasis will be placed on single component systems. Fluid motion treated from the point of view of thermodynamics and of mechanics for flow with and without friction. Steady flow versus non-steady flow. Introduction to the detailed mechanics of fluid motion and its relation to energy dissipation.

Application of the basic principles to the main types of fluid motions encountered in engineering problems and to the main classes of industrial heat engines, thermodynamic processes, and hydraulic machinery.

Laboratory demonstrations of thermodynamic and fluid mechanic principles. Tests of industrial heat engines and hydraulic machinery.

Instructors: Eldridge, Kyropoulos, Sabersky.

ME 16 ab. Thermodynamics. 9 units (3-0-6) first term; 6 units (2-0-4) second term.

Prerequisite: ME 15 abc.

Further discussion of engineering applications of thermodynamics, including more detailed analyses of the examples included in ME 15, and additional items such as the following: Heat transfer (correlate conduction and convection discussion with fluid mechanics discussion of turbulence); gas and vapor mixture; advanced treatment of second law, Joule-Thomson effect, Chemical thermodynamics.

Instructors: Rannie, Kyropoulos.

ME 20. Heat Engineering. 9 units (3-0-6); first term.

An abridgement of ME 15 and 16 for students in Civil Engineering.

Text: *Fundamentals of Thermodynamics*, Adams and Hilding

Instructor: Kyropoulos.

ME 25. Mechanical Laboratory. 9 units (0-6-3); third term.

Prerequisite: ME 15 abc.

Tests of thermodynamic power-plants (turbo and reciprocating). Principles of engineering measurements.

Instructor: Kyropoulos.

ME 50 ab. Engineering Conferences. 2 units (1-0-1); first, third terms.

A course in public speaking for engineers, on engineering topics.

Instructors: Daugherty, McCrery.

FIFTH-YEAR AND ADVANCED SUBJFCTS

ME 100. Advanced Work in Mechanical Engineering.

The staff of the mechanical engineering department will arrange special courses or problems to meet the needs of fifth-year students or qualified under-graduate students.

ME 101 abc. Advanced Machine Design. 9 units (1-6-2); first, second, and third terms.

Prerequisites: ME 5 abc, ME 10.

The application of machine elements to specific problems of design by combining them to form a self-contained unit for a definite purpose. Attack of such a design problem by setting up the different requirements of the specified unit, and showing how they may vary, according to the number of such units to be made, the methods of manufacture, space, weight, and cost limitations, required life, wear, and duty. Selection of materials and of permissible stresses and strains for various conditions. Examination and justification of established constructions, with a consideration of possible improvements and of different methods of approach.

Examples in the design course are chosen to broaden the students' knowledge of sound practice, and to show that for a good solution of such design problems a fundamental knowledge of mechanics, thermodynamics, and hydraulics is essential as well as a knowledge of the strength and properties of materials and the methods of forming them by casting, forging, welding, machining, and other processes.

Instructor: Hollander, Wood.

ME 104 abc. Machine Design. 7 units (2-6-1); first, second, third terms.

Prerequisites: ME 1, AM 1 abcd.

This subject is the same as ME 5 abc. but with reduced credit for graduate students in ıll departments except AE, CE, and ME. No graduate credit is given for this subject to students in AE, CE, and ME, except by the special approval of the Mechanical Engineer- ng Department.

ME 110 abc. Physical Metallurgy and Metallography. 9 units (3-0-6) first erm; 9 units (1-6-2) second and third terms.

Prerequisite: ME 10.

A study of phase equilibria of metallic systems, the structure of crystals, physical and nechanical properties of metals and alloys, recrystallization, precipitation hardening, the hysics of transformation and hardenability of steel, the heat flow in heating and cooling netals, the function of alloying elements in steel, grain size, and grain growth. Technique f metallographic laboratory practice including preparation of specimens, photomicrog- aphy, macroscopy, heat treatment, grain size, hardenability, and recrystallization.

Text: *Lecture notes, references, and laboratory notes.*

Instructors: Clark, Varney.

ME 114. Metallurgy. 9 units (3-3-6); third term.

Prerequisite: ME 3.

This subject is the same as ME 10, but with reduced credit for graduate students in all epartments except AE and ME. No graduate credit is given for this subject to students ı AE and ME, except by the special approval of the Mechanical Engineering Department.

ME 115 abc. Thermodynamics and Heat Transfer. 9 units (3-0-6); first, econd, and third terms.
erms.

Prerequisites: ME 15 abc, ME 16 ab.

Macroscopic thermodynamics and the elements of microcopic thermodynamics with pplications to engineering processes; the transport of energy by conduction, convection, nd radiation; the thermodynamics of flow systems.

Instructor: Rannie.

ME 124 ab. Thermodynamics. 7 units (3-0-6), first term; 4 units (2-0-4), econd term.

This subject is the same as ME 16 ab, but with reduced credit for graduate students in ll departments except AE, ChE, and ME. No graduate credit is given for this subject to udents in AE, ChE, and ME, except by the special approval of the Mechanical Engineer- ıg Department.

ME 125 abc. Engineering Laboratory. 9 units (1-6-2); first, second, third rms.

The techniques of making measurements encountered in engineering practice and search, with the use of special and standard measuring instruments, and the recognition precision and accuracy of data secured. The planning of tests and research, and the ıalysis of data.

Instructors: ME Department Staff.

ME 150 abc. Mechanical Engineering Seminar. 2 units (1-0-1); first, second, ıird terms.

Attendance required of graduate students in mechanical engineering. Conference on search work and reviews of new developments in engineering.

Instructor: Daugherty.

ME 200. Advanced Work in Mechanical Engineering.

The staff of the mechanical engineering department will arrange special courses on oblems to meet the needs of students beyond the fifth year.

ME 210 abc. Science of Metals. 9 units (3-0-6); first, second, third terms.

Prerequisite: ME 110 abc.

Atomic structure of metals, free atoms, assembly of atoms, physics of X-rays, elementary crystal structure. Methods of analysis by X-ray diffraction applied to metals and alloys. Structure of alloys, solid solutions, intermetallic compounds, electron compounds, electrical and magnetic properties. Plastic deformation, internal friction, age hardening, grain growth, recrystallization, and diffusion. During the latter part of the course, topics are assigned from the literature.

Text: *Atomic Theory for Students of Metallurgy,* Hume, Rothery; *Structure of Metals,* C. S. Barrett; *X-ray Metallography,* Taylor.
Instructor: Duwez.

ME 211 abc. Metallography Laboratory. 8 units (1-6-1); first, second, third terms.

Prerequisite: ME 110 abc.

Preparation of metallographic specimens, photomicrography, macroscopy, carburizing, heat treatment, grain size, hardenability, structure of welded and brazed joints, recrystallization, and special problems.

Text: *Principles of Metallographic Laboratory Practice,* Kehl.

Instructor: Clark.

ME 212 ab. X-ray Metallography. 6 units (0-6-0); second and third terms.

Prerequisites: ME 210 a, ME 211 a.

Experimental methods of obtaining diffraction patterns of metals. The interpretation and identification of diffraction patterns of metals and alloys. Study of phase diagrams, plastic deformation and grain orientation, recrystallization texture, precipitation and age hardening, determination of grain size, and stress measurement by X-ray diffraction methods.

Text: *An Introduction to X-ray Metallography,* Taylor.

Instructor: Duwez.

ME 215. Internal Combustion Engines. 9 units (3-0-6); one term.

Prerequisites: ME 15 abc, ME 16.

Advanced study of: engine cycles with real fuel-air mixtures, combustion processes, fuels, detonation, octane and cetane rating, engine performance, and design.

Instructor: Daugherty.

ME 216 ab. Refrigeration and Air Conditioning. 9 units (2-3-4); two terms.
Prerequisites: Heat Power (class and laboratory)

Principles of vapor and absorption refrigeration; composite cycles. Deep freezing and liquifaction of gases. Reversed cycles.

Principles of air conditioning: properties of air-water vapor mixtures, air conditioning cycles. Comfort air conditioning (residence, trains, airplanes), industrial air conditioning (food, photographic, textile, paper industries).

Instructor: Kyropoulos.

ME 217 abc. Turbomachines. 6 units (2-0-4); three terms.

Prerequisites: ME 115 abc or AE 258 abc, or equivalent.

Steam and gas turbine cycles; fluid mechanics of turbomachines; combustion chambers; turbine blade cooling; stress and vibration problems; materials; performance, with applications to stationary power plants and aircraft propulsion.
Instructor: Rannie.

ME 218 ab. Aircraft Power Plants (Reciprocating Engines). 9 units (2-3-4); two terms.

Prerequisites: Heat power and internal combustion engines (class and laboratory).

Range of application of reciprocating aircraft engines. Thermodynamics and performance of spark ignition engines at altitude. Blower and exhaust turbine performance. Cruising control. Flight testing cooling and cowling. Special design problems (injection, carburetion, lubrication, ignition).
Instructor: Kyropoulos.

ME 219. Experimental Background of Engine Research. 4 units (2-0-2); one term.

Prerequisite: ME 215, or to be taken concurrently.

Survey of combustion research in spark and ignition engines. Flame front observation. High speed indicators, detonation indicators. Study of experimental methods of fuel injection problems and droplet formation. Carburetion and direct injection in spark ignition engines. Hydrocarbon thermodynamics. Reaction kinetics. Measurement of ignition quality of spark and compression ignition fuels. Standard methods (ASTM-CFR). Power measurement at sea level and altitude. Preparation of power charts and cruising charts. Measurement of exhaust composition and temperature. Measurement of cooling requirements and performance.

Texts: *Science of Petroleum* (Oxford Press), *I. C. Engines*, Pye (Oxford Press), *The Chemical Background of Engine Research* (Interscience Publishers).

Instructor: Kyropoulos.

ME 220. Lubrication. 6 units (2-0-4); one term.

Prerequisites: Internal combustion engines, machine design, hydrodynamics.

Hydrodynamic theory of lubrication. Application to actual bearings. Boundary lubrication. Interaction between bearing surface and lubricant. Extreme pressure lubricants, detergent oils. Lubricant performance in the engine.

Flow of viscous fluids (Reynolds, Sommerfeld) viscosity and friction. Pressure distribution and load carrying capacity of theoretical and actual bearing. Dimensional analysis of the problem. Partial bearings, thrust bearings. Temperature rise and heat dissipation. Bearings for high speed. Clearances. Gear tooth lubrication.

Boundary lubrication problem, theory and experiment. Interaction between surface and lubricant. Constitution of lubricating oils. Addition agents. Detergents, extreme pressure lubricants. Lubricant behaviour in the engine, corrosion, sludge formation.

Bearing metals; tin, lead, silver, etc.

Texts: *Theory of Lubrication*, M. D. Hersey (Wiley, 1939); *Lubrication*, A. E. Norton. (McGraw-Hill, 1942).

Instructor: Kyropoulos.

ME 300. Thesis Research.

For Subjects in Jet Propulsion see page 236.

MODERN LANGUAGES

The subjects in modern 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 these subjects without consulting the department of modern languages.

Instructors: Bowerman, 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 these subjects without consulting the department of modern languages.

Instructors: Bowerman, Stern.

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. Readings in French or German. Units to be determined for the individual by the department. Elective, with the approval of the Registration Committee, in any term.

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. Prerequisites: 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.

Instructors: Bowerman, 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: Chaitkin.

FIFTH-YEAR AND ADVANCED SUBJECTS

L 105. Same as L 5. For graduate students.
L 140. Same as L 40. For graduate students.

PALEONTOLOGY

(See under Geological Sciences)

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

PHILOSOPHY, PSYCHOLOGY, AND SOCIOLOGY

UNDERGRADUATE SUBJECTS

Pl 1. Introduction to Philosophy.* 9 units (3-0-6).
Senior elective.
A study of the major problems of philosophy in terms of the most influential contemporary world views, including naturalism, idealism, theism, pragmatism and positivism.
Instructors: Mead, Bures.

Pl 2. Logic.* 9 units (3-0-6).
Senior elective.
A study of modern and traditional logic. An analysis of knowledge into basic symbolic forms. Detailed consideration of such logical concepts as: proposition, truth, variable, definition, implication, inference, class, syllogism, logical law, deductive system. Emphasis on the fundamental role of logical methods in the rational approach to knowledge.
Instructor: Bures.

Pl 3.* Current Tendencies in European Philosophy. 9 units (3-0-6).
Senior elective.
A critical analysis of the main trends in contemporary European philosophy, especially in France, Germany and Italy. The course will include neo-Kantianism, neo-Hegelianism, Bergsonism, Logical-Postivism, Phenomenology, neo-Thomism, and Existentialism, in their influence on the whole of modern culture.
Instructor: Stern.

Pl 4. Ethics.* 9 units (3-0-6).
Prerequisite: Pl 1.
Senior elective.
The principal concepts and conflicts of man's ethical thought, studied in terms of the major ethical systems. The problems of the good life, the nature of obligation, and the sources of moral authority are considered at length, particularly in relation to modern life and its ethical tensions.
Instructor: Bures.

Pl 5. Sociology.* 9 units (3-0-6).
Senior elective.
The genesis and evolution of human society. The influence of economic, religious and social forces. The nature of social control and the analysis of mores, morals, and legal codes. The development of social institutions and the nature of change in these institutions.
(Not offered in 1950-51.)

Pl 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.

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

FIFTH-YEAR AND ADVANCED SUBJECTS

Pl 100 abc. Seminar in Philosophy. 9 units (2-0-7); each term.

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.

Pl 101 abc. History of Thought. 9 units (2-0-7).

A full-year sequence. A study of the basic ideas of Western Civilization in their historical development. The making of the modern mind as revealed in the development of philosophy and in the relations between philosophy and science, art and religion. The history of ideas in relation to the social and political backgrounds from which they came.

Instructor: Mead.

PHYSICS

UNDERGRADUATE SUBJECTS

Ph 1 abc. Mechanics, Molecular Physics, Heat and Sound. 12 units (3-3-6); first, second, third terms.

Prerequisites: A high school course, or its equivalent, and trigonometry.

The first year of a general college course in physics extending through two years. It is a thorough analytical course, in which the laboratory carries the thread of the work, and the problem method is largely used. A bi-weekly demonstration lecture, participated in by all members of the department, adds the inspirational and informational element, and serves for the development of breadth of view.

Text: *Mechanics, Molecular Physics, Heat and Sound,* Millikan, Roller and Watson.
Instructors: Watson, Strong and Graduate Assistants.

Ph 2 abc. Optics, Electrostatics and Electrodynamics. 12 units (3-3-6); first, second, third terms.

Prerequisites: Ph 1 abc, Ma 1 abc, or their equivalents.

A continuation of Ph 1 abc to form a well-rounded two-year course in general physics.

Text: Vols. II and III, *Principles of Physics,* Sears.
Instructors: Neher and Graduate Assistants.

Ph 6 abc. Introduction to Mathematical Physics and Differential Equations. 15 units (5-0-10); first, second, third terms.

Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc.
An introduction to the application of mathematics, including vector analysis and differential equations, to physics; and practice in the solution of problems.
Text: *Principles of Mathematical Physics,* Houston.
Instructors: Anderson, Cowan and Walker.

Ph 7 abc. Electricity and Magnetism. 6 units (2-0-4); first, second, third terms.

Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc; AM 15.
A course in theoretical electricity and magnetism, primarily for electrical engineering students. Ph 9 (Electrical Measurements) must accompany this course.
Text: *Electromagnetism,* Slater and Frank.
Instructor: Langmuir

Ph 8. Electricity and Magnetism. 9 units (3-0-6); first term.

Prerequisite: Ph 6 abc.
A special course open only to students who have completed Ph 5 abc or Ph 6 abc.

Ph 9. Electrical Measurements. 6 units (0-3-3); second term.

Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc.
An advanced course in precision electrical measurements at d.c. and low frequencies, measurement of impedance, voltage, current, frequency, etc.
Instructors: Pickering and Graduate Assistants.

Ph 14 abc. Physics Conference. 3 units (1-0-2); first, second, and third terms.

Presentation and discussion of the current literature of physics. The technique of effective oral and written presentation of reports is emphasized through criticisms of the reports by a member of the department of English.

UNDERGRADUATE OR FIFTH YEAR SUBJECTS

Ph 102 abc. Introduction to Mathematical Physics and Differential Equations. 10 units; first, second, third terms.

Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc.
This subject is the same as Ph 6 abc but with reduced credit for graduate students.
Instructor: Anderson.

Ph 112 abc. Introduction to Atomic and Nuclear Physics. 9 units (3-0-6); first, second, third terms.

Prerequisites: Ph 6 abc, Ph 7 abc or equivalent.

An introductory problem and lecture course in the experimental and theoretical foundation of modern atomic and nuclear physics. Subjects include electromagnetic waves, radiation laws, specific heats, photo-electricity, thermionics, atomic structure and the quantum theory, X-rays, radioactivity, and artificial transmustations.

Text: *Introduction to Modern Physics*, Richtmeyer and Kennard.

Instructor: T. Lauritsen.

Ph 130 abc. Methods of Mathematical Physics. 12 units (4-0-8); first, second, third terms.

Selected topics from the fields of mechanics, elasticity, hydrodynamics, heat conduction and quantum mechanics, presented with emphasis on the mathematical structure of the physical theories.

Ph 131 abc. Electricity and Magnetism. 9 units (3-0-6); first, second, third terms.

Prerequisite: An average grade of C in Ph 6 abc or Ph 102 abc, or AM 15 abc.

A problem course in electricity, magnetism and electromagnetic waves, intended primarily as a preparation for graduate work in science.

Text: *Static and Dynamic Electricity*, Smythe.

Instructors: Smythe and Leighton.

Ph 133 abc. Analytical Mechanics. 12 units (4-0-8); first, second, third terms.

Prerequisite: An average grade of C in Ph 6 abc or Ph 102 abc or AM 15 abc.

A problem of lecture course dealing with the various formulations of the laws of motion of particles, rigid bodies and elastic and fluid media, and with both exact and approximate solutions of the resulting equations. Topics considered include canonical transformations, vibrations about equilibrium and about steady motion, the non-linear oscillator, wave motion and tensor analysis.

Text: *Dynamics*, Webster; and collateral reading.

Instructor: Davis.

Ph 135 ab. Optics. 9 units (3-0-6); first, second terms.

Prerequisite: Ph 6 abc, or Ph 102 abc.

A problem subject dealing with the fundamental principles of geometrical optics, of diffraction, interference, etc., and their experimental verification.

Text: *Theory of Optics*, Drude.

Instructor: King.

Ph 136 ab. Optics Laboratory. 3 units (0-3-0); first, second terms.

Advanced laboratory work in light, consisting of accurate measurements in diffraction, dispersion, interference, polarization, spectrophotometry.

Text: *Manual of Advanced Optics*, Taylor.

Instructor: King.

Ph 137. Spectroscopy. 9 units (3-0-6); third term.

Prerequisite: Ph 6 abc, or Ph 102 abc.

A discussion of observed spectra in terms of atomic structure theory.

Instructor: Bowen.

Ph 138. Spectroscopy Laboratory. 3 units (0-3-0); third term.

Laboratory work in the measurement and classification of spectral lines to accompany Ph 137.

Instructor: King.

Ph 139 abc. Nuclear Physics. 9 units (3-0-6); first, second, third terms.

Prerequisite: Ph 112 abc or equivalent.

A problem and lecture course in nuclear physics. Subjects include fundamental properties and structure of nuclei, nuclear forces, nuclear reactions, and the behavior of high energy particles and radiation including cosmic rays.

Text: *Nuclear Physics*, Fermi, and outside references.

Instructor: Fowler.

Ph 140 ab. Kinetic Theory of Matter. 9 units (3-0-6); first and second terms.

Prerequisites: Ph 1 abc, Ma 2 abc.

During the first term, the fundamental concepts of the molecular theory of matter are treated from the theoretical, experimental and technical viewpoints (Clausius, Maxwell, Boltzman, van der Waals, Knudsen equations). During the second term, advance problems on the constitution of matter as well as practical applications are discussed (such as thermodynamics of low temperature phenomena, liquifaction of gases, phase relations, specific heats, crystallization, plasticity.)

Instructor: Goetz.

Ph 143 abc. Principles of Quantum Mechanics. 9 units (3-0-6); first second and third terms.

Prerequisites: Ph 6 abc, or Ph 102 abc, Ph 112 abc.

The fundamental experimental basis and theoretical principles of quantum mechanics, including the concept of states, indeterminancy principle, Schroedinger equation, perterbation theory, collision theory, radiation theory, spin, Dirac equation, and fields.

Instructor: Christy.

Ph 147 abc. X-Rays. 9 units (3-0-6); first, second, third terms.

Prerequisites: Ph 6 abc, or Ph 102 abc, and Ph 112.

A course covering the generation of X-rays and their interactions with matter in theory and in practical applications to research physics; including the early history of X-rays in atomic research, X-ray tubes and high voltage power supplies, generation of continuous and characteristic X-rays in targets, X-ray intensity measurements, polarization, absorption, diffraction, refraction, scattering, X-ray spectroscopy, spectroscopic methods and instrumentation, the X-ray photoelectric effect, Compton effect, dynamical theory of X-ray diffraction, the Auger effect, scattering by liquids and gases, metallurgical applications, and relation of X-rays to atomic constants. During the latter part of the course, class members will be assigned topics to report from the literature.

Instructor: DuMond.

Ph 149. History of Modern Physics. 9 units (3-0-6); first term.

Prerequisites: Ph 1 abc, Ph 2 abc.

Instructor: Millikan.

Ph 172. Research in Physics. Units in accordance with the work accomplished. Approval of the department must be obtained before registering.

GRADUATE SUBJECTS

Ph 211. Thermodynamics. 12 units (4-0-8); first term.

Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc.

The two fundamental laws of thermodynamics. Entropy and the thermodynamic potentials. Equations of reciprocity. Applications to gases, perfect and imperfect, and to dilute solutions. Phase rule and chemical equilibrium. Nernst's theorem.

Instructor: Epstein.

Ph 212 ab. Mechanics of Continuous Media. 12 units (4-0-8); first and second terms.

Prerequisite: Ph 133 abc.

Hydrodynamics of non-viscous fluids. Equations of Euler and Lagrange. General integrals and special problems. Tensor theory of deformations and of stresses. Hydrodynamics of viscous fluids. Equations of Stokes-Navier with applications to special problems. Fundamental equations of the theory of elasticity. Applications to static deformations of solids. Theory of elastic oscillations in space and in plates.

Instructor: Plesset.

Ph 215. Theoretical Nuclear Physics. 9 units (3-0-6); third term.

Prerequisite: Ph 143 ab, or equivalent.

The subject matter may vary from year to year. The course may include Stability of nuclei; Theory of nuclear reactions, radiation and beta-decay; Theory of nuclear forces and its connection with cosmic rays; Neutron physics.

Instructor: Christy.

Ph 220 ab. Applications of Maxwell's Equations. 12 units (3-0-9); second and third terms.

Prerequisite: Ph 131 abc.

A mathematical problem course in the use of retarded potentials and orthogonal solutions of the electromagnetic propagation equations. It includes the radiation patterns and impedances of antennas; diffraction; surface waves; coupling, input impedances and attenuation in wave guides and cavities.

Instructor: Smythe.

Ph 222. Electricity and Magnetism. 12 units; first term.

Prerequisites: Ph 7 abc, Ph 131 abc, Ma 10, Ma 108 abc.

Electrostatics, magnetostatics, stationary currents and their fields, electromagnetic induction, Maxwell's equations, electromagnetic waves.

Instructor: Epstein.

Ph 223. Theory of Electromagnetic Waves. 12 units (4-0-8); second term.

Prerequisite: Ph 131 abc.

Mathematical study of Maxwell's equation, propagation of waves, absorption and reflection, approximate and rigorous treatment of diffraction, theory of dispersion, electro- and magneto-optics.

Instructor: Epstein.

Ph 224. Physical Optics. 12 units (4-0-8).

Prerequisite: Ph 135 ab.

Metal optics, theory of dispersion, Zeeman effect, Stark effect, optical activity, and other problems of electro- and magneto-optics.

Instructor: Epstein.

Ph 225. Theory of Electrons. 12 units (4-0-8); third term.

Prerequisites: Ph 131 abc, Ph 223.

Retarded potentials. Radiation of a point charge. Theory of dielectrics. Electron theory of dia-, para- and ferromagnetism. Phenomena in moving bodies and experimental foundations of the theory of relativity.

Instructor: Epstein.

Ph 226. Heat Radiation and Quantum Theory. 12 units (4-0-8); second term.

Prerequisites: Ph 133 abc, Ph 211.

Historical treatment of the development of the mathematical theory of heat radiation and of the application of the theory of quanta to the phenomena of specific heats of solid and gaseous bodies, photoelectricity, photochemistry, chemical constants, etc.

Instructor: Epstein.

Ph 228. Modern Aspects of the Quantum Theory. 12 units (4-0-8); third term.

Prerequisites: Ph 133 abc, Ph 139 abc, Ph 229.

This course is devoted to review of recent developments in the quantum theory, especially in the fields of theory of radiation and of the electron theory of metals. The subject matter varies from year to year.

Instructor: Epstein.

Ph 232. Dispersion and Absorption of Ultra-Short Electromagnetic Waves. 6 units (2-0-4); first term.

Propagation of waves. Maxwell's dispersion and absorption in semi-conductors and metals. Electronic and dipolar dispersion and absorption in dielectrics. Dispersion and absorption in electrolytes. Waves along wires and dispersion in magnetic substances.

Experimental results on dispersion and absorption of ultra-short waves in dielectrics, electrolytes, and magnetic substances.

Instructor: Potapenko.

Ph 234. Topics in Theoretical Physics. 9 units (3-0-6); one term.

The content of this course will vary from year to year. Typical Topics: Non-relativistic Quantum Theory; Relativistic Quantum Theory.

Instructor: Christy.

Ph 235 abc. The Theory of Relativity. 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 235 a may be taken separately by students who are interested only in the principles and applications of the special theory of relativity.

Text: *Relativity, Thermodynamics and Cosmology*, Tolman.

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: Epstein, Christy and Feynman.

Ph 241. Research Conferences 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: Epstein.

Ph 242. Research in Physics. Units in accordance with work accomplished.

Opportunities for research are offered to graduate students in all the main branches of physics. The students should consult the department and have a definite program of research outlined before registering.

PSYCHOLOGY

(See under Philosophy)

RUSSIAN

(See under Modern Languages)

SOCIOLOGY

(See under Philosophy)

PART FOUR

Degrees, Honors, and Awards, 1949-50

DEGREES CONFERRED JUNE 9, 1950

Doctor of Philosophy

Robert Train Adams. (Chemistry and Animal Physiology), B.S., University of California, 1942.

Fred Peter Adler. (Electrical Engineering and Physics), B.S., University of California, 1945; M.S., California Institute of Technology, 1948.

Jack Leland Alford. (Mechanical Engineering and Electrical Engineering), B.S., California Institute of Technology, 1942; M.S., 1946.

Morton Alperin. (Aeronautics and Mathematics), B.Ae.E., New York University, 1939; M.S., California Institute of Technology, 1947.

Spencer Roe Baen, Capt., U.S.A. (Mechanical Engineering and Electrical Engineering), B.S., Agricultural and Mechanical College of Texas, 1943; M.S., California Institute of Technology, 1947.

William Alvin Baum. (Physics and Electrical Engineering), B.A., University of Rochester, 1943; M.S., California Institute of Technology, 1945.

Stanley Urner Benscoter. (Aeronautics and Civil Engineering), B.S., University of Illinois, 1932; M.S., Agricultural and Mechanical College of Texas, 1935; C.E., University of Illinois, 1941.

Prabhat Kumar Bhattacharya. (Geophysics and Physics), M.S., Calcutta University, 1942; M.S., California Institute of Technology, 1947.

Robert Hockman Blaker. (Chemistry and Physics), A.B., Berea College, 1942.

Marvin Charles Brooks. (Chemistry and Mathematics), B.S., Yale University, 1942; M.S., New York University, 1944.

Alfred Bruce Brown, Jr. (Physics and Mathematics), B.S., Lehigh University, 1942; M.S., California Institute of Technology, 1947.

Werner Buchholz. (Electrical Engineering and Physics), B.S., University of Toronto, 1945; M.S., 1946.

Stanley Campbell Burket. (Chemistry and Physics), B.A., Linfield College, 1939; M.A., University of Kansas, 1943.

Richard Raymond Carhart. (Physics and Mathematics), B.A., University of California at Los Angeles, 1940.

Chieh-Chien Chang. (Aeronautics and Mathematics), B.A., National Northeastern University, 1932; M.S., California Institute of Technology, 1941.

Feng-Kan Chuang. (Aeronautics and Mathematics), B.S., Chiao Tung University, 1946; M.S., California Institute of Technology, 1948.

James Carroll Conly. (Chemistry and Genetics), B.A., University of Rochester, 1942.

Thomas Joseph Connolly. (Chemical Engineering and Chemistry), B.Ch.E., Syracuse University, 1943; M.S., Cargenie Institute of Technology, 1947.

Harold Miller DeGroff, Jr. (Aeronautics and Mathematics), B.Ae., Rensselaer Polytechnic Institute, 1946; M.S., California Institute of Technology, 1947; Ae.E., 1948.

Peter Dehlinger. (Geophysics and Geology), B.S., University of Michigan, 1940; M.S., California Institute of Technology, 1943.

John Edward Denby-Wilkes. (Mathematics and Aeronautics), B.A., University of Paris, 1939; B.S., 1940; B.A., Columbia University, 1942.

Mayette Elner Denson, Jr. (Geophysics and Geology), B.S., Montana State College, 1941; M.S., California Institute of Technology, 1948.

Leendert deWitte. (Geophysics and Petroleum Geology), States University of Grönigen, Holland; M.S., California Institute of Technology, 1947.

W. Smith Dorsey, Jr. (Chemistry and Chemical Engineering), B.S., Iowa State College, 1940.

Worthie Lefler Doyle. (Mathematics and Physics), B.A., University of Washington, 1943.

Kazim Ergin. (Geophysics and Mathematics), B.S., Massachusetts Institute of Technology, 1942; M.S., California Institute of Technology, 1943.

Frank Behle Estabrook. (Physics and Mathematics), A.B., Miami University, 1943; M.S., California Institute of Technology, 1947.

Paul Stephen Farrington. (Chemistry and Chemical Engineering), B.S., California Institute of Technology, 1941; M.S., 1947; Ch.E., 1948.

JACK EDWARD FROEHLICH. (Aeronautics and Mathematics), B.S., California Institute of Technology, 1947; M.S., 1948.

LOUIS ADAMS GIAMBONI. (Physics and Mathematics), B.S., University of California at Los Angeles, 1941; M.S., California Institute of Technology, 1947.

DONALD ARTHUR GLASER. (Physics and Mathematics), B.S., Case School of Applied Science, 1946.

LEON GREEN, JR. (Mechanical Engineering and Aeronautics), B.S., California Institute of Technology, 1944; M.S., 1947.

ROBERT RUSSELL GRINSTEAD. (Chemistry and Electrical Engineering), B.S., University of California, 1946.

RICHARD MANNING HERMES. Mechanical Engineering and Mathematics), B.E.E., University of Santa Clara, 1934; M.A., 1938.

ARMIN JOHN HILL. (Physics and Astronomy), B.S., Montana State College, 1932; M.S., 1938; M.S., California Institute of Technology, 1949.

HARVEY AKIO ITANO. (Chemistry and Physics), B.S., University of California, 1942; M.D., St. Louis University, 1945.

RODMAN JENKINS. (Chemical Engineering and Chemistry), S.B., Massachusetts Institute of Technology, 1946.

ROBERT CLARKE JOPSON. (Physics and Mathematics), B.S., California Institute of Technology, 1944.

DAVID LOCKHART JUDD. (Physics and Mathematics), A.B., Whitman College, 1943; M.S., California Institute of Technology, 1947.

BERTRAM KEILIN. (Chemistry and Physics), B.A., New York University, 1942; M.S., California Institute of Technology, 1945.

NATHAN HART KOENIG. (Chemistry and Physics), B.S., University of Chicago, 1937.

HENRY LEMAIRE. (Chemistry and Physics), B.S., Massachusetts Institute of Technology, 1942.

LEONARD SOLOMON LERMAN. (Chemistry and Physics), B.S., Carnegie Institute of Technology, 1945.

TING-YI LI. (Aeronautics and Mathematics), B.S., National Central University, 1940; Ae.E., California Institute of Technology, 1947.

HAROLD LURIE. (Aeronautics and Mathematics), M.S., University of South Africa, 1946.

ROBERT V. MACALLISTER. (Chemistry and Chemical Engineering), A.B., Wartburg College, 1934.

HAROLD CLIFFORD MARTIN. (Aeronautics and Mathematics), B.S., New York University, 1934; M.S., 1937.

JOHN LATIMER MASON. (Chemical Engineering and Chemistry), B.S., University of Chicago, 1944; B.S., California Institute of Technology, 1947; M.S., 1948.

FRANK AMBROSE MCCLINTOCK. (Mechanical Engineering and Mathematics), B.S., Massachusetts Institute of Technology, 1943; M.S., 1943.

JACK ENLOE MCLAUGHLIN. (Mathematics and Physics), B.S., University of Idaho, 1944.

MELVIN LEROY MERRITT. (Physics and Mathematics), B.S., California Institute of Technology, 1943.

HAROLD MORTON MOONEY. (Geophysics and Physics), B.S., Harvard College, 1943; M.S., California Institute of Technology, 1948.

JAMES DONALD O'REILLY, REVEREND. (Physics and Mathematics), B.S., St. Patrick's College (Maynooth), 1938; S.T.B., 1940; M.S., California Institute of Technology, 1946.

FRANKLIN PAGE, JR. (Chemical Engineering and Mechanical Engineering), B.A., San Diego State College, 1947.

WEN-KWE PAO. (Genetics and Biochemistry), B.A., National Central University, 1939.

JAMES HOWARD PINCKARD. (Chemistry and Biology), B.A., Arizona State College, 1938; M.A., 1939.

VOLNEY KINNE RASMUSSEN, JR. (Physics and Mathematics), B.S., California Institute of Technology, 1939.

BERNARD RASOF. (Aeronautics and Mathematics), B.S., Illinois Institute of Technology, 1941; M.S., California Institute of Technology, 1944.

EBERHARDT RECHTIN. (Electrical Engineering and Physics), B.S., California Institute of Technology, 1946.

ROBERT KENNETH RONEY. (Electrical Engineering and Physics), B.S., University of Missouri, 1944; M.S., California Institute of Technology, 1947.

WILLIAM TRELOAR RUSSELL, MAJOR, U.S.A. (Mechanical Engineering and Electrical Engineering), B.S., University of Washington, 1942; M.S., California Institute of Technology, 1947.

ADAM FRANK SCHUCH. (Chemistry and Physics), B.S., Michigan State College, 1930; M.S., 1931.
GLENN AUGUST SCHURMAN. (Mechanical Engineering and Physics), B.S., Washington State College, 1944; M.S., California Institute of Technology, 1947.
ALBERT MILLS SOLDATE. (Chemistry and Mathematics), A.B., Stanford University, 1941; A.M., 1942.
BERNARD SAMUEL STRAUSS. (Biochemistry and Immunology), B.S., College of the City of New York, 1947.
JOHN HENRY SULLIVAN. (Chemistry and Physics), B.A., University of California at Los Angeles, 1943.
YOU-CHI TANG. (Chemistry and Physics), B.S., National Tung-Chi University, 1942.
ALVIN VIRGIL TOLLESTRUP. (Physics and Mathematics), B.S., University of Utah, 1944.
MAX LEA WILLIAMS, JR. (Aeronautics and Mathematics), B.S., Carnegie Institute of Technology, 1942; M.S., California Institute of Technology, 1947; Ae.E., 1948.
MARTYNAS FREELANDAS YCAS. (Embryology and Invertebrate Zoology), B.A., University of Wisconsin, 1947.

ENGINEER'S DEGREES

AERONAUTICAL ENGINEER

HARRY ISRAEL ASHKENAS, B.S., University of California, 1944; M.S., California Institute of Technology, 1946.
DAVID T. BARISH, LT., U.S.A.F., B.S., Air Force Institute, Wright Field, 1948; M.S., California Institute of Technology, 1949.
WILLIAM CYRUS BARKER, B.S., University of California, 1942; M.S., California Institute of Technology, 1948.
WILLIAM CLEVELAND BRYAN, LT. COMDR., U.S.N., B.S., United States Naval Academy, 1940.
PATRICK STANLEY CHASE, B.S., California Institute of Technology, 1943; M.S., 1946.
RICHARD DANIEL DELAUER. LT., U.S.N., A.B., Stanford University, 1940.
LEO FRANCIS FRICK, LT. COMDR., U.S.N.
RALPH LEWIS GEISBERG, B.M.E., Clemson Agricultural College, 1937; M.S., California Institute of Techonology, 1944.
JOHN CLARENCE KANE, LT., U.S.N., B.S., United States Naval Academy, 1943.
ROGER EDWARD MATZDORFF, B.S., California Institute of Technology, 1948; M.S., 1949.
ROBERT NORRIS OLIVER, B.S., Massachusetts Institute of Technology, 1948; M.S., California Institute of Technology, 1949.
JAMES VICTOR ROWNEY, LT. COMDR., U.S.N., B.S., United States Naval Academy, 1942.
LEE RICHARD SCHERER, LT., U.S.N., B.S., United States Naval Academy, 1942.
LOUIS VINCENT SCHMIDT, B.S., California Institute of Technology, 1946; M.S., 1948.
JOHN TYLER SHEPHERD, LT., U.S.N., B.S., United States Naval Academy, 1942.
BASIL STAROS, B.S., Massachusetts Institute of Technology, 1941; M.S., California Institute of Technology, 1948.
JOSEPH WOLFF WECHSLER, B.S., California Institute of Technology, 1948; M.S., 1949.
FRANK WELCH, JR., LT. COMDR., U.S.N., B.S., United States Naval Academy, 1941.

Chemical Engineer

HARRY WARD BROUGH, B.S., California Institute of Technology, 1945.

Electrical Engineer

GEORGE EPPRECHT, B.S., Swiss Federal Institute of Technology, 1946.

Geophysical Engineer

MILNER DARWIN QUIGLEY, B.S., Michigan State College, 1941; M.S., Northwestern University, 1947.

Industrial Designer

HARRY LACELLES MASSER, JR., B.S., University of California 1947.

Mechanical Engineer

HARRY EASTWOOD CROSSLEY, B.S., University of Vermont, 1943; M.S., Massachusetts Institute of Technology, 1947.
RICHARD LEE ROBINSON, B.S., Massachusetts Institute of Technology, 1947; M.S., California Institute of Technology, 1948.

MASTER OF SCIENCE IN SCIENCE

Astronomy

FREDERICK HAROLD LEINBACH, JR., B.S., South Dakota State College of Agriculture and Mechanical Arts, 1949.
MORTON S. ROBERTS, B.A., Pomona College, 1948.
JOHN WHITTLESEY, B.S., California Institute of Technology, 1948.

Biology

CHUNG HSIEN LI, B.S., National University of Peking, 1935.

Chemistry

ROY PHILLIP CRAIG, B.A., University of Colorado, 1948.
ROBERT FREDERICK PETZOLD, B.S., Massachusetts Institute of Technology, 1945.

Chemical Engineering

FORREST STURDEVANT ALLINDER, JR., B.S., California Institute of Technology, 1949.
DONALD HARDING BAER, B.S., University of New Mexico, 1949.
ROBERT BAYARD FUNK, B.S., California Institute of Technology, 1949.
RICHARD ALAN MCKAY, B.S., California Institute of Technology, 1949.
GLENN DAVID ROBERTSON, JR., B.S., Rice Institute, 1949.
ROBERT MITCHELL SHERWIN, B.S., California Institute of Technology, 1943.
ROBERT MALCOLM STEWART, JR., B.S., California Institute of Technology, 1949.

Geological Sciences

JOSEPH BRIGHTWELL ALEXANDER, B.S., Royal School of Mines, 1933.
JOSEPH HAROLD BIRMAN, B.A., Brown University, 1948.
PHILLIP GRANVILLE COOK, B.S., Ohio University, 1948.
PAUL BERNARD HARRIS, B.S., California Institute of Technology, 1949.
WILLIAM PORTER IRWIN, B.S., New Mexico School of Mines, 1944.
EDWARD MALCOLM MACKEVETT, JR., B.A., University of California at Los Angeles, 1947.
CAREL OTTE, JR., B.S., University of Amsterdam, 1943.
GEORGE PIERCE RIGSBY, B.S., California Institute of Technology, 1948.
JAMES ARCHIBALD RODDICK, B.S., University of British Columbia, 1948.

Geophysics

C. WALTER FAESSLER, B.S., Université Laval, 1948.
ROBERT DONALD FORESTER, B.S., California Institute of Technology, 1949.
JAMES PAUL HEPPNER, B.S., University of Minnesota, 1948.
JOSEPH ROBERT MORAN, B.A., Pomona College, 1948.
ROBERT LESLIE NELSON, B.A., Williams College, 1948.
JOHN RENOWDEN REESE, B.S., Purdue University, 1947.

Meteorology

JAMES BAXTER GARRISON, JR., B.S., University of Arkansas, 1947.
EDWARD FOY MCDANIEL, B.S., Southern Methodist University, 1949.
DAVID ALLOWAY STRANGE, A.B., University of California, 1948.

Physics

John Milton Andres, B.S., California Institute of Technology, 1949.
Philip Joseph Closmann, B.E., (Ch.E.), Tulane University, 1944; S.M. (Ch.E.), Massachusetts Institute of Technology, 1948.
Warren Evald Danielson, B.S., California Institute of Technology, 1949.
Milford Hall Davis, B.S., Yale University, 1949.
John Nathaniel Harris, B.S., California Institute of Technology, 1948.
Robert Edward McMillan, B.S., Louisiana State University, 1942.
Edmund Alexander Milne, B.A., Oregon State College, 1949.
Rolland Albert Missman, Jr., B.S., Oregon State College, 1949.
Don H. Pickrell, Jr., B.S., California Institute of Technology, 1949.
Frank Harvey Shelton, B.S., California Institute of Technology, 1949.
Alexander Stolovy, B.S., Brooklyn College, 1948.
William Dennis Warters, B.A., Harvard College, 1949.
Calvin Wong, B.S., Massachusetts Institute of Technology, 1948.

MASTER OF SCIENCE IN ENGINEERING

Aeronautics

Thomas Charles Adamson, Jr., B.S., Purdue University, 1949.
John William Baxter, B.S., Louisiana State University, 1948.
Nick S. Diaconis, B.S., University of Pittsburgh, 1949.
Donald Allen Dooley, B.S., University of Notre Dame, 1949.
Andrew George Fabula, B.S., Princeton University, 1949.
James Edwin Francis, B.S., Agricultural and Mechanical College of Texas, 1948.
Raimo Jaakko Häkkinen, Dipl.ins., Finland Institute of Technology, 1948.
Paul H. Jackson, Jr., B.S., University of Kansas, 1949.
Robert Hani Korkegi, B.S., Lehigh University, 1949.
Robert Richard Larson, B.S., University of Washington, 1949.
Robert McMillan, B.S., University of Saskatchewan, 1938.
Robert Vartan Meghreblian, B.S., Rensselaer Polytechnic Institute, 1943.
Robert Chase Miller, B.S., Massachusetts Institute of Technology, 1945.
Calvin Etheridge Porcher, B.S., University of Texas, 1948.
Valluri SitaRama Rao, B.Sc., Benares Hindu Institute, 1948; D.I.I.Sc., Indian Institute of Science, 1949.
Scott Carson Rethorst, B.S., Massachusetts Institute of Technology, 1936.
Howard Richard Schmidt, Capt, U.S.A.F., B.S., (M.E.), University of Illinois, 1942; M.S., (M.E.), Rennselaer Polytechnic Institute, 1946.
Jack Lawrence Shoenhair, Comdr., U.S.N., B.S., Rensselaer Polytechnic Institute, 1950.
George Edward Solomon, B.S., University of Washington, 1949.
William Walter Willmarth, B.S., Purdue University, 1949.

Civil Engineering

Frederick Clark Badger, Lt., U.S.A., B.S., United States Military Academy, 1946.
Arthur Elwin Bruington, B.S., California Institute of Technology, 1949.
Robert Edward Crawford, B.S., University of Texas, 1949.
Thomas Edward Dowd, Jr., Lt., U.S.A., B.S., United States Military Academy, 1949.
Leonard Edelstein, Lt., U.S.A., B.S., United States Military Academy, 1946.
Rudolf Christof Frey, B.S., Marquette University, 1949.
Peter Grosz, Jr., Lt., U.S.A., B.S., United States Military Academy, 1946.
James Hart Hottenroth, Major, U.S.A., B.S., United States Military Academy, 1942.
William Farbridge Jones, B.S., King's College, University of Durham, 1949.
Robert Bruce Linderman, B.S., Utah State Agricultural College, 1949.
Robert Clough Nelson, Lt., U.S.A., B.S., United States Military Academy, 1945.
John Brisbin Rutherford, B.S., Lehigh University, 1949.
William Powers Schneider, Lt., U.S.A., B.S., United States Military Academy, 1946.
James Alfred Vivian, Major, U.S.A., B.S., United States Military Academy, 1942.
Amos Luther Wright, Lt., U.S.A., B.S., United States Military Academy, 1945.

Electrical Engineering

HENRY ARCHIBALD CORRIHER, JR., B.S., North Carolina State College, 1949.
JEROME KING DELSON, B.S., Illinois Institute of Technology, 1949.
DONALD JEROME GIMPEL, B.S., Illinois Institute of Technology, 1949.
JAMES CECIL GOODWYN, B.S., College of William and Mary, 1948.
MICHEL JOSEPH-JEAN GOSSOT, B.A., Université de Paris, 1942; B.E., Ecole Polytechnique, 1949.
FREDERICK A. GROSS, B.A., University of Southern California, 1943.
PALMER EINO HAKALA, B.S., Montana State College, 1949.
WALTER JOSEPH HIRSCHBERG, B.S., California Institute of Technology, 1949.
GEOFFREY BISHOP HOLMES, B.S., Agricultural and Mechanical College of Texas, 1948.
JAMES ROBERT HOLMES, B.S., Stevens Institute of Technology, 1945.
ROBERT CHARLES HOWARD, B.A., Whitman College, 1944.
ROBERT VERNON KNOX, B.S., California Institute of Technology, 1945.
WILLIAM KROLL, B.S. (M.E.), University of Illinois, 1947; B.S., (E.E.), University of Michigan, 1949.
RUBIN WILLIAM LUDWIG, B.S., University of Texas, 1947.
GERALD STEVEN MAYNER, B.E., University of Southern California, 1949.
LEWIS MICHNIK, B.E., Johns Hopkins University, 1948.
ALFRED JAMES MONROE, B.S., Michigan State College, 1949.
MERLE LOREN MORGAN, B.S., California Institute of Technology, 1949.
WILLIAM THOMAS MORGAN, B.S., University of Akron, 1948.
DONALD JOHN NELSON, B.S., Oregon State College, 1948.
HARVEY LEWIS PASTAN, B.S., Worcester Polytechnic Institute, 1949.
ROBERT WILLIAM PAULSON, LT. COL., U.S.A.F., B.S., University of Washington, 1946.
WILLIAM ISAAC RUMER, B.S., California Institute of Technology, 1949.
BURTON BENJAMIN RUTKIN, B.S., California Institute of Technology, 1949.
DALE DELBERT RYDER, B.S., California Institute of Technology, 1949.
CLEMENT JOSEPH SAVANT, JR., B.S., California Institute of Technology, 1949.
GARLAND BERTE SEABORN, JR., B.S., Clemson Agricultural College, 1949.
HENRY SUSUMU TAKEMURA, B.S., University of California at Los Angeles, 1949.
ROBERT REID WATERS, B.S., California Institute of Technology, 1949.
JAMES HOWARD WATKINS, CAPT., U.S.A.F., B.S., United States Military Academy, 1943.

Mechanical Engineering

ROGER ALAN ANDERSON, B.S., California Institute of Technology, 1949.
DONALD ROBERT BARTZ, B.S., University of California, 1949.
ERLE J. BROWN, JR., B.S., California Institute of Technology, 1949.
ROBERT DUFF CLARK, B.S., Stanford University, 1949.
WILLIAM NELSON HARRIS, B.S., California Institute of Technology, 1949.
HAROLD HARTY, B.S., University of Washington, 1948.
VICTOR GUY JACKSON, B.S., University of Illinois, 1949.
JAMES EDGAR JOHNSON, B.S., California Institute of Technology, 1949.
JAMES THEODORE KENNEY, JR., B.S., California Institute of Technology, 1949.
TARAS KICENIUK, B.S., Neward College of Engineering, 1949.
HENRY ALLAN LONG, B.S., California Institute of Technology, 1949.
ROBERT BRUCE MCCLURE, B.S., Purdue University, 1949.
JOHN HAWES MCNAMARA, B.A., Dartmouth College, 1948; B.S., Thayer School of Engineering, 1949.
RALPH LUCAS MERRILL, B.S., Purdue University, 1947.
WILLIAM EATON PALMER, B.S., California Institute of Technology, 1949.
CHARLES HERRICK ROSE, B.S., California Institute of Technology, 1940.
PHILIP ROSENBLUM, B.S.E., University of Michigan, 1940.
HAROLD LEWIS SLETTEN, B.S., North Dakota Agricultural College, 1948.
EZRA SPEVAK, B.S., University of Toledo, 1949.
THAD VREELAND, JR., B.S., California Institute of Technology, 1949.
HUGH ROSS WAHLIN, B.S., University of Wisconsin, 1949.

Bachelor of Science in Science

Jared Abell
James Russell Allder
Harvey Jerome Amster
George Myron Arcand*
Donald Owen Asquith
Donald Roy Baker
J. Allan Beek, Jr.
Christian James Blom†
Louis Bogart
Stanley Clyde Boicourt†
Julian Brody
Raymond Edward Brow
Richard Pierson Buck
William Louis Burriss
William Denmam Calhoun
Odell Edward Carson
Paul Torkelson Clark
Thomas Paul Coons
Duane Herbert Cooper*
Fernando José Corbató*
William Parker Cox*†
William Craven Culbertson
William D. Dean
Herbert Amasa Forrester*
Carroll Leslie Friswold
James Basil Gerhart*
Lester Kepner Goodwin*
John Morgan Greene*
Kenneth James Hammond
James Briggs Hendrickson*†
Shigeru Irwin Honda
Peter Adam Howell
John David Hughes
Floyd Bernard Humphrey
John Keith Inman
Norman Ford Jacobson
Robert Ross Jennings*
Eric Bertil Johansson
Walter John, Jr.*
Wilbur Lawrence Knight
Richard Hubert Knipe
Peter T. Knoepfler
James Lorenz Kohl*
Ralph Harvey Lovberg*†
Ralph Lutwack
Scott Lynn*
David Brindley MacKenzie*†
James Matterson Mansfield
Monte Lee Marks
Jerry Orchard Matthews
Richard Moore McIntyre
Donald Paul Merrifield*
Marco Antonio Montemezzi
Donald William Moore
Thomas Warner Moore
Wheeler J. North
David Charles Oakley
Breck Parker
Roger A. Picciotto*
Richard Scott Pierce*
John William Reeds
Edward A. Revay
Werner Boris Riesenfeld*
Bruce Robinson, Jr.†
Lee Wallace Ross
Willis Andrew Rosser, Jr.
James E. Schofield
Leonard Gene Schultz
Arent Henry Schuyler, Jr.
John Michael Sellen, Jr.†
Donald Lee Shepard
Donald Lee Smathers
Jack Wendell Smith
Roland Nesbit Smoot
Melvin A. Baren Sprecher
Hugh Franklin Stoddart
Ralph Jay Stone
Bruce Bernot Stowe*†
Harold Alwin Streaker
Victor Anton Jacobus van Lint*
David Richard Viglierchio*
John J. Vrolyk
Martin Walt, IV*
LeRoy William Weeks
Robert Stephen Welte*
Wilbur Andrew Wikholm
Stanley Alan Zwick*

Bachelor of Science in Engineering

Donald Shaw Barrie
Leon Joseph Bass
Charles Richard Bennett
Arthur Robert Benton, Jr.
Weldon Oscar Bergreen
Galt Buhler Booth*
Theodore Munson Bowen
Wilson Bradley†
Andrew John Check
Harry Fay Clark, Jr.
Howard Ellsworth Clark
Lowell C. Cockel, Jr.
Harold Keith Coulter
Robert Nelson Curtis
Bain Dayman, Jr.*
Cecil William Drinkward
Frederick Weed Drury, Jr.
Gardner Wade Earle, Jr.

Vern A. Edwards
Ralf Austin Erickson
Albert Eschner, Jr.*†
Richard Snowden Fairall
Norman Stanley Fink
Carl Edward Fox†
John Prescott Francis
William August Freed†
Boyd MacIntosh Gage*
Abram N. George
Robert Larimer Gottier
Geoffrey Hamline Grey
William White Haefliger
Clinton Darle Hale
Michael Alexander Hall
Dirck T. Hartmann
Malcolm Van Cleve Hickey
William Bernard Higgins
Charles Stetson Howard, Jr.
Jerome E. Jacobs*
Donald B. Jennings
Merle Thayne Kealiikapu Kam
Louis Katz
Donald V. Kendall
Max Stewart Kreston
Warren Eugene Krum
Thomas Glenn Lang
William D. Lansdown
Almon Elsdon Larsh, Jr.
Donald D. MacDougall*
Daniel Markoff
Craig Marks*
Max Vernon Mathews*
James Oeland McCaldin*
Richard Alexander McKinnon
Albert Edward McLellan
William Howard McLellan
H. Reha Mesara
John Paul Moffat, Jr.
Jay Allen Montgomery
John Thomas Mosich
Walter LeRoy Mudgett
Gibson Oakes
Irving Lee Odgers*
Donald Jay Oswald*
Robert Eames Parker
Richard Holden Perry
John Kimball Poindexter
Roswell Harry Potts
William Howard Proud
Ronald Lewis Quandt*
Dean Arthur Rains
Howard Edwin Reinecke
Marco Antonio Romero
Martin Neal Ross
Donald Frazer Royce†
Charles Anthony Savant*
John Robert Scantlin
Dwight Clare Schroeder
Henry Shapiro
Virgil Jones Sims, Jr.*
Winsor Soule, Jr.
Eugene Godfrey Spencer
William Thomas Staats, Jr.
Tom Hamilton Stauffer
Robert Leavens Stert
Robert Tarrant Stevens
Dale Frederick Stewart
Donald Wayne Stillman
William Ainsworth Sylvies
Howell Newbold Tyson, Jr.
Harry Van Akin
Norris Dudley Whitehill
Warren G. Whiting
James Rutledge Wilcox
Jack Kester Willis
Kam Leung Wong
Edsel Augustus Worrell*
Richard Bruce Wright*

*Graduated with honor in accordance with a vote of the Faculty.
†Awarded the Honor Key by the Associated Students, CIT, for participation in student activities.

HONORS AND AWARDS

HONOR STANDING

The undergraduate students listed below have been awarded honor standing for the current year, on the basis of the excellence of their academic records for the year 1949-50:

Class of 1951

Basin, M.A.
Beebe, W. M.
Bemis, R. C.
Bumb, F. C.
Davis, E. F.
Goodman, F. R.
Helfrey, P. F.
Holmes, J. L.
Ibers, J. A.
Merten, U.
O'Connell, R. F.
Pardee, R. S.
Peck, D.
Rappaport, H. P.
Rogers, J. J. W.
Sampson, W.
Stern, E. A.
Sweet, S. S.
Taylor, R. B.
Trilling, G.
Wennstrom, A. E.
Whitney, W. M.
Wright, W. V.

Class of 1952

Bridges, R. L.
Dibble, W. E.
Einwohner, T. H.
Gray, N. E.
Helmuth, J. G.
Herscovici, B. H.
Israelson, B. P.
Johnston, A. R.
Jones, R. T.
Kamb, W. B.
Levy, M.
McCool, J. M.
Miller, C. R.
Oliver, R. E.
Orville, P. M.
Perrault, R. E.
Riggs, D. D.
Shreve, R. L.
Verdier, P. H.
Webber, M. M.
Weil, J. L.

Class of 1953

Benjamin, C. E.
Crespo, M. J.
Deverill, R. S.
Haire, A. M.
Ham, R. G.
Kliegel, J. R.
Knapp, D. E.
LaTourrette, J. T.
MacDonald, D. J.
Ogawa, H.
Scott, B. L.
Seele, G. D.
Shugart, H. A.
Stasney, A. J.
Stevens, D. F.
Thomas, T. N.
Thorson, W. R.
Vartanian, P. H., Jr.
Vickman, L. L.
Wood, R. H.

AWARDS

Conger Peace Prize Oration

First Prize: Ralph Stone
Second Prize: Swaroop Chandra Bhanjdeo

Mary A. Earl McKinney Prize in English

First Prize: David Elliott
Second Prize: James A. Ibers

Frederic W. Hinrichs, Jr., Memorial Award

Ralph H. Lovberg

GENERAL INDEX