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California Institute of Technology

Catalogue

1955-56

PASADENA, CALIFORNIA

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CALIFORNIA INSTITUTE OF TECHNOLOGY

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

CATALOGUE
1955-1956

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PASADENA, CALIFORNIA

CONTENTS

PART ONE. GENERAL INFORMATION

Part Two. Detailed Information for Present and Prospective Underground and Graduate Students

Part Three. Course Schedules and Subjects of Instruction

Part Four. Degrees, Honors, and Awards, 1954-55

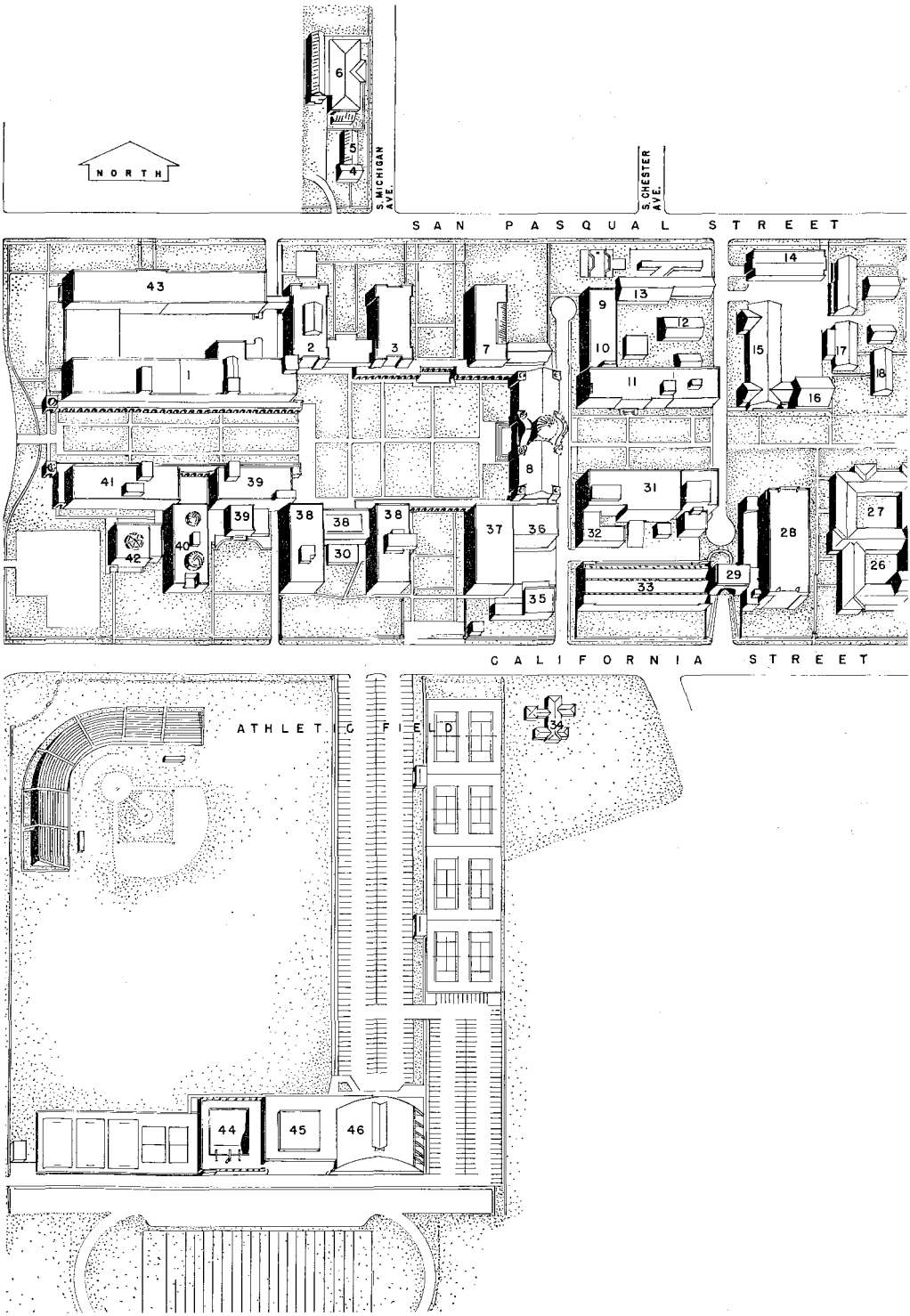
THE CAMPUS OF THE CALIFORNIA INSTITUTE

The following two pages show 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 clubhouse for the use of the graduate students; the staffs of the Institute, the Mount Wilson Observatory and the Huntington Library; and the California Institute Associates.

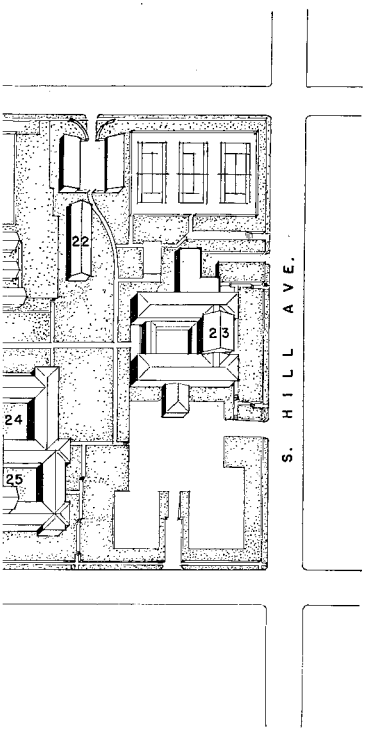
Tournament Park, the area lying south of East California Street, was originally the property of the City of Pasadena. In March, 1947, the citizens of the city voted to authorize the sale of Tournament Park to the Institute, and the formalities involved in the transfer of title were completed early in 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 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 a gymnasium and swimming pool.

CAMPUS • CALIFORNIA



INSTITUTE OF TECHNOLOGY



1. Kerckhoff Laboratories (Biological Sciences)
2. Crellin Laboratory (Chemistry)
3. Gates Laboratory (Chemistry)
4. Dolk Laboratory (Plant Research)
5. Clark Laboratory (Plant Research)
6. Earhart Laboratory (Plant Research)
7. Dabney Hall (Humanities)
8. Throop Hall (Administration; Electrical Engineering)
9. Chemical Engineering Laboratory
10. Heating Plant
11. Engineering Building (Civil and Mechanical Engineering)
12. Electrical and Mechanical Maintenance Shop
13. Mechanical Engineering Shop
15. Coffee Shop and Dormitory
16. Throop Club
17. Carpenter Shop
18. Paint Shop
19. Bldg. T-1 (Y.M.C.A.; Air Force ROTC; Sanitary Engineering Laboratory)
20. Bldg. T-2 (Offices and Graduate Students' Studies)
21. Bldg. T-3 (Chemical Engineering Offices and Shop)
22. Health Center
23. Athenaeum
24. Ricketts House
25. Blacker House
26. Dabney House
27. Fleming House
28. Synchrotron Laboratory
29. Merrill Wind Tunnel
30. Cosmic Ray Laboratory
31. Guggenheim Laboratory (Aeronautics)
32. Hydrodynamics Laboratory
33. Central Machine Shop
34. Arden House
35. Buildings and Grounds Office; Receiving Room and Central Warehouse
36. Kellogg Laboratory (Electrical Engineering; Physics)
37. High Voltage Research Lab.
38. Bridge Laboratory (Physics)
39. Arms Laboratory (Geological Sciences)
40. Robinson Laboratory (Astrophysics)
41. Mudd Laboratory (Geological Sciences)
42. Culbertson Hall (Auditorium; Industrial Relations)
43. Church Laboratory (Chemical Biology)
44. Alumni Swimming Pool
45. Locker Rooms

CALENDAR

1955

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CALENDAR 1955-1956

FIRST TERM

1955	
September 22	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 22	Registration of students transferring from other colleges, 8:00 a.m. to 12 noon.
September 22-24	Student Camp.
September 26	General Registration—8:30 a.m. to 3:30 p.m.
September 27	Beginning of instruction—8:00 a.m.
October 14	Last day for adding courses.
October 15	Examinations for the removal of conditions and incompletes.
October 22	Parents' Day.
October 31-November 5	Mid-Term Week.
November 5	MID-TERM.
November 7	Mid-term deficiency notices due—9:00 a.m.
November 11	Last day for dropping courses.
November 18	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
November 21-25	Pre-registration for 2nd term, 1955-56.
November 24-27	Thanksgiving recess.
November 24-27	Thanksgiving holiday for employees.
December 3	College Entrance Board examinations for admission to the freshman class, September, 1956.
December 3	Students' Day.
December 12-16	Final examinations—1st term, 1955-56.
December 16	Last day for admission to candidacy for the degree of Doctor of Philosophy in June, 1956.
December 17	End of 1st term, 1955-56, 12 M.
December 17 January 3	Christmas vacation.
December 26	Christmas holiday for employees.
December 27	Registration Committee—9:00 a.m.

SECOND TERM

1956	
January 2	New Year's holiday for employees.
January 3	General Registration—8:30 a.m. to 3:30 p.m.
January 4	Beginning of instruction—8:00 a.m.
January 14	College Entrance Board examinations for admission to the freshman class, September, 1956.
January 20	Last day for adding courses.
January 21	Examinations for the removal of conditions and incompletes.
January 30-February 4	Mid-term Week.
February 4	MID-TERM.
February 6	Mid-term deficiency notices due—9:00 a.m.
February 10	Last day for dropping courses.
February 17	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
February 20-24	Pre-Registration for 3rd term, 1955-56.
March 12-16	Final Examinations—2nd term, 1955-56.
March 17	College Entrance Board examinations for admission to the freshman class, September, 1956.
March 17	End of 2nd term, 1955-56, 12 M.
March 23	Registration Committee—9:00 a.m.

THIRD TERM

1956	
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 1956-57.
May 19	College Entrance Board examinations for admission to the freshman class, September, 1956.
May 25	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy.
May 30	Memorial Day holiday.
May 30	Memorial Day holiday for employees.
May 28-June 1	Final examinations for senior and graduate students—3rd term, 1955-56.
June 4-8	Final examinations for undergraduate students—3rd term, 1955-56.
June 6	Meetings of committees on Courses in Science and Engineering, 10:00 a.m.
June 6	Faculty meeting—2:00 p.m.
June 7	Class Day.
June 8	Commencement.
June 8-9	Examinations for admission to upper classes, September, 1956.
June 9	End of 3rd term, 1955-56, 12 M.
June 18	Registration Committee—9:00 a.m.
July 4	Independence Day holiday.
July 4	Independence Day holiday for employees.

FIRST TERM, 1956-57

1956	
September 3	Labor Day holiday for employees.
September 20	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 20	Registration of students transferring from other colleges, 8:00 a.m. to 12 noon.
September 20-22	Student Camp.
September 24	General Registration—8:30 a.m. to 3:30 p.m.
September 25	Beginning of instruction—8:00 a.m.

PART ONE

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1955-56

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RENATO DULBECCO, M.D.	Biology
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ARIE JAN HAAGEN-SMIT, Ph.D.	Bio-Organic Chemistry
NORMAN H. HOROWITZ, Ph.D.	Biology
HERSCHEL K. MITCHELL, Ph.D.	Biology
RAY D. OWEN, Ph.D.	Biology
ROGER W. SPERRY, Ph.D.	Psychobiology
ALFRED H. STURTEVANT, Ph.D., D.Sc.	Genetics
ALBERT TYLER, Ph.D.	Embryology
ANTHONIE VAN HARREVELD, Ph.D., M.D.	Physiology
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ALBERT E. LONGLEY,[2] Ph.D.	Biology
LORD ROTHSCHILD, [3]Ph.D.	Biology
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JAMES D. WATSON, Ph.D.	Biology
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[7]Guggenheim Foundation Fellow
[8]Commonwealth Fund Fellow
[9]American Cancer Society Fellow
[10]Foreign Operations Administration Fellow
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[12]National Academy of Science—National Research Council
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[14]Carnegie Institution of Washington, Stanford University
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CARL G. NIEMANN, Ph.D. ..... Organic Chemistry
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JAMES G. MADDOX ..... International Affairs
FRED WARNER NEAL ..... International Affairs
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[1]Emeritus.
[2]On leave of absence, 1955-56.

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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.

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1954-55

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DOUGLAS EINAR APPLEQUIST, *National Science Foundation Fellow, Chemistry*
B.S., University of California, 1952

THOMAS HOOD APPLEWHITE, *Graduate Teaching Assistant, Laws Scholar, Chemistry*
B.S., California Institute, 1953

GEORGE MYRON ARCAND, *General Electric Fellow, Chemistry*
B.S., California Institute, 1950

MICHEL BADER, *Graduate Research Assistant, Dobbins Scholar, Physics*
B.S., California Institute, 1952

LEO LON BAGGERLY, *Graduate Research Assistant, Laws Scholar, Physics*
B.S., California Institute, 1951; M.S., 1952

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B.S., University of Pittsburgh, 1951; M.S., 1953

KERMIT MARC BANDT, *National Science Foundation Fellow, Geology*
B.S., South Dakota School of Mines, 1954

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B.S., California Institute, 1953

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Geoph.Eng., Colorado School of Mines, 1952

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B.S., Oregon State University, 1950; M.S., Yale University, 1951

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Leroy B. Sherry
Dana C. Smith
Howard G. Smits
Keith Spalding
Mrs. Keith Spalding
Mrs. Silsby M. Spalding
Charles F. Stern
Mrs. Dillon Stevens
Ron Stever
W. L. Stewart, Jr.
Charles H. Strub
Reese H. Taylor
Mrs. Richard C. Tolman
Mrs. John Treanor
Ford J. Twaits
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
Leland K. Whittier
R. J. Wig
Lawrence A. Williams
P. G. Winnett
Thomas Wolfe
Mrs. Archibald B. Young
Gerald C. Young

HISTORICAL SKETCH

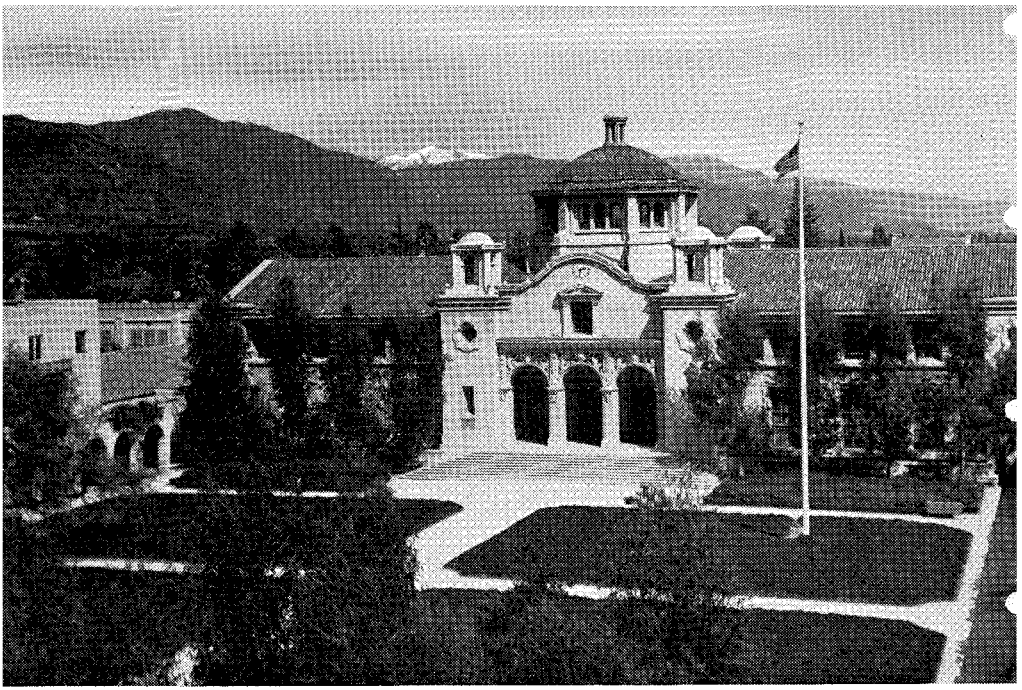
The California Institute of Technology, as it has been called since 1920, developed from a local school of arts and crafts, founded in Pasadena in 1891 by the Honorable Amos G. Throop and named, after him, Throop Polytechnic Institute. It had at first been called Throop University, but the title was soon considered too pretentious. The Institute contained, during its first two decades, a college, a normal school, an academy, and, for a time, an elementary school and a commercial school. It enjoyed the loyal support of the citizens of Pasadena, and by 1908 the Board of Trustees had as members Dr. Norman Bridge, Arthur H. Fleming, Henry M. Robinson, J. A. Culbertson, C. W. Gates and Dr. George Ellery Hale. It was the dedication, by these men, of their time, their brains and their fortunes that transformed a modest vocational school into a university capable of attracting to its faculty some of the most eminent of the world's scholars and scientists. A statement in The Throop Institute Bulletin of December 1908 shows the situation at this time and the optimism of the friends of the Institute:

"Although Throop Institute requires from $80,000 to $90,000 a year to pay its operating expenses and meet its current obligations, the financial condition of the school was never sounder than at present. Its revenues are not sufficient to pay its expenses, but good friends are each year found willing and able to contribute to its deficiency fund. It is in the certainty of a continuance of this confidence in its work and mission that its officers and trustees are pressing forward toward a realization of larger plans for the Institute."

These larger plans were the vision of George Ellery Hale, astronomer and first director of the Mount Wilson Observatory, who foresaw the development in Pasadena of a distinguished institution of engineering and scientific research. Hale well knew that a prime necessity was modern, well-equipped laboratories, but he stressed to his fellow-trustees that the aim was not machines, but men. "We must not forget," he wrote in 1907, "that the greatest engineer is not the man who is trained merely to understand machines and apply formulas, but is the man who, while knowing these things, has not failed to develop his breadth of view and the highest qualities of his imagination. No great creative work, whether in engineering or in art, in literature or in science, has been the work of a man devoid of the imaginative faculty."

The realization of these aims meant specializing, so the Trustees decided in 1908 to separate the elementary department, the normal school and the academy, leaving only a college of technology which conferred Bachelor of Science degrees in electrical, mechanical and civil engineering.

In 1910 the College of Technology moved from its crowded quarters in the center of Pasadena to a new campus of twenty-two acres on the southeastern edge of town, the gift of Arthur H. Fleming and his daughter Marjorie. The president, Dr. James A. B. Scherer, and his faculty of 12, brought 34 students with them, including four young ladies who were making up a liberal education from the non-technical courses offered. When, on March 21, 1911, Theodore Roosevelt delivered an address at Throop Institute, he declared, "I want to see institutions like Throop turn out perhaps ninety-nine of every hundred students as men who are to do given pieces of industrial work better



Throop Hall, located in the center of the campus, is the Institute's administration building.

than any one else can do them; I want to see those men do the kind of work that is now being done on the Panama Canal and on the great irrigation projects in the interior of this country—and the one hundredth man I want to see with cultural scientific training."

It would have surprised Roosevelt to know that within a decade the little College of Technology would have again raised its sights, leaving to others the training of mere efficient technicians and concentrating its own efforts on Roosevelt's "hundredth man." On November 29, 1921, the Trustees declared it to be the express policy of the Institute to pursue scientific researches of the greatest importance and at the same time "to continue to conduct thorough courses in engineering and pure science, basing the work of these courses on exceptionally strong instruction in the fundamental sciences of mathematics, physics and chemistry; broadening and enriching the curriculum by a liberal amount of instruction in such subjects as English, history and economics; and vitalizing all the work of the Institute by the infusion in generous measure of the spirit of research."

Perhaps some causes of this change are the rapid growth of southern California between 1911 and 1921, the springing up everywhere of high schools and vocational schools which relieved Throop of some of its responsibilities, and the increasing public interest in scientific research as the implications of modern physics became better known. But the immediate causes of the change in the Institute at Pasadena were men. George Ellery Hale still held to his dream. Arthur Amos Noyes, Professor of Physical Chemistry and sometime Acting President of the Massachusetts Institute of Technology, served part of each year as Professor of General Chemistry and Research Associate from

1913 to 1919, when he resigned from M.I.T. to devote full time to Throop as Director of Chemical Research. In a similar way Robert Andrews Millikan began, before the war, to spend a few months a year at Throop as Director of Physical Research. In 1921, when Dr. Norman Bridge agreed to provide a research laboratory in physics, Dr. Millikan resigned from the University of Chicago and became administrative head of the Institute as well as director of the Norman Bridge Laboratories.

The great period of the Institute's life began, then, under the guidance of three men of vision—Hale, Noyes and Millikan. They were all distinguished research scientists, and they soon attracted graduate students. In 1920 the enrollment was 9 graduate students and 359 undergraduates under a faculty of 60; a decade later there were 138 graduate students to 510 undergraduates and a faculty of 180. (At the present time there are about 600 undergraduates, 425 graduate students, and a faculty of about 300.)

The Institute also attracted financial support, from individuals, corporations and foundations. In January, 1920, the endowment had reached half a million dollars. In February of that year it was announced that $200,000 had been secured for research in chemistry and a like amount for research in physics. Other gifts followed, from Trustees and friends, southern Californians who could now feel pride in the Institute as well as hope. The Southern California Edison Company provided a high voltage laboratory, with the million-volt Sorensen transformer. Philanthropic foundations bearing the names of Carnegie, Rockefeller and Guggenheim came forth with needed help when new departments or projects were organized.

In 1923 Millikan received the Nobel Prize in Physics. (The next year, if anyone had known where to look, he could have found two future Nobel Laureates on the campus—one in the freshman class and another in the sophomore class.) He had attracted to the Institute such men as Charles Galton Darwin, Paul Epstein and Richard C. Tolman. In 1924 the Ph.D. degree was awarded to nine candidates.

It was inevitable that the Institute would enlarge its field; it could not continue to be merely a research and instructional center in physics, chemistry and engineering. But the Trustees pursued a cautious and conservative policy, not undertaking to add new departments except when the work done in them would be at the same high level as that in physics and chemistry. In 1925 a gift of $25,000 from the Carnegie Corporation of New York made possible the opening of a department of instruction and research in geology. A seismological laboratory was constructed, and Professors John P. Buwalda and Chester Stock were brought from the Carnegie Institution of Washington to head the new division. Later gifts, especially from Mr. and Mrs. Allan C. Balch, and the gift of the Arms and Mudd laboratories, contributed further to the establishment of the geological sciences at Caltech.

In 1928 the California Institute began its program of research and instruction in biology. There had been a chair of biology, named for Charles Frederick Holder, in the old Throop Institute, but it was not until the efforts of the C.I.T. trustees, the General Education Board, the Carnegie Institution of Washington and William G. Kerckhoff were combined that a program of research and teaching at the highest level was inaugurated. Thomas Hunt Morgan became the first chairman of the new Division of Biology and a member of the Executive Council of the Institute. Under Morgan's direction

the work in biology developed rapidly, especially in genetics and biochemistry. Morgan received the Nobel Prize in 1933.

The Guggenheim Graduate School of Aeronautics was founded at the Institute in the summer of 1926, and the laboratory finished in 1929, but courses in theoretical aerodynamics had been given at the Institute for many years by Professors Harry Bateman and P. S. Epstein. As early as 1917 the Throop Institute had a wind tunnel in which, the catalogue proudly boasts, constant velocities of 4 to 40 miles an hour could be maintained, "the controls being very sensitive." The new program, under the leadership of Theodore von Kármán, included graduate study and research at the level of the other scientific work at the Institute, and GALCIT was soon a world-famous research center in aeronautics.

In 1928 George Ellery Hale and his associates at the Mt. Wilson Observatory developed a proposal for a 200-inch telescope and attracted the interest of the General Education Board in providing $6,000,000 for its construction. The Board proposed that the gift be made to the California Institute and the Institute agreed to be responsible for the construction and operation. The huge instrument was erected on Palomar Mountain and the Mount Wilson and Palomar Observatories are now operated jointly through an agreement between the Institute and the Carnegie Institution of Washington. Teaching and research in astronomy and astrophysics thus became a part of the Institute program.

Although the emphasis upon the humanities or liberal arts as an important part of the education of every scientist and engineer was traditional even in the Throop College days, a reiterated insistence upon this principle was made when Hale, Noyes and Millikan created the modern Caltech. In 1924 when a five-year engineering course leading to the M.S. degree was offered, the humanities requirement was included. In 1925 William Bennett Munro, Chairman of the Division of History, Government and Economics at Harvard, joined the Institute Staff, and he soon became a member of the Executive Council. In 1928 Mr. and Mrs. Joseph B. Dabney gave the Dabney Hall of the Humanities, and friends of the Institute provided an endowment of $400,000 for the support of instruction in humanistic subjects. Later Mr. Edward S. Harkness added a gift of $750,000 for the same purpose.

Largely on the initiative of Henry M. Robinson the California Institute Associates were organized in 1925. These men and women, now numbering 240, are the successors of those early dedicated pioneers who saw in Throop College the potentiality of becoming a great and famous institution. The Institute Associates, by their continued support, have played a vital part in the Institute's progress. In 1950 the Industrial Associates was organized as a mechanism for providing corporations with the opportunity of supporting fundamental research at the Institute and of keeping in touch with new developments in science and engineering.

For the five years beginning with the summer of 1940, the Institute devoted an increasingly large part of its personnel and facilities to the furthering of national defense and the war effort. The Institute's work during this period fell for the most part into two main categories: special instructional programs, and research on the development of the instrumentalities of war. The first included participation in the Engineering, Science and Management War Training Program, in which a total of over 24,000 students were enrolled in

Institute-supervised courses; advanced meteorology for Army Air Force cadets; advanced work in aeronautics and ordnance for Army and Navy officer personnel; and the provision of instruction (as well as housing and subsistence) for a unit of the Navy V-12 Engineering Specialists. The research and development work was carried on for the most part under 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. Rockets, jet propulsion and anti-submarine warfare were the chief fields of endeavor.

In 1945 R. A. Millikan retired as chairman of the executive committee; he served as vice-chairman of the Board of Trustees until his death in 1953. Dr. Lee A. DuBridge became President of the California Institute on September 1, 1946.

Since the war the energies of the Institute have been directed to research and teaching, with new development taking place in all of the divisions. In 1948 the Palomar Observatory and the 200-inch Hale telescope were dedicated. In 1949 the Earhart Plant Research laboratory was completed. In 1951 a cosmic ray laboratory was built and in the next year a synchrotron was constructed for the study of atomic nuclei. In 1954 the building of the Norman W. Church Laboratory for Chemical Biology pointed to new activities in an important field of science. In the same year the generosity of the alumni, and of the late Scott Brown, a member of the Associates, provided a gymnasium and swimming pool. The California Institute now has alumni scattered all over the world, many of them eminent in their fields of engineering or science.

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 conservasion 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.

THE INDUSTRIAL RELATIONS SECTION

The Industrial Relations Section was established in 1939 through special gifts from a substantial number of individuals, companies, and labor unions. The work and program of the Section are guided by the Committee of the Industrial Relations Section, consisting of Trustees appointed by the Board and Faculty members appointed by the President.

The Section has developed a five-fold program of activities and service for companies, unions, associations, and individuals: (1) a reference library of books, pamphlets, magazines, and other materials related to industrial relations, 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 these activities.

Detailed information about the specific services of the Section and the fees involved can be secured from the Director of the Industrial Relations Section, Culbertson Hall.

INDUSTRIAL ASSOCIATES

The Industrial Associates, established in 1949, consists of companies which have chosen to participate in an organized plan of collaboration between Institute Faculty members and industrial personnel. An annual fee qualifies a com-

pany for membership; income of this kind is unrestricted in nature and is employed in support of current research. The cooperation involves primarily an effort to relate the talents and the interests of the Faculty members to industrial problems and possibilities, to the benefit of both industry and the academic program of the Institute. Specifically included in the plan are special conferences, distribution of research reports, and a regular exchange of visits by personnel of the companies and Institute Faculty members. The influence of the plan upon the character of the educational and research program, while indirect, is believed to be important. The plan in no way affects the cordial relationships which exist generally between industrial personnel and the Faculty of the Institute.

Additional information concerning terms of membership, responsibilities of individual Faculty members, and so forth, is available at the Office for Industrial Associates, Room 110, Throop Hall.

The members of the Industrial Associates as of September 1, 1955, are listed below.

Aerojet—General Corporation

Beckman Instruments, Inc.

Bendix Aviation Corporation

Byron Jackson Company

California Research Corporation

Carnation Company

Continental Oil Company

Convair—A Division of General Dynamics Corporation

Douglas Aircraft Company

E. I. du Pont de Nemours and Company, Inc.

Esso Research and Engineering Company

Ford Motor Company

General Motors Corporation

General Petroleum Corporation—Socony Mobil Oil Company, Inc.

G. M. Giannini and Company, Inc.

Gilfillan Bros., Inc.

Great Lakes Carbon Corporation

Gulf Research and Development Company

Hercules Powder Company

Hycon Manufacturing Company

Hughes Aircraft Company

International Business Machines Company

Lockheed Aircraft Corporation

North American Aviation, Inc.

Ramo-Wooldridge Corporation

The Rand Corporation

Richfield Oil Corporation

Shell Oil Company

Stanolind Oil and Gas Company

The Texas Company

Union Carbide and Carbon Corporation

Union Oil Company of California

United States Steel Corporation—Columbia-Geneva Steel Division and Consolidated Western Steel Division

The Upjohn Company

Westinghouse Electric Corporation

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

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

The gift of the late Dr. Norman Bridge, of Los Angeles, President of the Board of Trustees of the Institute, 1896-1917.

HIGH-VOLTAGE RESEARCH LABORATORY, 1923.

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

GUGGENHEIM AERONAUTICAL LABORATORY, 1929.

Erected with funds provided by the Daniel Guggenheim Fund for the Promotion of Aeronautics. A substantial addition was erected in 1947.

WILLIAM G. KERCKHOFF LABORATORIES OF THE BIOLOGICAL SCIENCES: first unit, 1928; second unit, 1938; annex, 1948.

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

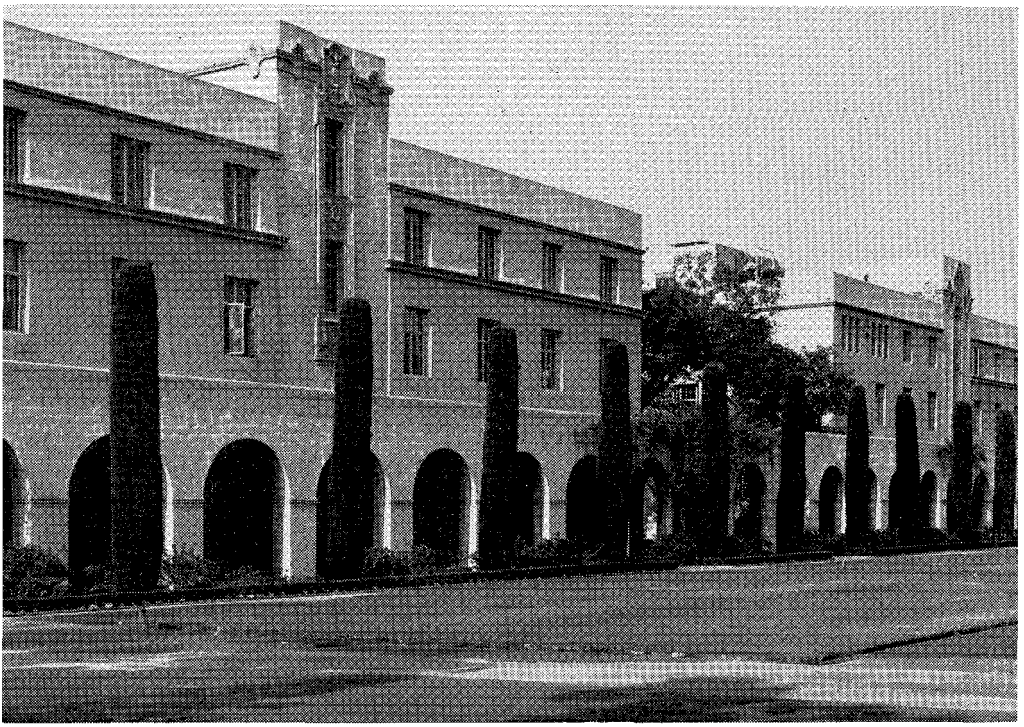
DOLK PLANT PHYSIOLOGY LABORATORY (of the Division of Biology), 1930.

Named in memory of Herman E. Dolk, Assistant Professor of Plant Physiology from 1930 until his death in 1932.

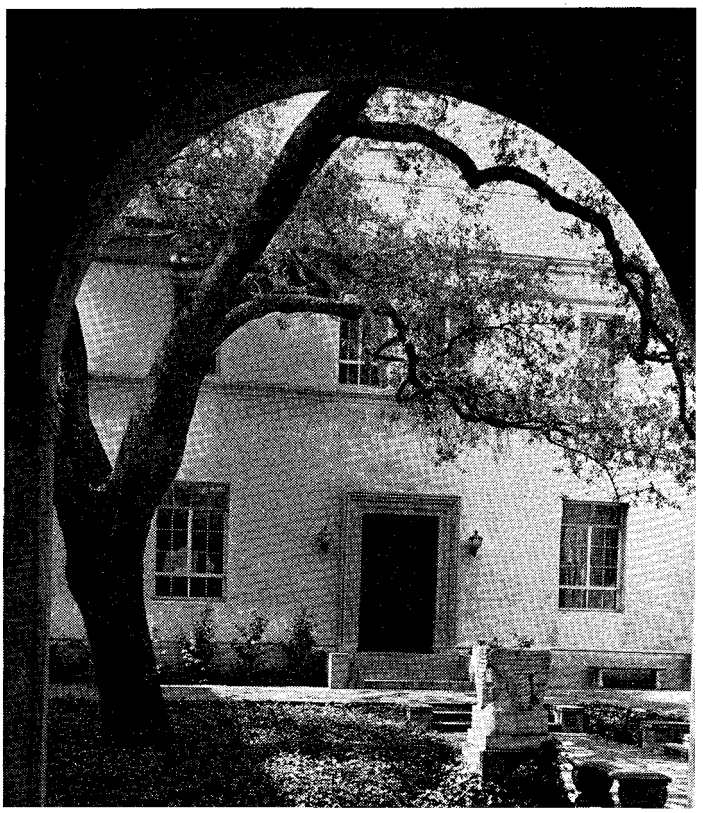
ATHENAEUM, 1930.

The gift of the late Mr. and Mrs. Allan C. Balch, of Los Angeles, President of the Board of Trustees of the Institute, 1933-1943.

A clubhouse for the use of the staffs of the California Institute, the Huntington Library, and the Mt. Wilson Observatory; and the California Institute Associates.



rms and Mudd Laboratories
f the Geological Sciences.



obinson Astrophysical Labo-
atory faces this court be-
veen Arms and Mudd Labo-
atories.

STUDENT HOUSES, 1931.

Blacker House.
The gift of the late Mr. and Mrs. R. R. Blacker, of Pasadena.

Dabney House.
The gift of the late Mr. and Mrs. Joseph B. Dabney, of Los Angeles.

Fleming House.
Erected with funds provided by some twenty donors, and named in honor of the late Mr. Arthur H. Fleming, of Pasadena, President of the Board of Trustees of the Institute, 1917-1933.

Ricketts House.
The gift of the late Dr. L. D. Ricketts and Mrs. Ricketts, of Pasadena.

CENTRAL MACHINE SHOP, 1931.
Erected with funds provided by the International Education Board and the General Education Board. Formerly the Astrophysical Instrument Shop until the completion of the Palomar Observatory.

W. K. KELLOGG LABORATORY OF RADIATION, 1932.
The gift of the late Mr. W. K. Kellogg, of Battle Creek, Michigan.

HENRY M. ROBINSON LABORATORY OF ASTROPHYSICS, 1932.
Erected with funds provided by the International Education Board and the General Education Board, and named in honor of the late Mr. Henry M. Robinson of Pasadena, member of the Board of Trustees and the Executive Council.

SYNCHROTRON LABORATORY, 1933.
Erected with funds provided by the International Education Board and the General Education Board. Following the completion of the Palomar Observatory, this building was converted into a Synchrotron Laboratory.

SEDIMENTATION LABORATORY, 1936.
Provided by the Department of Agriculture of the United States Government.

CHARLES ARMS LABORATORY OF THE GEOLOGICAL SCIENCES, 1938.
The gift of the late Mr. and Mrs. Henry M. Robinson, of Pasadena, in memory of Mrs. Robinson's father, the late Mr. Charles Arms.

SEELEY W. MUDD LABORATORY OF THE GEOLOGICAL SCIENCES, 1938.
The gift of the late Mrs. Seeley W. Mudd, of Los Angeles, in memory of her husband.

CLARK GREENHOUSE (of the Division of Biology), 1940.
The gift of Miss Lucy Mason Clark, of Pasadena.

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.

ALUMNI SWIMMING POOL, 1954.
Provided by the Alumni Fund through contributions by members of the Alumni Association of the Institute.

SCOTT BROWN GYMNASIUM, 1954.
The funds for this building were provided by a trust established by the late Mr. Scott Brown, of Pasadena and Chicago, a member and director of the California Institute Associates.

NORMAN W. CHURCH LABORATORY FOR CHEMICAL BIOLOGY, 1955. The funds for the erection of this laboratory were provided through gift and bequest by the late Mr. Norman W. Church, of Los Angeles, a member of the California Institute Associates.

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. Two of these provide for Air Force ROTC headquarters, library, and class rooms; The Institute YMCA; a sanitary engineering laboratory; and studies for graduate students. The third is used for a chemical engineering shop, and the fourth, for 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.

SEISMOLOGICAL RESEARCH LABORATORY (of the Division of the Geological Sciences), 220 North San Rafael Avenue, 1928.

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

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

JET PROPULSION LABORATORY, 4800 Oak Grove Drive, 1944.

Owned and sponsored by the Department of Defense and operated by the Institute.

OREANDO GREENHOUSE (of the Division of Biology), 860 Orlando Road, San Marino, California, 1942.

The gift of Mr. and Mrs. Roy E. Hanson, of San Marino, California.

SOUTHERN CALIFORNIA COOPERATIVE WIND TUNNEL, 950 South Raymond Avenue, 1945.

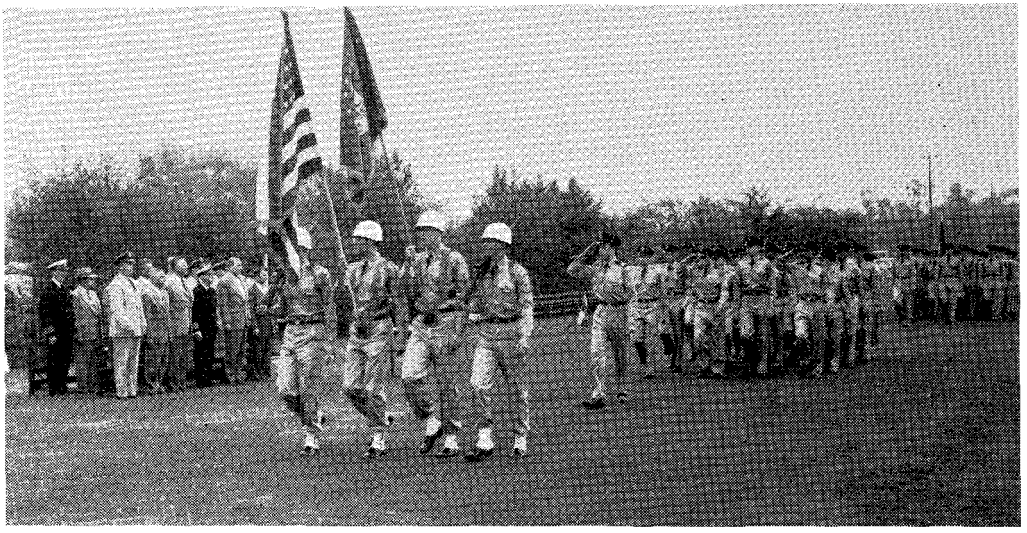
Owned by five cooperating aircraft companies and operated under a management agreement by the Institute.

HYDRODYNAMICS LABORATORY, Azusa, 1946.

Owned by the Institute together with the Navy Bureau of Yards and Docks and operated by the Institute.

PALOMAR OBSERVATORY, 1948.

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



Air Force ROTC review.

STUDY AND RESEARCH AT THE CALIFORNIA INSTITUTE

AIR FORCE RESERVE OFFICER'S TRAINING CORPS

The California Institute has a unit of the Air Force ROTC. Membership in the unit is voluntary. Students may join only at the beginning of the freshman year. All freshmen may join the unit regardless of the option in engineering or science which they may eventually select. Students who remain in the AFROTC program through graduation may be commissioned as second lieutenants in the Air Force Reserve. These commissions will be for service as non-rated officers in technical and scientific assignments. No flight training will be given at the Institute; however, graduates of the program, may if they wish, apply for flight training after graduation provided they are admitted into the advanced course. No test, either mental or physical, other than those necessary for entrance to the California Institute are required to enter the basic course which covers the first two years. At the end of the sophomore year those in the basic course will be screened for aptitude and must pass the physical examination required of non-flying personnel before going on to the advanced course in the junior and senior years.

It is expected that those entering the basic course will continue in the program through graduation subject to the needs of the Air Force. However, a student who has neither entered the advanced course nor obtained draft deferment during the basic course may, at the discretion of the professor of Air Science and Tactics, be permitted to withdraw. Deferment from Selective Serv-

ice may be granted to all who remain in good standing with both the Institute and the AFROTC. To obtain this deferment the student must agree to continue in the program until its completion, to accept a commission in the Air Force Reserve, and to serve two years of active duty upon graduation. Those who fail to adhere to this agreement will be denied graduation unless a special exception is made by the Air Force. The California Institute can assume no responsibility for the decisions of the Air Force in continuing students in the program. These decisions are necessarily governed by the needs of the Air Force at the time.

Uniforms are furnished by the Air Force and required to be worn only during military exercises. Students in the basic course receive no pay. Those in the advanced course receive about $27 per month for subsistence allowance.

For AFROTC course requirements for the first year see page 194.

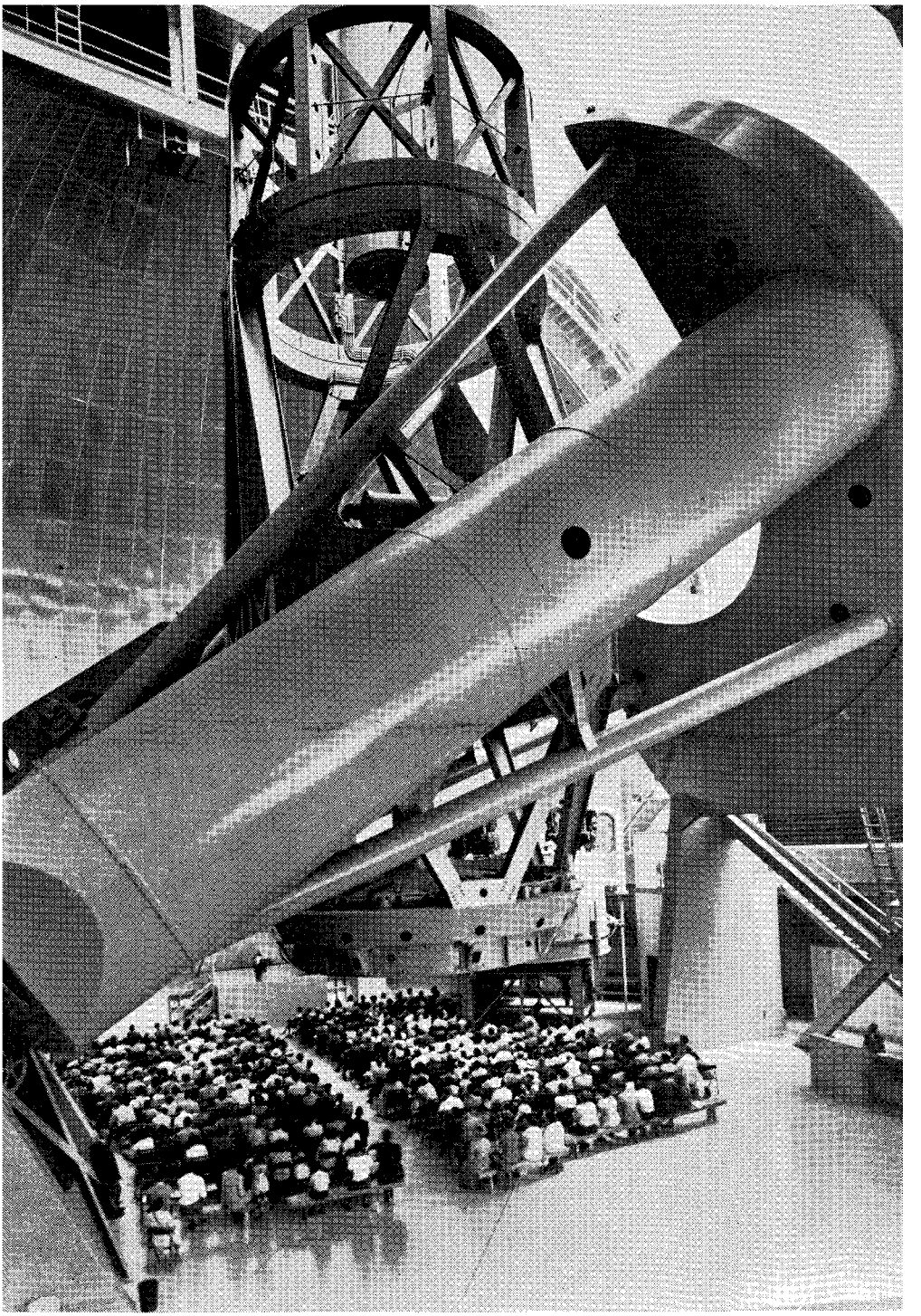
1. THE SCIENCES

ASTRONOMY

The Rockefeller Boards provided in 1928 for the construction by the Institute of an astronomical observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, 48-inch and 18-inch schmidt wide-angle telescopes and other auxiliary instruments, together with an astrophysical laboratory, on the Institute campus. The purpose of this observatory is to supplement, not to duplicate, the facilities of the Mount Wilson Observatory of the Carnegie Institution of Washington, which, while not a part of the California Institute, is located even closer to Pasadena than is Palomar Mountain. The increased light-collecting power of the 200-inch telescope permits further studies of the size, structure and motion of the galactic system; of the distance, motion, radiation composition and evolution of the stars; and the interstellar gas of the spectra of the brighter stars under very high dispersion; of the distance, motion and nature of remote nebulae; and of many phenomena bearing directly on the constitution of matter. The 48-inch schmidt is making possible a complete survey of the sky as well as an attack upon such problems as the structure of clusters of nebulae, the luminosity function of nebulae and absolutely faint stellar systems, intergalactic matter, extended gaseous nebulae, and the stellar contents of the milky way. These two unique instruments supplement each other as well as the telescopes on Mount Wilson; the one reaches as far as possible into space in a given direction, while the other photographs upon a single plate an entire cluster of distant nebulae or a star cloud in our own galaxy.

The Mount Wilson and Palomar Observatories constitute a unique and unprecedented concentration of scientific facilities in astronomy. Outstanding scientific talent is present both in the field of astronomy and in the neighboring fields of physics and mathematics. The California Institute of Technology and the Carnegie Institution of Washington have recognized the advantages implicit in the creation of a great astronomical center in which a unitary scientific program would be pursued under highly favorable circumstances, that would attract distinguished investigators to collaborate with the staff of the observatories in scientific matters, and that would draw young men of great ability to graduate studies where they might enjoy the inspiration of leading minds, and familiarize themselves with powerful tools of exploration. For this purpose a plan for the unified operation of the two observatories, in which they function as a single scientific organization under the direction of Dr. I. S. Bowen, was approved by the Trustees of the two institutions. Under this plan all the equipment and facilities of both observatories are made available for the astronomical investigations of the staff members of the combined observatories and the unified research program is paralleled by undergraduate and graduate training in astronomy and astrophysics in which members of the Staff of the Mount Wilson Observatory 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



The 200-inch Hale Telescope at Palomar Observatory.

astrophysics. In 1955 work has been started in radio astronomy and plans are now being made for the design and construction of a radio telescope capable of using interferometric methods of observation.

The instructional program is superimposed upon an especially thorough preparation in mathematics and physics 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 interested in and well-qualified for such work should undertake graduate study and research.

BIOLOGICAL SCIENCES

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 physico-chemical 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.

The undergraduate course for premedical students is essentially the same as that for biology students and is intended as a basis for later careers in research as well as in the practice of medicine. It differs in some respects from premedical curricula of other schools; however, it has been quite generally accepted as satisfying admission requirements of medical schools. Slight modifications in the curriculum may be required for admission to certain medical schools or in cases in which the student wishes to try to complete admission requirements in three years instead of four. The student should consult with the premedical adviser about this.

Graduate work leading to the Ph.D. degree is chiefly in the following fields: animal biochemistry, plant biochemistry, bio-organic chemistry, experimental embryology, animal and plant genetics, chemical genetics, immunology, biophysics, mammalian physiology, comparative physiology, plant physiology, psychobiology and virology. These represent the fields in which active research is now going on in the Division. The emphasis in graduate work is

placed on research. This is supplemented by courses and seminars in advanced subjects aimed to develop the student's insight and critical ability as an investigator.

PHYSICAL FACILITIES

The Norman W. Church Laboratory of Chemical Biology, completed in the summer of 1955, and the William G. Kerckhoff Laboratories of the Biological Sciences consist of three adjacent units. They contain classrooms and undergraduate laboratories, a biology library, an annex housing experimental animals, and numerous laboratories equipped for biological, biochemical and physiological research at the graduate and doctoral level. The constant temperature equipment includes rooms for the culturing of the Institute's valuable collection of mutant types of Drosophila and Neurospora and complete facilities for plant and animal tissue culture. In addition to standard laboratory equipment for physico-chemical research, there are special facilities for work with radioactive tracers, including automatic counting apparatus; and for work with automatic fraction collectors, phase contrast microscopy, automatic spectrophotometric measurements, liquid and solid phase electrophoresis, and preparative and analytical ultracentrifugation.

Adjacent to the campus there are the Plant Physiology Laboratories, with several air-conditioned greenhouses, and the Earhart Plant Research Laboratory. The Earhart Laboratory is a unique instrument for the study of plant growth under complete weather control. All the elements of climate, such as light, temperature, humidity, wind, rain, and gas-content of air, can be controlled simultaneously. These laboratories offer the opportunity to study plants under different synthetic climatic conditions, yet with complete reproducibility of experimental results.

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

At Arcadia, about five miles from the campus, is the Institute farm. Equipped with a laboratory and greenhouse, the experimental 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 acquaria 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.

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 space approxi-

mately 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.

In addition, the Division of Chemistry and Chemical Engineering will occupy space in the new Norman Church Laboratory of Chemical Biology. It is expected that this laboratory will be completed by the fall of 1955.

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 243.

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, reaction kineties, and combustion.

GEOLOGICAL SCIENCES

The Division of Geological Sciences is closely allied with the other active and creative fields of science and engineering at Caltech. Accordingly, a favorable intellectual atmosphere exists for education and research in geology, geobiology, geochemistry, and geophysics. The geographic position and geological setting of the Institute are nearly ideal for students and research workers, who can derive materials, ideas, and inspiration from the wide variety of easily accessible field environments. The staff as listed on an earlier page of this catalogue represents a variety of allied and integrated interests and is active in both teaching and research.

Physical facilities, both natural and man-made, are excellent. All the classroom instruction and most of the laboratory research in geology and geochemistry, as well as part of that in geophysics, are carried on in the Arms and Mudd laboratories. These are modern, five-story buildings which were specifically designed for these activities and to provide office space for the staff and students. They also house the Division Library; paleontologic, rock and mineral collections; spectrographic and X-ray equipment; and laboratories for rock and mineral analyses, sedimentation studies, thin and polished section work, and other tools required for comprehensive studies in the earth sciences.

Extensive facilities are available for the application of techniques of nuclear chemistry to problems in the earth sciences. These facilities include chemical

laboratories for trace-element studies, a silicate analysis laboratory, and two super-clean laboratories for isotopic work. Available equipment includes mass spectrometers, emission counters, an induction furnace, and extensive mineral separation facilities in addition to the usual geological and chemical items.

Favorable opportunity for study of dynamic aspects of paleontology and evolution as revealed by morphology, ecology, and biogeochemistry is provided by the combination of personnel, reference collections, and modern geochemical tools and techniques available here. Biologic principles and processes, past and present, of significance to geology may be interpreted from experimentation and studies at the Kerckhoff Marine Laboratory at Corona del Mar, operated under auspices of the Division of Biology.

The Seismological Laboratory of the California Institute is located about three miles west of the campus on a crystalline bedrock ridge affording firm foundation for the instrument piers and tunnels. The central laboratory, together with more than a dozen outlying auxiliary stations in southern California—built and maintained with the aid of cooperating companies and organizations—constitutes a fine center for education and research in seismology. Other phases of geophysical training and investigation are carried on in the regular campus buildings.

Conditions for field study and research in the earth sciences in southern California are excellent. A great variety of rock types, geologic structures, active geologic processes, physiographic forms, and geologic environments occur within convenient reach of the Institute. The relatively mild climate permits field studies throughout the entire year, consequently year-around field training is an important part of the departmental program.

The student body is purposely kept small and usually consists of 35 to 40 graduate students and 20 to 30 undergraduates. The small size of the student group and large size of the staff give a highly favorable ratio of students to staff and result in close associations and contacts which enhance the value of the educational program.

UNDERGRADUATE WORK

The aim of the undergraduate program in the Geological Sciences is to provide thorough training in basic geological disciplines and wherever possible to integrate the geological studies with and build upon the courses in mathematics, physics, chemistry, and biology taken during the earlier years at the Institute. Special emphasis is also placed on field work because it provides first-hand experience with geological phenomena that never can be satisfactorily grasped or understood solely from classroom or laboratory treatment. Options are offered in geology (including paleontology and paleoecology), geophysics, and geochemistry. Sufficient flexibility in electives is provided to permit a student to follow lines of special interest in related scientific or engineering fields. Men who do well in the basic sciences and at the same time have a compelling curiosity about the earth and its natural features are likely to find their niche in the Geological Sciences, especially if they possess a flexible and imaginative mind that enables them to grapple with complex problems in which it is difficult to get sufficient data on all the unknowns.

Men trained in the earth sciences find employment in research, teaching, and a wide variety of other professional activities. Many work for the petro-

leum industry both in the field and in the laboratory on theoretical as well as applied problems. Some eventually become administrators and executives. Mining companies, railroads, large utilities, and other organizations engaged in development of natural resources, employ men trained in the geological sciences, as do a number of Federal and state bureaus, such as the U. S. Geological Survey and the Bureau of Reclamation.

GRADUATE WORK

The number of courses required within the Division for an advanced degree is purposely held to a minimum to permit individuality and flexibility in the various programs. Facilities are available for research and study in such subjects as geochemistry, geophysics, seismology, paleoecology, paleontology, petrology, geomorphology, glaciology, structural geology, stratigraphy, sedimentation, tectonophysics, and mineral deposits.

The Division is especially interested in graduate students who not only have a good background in geology, but also have sound and thorough training in physics, chemistry, biology, and mathematics. Applicants with majors in these subjects and with a strong interest in the earth sciences will be given consideration for admission and appointment along with geology majors.

MATHEMATICS

UNDERGRADUATE WORK

The four-year undergraduate program in mathematics leads to the degree of Bachelor of Science. The purpose of the undergraduate option is to give the student an understanding of the broad outlines of modern mathematics, to stimulate his interest in research, and to prepare him for later work either in pure mathematics or allied sciences.

Since 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 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. In particular, seniors intending to proceed to graduate work in mathematics are expected to choose a full year's graduate course in mathematics for one of their electives. Electives may be chosen in consultation with the department from courses in mathematics and cognate fields. The details are given on page 203.

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

GRADUATE WORK

Graduate work in mathematics is planned to give 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 114 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. 169-173; additional requirements for mathematics are found on p. 184. The special prerequisites for the course requirements in the minor subjects are listed under the separate departments. In particular those for physics are listed on pp. 292-297.

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

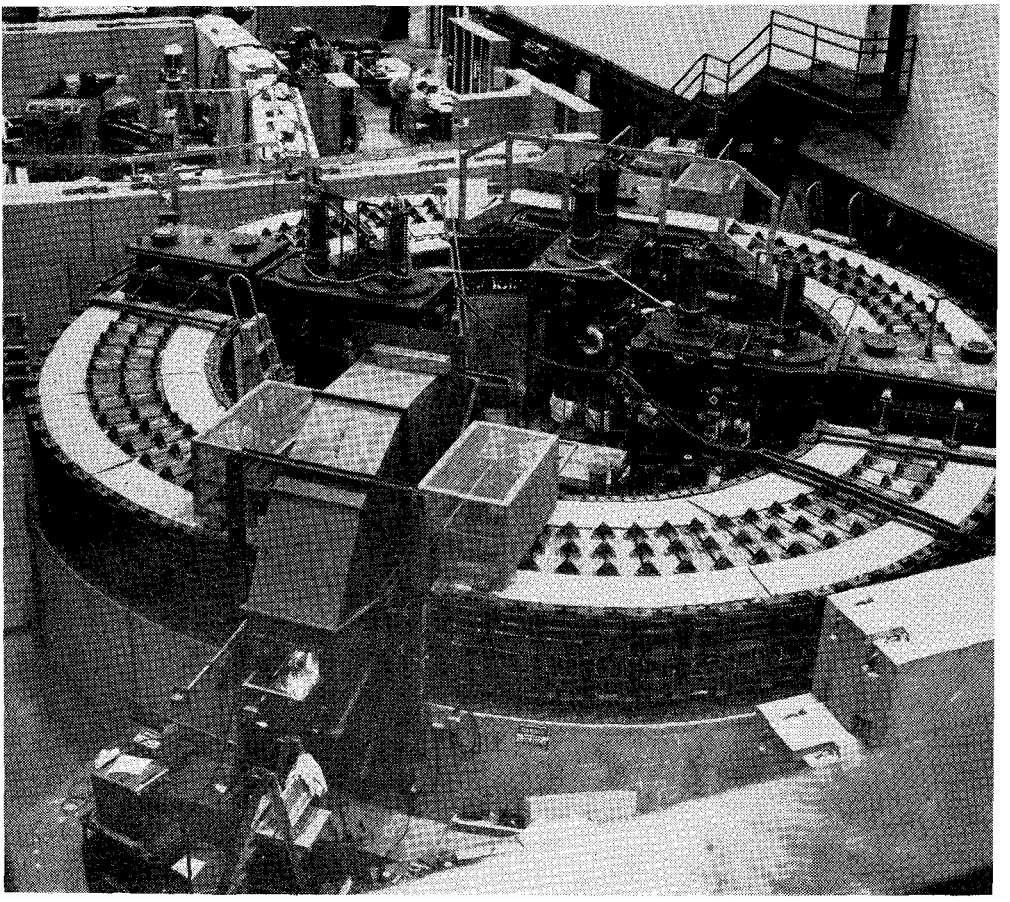
Master's degree. Students initially planning to take only a master's degree are accepted only under very special circumstances. When the complete Ph.D. requirements cannot be met, a master's degree may be awarded upon passing at least five courses listed under B or C on page 202, taking graduate humanities electives for a total of 27 units or more and submission of a thesis. The thesis requirement may be waived at the discretion of the department.

PHYSICS

UNDERGRADUATE WORK

The distinctive feature of the undergraduate work in physics at the California Institute is the creative atmosphere in which the student at once finds himself. This results from the combination of a large and very productive graduate school with a small and carefully selected undergraduate body.

Since the best education is that which comes from the contact of youth with creative and resourceful minds, the members of the staff of the Norman Bridge Laboratory of Physics have been from the beginning productive physicists



The Synchrotron is used to study the structure of the atomic nucleus and the forces holding the nucleus together. It has already attained electron energies of 500 million volts and will be raised eventually to over one billion electron volts.

rather than merely teachers. The instruction is done by the small group method, twenty to a section, save for one demonstration lecture every other week throughout the freshman and sophomore years. Most of the members of the staff participate in these lectures. The entering freshman thus makes some contact in his first year with many senior members of the staff, and he has the opportunity to maintain that contact throughout his four undergraduate years, and his graduate work as well, if he elects to go on to the higher degrees.

In order to provide the thorough training in physics required by those who are going into scientific or engineering work, two full years of general physics are required of all students. Those who desire to major in physics take during their junior, 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 working toward the Ph.D. degree should complete the requirements for admission to candidacy for the doctor's degree as soon as possible. (See page 182.) The courses required to be passed either regularly or by examination provide an unusually thorough grounding in the fundamentals of physics, and the student learns to use these principles in the solution of problems. After the first year of graduate work, students with special technical training will find it comparatively easy to obtain part-time work during the summer on one or another of the research projects in physics. Students so employed are also expected to register for 15 or more units of research.

The Norman Bridge Laboratory of Physics is equipped to carry on research in most of the principal fields of physics. An addition to this laboratory has been especially constructed for the work in cosmic rays and the study of elementary particles. Special facilities for research in nuclear physics are also provided in the W. K. Kellogg Radiation Laboratory—which is equipped with three electrostatic generators and auxiliary equipment which makes the facilities especially good for precision work in the field of light nuclei. The Synchrotron Laboratory houses an electron accelerator which operated for two and a half years at 500 million electron volts and which is now being modified to increase the maximum energy to more than one billion electron volts. Work in high-energy physics bridges the gap between the nuclear physics research in the Kellogg Laboratory and the cosmic ray and elementary particle investigations that have been carried on for many years in the Norman Bridge Laboratory. Special facilities are available in the Norman Bridge Laboratory for the precision investigation of high-energy x-rays and gamma rays and the study of beta ray spectra. Liquid helium is available and there is a laboratory for work in low-temperature physics. Opportunities for study in theoretical physics in any one of a number of fields are particularly good, for a limited number of students whose ability and background qualify them for theoretical work.

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

There is a general seminar or research conference each week which is regularly attended by all research workers and graduate students. In addition, 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 nuclear physics, x-rays, and high energy physics.

For graduates in physics the main outlets are positions in colleges and universities, in the research laboratories of the government, and in the increasing number of industrial research laboratories of the country. There is at present a continuing demand for physicists in the National Defense activities of the government, and many graduates are engaged in such work.

In order to make it possible for students to carry on their researches even after they have satisfied the requirements for the doctor's degree, a number of post-doctoral research fellowships are available.

2. ENGINEERING

UNDERGRADUATE WORK

"The four-year Undergraduate Course in Engineering," as prescribed in the Educational Policies of the Institute, "shall be of general, fundamental character, with a minimum of specialization in the separate branches of engineering. It shall include an unusually thorough training in the basic sciences of physics, chemistry, and mathematics, and a large proportion of cultural studies, the time for this being secured by eliminating some of the more specialized technical subjects commonly included in undergraduate engineering courses. It shall include, however, the professional subjects common to all branches of engineering. It is hoped in this way to provide a combination of a fundamental scientific training with a broad human outlook, which will afford students with engineering interests the type of collegiate education endorsed by leading engineers—one which avoids on the one hand the narrowness common among students in technical schools, and on the other the superficiality and the lack of purpose noticeable in many of those taking academic college courses." The Course is designed to provide a thorough basis for general engineering practice, for advanced study and research, or for industrial and administrative work.

The plan of instruction in engineering embodies a four-year course for the degree of Bachelor of Science. 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, latitude in course selection exists, and a student may, if he wishes engage in research in a field of his own selection under the guidance of a staff representing a wide range of experience and current activity.

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 engineer-

ing, 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, Mechanical Engineering, and Engineering Science leading to the degree of Doctor of Philosophy. In all phases of the graduate program students are encouraged to include in their courses of study a considerable amount of work outside of their specialized fields, particularly in mathematics and physics.

The Division of Engineering includes those curricula and facilities which are a part of the options of Civil, Electrical, Mechanical Engineering and Aeronautics and Engineering Science in which degrees designated with these options are given. In addition, the Division includes subjects and research facilities in which no specific degree is offered, but which form a part of a student's course of study or are available to him as optional work. These subjects are Applied Mechanics, Hydraulics and Hydrodynamics, Jet Propulsion, and Metallurgy. Some of the specialized laboratory facilities available for instruction and research are the various wind tunnels, 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

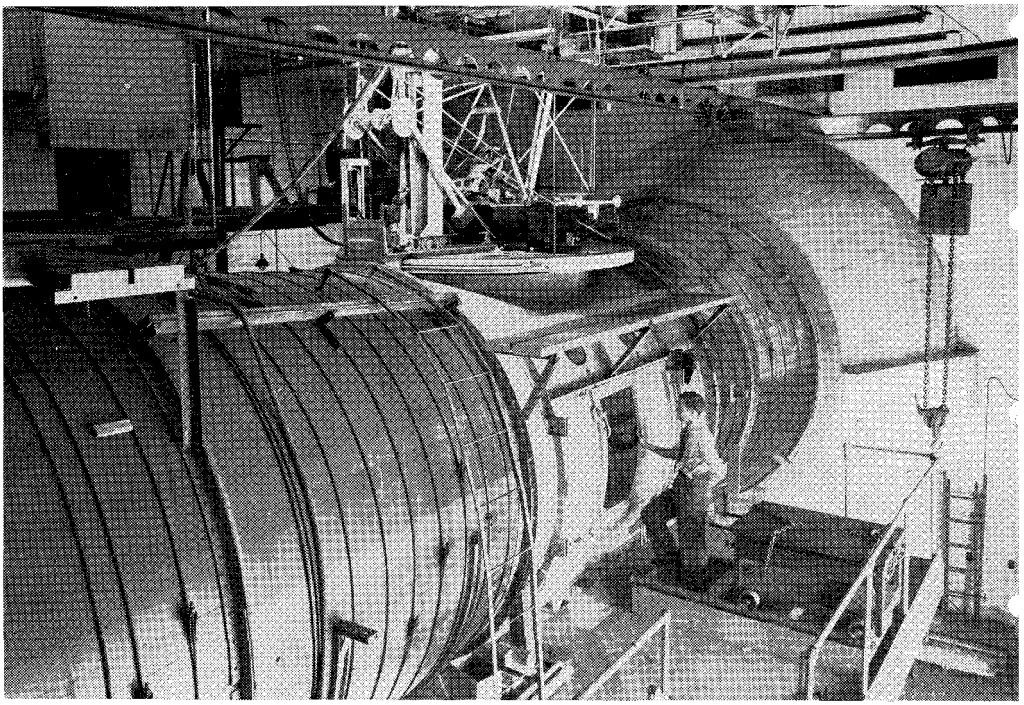
The graduate school of Aeronautics and Guggenheim Aeronautical Laboratory, widely known as the GALCIT, were established in 1928 at the California Institute with the aid of the Daniel Guggenheim Fund for the Promotion of Aeronautics. Since their inception the staff has been actively engaged in the fields of Aeronautics and the allied sciences. During 1948, a Jet Propulsion Center to provide facilities for postgraduate study in that field, was established by the Daniel and Florence Guggenheim Foundation. (See page 118.) The following program of instruction at the postgraduate level and of advanced research is now in progress.

1. A comprehensive series of theoretical courses in aerodynamics, fluid mechanics, and elasticity, with the underlying mathematics, mechanics, thermodynamics, and physics.

2. A group of practical courses in airplane design conducted by the Institute's staff in cooperation with practicing engineers in the vicinity.

3. Experimental and theoretical researches on:

   a. The basic problems of fluid mechanics with particular emphasis on the effects of viscosity and compressibility.



The 10-foot wind tunnel in the Guggenheim Aeronautical Laboratory, showing the model suspension system above the working section of the tunnel.

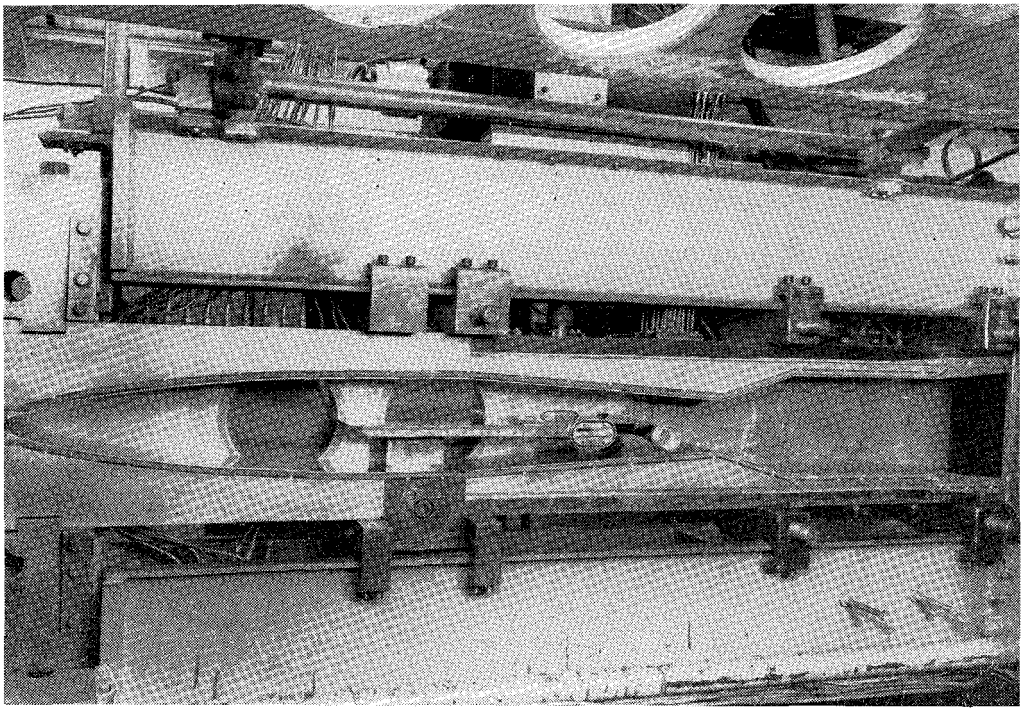
b. The fundamentals of solid mechanics relating to the properties of materials and to the elastic or plastic behavior of structures and structural elements, primarily for aircraft and guided missiles.

c. The concepts of aeroelasticity in which the dynamical structural deformations are correlated with their attendant aerodynamic effects.

d. The performance, stability, and dynamical behavior of aircraft, guided missiles, and projectiles.

e. Problems in jet propulsion with special emphasis on the underlying fluid mechanics, thermodynamics, dynamics, and chemistry. (See page 118.)

The campus laboratory houses a wind tunnel of the closed circuit type with a working section 10 feet in diameter. A 750 horsepower motor and propeller produce test section wind velocities in excess of 200 miles per hour. A complete set of balances permits the rapid testing of aircraft models as well as the



A flat plate for boundary layer investigations installed in one of the two hypersonic wind tunnel test sections. The side wall has been raised to show the nozzle, test section, and diffuser.

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 is available for the study of stress distribution by optical methods. The laboratory is also equipped with excellent shop facilities for the manufacture of testing equipment 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 1,000 persons, of whom about 275 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. By the end of 1955, this tunnel will have approximately 45,000 installed horsepower, with a number of interchangeable working sections, and will be able to develop speeds considerably in excess of the velocity of sound.

The facilities of the Institute are available to students working towards advanced degrees, and to qualified workers who wish to carry out researches in the fields outlined above. In some cases the off-campus facilities can also be made available for such purposes. A few fellowships can be granted to selected men.

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

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

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

CHEMICAL ENGINEERING AND APPLIED CHEMISTRY

(See pages 102-104)

CIVIL ENGINEERING

In Civil Engineering instruction is offered leading to the degrees of Bachelor of Science, Master of Science, Civil Engineer, and Doctor of Philosophy.

The fifth year of study at the Institute is organized to be a logical continuation of the first four years of study. The emphasis during the first four years at the Institute is on the basic subjects in science and engineering. In particular, strong emphasis is placed on physics, mathematics, and solid and fluid mechanics. The fifth year of study involves more specialized engineering subjects but the student is not encouraged to overspecialize in one particular field of civil engineering.

Greater specialization is provided by the work for the engineer's and for the doctor's degree. The candidate for these degrees is allowed wide latitude in selecting his program of studies, and is encouraged to elect related course work of advanced nature in the basic sciences. The engineer's degree of Civil Engineer is considered to be a terminal degree for the student who desires advanced training more highly specialized and with less emphasis on research than is appropriate to the degree of Doctor of Philosophy. Research leading to a thesis is required for the engineer's degree and for the doctor's degree.

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.

The distinctive features of undergraduate work and graduate work in electrical engineering at the California Institute of Technology are the creative atmosphere in which the student finds himself and the large amount of physics and mathematics courses included in the engineering curricula. The graduate work in electrical engineering greatly strengthens the undergraduate courses by bringing students who feel the fourth and fifth year courses best adapted to their needs in close touch with research men and problems.

Of the several electrical engineering laboratories at the California Institute, the High Voltage Research Laboratory, the Analysis Laboratory, the Servomechanism Laboratory and the Electron and Microwave Tube 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 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 analog and digital 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 large-scale general purpose electric analog computer and an IBM digital computing installation. Other analog and digital computers are under development.

These computers are available not only as aids to the research of members of the Institute staff but also as instruments of general service to the engineering staffs of the Southern California industrial area and to the armed forces research groups.

A *Servomechanisms Laboratory* has recently been established for instruction and research on feedback control systems. The facilities of this laboratory

provide excellent opportunities for research leading to all graduate degrees. One important feature is a new electric analog computer suitable for general mathematical analysis and detailed studies of control system components in a complete system.

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 are also available.

ENGINEERING SCIENCE

Advanced programs of study leading to the degree of Doctor of Philosophy in Engineering Science are offered by the Division of Engineering. These programs are complementary to those leading to the degrees of Doctor of Philosophy in Civil, Mechanical, Electrical, and Aeronautical Engineering and are designed to meet the needs of currently developing fields of engineering that are not included in the already established engineering disciplines. The general requirements for the doctorate in Engineering Science are similar to those for the degree in the other fields of engineering, including the completion of satisfactory thesis research. The fields of study may include topics in engineering and science, such as applied mechanics, fluid mechanics, physical metallurgy, the application of modern physics and chemistry to engineering, and the guidance and control of engineering systems.

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 in Mechanical Engineering facilities are provided in four general areas: (1) hydrodynamics, (2) design, mechanics, and dynamics, (3) physical metallurgy and mechanics of materials, and (4) thermodynamics and heat power. In hydrodynamics extensive facilities are available as described under a separate section of the 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 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 116.) This laboratory is built around an analog computer, which merges the various interests in applied mechanics, applied mathematics, and electrical engineering in the solution of problems. The computer is valuable not only for solution of specific research problems but also as research in itself in the development of new elements to extend the usefulness of the computer to more general mathematical analysis.

Close connections are maintained by the Mechanical Engineering staff with the many industries and governmental research agencies in the area which provide new, basic problems and facilities for study and research in the broad field of mechanical engineering.

GUGGENHEIM JET PROPULSION CENTER

During 1948 at the California Institute of Technology, a Jet Propulsion Center was established by the Daniel and Florence Guggenheim Foundation. This Center was created specifically to provide facilities for postgraduate education and research in jet propulsion and rocket engineering, with particular emphasis on peace-time uses. The objectives of this Center are to provide training in jet propulsion principles, to promote research and advanced thinking on rocket and jet propulsion problems, and to be a center for peace-time commercial and scientific uses of rockets and jet propulsion. The Guggenheim Jet Propulsion Center is a part of the Division of Engineering of the California Institute of Technology. All instruction in the Guggenheim Center is on the graduate level.

The solution of the engineering problems in jet propulsion draws on the knowledge and practice of the older branches of engineering, in particular, mechanical engineering and aeronautics. Thus, it is proper that the program of instruction in jet propulsion include material from both of these engineering fields. Similarly, it is expected in general that students entering the course work in jet propulsion will have had their undergraduate preparation in mechanical engineering or aeronautics. Thus, the program of instruction in jet

propulsion has two separate options, allowing men from both aeronautics and mechanical engineering to follow their previous inclinations and developments. The Mechanical Engineering option leads to the degree of Master of Science upon completion of the fifth year program. For men in the Aeronautics Option, the degree of Aeronautical Engineer will be given upon 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 in Aeronautics and in Mechanical Engineering, are available to students working towards advance degrees. Under the present regulations, students who wish to use the facilities of the Jet Propulsion Laboratory must, however, first obtain clearance from the Armed Services.

HYDRODYNAMICS

Hydrodynamics and hydraulic engineering represent subjects in Fluid Mechanics which complement other Institute work in Aerodynamics and in which a vigorous program of research and instruction is maintained. While no specific degree in Hydrodynamics is given, the several specialized laboratories provide excellent facilities for graduate student research.

Hydraulic Machinery Laboratory. This laboratory is designed for carrying out basic and precise research studies in the hydrodynamics of centrifugal and propeller pumps, turbines, and allied flow problems. Dynamometers with precision speed controls are available up to 450 horsepower output or input, and for speeds up to 5,000 r.p.m. Accurate instruments for measuring pressures, flow rates, speeds, and torques are provided. Special equipment for the study of cavitation has been developed. Special test facilities serve for the detailed study of flow characteristics of individual components of hydraulic machinery designed with the object of comparing the theoretical and actual flow patterns.

Hydrodynamics Laboratory. This laboratory is a three-story wing adjoining the Hydraulic Machinery Laboratory. Its equipment is designed for the determination of the dynamics of the motion of underwater bodies. Major research programs are now being carried on under the sponsorship of the Bureau of Ordnance and the Office of Naval Research of the Navy. The facilities are also available for graduate research. The equipment includes (a) a High Speed Water Tunnel with a 14-inch working section and velocities up to 100 feet per second, (b) a Free Surface Water Tunnel, (c) a large Controlled Atmosphere Launching Tank, and (d) a Polarized Light Flume. Force balance and pressure distribution measuring equipment are available for the tunnels. Much additional auxiliary equipment has been developed, including a flash-type motion picture camera for work up to 30,000 exposures per second. Well equipped photographic dark rooms and 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.

SEDIMENTATION LABORATORY. This laboratory, originally operated for soil conservation studies, has become a center for basic investigations into the mechanism of entertainment, transportation, and deposition of solid particles by flowing fluids. The equipment includes (a) two closed circuit flumes for studying sediment transportation; (b) an outdoor model basin for studying field problems requiring either clear or sediment-laden flows: (c) a sediment analysis laboratory, and (d) a water tunnel for studying diffusion and turbulence. 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 Public Affairs Room, and a student lounge which opens upon a walled garden of olive trees.

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

In addition to the regular staff of the Institute, scholars from other institutions give instruction or lectures in the Division of the Humanities. The proximity of the Huntington Library, with its unique opportunities for research in literature, history, and economics, is assurance that the instruction given at the Institute in these fields will continue in the future, as in the past to be strengthened by the association of visiting scholars.

STUDENT LIFE

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

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

Each of the four Houses, Blacker, Dabney, Fleming, and Ricketts, has its own elected officers and is given wide powers in the matter of arranging its own social events, preserving its own traditions, and promoting the general welfare of the House. The Houses are under the general supervision and control of a member of the Faculty known as the Master of the Student Houses.

Since the demand for rooms often exceeds the supply, newly entering students are advised to file room applications with the Master of Student Houses immediately upon being notified by the Dean of Admissions of admittance to the Institute. When there are not sufficient rooms to satisfy the demand, freshmen are assigned rooms from a priority list based on the geographical distance between the student's home and the Institute. Students failing to obtain admission to the Student Houses, who wish to avoid commuting, can find comfortable rooms for rent in private homes near the Institute campus.

Off Campus Housing. The Housing Office, 203 Throop, maintains a file of listings for rooms, apartments and houses. Assistance will be given upon arrival, but no arrangements or reservations can be accomplished in advance. If specific information is desired, it should be requested through this office, and not through the office of the Master of Student Houses.

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

Interhouse Activities. The presidents and vice-presidents of the four Student Houses and Throop Club make up the Interhouse Committee, which determines matters of general policy for all five organizations. While each sponsors independent activities, there is at least one joint dance held each year. The program of intramural sports is also carried on jointly. At present it includes football, softball, cross-country, swimming, water polo, skiing, basketball, and handball.

Dabney Hall of the Humanities.

Public Affairs Room
in Dabney Hall.

Interhouse Scholarship Trophy . A trophy for annual competition in scholarship among the four Student Houses and the Throop Club has been provided by an anonymous donor. With the approval of the donor the trophy has been designated as a memorial to the late Colonel E. C. Goldsworthy who was Master of the Student Houses and commemorates his interest and effort in the field of undergraduate scholarship.

"ASCIT." The undergraduate students are organized as the "Associated Students of the California Institute of Technology, Incorporated," (ASCIT). All students pay the student body fees and are automatically members of this organization, which deals with affairs of general student concern and with such matters as may be delegated to it by the faculty. Membership in the corporation entitles each student to (a) admission to all regular athletic or forensic contests in which Institute teams participate, (b) a subscription to The California Tech, (c) one vote in each corporate election, and (d) the right to hold a corporate office.

Board of Directors. The executive body of the ASCIT corporation is the Board of Directors, which is elected by the members in accordance with the provisions of the By-Laws. The Board interprets the By-Laws, makes awards for athletic and extra-curricular activities, authorizes expenditures from the corporation funds, and exercises all other powers in connection with the corporation not otherwise delegated.

Board of Control. The Honor System is the fundamental principle of conduct of all students. More than merely a code applying to conduct in examinations, it extends to all phases of campus life. It is the code of behavior governing all scholastic and extra-curricular activities, all relations among students, and all relations between students and faculty. The Honor System is the outstanding tradition of the student body, which accepts full responsibility for its operation. The Board of Control, which is composed of elected representatives from each of the four undergraduate classes, is charged with interpreting the Honor System. If any violations should occur, the Board of Control considers them and may recommend appropriate disciplinary measures to the Deans.

Faculty-Student Relations. Faculty-student coordination and cooperation with regard to campus affairs is secured through periodic joint meetings of the Faculty Committee on Student Relations, and 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 as a member of the Southern California Intercollegiate Athletic

The east front of the Student Houses.

Each of the four Student Houses has its own inside court.

Conference, schedules contests in nine sports with the other members of the Conference—Occidental, Pomona-Claremont, Redlands, and Whittier as well as with many other neighboring colleges. In addition, the Caltech Sailing Club sails a fleet of Institute-owned dinghies based at Los Angeles Harbor.

The California Institute Athletic Field, of approximately twenty-three acres, includes a football field, standard track, baseball stadium and championship tennis courts. The Scott Brown Gymnasium and the Alumni Swimming Pool, completed early in 1955, provide attractive modern facilities for intercollegiate, intramural, or recreational competition in badminton, basketball, volleyball, swimming, and water polo. Funds for the pool were contributed by the Alumni of the California Institute; construction of the gymnasium was made possible through a bequest of the late Scott Brown.

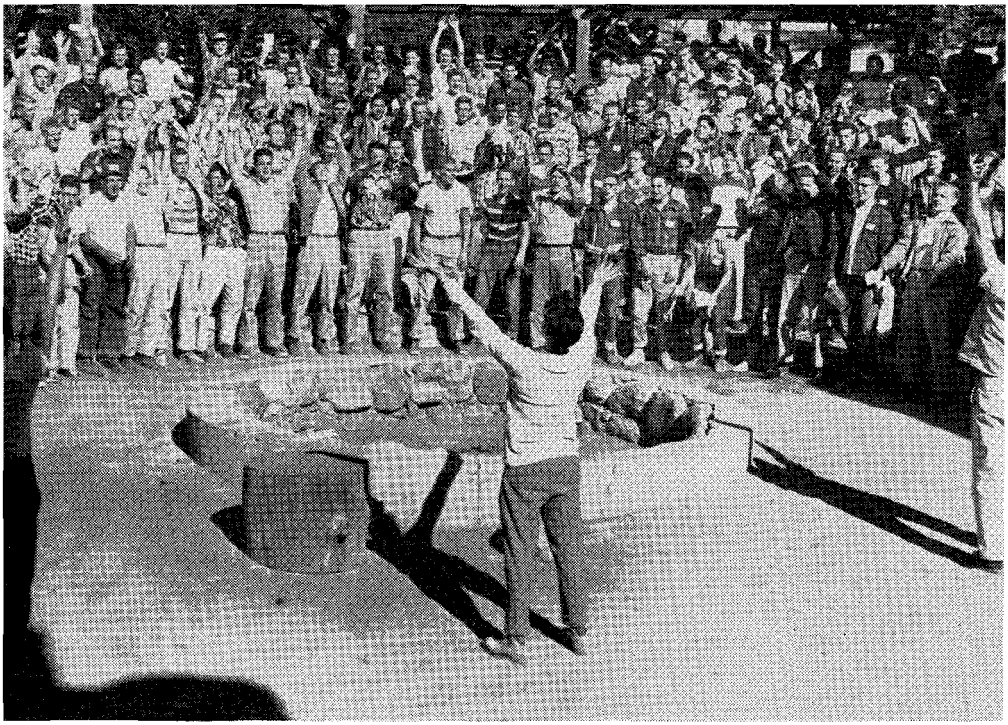
The Institute sponsors an increasingly important program of intramural athletics. There is spirited competition among the five groups composed of the Student Houses and the Throop Club for the possession of three trophies. The Interhouse Trophy is awarded annually to the group securing the greatest number of points in intramural competition during the year. The Varsity and Freshman Rating Trophy is presented to the group having the greatest number of men participating in intercollegiate athletics. The third trophy, "Discobolus," is a bronze replica of Myron's famous statue of the discus thrower. "Discobolus" is a challenge trophy, subject to competition in any sport. It remains in the possession of one group only so long as that group can defeat the challengers of any of the other groups.

Student Body Publications. The publications of the student body include a weekly paper, the *California Tech*; a literary magazine called *Pendulum*, published three times a year; *Farrago*, a comic magazine; an annual; and a student handbook, which gives a survey of student activities and organizations and serves as a campus directory. These publications are staffed entirely by undergraduates. Through them ample opportunity is provided for any student who is interested in obtaining valuable experience not only in creative writing, art work, and in the journalistic fields of reporting and editing, but in the fields of advertising and business management as well.

Musical Activities. The Institute provides qualified directors and facilities for a band, orchestra, and glee club. A series of chamber music concerts is given on Sunday evenings in the lounge of Dabney Hall. The Musicale is an organization which encourages interest 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. From a special loan library, records may be borrowed for students' private use.

Student Societies and Clubs. There is at the Institute a range of undergraduate societies and clubs wide enough to satisfy the most varied interests. The American Institute of Electrical Engineers, the American Society of Civil Engineers, and the American Society of Mechanical Engineers all maintain active student branches.

The Institute has a chapter (California Beta) of Tau Beta Pi, the national scholarship honor society of engineering colleges. Each year the Tau Beta Pi chapter elects to membership students from the highest ranking eighth of the junior class and the highest fifth of the senior class.



Freshmen and transfer students learn about Caltech ways at the New Student Camp, which is held every year just before the beginning of the Fall term.

The Institute also has a chapter of Pi Kappa Delta, the national forensic honor society. Members are elected annually from students who have represented the Institute in intercollegiate debate, or in oratorical or extempore speaking contests.

In addition to the national honorary fraternities there are four local honorary groups: the Beavers, membership in which is a recognition of service to the student body; the Varsity Club, which is composed of students who have earned letters in intercollegiate athletics; the Press Club, which elects members who are active in student publications; and the Drama Club, in which membership is conferred as an award for student dramatic talent. Another service group, the Instituters, is composed of those students who volunteer their assistance in support of various activities of general undergraduate interest.

Special interests and hobbies are provided for by the Chemistry, Mathematics, and Physics Clubs, the Radio Club, the Sailing Club, and the Ski Club. The Christian Fellowship Group, Christian Science Group, Episcopal Group, and the Newman Club are organized on the basis of religious interests. The Inter-Nations Association is an organization composed of foreign students from various countries, as well as interested Americans. Its object is to make the students' stay at Caltech more valuable by introducing them to Americans, their customs and way of life. Conferences, weekly teas, and trips to points of interest in the vicinity are among the activities.

Student Shop. The Student Shop is located in one of the service buildings on the campus near the Student Houses. It was equipped by the Institute, largely through donations, and is operated by the students under faculty supervision. It has no connection with regular Institute activities, and exists only as a place where qualified students may work on private projects that require tools and equipment not otherwise available. All students are eligible to apply for membership in the Student Workshop organization. These applications are acted upon by a governing committee of students, and this committee is charged with the responsibility of admitting only those who can demonstrate their competence in the operation of the machines in the shop. Yearly dues are collected to provide for maintenance and replacement.

Speech Activities. Practical training in public speaking is the keynote of the Institute's forensics program. A variety of experiences ranging from intercollegiate debate tournaments to local speech events can be had by all who wish to improve their abilities. Debaters take part in an average of six intercollegiate tournaments during the year. These tournaments, including extempore speaking, oratory, impromptu speaking and discussion, comprise such events as the Western Speech Association tournament, the regional Pi Kappa Delta tournament, and the annual Caltech invitational debate tournament held on the Institute's campus. Bi-annually the Institute is represented at the National Pi Kappa Delta speech tournament. Local activities include the annual Conger Peace Prize oration contest, and the inter-house speech contest for the Lincoln trophy. Student toastmasters' clubs, panels, and students competing for public speaking prizes of the national engineering societies are given guidance.

Y.M.C.A. The California Institute Y.M.C.A. is a service organization whose purpose is to supplement a technical and scientific education with a program emphasizing social and religious values. The "Y" is one of the most active student organizations on the campus and welcomes as members all students taking an active part in its regular program of activities. The program includes weekly luncheon clubs, discussion groups, which bring speakers representing many interests to the campus, forums and lectures, student-faculty firesides, inter-collegiate conferences and work with local church groups. It also sponsors an annual freshman tea dance. The "Y" services to the student body include a used textbook exchange, a loan fund, an all-year calendar of student events and the use of the lounge and offices. The excutive secretary of the Y.M.C.A., Wesley L. Hershey, is always available to help students with their personal problems. Friends of the Institute "Y" have provided a residence near the campus for the executive secretary, especially built to accommodate informal meetings of discussion groups.

Bookstore. The Student Store serving students, faculty and staff is located on the ground floor of Throop Hall. The store, which is owned and operated by the Institute, carries a complete stock of required books and supplies, many reference books and many extra-curricular items—athletic supplies, stationery, fountain pens, etc. Net income from operation of the store is used for undergraduate scholarships and for payment of a dividend to the Associated Students for student body activities.

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) letters of recommendation, and a personal interview when this is feasible. 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 Admissions Office not later than March 1, 1956. (Application to take entrance examinations must be made directly to the College Board at an earlier date, for which see below.)

Applicants living outside of the United States must submit their credentials by December 1, 1955.

Transcripts of records covering three and a half years of high school should be submitted as soon as the grades of the first semester of the senior year are available. Those attending schools which operate on the quarter system should submit records covering the first three years and the first quarter of the senior year. They must also arrange for a supplementary transcript showing the grades for the second quarter to be sent as soon as possible. Applicants must be sure to list in space provided on the application blank the subjects they will take throughout the senior year.

Arrangements to take the tests must be made by writing to the College Entrance Examination Board in advance of the closing dates and according to the instructions listed below.

HIGH SCHOOL CREDITS. Each applicant must be thoroughly prepared in at least fifteen units of preparatory work, each unit representing one year's work in a given subject in an approved high school at the rate of five recitations weekly. Each applicant must offer all of the units in Group A and at least five 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, a year of geology or biology, basic elementary shop work, and as much extra instruction in English grammar and composition as is available in the high school curriculum.

ENTRANCE EXAMINATIONS. In addition to the above credentials, all applicants for admission to the freshman class are required to take the following entrance examinations given by the College Entrance Examination Board: the scholastic aptitude test (morning program); the afternoon program consisting of achievement tests in advanced mathematics and any two of the following: physics, chemistry, English. Note that the scholastic aptitude and the advanced mathematics tests must be taken, and that the choice lies only between physics, chemistry and English of which two must be taken. No substitution of other tests can be permitted.

In 1956 these tests may be taken either on Saturday, January 14, or on Saturday, March 17. Most applicants will find themselves better prepared if they wait until the latter date. *It is important to note that no applicant can be considered with the original group to be admitted in 1956 who has not completed the tests by the March 17 date; however, those who for any reason fail to complete the tests by that date may take the next series which will be given on May 19, and will be considered to fill any vacancies that may result from cancellations from among the original group selected.* 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 on page 133. 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, 4640 Hollywood Boulevard, 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. Please note that the examination fee is *not* sent to the California Institute, but to the appropriate College Board office. No fee is due the California Institute until after an applicant has been admitted.

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

	For examination centers located	
To take tests on	In the United States, Canada, the Canal Zone, Mexico, or the West Indies, applications must be received by	Outside the United States, Canada, the Canal Zone, Mexico, or the West Indies, applications must be received by
January 14, 1956	December 17, 1955	November 26, 1955
March 17, 1956	February 25, 1956	January 28, 1956

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.

LETTERS OF RECOMMENDATION. On or about March 1 Teacher Recommendation Forms will be sent to all those whose entrance application blanks and high school transcripts are on file in the admissions office. Three forms will be sent to each applicant, and one is to be given to each of three members of the staff—the principal, teachers or counselors—of the school which the applicant is attending. The applicant should select the staff members who in his opinion are best qualified to furnish the information asked for in the forms. At least two of these persons should be ones who have taught or advised the applicant during his senior year. The forms are to be returned directly by the person who fills them out and must arrive in the admissions office not later than April 1. No other letters of recommendation are required, but all those who wish to be considered for admission must have these forms on file by April 1 of the year in which admission is desired. In some cases a member of the Admissions Committee may visit the school which the applicant is attending for an interview with the applicant and his teachers, but the applicant has no responsibility with regard to an interview unless and until a notice of an interview appointment 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 final acceptance for admission, each applicant is required to submit a report of physical examination on a form which will be sent him at the time he is notified of admission. It is the applicant's responsibility to have this form filled out by a Doctor of Medicine (M.D.) of his own choosing. (See page 146.) Admission is tentative pending such examination, and is subject to cancellation if the results of the examination are unsatisfactory.

Vaccination at the time of the examination is a requirement. Students will not be admitted unless the physical examination form bears evidence of such vaccination.

SCHOLARSHIPS. For information regarding scholarships for entering freshmen see pages 153 to 159. Please note especially the distinction between Honors at Entrance and scholarship grants and that the latter are awarded on the basis of financial need as well as high standing on the entrance examinations. No one can be considered for a scholarship grant who has not sent in a scholarship form according to the instructions on page 153.

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.

STUDENTS' DAY. The California Institute holds an annual invitational Students' Day on the first Saturday in December of each year. This popular event is conducted by invitation to allow a more intimate view of the work in the laboratories of science and engineering with the hope that this contact will assist the student in his choice of a future career. Science students and their teachers are invited, upon nomination by secondary schools throughout Southern California, to view exhibits of the work in the various Divisions of the Institute and to attend selected demonstration lectures given by students and faculty members. Student life on the campus is an important feature of Students' Day with the undergraduate student body serving as host and responsible for the actual operation under the direction of a joint faculty-student committee. To avoid overcrowding at the exhibits and lectures it is necessary to limit attendance at this event to those who have been selected by their schools and whose names have been sent to the Students' Day Committee in advance.

AIR FORCE ROTC. For details of admission to the AFROTC see page 97.

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 131-135 or as upper classmen in the manner described below. Those who have pursued col-

lege 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 131-135.) 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 141.)

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 Office of Admissions upon request, but only after transcripts are on file. Transcripts and applications must be on file by April 1. Applicants living in foreign countries must have applications and transcripts on file by March 1 at the latest and should understand that no information with regard to acceptance or rejection can be sent before June 20. 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 194-207) or make up their deficiencies as soon as possible after admission.

It is not possible to answer general questions regarding the acceptability of courses taken elsewhere. The nature of the work at the Institute is such as to demand that all courses offered for credit be scrutinized individually. Even when a transcript of record is submitted it is not always possible to tell whether the courses taken are equivalent to 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 the applicants previous records and of the results of their 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, 1956, is as follows:

Mathematics	9:00 a.m.	June 1, 1956
English	1:00 p.m.	June 1, 1956
Physics	9:00 a.m.	June 2, 1956
Chemistry	1:00 p.m.	June 2, 1956

No other examinations for admission to upper classes will be given in 1956.

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 141-145.) In addition, they should note that to be permitted to register for any science or engineering options during their junior and senior years they must meet the scholastic requirements of the divisions concerned. (See page 143.)

Physical examinations and vaccination are required as in the case of students entering the freshman class. (See page 134.) 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 135.) In the event of subsequent cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute.

THE 3-2 PLAN. Arrangements exist between the California Institute and Occidental College in Los Angeles, California; Pomona College in Claremont, California; Reed College in Portland, Oregon; Whitman College in Walla Walla, Washington, whereby students enrolled in these liberal arts colleges may follow a certain prescribed course for the first three years and then transfer into the third year of one of the engineering options at the California Institute without further formality provided that they have the unqualified recommendation of the officials at the liberal arts college which they are attending. After satisfactorily completing in two years at the California Institute all remaining work required for a bachelor's degree in engineering they will be awarded a bachelor of arts degree by the college from which they transferred and a bachelor of science degree in engineering by the California Institute. Application for admission at the freshman level under this plan should be made to the liberal arts college.

REGISTRATION REGULATIONS

Registration Dates		*Fees Payable*	*Instruction Begins*
Freshmen and Transfer Students	Sept. 22, 1955	Sept. 22, 1955	Sept. 27, 1955
Upperclassmen and Graduate Students	Sept. 26, 1955	Sept. 26, 1955	Sept. 27, 1955

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. A grade of F will be given in any course for which a student registers and which he does not either complete satisfactorily or drop. A course is considered dropped only after student has turned in to the Registrar's Office a drop card properly filled out and signed by the instructor concerned. A student may not withdraw from a course after the last date for dropping courses as shown on the Institute calendar without, in addition, obtaining the permission of one of the Deans. A student may not at any time withdraw from a course which is required for graduation in his option without the permission of one of the Deans. A student may, with the consent of the instructor concerned, add a course after he has completed his regular registration and before the last date for adding courses as shown on the Institute calendar. If the addition brings the total units for which he is registered above 56 including Physical Education or ROTC he must obtain the recommendation of his Departmental Advisor and the approval of the Registration Committee to carry excess units (see page 144). Registration for added courses is complete only after a student has turned in to the Registrar's Office an add card properly filled out and signed by the instructor concerned. No credit will be given for a course for which a student has not properly registered.

General Regulations

Every student is expected to attend all classes and to satisfy the requirements in each of the courses in such ways as the instructor may determine.

Students are held responsible for any carelessness, willful destruction, or waste. At the close of the year, or upon the severance of their connection with any part of the work of the Institute, students are required to return immediately all locker keys and other Institute property.

It is taken for granted that students enter the Institute with serious purpose. The moral tone is exceptionally good; the honor system prevails in examinations, and in all student affairs. A student who is known to be engaging in immoral conduct or exercising a harmful influence on the student life of the Institute may be summarily dismissed, whatever be his scholastic standing.

Auditing of Courses

Persons not regularly enrolled in the Institute may, with the consent of the instructor in charge of the course and the Chairman of the Division concerned. be permitted to audit courses upon payment of a fee in the amount of $12.50 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.

"Conditions" indicate deficiencies that may be made up without actually repeating the subject. grade of 'D' is given when the work is completed.

The grade "incomplete" is given only in case of sickness or other emergency which justifies the non-completion of the work at the usual time. An "*incomplete*" will be recorded only if the reasons for giving it are stated by the instructor on a form which will be sent with each grade sheet and only if, in the opinion of the appropriate committee, (Registration Committee for Undergraduates and Master of Science Candidates, and Graduate Study for those working for Engineers or Ph.D. degrees) the reasons justify an incomplete. If, in the opinion of the appropriate committee, the incomplete is not justified, a condition will be recorded.

An incomplete or a condition in any term's work must be removed during the next term in residence by the date fixed for the removal of conditions and incompletes. Each student receiving such grades should consult with his instructor at the beginning of his next term in residence. Any condition or incomplete not so removed automatically becomes a failure unless otherwise recommended in writing to the Registrar by the instructor prior to the date for removal of conditions and incompletes.

Failed means that credit may be secured only by repeating the subject, except that in special cases the Registration Committee may, with the instructor's approval, authorize a removal of an "F" by three 3-hour examinations. When a grade of "F" is removed either by repeating the work or by three 3-hour examinations, the instructor may award whatever grade he believes the student has earned. The new units, grade and credits appear on the record and are added to the total to obtain grade-point average. See page 142.) However, the original grade of "F" also remains on the record, and the original units are 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.) Units and credits in military subjects taken by Air Force ROTC students are counted in computing grade-point average. Physical education units and units in graduate research are not included in computing grade-point average.

Ineligibility for registration. Any undergraduate student or Master's candidate is ineligible to register:

(a) If he fails during any one term to obtain a grade-point average of at least 1.30.

(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

TABLE OF CREDITS CORRESPONDING TO GRADE AND NUMBER OF UNITS

No. of Units	Grade A+	A	A−	B+	B	B−	C+	C	C−	D+	D	F
1	4	4	4	3	3	3	2	2	2	1	1	0
2	9	8	7	7	6	5	5	4	3	3	2	0
3	13	12	11	10	9	8	7	6	5	4	3	0
4	17	16	15	13	12	11	9	8	7	5	4	0
5	22	20	18	17	15	13	12	10	8	7	5	0
6	26	24	22	20	18	16	14	12	10	8	6	0
7	30	28	26	23	21	19	16	14	12	9	7	0
8	35	32	29	27	24	21	19	16	13	11	8	0
9	39	36	33	30	27	24	21	18	15	12	9	0
10	43	40	37	33	30	27	23	20	17	13	10	0
11	48	44	40	37	33	29	26	22	18	15	11	0
12	52	48	44	40	36	32	28	24	20	16	12	0
13	56	52	48	43	39	35	30	26	22	17	13	0
14	61	56	51	47	42	37	33	28	23	19	14	0
15	65	60	55	50	45	40	35	30	25	20	15	0

*The units used at the California Institute may be reduced to semester hours by multiplying the Institute units by the fraction 2/9. Thus a twelve-unit course taken throughout the three terms of an academic year would total thirty-six Institute units or eight semester hours. If the course were taken for only one term, it would be the equivalent of 2.6 semester hours.

†For the assignment of credits to undergraduate grades with plus or minus designators see the following table.

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 below.)

(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 a 1.50 grade point average during any one term will be required to report to the Dean before registering and may be requested to withdraw from all extracurricular activities and outside employment or reduce the number of subjects he is carrying sufficiently to enable him to meet the scholastic requirements in succeeding terms.

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 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 1.90. In addition to the above requirement a member of the Air Force ROTC unit must satisfactorily complete the basic course unless relieved of this obligation by the Air Force. If a member of the AFROTC has entered the advanced course or if he has at any time at the California Institute secured deferment under Selective Service by reason of membership in the AFROTC, he must satisfactorily complete the AFROTC course and must accept a commission in the Air Force if one is offered unless excused from these obligations by action of the Air Force.

Residence requirement. All transfer students who are candidates for the Bachelor of Science degree must complete at least one full year of residence in the undergraduate school at the Institute immediately preceding the com-

*The curriculum of the Institute is organized under six divisions, as follows:
Division of Physics, Mathematics, and Astronomy.
Division of Chemistry and Chemical Engineering.
Division of Civil, Electrical, and Mechanical Engineering, and Aeronautics.
Division of Geological Sciences.
Division of Biology.
Division of the Humanities.

pletion of the requirements for graduation. At least ninety of the units taken must be in subjects in professional courses. A full year of residence is interpreted as meaning the equivalent of registration for three terms of not less than 49 units each.

Honor standing. At the close of each academic year the Committee on Undergraduate Scholarships and Honors awards Honor Standing to fifteen or twenty students in each of three classes remaining in residence. These awards awards are based on the scholastic records of the students. A list of these students attaining Honor Standing on the basis of their academic records for 1954-55 appears on page 313.

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 in Honor Standing who in any subsequent term fails to maintain a scholastic standard set by the Committee on Undergraduate Scholarships and Honors may lose these privileges.

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 division and the Committee on Undergraduate Scholarships and Honors and approval of the Faculty.

Term examinations will be held in all subjects unless the instructor in charge of any subject shall arrange otherwise. No 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. Undergraduates who wish to register in any term for more than 56 units inclusive of Physical Education or Air Science must obtain the recommendation of the Departmental Advisor and the approval of the Registration committee. Master's candidates, see page 165.

Registration 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 except members of the Air Force ROTC are required to participate in some form of physical training for at least one hour a day three days a week. This requirement may be satisfied by engaging in organized sports, which include both intercollegiate and intramural athletics, or by regular attendance at physical education classes.

Men may be excused from the requirement of physical education by petitioning the Physical Education Committee for such excuse when they become 24 years of age, or can show credit for 4 years of P.E. at the college level. It is the responsibility of students who wish to be excused and who are eligible under this ruling to make application for excuse at the Athletic Office.

For Graduate Students there is no required work in physical education, but opportunities are provided for recreational exercise.

STUDENT HEALTH

PHYSICAL EXAMINATION AND VACCINATION

All admissions, whether graduate or undergraduate, are conditional until a report of physical examination and vaccination is received and approved by the Director of Student Health. See page 134.

THE DISPENSARY AND INFIRMARY

A dispensary and six-bed infirmary are located on the campus. The services offered by the dispensary are available to graduate and undergraduate students, their wives and families and to employees. Only graduate and undergraduate students and male employees are admitted to the infirmary. Students have priority on the available beds.

The staff consists of physicians, two of which are consultants, and nurses. The infirmary is operated twenty-four hours a day, seven days a week, during the academic year. The dispensary is open during the academic year from 8 a.m. to 5 p.m. from Monday through Friday, and 8 a.m. to 12 noon on Saturday. During the summer vacation, a somewhat restricted dispensary service is offered. A medical consultant in radiological safety is on the consulting staff.

General office medical care is provided, minor emergency surgery is performed, and complete laboratory facilities are available at the dispensary and through the Pasadena Clinical Laboratory. Close co-operation is maintained with medical specialists in all fields in the community of Pasadena. The services of these doctors are used freely in maintaining high standards of modern medical care. The medical services do not include optometric or dental care.

The services offered by the infirmary and dispensary are aided by the Caltech Service League, an organization composed of mothers of present and former students, and wives of faculty members.

HEALTH FEE

Each undergraduate and graduate student pays a health fee of $18.00 per academic year, $6.00 of which is paid into an Emergency Health Fund.

The remaining portion of the health fee, consisting of $12.00, entitles a student to the services of the dispensary during the academic year, except for the cost of medications given and of extensive laboratory work. A schedule of charges for cost of medicines, injections, and laboratory work, is posted in the dispensary; the rates are on a non-profit basis. The cost of a student's stay in the infirmary is charged to the Emergency Health Fund, described below. Costs of all medical and surgical services and hospitalization which need to be secured outside of the infirmary and dispensary are the responsibility of the student. Accidents occurring off campus and out of jurisdiction of the school,

(i. e. non-authorized athletics, or automobile accidents) may be cared for in the infirmary but charges will be borne by the student.

The services of the dispensary are available throughout the year, to the wives and children of graduate or undergraduate students, faculty members and their families, and employees, at a fee of $3.00 for each visit, plus the cost of medication and laboratory services needed. During the summer vacation graduate and undergraduate students pay a fee of $2.00 per visit, plus cost of medicine and laboratory services. Male employees may be hospitalized in the infirmary. Rates for this hospitalization are available on request.

THE EMERGENCY HEALTH FUND

The purpose of the Emergency Health Fund is to assist a student in meeting the costs of medical, surgical, and hospitalization services in emergencies. The Fund is not an insurance plan.

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

1. The funds derived from the students health fee, $6.00 per academic year, are credited to a special account. The Institute as the custodian invests the funds and credits the Fund with income earned. The Fund shall not be used for any other purpose than for the payment of the student's medical, surgical, and hospital expenses, including infirmary charges. Whether a case is one within the scope of the Fund will be decided by the Medical Director in consultation with the Faculty Committee on Student Health.

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

2. The Fund is not, in general, applicable to accidents, as distinguished from other emergency medical conditions, which occur away from the grounds of the Institute, unless these occur during authorized activities of the Institute.

3. The Fund does not cover conditions requiring treatment which arise during vacation periods.

4. The Fund does not cover conditions which existed at the time of admission to the Institute; nor does it cover chronic disease conditions which may develop while the student is at the Institute.

5. The Fund does not cover treatment required after leaving the hospital, nor special equipment needed for recovery.

6. The Fund does not cover injuries incurred in connection with authorized intercollegiate athletics. But in defraying the cost of any treatment required for such injuries, the student is aided by the Department of Physical Education. The normal maximum allowance for a single injury is $250.00. However, at the discretion of the Physical Education Committee, this maximum may be increased, for any one injury, to an amount not exceeding $500.

7. The Fund does not provide for families of graduate or undergraduate students.

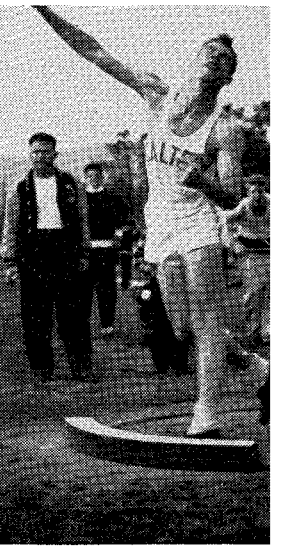
8. The maximum that will be allowed from the Fund for any one illness or injury is $125.00, but the Fund is not obligated to pay this maximum, nor is there any obligation to pay for such expenses beyond the available balance of the Fund. The Faculty Committee on Student Health reviews each case with the Medical Director and determines the amount of assistance to be granted from the Fund.

9. Donations to the Fund will be gratefully received.

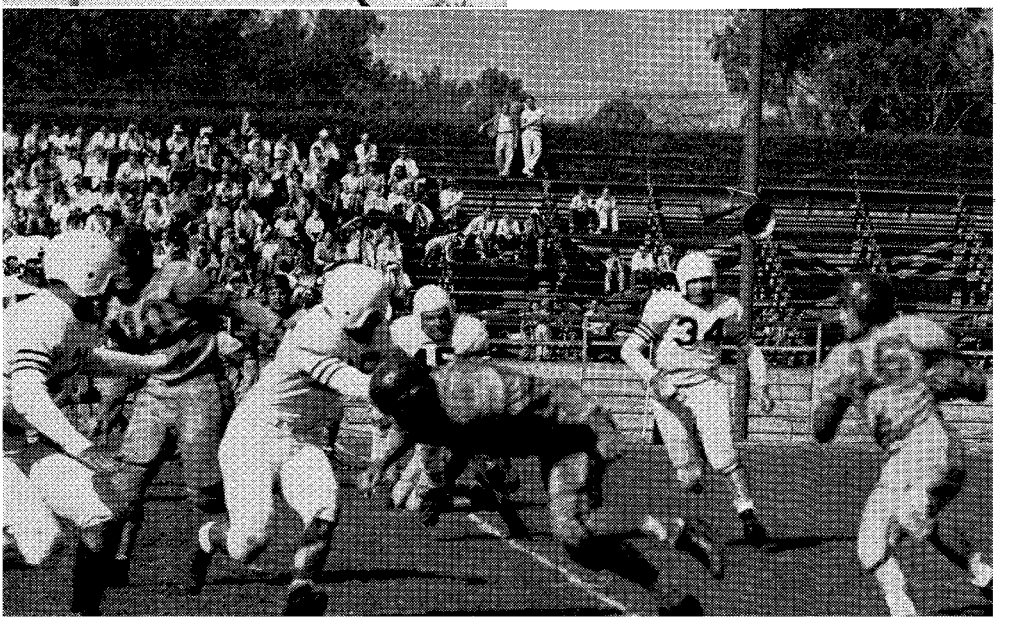
RESPONSIBILITY OF THE STUDENT

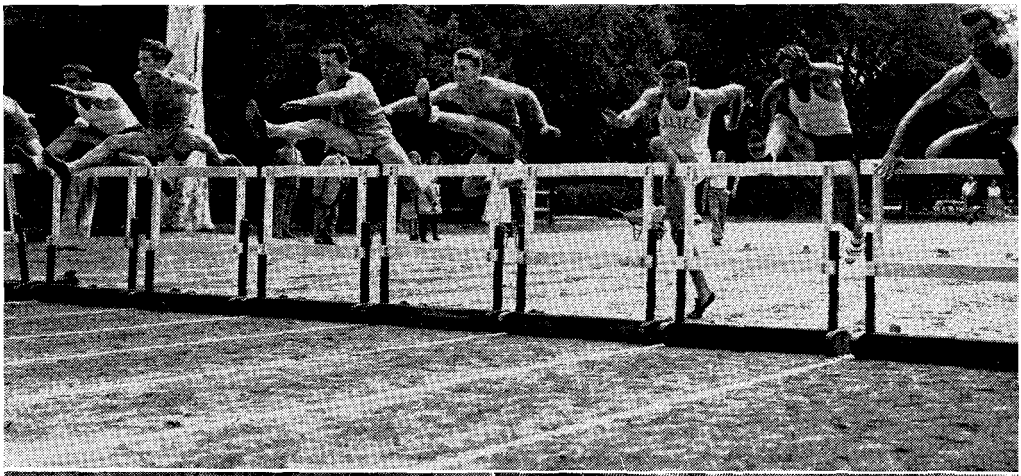
The responsibility for securing adequate medical attention in any contingency, whether an emergency or not, is solely that of the student, whether the student is residing on or off campus. Apart from providing the opportunity for consultation and treatment at the dispensary and infirmary as described above, the Institute bears no responsibility for providing medical attention.

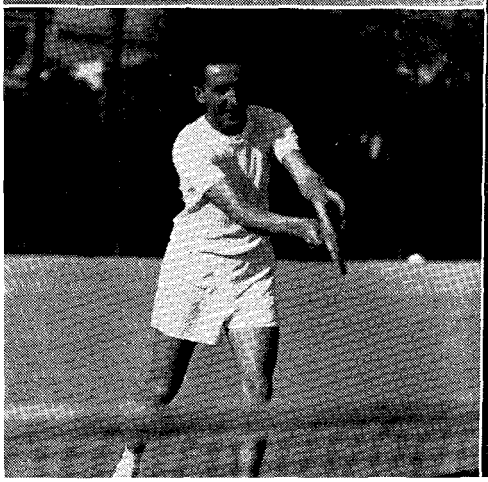
Any expenses incurred in securing medical advice and attention in any case are entirely the responsibility of the student, except as specified above.

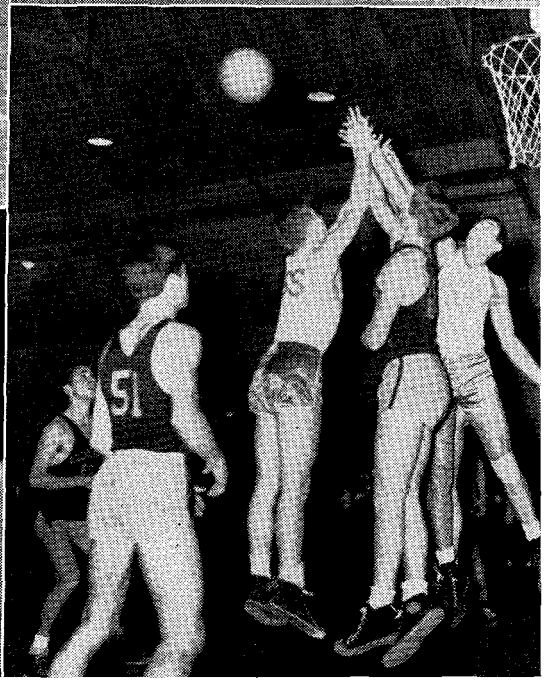


The athletic program includes a wide variety of inter-collegiate and intramural sports.









EXPENSES

The following is a list of student expenses at the California Institute of Technology for the academic year of 1955-56, 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.

UNDERGRADUATE STUDENTS

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
Sept. 22, 1955: Freshmen and transfer students Sept. 26, 1955: All others	Tuition, 1st term		250.00
	Board and Room, 1st term 21 meals per week		241.30[2]
	First Term Incidental Fees:		
	Associated Student Body Dues	5.50	
	Subscription to California Tech for 1955-56	1.50	
	Health and Hospitalization Fee	18.00[3]	
	Total		25.00
	Locker Rent, 1st term		1.00[4]
	Parking Fee, 1st term		1.50[4]
	Student House Dues, 1st term		5.00
January 3, 1956	Tuition, 2nd term		250.00
	Board and Room, 2nd term 21 meals per week		221.40[2]
	Second Term Incidental Fees:		
	Associated Student Body Dues		6.75
	Locker Rent, 2nd term		1.00[4]
	Parking Fee, 2nd term		1.50[4]
	Student House Dues, 2nd term		5.00
March 26, 1956	Tuition, 3rd Term		250.00
	Board and Room, 3rd term 21 meals per week		217.45[2]
	Third Term Incidental Fees:		
	Associated Student Body Dues		6.75
	Locker Rent, 3rd term		1.00[4]
	Parking Fee, 3rd term		1.50[4]
	Student House Dues, 3rd term		5.00

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

A. Without Board and Room

Tuition	750.00	
Health Fee	18.00	
Student Body Dues	20.50	788.50

B. With Board and Room

As under (A)	788.50	
Board and Room	680.15	
Student House Dues	15.00	1,483.65

GRADUATE STUDENTS

	First Term:		
September 26, 1955	Tuition	250.00	
	Health and Hospitalization Fee	18.00[3]	
	General Deposit (see page 147)	25.00	
	Second Term:		
January 3, 1956	Tuition	250.00	
	Third Term:		
March 26, 1956	Tuition	250.00	
TOTAL FOR ACADEMIC YEAR			793.00

Tuition Fees for fewer than normal number of units:

Over 32 units Full Tuition[5]	
32 to 25 units	$187.50 per term
24 to 10 units	$7.50 per unit per term
Minimum per term	$75.00[6]
Auditor's Fee	$12.50 per term, per lecture hour

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.[7] 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]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.

[3]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 $12.00 and $6.00, respectively to cover balance of school year.

[4]Optional.

[5]Although the Institute charges full tuition for over 32 units, the Veteran 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 193.

[6]Graduate Students see paragraph 6, page 170.

[7]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 146-149).

Associated Student Body Fee. The Associated Student Body Fee of $19.00 is payable by all undergraduate students. This fee is used for the support of athletics, the BIG T, and any other student activity that the Board of Directors of the Associated Students of the California Institute of Technology may deem necessary. The subscription to the CALIFORNIA TECH, $1.50 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 140) is $12.50 per term, per lecture hour.

Unpaid Bills. All bills owed the Institute must be paid when due. Any student whose bills are delinquent may be refused registration for the term following that in which the delinquency occurs. Students who have not made satisfactory arrangements regarding bills due and other indebtedness to Institute by the date of graduation will be refused graduation.

SCHOLARSHIPS, STUDENT AID, AND PRIZES*

FRESHMAN HONORS: AND SCHOLARSHIP GRANTS

In order that appropriate awards may be made to students as they most deserve or need them, the California Institute makes a clear distinction between recognition of academic honor and achievement and recognition of need for financial assistance. This distinction is made with two types of awards: Honors at Entrance and Scholarship Grants.

HONORS AT ENTRANCE

In recognition of distinguished academic achievement Honors at Entrance are awarded to the top ten percent of those admitted to the freshman class. They are awarded without regard to financial need, and carry no monetary grant. No application for consideration for Honors at Entrance is needed.

FRESHMAN SCHOLARSHIP GRANTS

The recipients of scholarship grants are selected by the Admissions Committee from the candidates who have stood sufficiently high on the entrance examinations and have otherwise satisfied the entrance requirements of the Institute.

Scholarship grants are awarded to the extent of available funds where financial need is demonstrated. Awards are made on the basis of all the information available in regard to the applicants—the results of their examinations, their high school records and recommendations, the statements submitted as to their student activities and outside interests, and the result of personal interviews where these are possible.

Commencing with the freshman class entering in September, 1955, the California Institute will use a uniform scholarship grant application which has been adopted by many colleges in the United States. All applications for scholarship grants where financial need exists must be made on this form. The form may be obtained by writing to the Admissions office at the California Institute or by calling at the office. The form is put out by the College Entrance Examination Board and is to be returned directly to the appropriate office of the College Board (see page 132) and not to the California Institute. Space is provided on the form for the applicant to indicate that he wishes a copy sent to the California Institute and to such other colleges as he may desire. A fee of one dollar is required for each college to which a copy of the form is to be sent. This fee must accompany the form when it is returned to the College Board.

Scholarship grant forms must be sent to the appropriate College Board office not later than March 1 of the year in which admission is desired.

*For further information on Graduate Scholarships and Fellowships see page 185.

HONORARY SCHOLARSHIPS

In addition to the above there are two honorary awards which carry stipends. The Sloan scholarships and the Regional scholarships described below are given without consideration of financial need. All applicants for admission are automatically considered for the Sloan scholarships. Candidates for Regional scholarships are nominated by the principals or headmasters of their schools. Only when need exists is it necessary to file a scholarship grant form in connection with these awards.

Recipients of honorary scholarships and of scholarship grants are expected to maintain a satisfactory standing in their academic work during the year for which the scholarship is granted. If the recipient fails to maintain such an academic standing, or if, in the opinion of the Committee on Undergraduate Scholarships and Honors, the recipient in any other way fails to justify the confidence placed in him, the Committee may cancel the scholarship for the balance of the academic year. Freshmen who receive scholarship awards for the freshman year only will be considered for scholarship aid in subsequent years on the basis of need if they stand in the top half of the class.

UPPER CLASS SCHOLARSHIPS

Sophomores, juniors, and seniors are considered for scholarships if need is demonstrated and if they rank in the top half of their respective classes. Awards are made in order of rank to the extent of the funds available. In addition they must throughout the preceding academic year on which the rank is computed have carried at least the normal number of units required in their respective options. Most awards are for full or part tuition. When individual scholarships carry amounts in excess of full tuition this fact is noted in the list of scholarships below. Students who are academically qualified to make application will be notified and may obtain an application from the Admissions 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.

SCHOLARSHIP FUNDS

Funds for Freshman and Upperclass Scholarships, are provided in large part from the special scholarship funds named below.

AiResearch Manufacturing Company Scholarships: the AiResearch Manufacturing Company of Los Angeles has established two scholarships of $1000 each to be awarded to juniors or seniors majoring in mechanical engineering or applied chemistry, and to fifth year students in mechanical engineering and chemical engineering.

Alumni Scholarship: The Alumni Association of the California Institute provides a scholarship covering full tuition to be awarded to an entering freshman. The recipient of this scholarship can expect to receive this amount for four years provided his conduct and grades continue to be satisfactory.

Edward C. Barrett Scholarship: Friends of Edward C. Barrett, who for forty-one years was Secretary of the California Institute, have established in his name a scholarship to be awarded annually to an undergraduate student.

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

Blacker Scholarships: Mr. and Mrs. Robert Roe Blacker of Pasadena, in 1923, established the Robert Roe Blacker and Nellie Canfield Blacker Scholarship and Research Endowment Fund. A portion of the income of this fund, as determined by the Board of Trustees, may be used for undergraduate scholarships.

C. F. Braun and Company Scholarships: C. F. Braun and Company of Alhambra, California has established three scholarships of $1000 each to be awarded to entering freshmen for the 1955-56 academic year. In selecting candidates preference will be given to those who indicate that they wish to pursue a course in engineering.

Caltech Bookstore Scholarships: the profits from the Caltech Bookstore on the California Institute campus are used to furnish a number of scholarships for undergraduates in all options.

California Scholarship Federation Scholarship: The California Institute will each year award a scholarship to a C.S.F. member who is also a sealbearer provided that such a candidate is available who has met the Institute's requirements for a freshman scholarship grant. Sealbearer status must be verified by the C.S.F. adviser at the time of submitting the regular application for a scholarship grant.

Class of 1927 Scholarship: The Class of 1927 has recently established the Class of 1927 Scholarship Endowment Fund. The income from this fund is to be used for an undergraduate scholarship.

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.

Douglas Aircraft Company Scholarship: The Douglas Aircraft Company has made provision for a $1,000 scholarship for the 1955-56 academic year to be awarded to a senior in aeronautical engineering.

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.

General Motors Corporation Scholarship: The General Motors Corporation has established a scholarship at the California Institute to be awarded to an entering freshman. The award may range from a prize scholarship of $200 for a student not in need of financial assistance to an amount as high as $2,000 a year depending on need. Holders of this scholarship may expect it to be renewed in each of the three upper-class years provided the holder's grades and conduct remain satisfactory.

The Gnome Club Scholarship: The alumni of the Gnome Club have established at the California Institute a scholarship to be awarded to a student in the junior class.

Graham Brothers Foundation Scholarship: The Graham Brothers Foundation of Long Beach has made possible the award of a full tuition scholarship to an entering freshman for the 1955-56 academic year.

Harriet Harvey and Walter Humphry Scholarships: The late Miss Harriet Harvey and the late Mrs. Emily A. Humphry made provision for two scholarships. The first of these, the Harriet Harvey Scholarship, is to be awarded preferably to a well-qualified candidate from the state of Wisconsin. If there is no such candidate the Institute may award the scholarship elsewhere. The second, the Walter Humphry Scholarship, is to be awarded preferably to a well-qualified candidate from the state of Iowa. If there is no such candidate, the Institute may award the scholarship elsewhere.

Robert Haufe Memorial Scholarship: This scholarship is supported by a fund established in 1950 by Mr. and Mrs. J. H. Haufe as a memorial to their son Robert Haufe.

The Holly Scholarship: The Holly Manufacturing Company has established a half tuition scholarship to be awarded to a senior in any engineering option.

Hydro-Aire Incorporated Scholarship: The Hydro-Aire Corporation of Los Angeles has established a full tuition scholarship to be awarded at the end of the sophomore year to a student in engineering.

J. B. Keating Scholarship: Mr. John B. Keating has made possible the award of two scholarships for undergraduates majoring in mechanical engineering.

Kelman Scholarships: Mr. J. N. Kelman of Los Angeles has made possible the award of a scholarship of one thousand dollars for an entering freshman. The recipient of this scholarship can expect to receive this amount each year for your years provided that his 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.

Lockheed National Engineering Scholarship: The Lockheed Aircraft Corporation of Burbank, California has established a scholarship covering tuition and certain other expenses totaling $1300 a year. This scholarship is to be awarded to an entering freshman who indicates that he intends to pursue a course in engineering. The recipient of this scholarship may expect to continue to receive this award during each of the three upperclass years provided that his grades and conduct remain satisfactory.

Mayr Foundation Scholarships: The George H. Mayr Foundation of Beverly Hills granted funds for twenty-four undergraduate scholarships for the academic year 1955-56. Not open to entering freshmen.

Management Club of California Institute of Technology Scholarship: The Management Club at the Institute has established a tuition scholarship to be awarded to an undergraduate student in one of the three upperclasses.

Monsanto Chemical Company Scholarship: Monsanto Chemical Company has established a full tuition scholarship for a student in the Applied Chemistry Option. Not open to entering freshmen.

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. Application for the academic year 1956-57 should be submitted by May, 1956 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.

Frances W. Noble Scholarship: This scholarship has been established from funds given to the Institute by Mrs. Frances W. Noble.

La Verne Noyes Scholarship: Under the will of the late La Verne Noyes, of Chicago, funds are provided for paying the tuition, in part or in full, for deserving students needing this assistance to enable them to procure a university or college training. This is to be done without regard to differences of race, religion, or political party, but only for those who shall be citizens of the United States of America and either: first, shall themselves have served in the army or navy of the United States of America in the war into which our country entered on the 6th of April, 1917, and were honorably discharged from such service, or second, shall be descended by blood from some one who has served in the army or navy of the United States in said war, and who either is still in said service or whose said service in the army or navy was terminated by death or an honorable discharge. The recipients are designated La Verne Noyes Scholars.

Procter and Gamble Company Scholarship: The Procter and Gamble Company has provided for a four-year undergraduate scholarship in the amount of $850 a year. This four-year award is open to entering freshmen only.

Radio Corporation of America Scholarship: The Radio Corporation of America has provided funds for an undergraduate scholarship for 1955-56 in the amount of $800. Freshmen are not eligible for this award.

Regional Prize Scholarships: A Regional Prize Scholarship is awarded to one entering freshman student each year in each of six regions in the United States. The scholarship carries a stipend of $1000 for the freshman year. Regional Scholarships are an academic honor and are awarded, without regard

to financial need, on the basis of high scholastic grades, high scores on the College Board Examinations required for admission, the recommendations of teachers and principals or headmasters, and on the result of a personal interview with a member of the Admissions Committee (see page 134). To be eligible to compete for these scholarships an applicant must be nominated by the principal or headmaster of his school and must be attending school in one of the following regions: Region I: Montana, Oregon, Idaho, Washington; Region II: Arizona, Colorado, Nevada, New Mexico, City of El Paso, Utah; Region III: Iowa, Minnesota, Missouri, Nebraska, Illinois, Wisconsin; Region IV: Indiana, Michigan, Ohio; Region V: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Region VI: New York, New Jersey, Pennsylvania, Delaware, Maryland. Nomination forms will be sent on request to principals or headmasters of schools in these regions.

Shepherd Tractor and Equipment Company Scholarship: The Shepherd Tractor and Equipment Company of Los Angeles has made possible a four-year, full tuition scholarship to be awarded to a freshman student entering in the fall of 1956.

Alfred P. Sloan National Scholarships: The Alfred P. Sloan Foundation of New York has established at the California Institute a minimum of four scholarships to be awarded to entering freshmen without restriction as to the field of study to be pursued. Original selection of the holders of these scholarships is made without regard to financial need. Once selection has been made awards will range from a prize scholarship of $200 per year for students not in need of financial assistance to amounts as high as $2000 per year to those whose need warrants such consideration. Holders of these scholarships may expect them to be renewed in each of the three upperclass years provided the holder's grades and conduct remain satisfactory.

Socony Vacuum Oil Company-General Petroleum Corporation has established a scholarship of $750 for a junior or senior student in engineering and another of the same amount for a junior or senior student in geology for the 1955-56 academic year.

The Square D Company of Los Angeles has established a full tuition scholarship to be awarded to a student entering the junior year who is majoring in engineering.

Fox Stanton Scholarship: An alumnus of the California Institute has established a scholarship in memory of Fox Stanton, who for many years was Director of Athletics at the California Institute. This award of $600, covering full tuition for the freshman year only, is made to an entering freshman who, in addition to being otherwise eligible for scholarship consideration, has demonstrated an interest in extra-curricular activities. This scholarship is not available in 1955-56.

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

Union Carbide Scholarships: The Union Carbide and Carbon Corporation has established at the California Institute four scholarships covering full tuition and certain other expenses amounting to a total of $850 a year. Recipients of these scholarships may expect the award to continue through the three

upperclass years provided the recipient's grades and conduct continue to be satisfactory.

West Coast Electronic Manufacturers Association Scholarship: West Coast Electronic Manufacturers Association of Los Angeles has provided for one or more scholarships for junior or senior students in the Electrical Engineering Option. The purpose of these scholarships is to promote interest in the electronics field.

Claudia Wheat Scholarship: Mr. A. C. Wheat has established a full tuition scholarship in memory of his wife. The award goes to an entering freshman, and preference is given to a graduate of Alhambra High School in Alhambra, California.

Brayton Wilbur-Thomas G. Franck Scholarship: Mr. Brayton Wilbur and Mr. Thomas G. Franck of Los Angeles, have established the Brayton Wilbur-Thomas G. Franck Scholarship Fund, the income to be used for a scholarship for a deserving student at the Institute.

The following organizations donated scholarships which were awarded in the 1954-55 academic year: the Automotive Council of Los Angeles, the Electric Club of Los Angeles.

In addition to the foregoing named scholarships, there is a Scholarship Endowment Fund made up of gifts of various donors.

STUDENT AID

LOAN FUNDS

Thanks to the generous gifts of numerous donors, the Institute is enabled to make loans to many students who, without assistance, could not complete their education. The Committee on Student Aid administers the loan funds according to the specific wishes of the donors, which vary widely; but in general preference is given to unmarried upperclassmen and to graduate students in high standing who earn part of their expenses through their own efforts. The names of the loan funds are as follows:

The Gustavus A. Axelson Loan Fund

The Olive Cleveland Fund

The Hosea Lewis Dudey Loan Fund

The Dudley Foundation Loan Fund

The Roy W. Gray Fund

The Raphael Herman Loan Fund

The Vaino A. Hoover Student Aid Fund

The Howard R. Hughes Student Loan Fund

The Thomas Jackson Memorial Fund

The Ruth Wydman Jarmie Loan Fund

The David Joseph Macpherson Fund

The John McMorris Memorial Loan Fund

The Noble Loan and Scholarship Fund

The Pasadena Optimists Club Fund

The James R. Page Loan Fund

The Scholarship and Loan Fund

The Albert H. Stone Educational Fund

STUDENT EMPLOYMENT

The Institute tries to help students to find suitable employment when they cannot continue their education without thus supplementing their incomes. The requirements of the courses at the Institute are so exacting, however, that under ordinary circumstances students who are entirely or largely self-supporting should not expect to complete a regular course satisfactorily in the usual time. It is highly inadvisable for freshman students to attempt to earn their expenses. Students wishing employment are advised to write, before coming to the Institute, to the Director of Placements.

PLACEMENT SERVICE

The Institute maintains a Placement Office under the direction of a member of the Faculty. With the services of a full-time staff, this office assists graduates and undergraduates to find employment.

During the second and third terms, schedules are arranged for students to be interviewed by representatives of organizations who visit the campus. Students both graduate and undergraduate, wanting part-time employment during the school year or during vacations, should register at the Placement Office. Assistance will be given whenever possible in securing employment for summer vacations. Alumni who are unemployed or desire improvement in their positions should register at the Placement Office.

A large number of brochures published by industrial organizations and Government agencies are available. These show placement opportunities in the fields of science and engineering. The Director of Placement is always available for consultation and guidance on placement problems.

It should be understood that the Institute assumes no responsibility in obtaining employment for its graduates, although the Placement Office will make every effort to find employment for those who wish to make use of this service.

PRIZES

THE 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 MC KINNEY PRIZE IN ENGLISH

The Mary A. Earl McKinney Prize in English was established in 1946 by the late Samuel P. McKinney, M.D., of Los Angeles, a graduate in Civil Engineering of Rensselaer Polytechnic Institute, class of 1884, as a memorial to his mother. It is provided for by the annual income from $3,500.

The contest for this prize is designed to cultivate proficiency in English. Eligibility is limited to the junior and senior classes. Any contestant in his junior year who has not won a prize may again be a contestant in his senior year. Each year the Faculty in English announces the subject for an essay which shall be based on certain prescribed books. The several students submitting the best essays engage in a final discussion before a group of judges, who award a first and a second prize, each consisting of a sum of money and a trophy in the form of a valuable book. Each of the other final contestants also receives such a trophy. The awards are announced at Commencement.

THE DON SHEPARD AWARD

Relatives and friends of Don Shepard, class of 1950, have provided an award in his memory. This award is presented to a student, the basic costs of whose education have already been met but who would find it difficult, without additional help, to engage in extracurricular activities and in the cultural opportunities afforded by the community. The recipient is selected on the basis of his capacity to take advantage of and to profit from these opportunities rather than on the basis of his scholastic standing. Not open to entering freshmen.

INFORMATION AND REGULATIONS FOR THE GUIDANCE OF GRADUATE STUDENTS

A. GENERAL REGULATIONS

I. REQUIREMENTS FOR ADMISSION TO GRADUATE STANDING

1. The Institute offers graduate work leading to the following degrees: Master of Science after a minimum of one year of graduate work; the degrees of Aeronautical Engineer, Chemical Engineer, Civil Engineer, Electrical Engineer, Geological Engineer, Geophysical Engineer, and Mechanical Engineer, after a minimum of two years of graduate work; and the degree of Doctor of Philosophy.

2. To be admitted to graduate standing an applicant must in general have received a bachelor's degree representing the completion of an undergraduate course in science or engineering substantially equivalent to one of the options offered by the Institute. He must, moreover, have attained such a scholastic record and, if from another institution, must present such recommendations as to indicate that he is fitted to pursue with distinction advanced study and research. In some cases examinations may be required.

3. Application for admission to graduate standing should be made to the Dean of Graduate Studies, on a form obtained from his office. Admission to graduate standing will be granted *only to a limited number of students of superior ability*, and application should be made as early as possible. Women students are admitted only in exceptional cases. In general, admission to graduate standing is effective for enrollment only at the beginning of the next academic year. If the applicant's preliminary training has not been substantially that given by the four-year undergraduate options at the Institute, he may be admitted subject to satisfactory completion of such undergraduate subjects as may be assigned. Admission sometimes may have to be refused solely on the basis of limited facilities in the department concerned. Students applying for assistantships or fellowships (see page 185) need not make separate application for admission to graduate standing. For requirements in regard to physical examination, see pages 134 and 146.

4. Admission to graduate standing does not of itself admit to candidacy for a degree. Application for admission to candidacy for the degree desired must be made as provided in the regulations governing work for the degree.

5. Foreign students who are admitted to graduate standing may be required to confine their work during their first term of residence to undergraduate courses when this is necessary in order to familiarize them with American teaching methods and vernacular English.

II. GRADUATE RESIDENCE

One term of residence shall consist of one term's work of not fewer than 45 units of advanced work in which a passing grade is recorded. If fewer than 45 units are successfully carried, the residence will be regarded as shortened in the same ratio; but the completion of a larger number of units in any one term

will not be regarded as increasing the residence. See pages 165, 166, 171 for special requirements for residence.

Graduate students expecting to receive a degree will be required to maintain their admission status until the degree is obtained, either by continuity of registration or on the basis of approved leave of absence. In case of lapse in graduate standing, readmission must be sought before academic work may be resumed or the degree may be conferred.

Graduate students are encouraged to continue their research during the whole or a part of the summer, but in order that such work may count in fulfillment of the residence requirements, the student must file a registration card for such summer work in the office of the Registrar between May 15 and June 15. Students who are registered for summer research will not in general be required to pay tuition for the research units.

A graduate student who undertakes activities related to the Institute (studies, research, and assisting or other employment) aggregating more than 62 hours per week must receive prior approval therefor from the Dean of Graduate Studies. Petition forms for this purpose may be obtained from the Registrar, and must carry the recommendation of the student's major department before submission to the Graduate Office.

A graduate student will be considered to be ineligible for registration at the beginning of his second term at the Institute unless his photograph for the Registrar's record card is affixed thereto, or a certification from the photographer is obtained to show that such photograph is in course of preparation on the date of registration. The Registrar provides the opportunity to have these photographs made, without cost to the student, on the registration days of the first and second terms of each year. Photographs taken for this purpose at other times are provided by the student at his own expense.

III. TUITION FEES

The tuition charge for all students registering for graduate work is $750 per academic year, payable in three installments at the beginning of each term. Graduate students who cannot devote full time to their studies are allowed to register only under special circumstances. Except by specific action of the Committee on Graduate Study, graduate students will be required to register for at least 36 units during each of their first three terms of attendance at the Institute. A graduate student who is registered for 36 or more units is classed as a full-time graduate student. Students desiring permission to register for fewer than 33 units should petition therefore on a blank obtained from the Registrar. If such reduced registration is permitted, the tuition is at the rate of $187.50 a term for 32 to 25 units, and at the rate of $7.50 a unit for fewer than 25 units, with a minimum of $75 a term. If the courses registered for do not correspond to the full educational facilities made available to the student, additional tuition will be charged.

The payment of tuition by graduate students is required (a) without reference to the character of the work of the student, which may consist in the prosecution of research, in independent reading, or in the writing of a thesis or other dissertation, as well as in attendance at regular classes; (b) without reference to the number of terms in which the student has already been in

residence; and (c) without reference to the status of the student as an appointee of the Institute, except that members of the academic staff of rank of Instructor or higher are not required to pay tuition. (See page 170, paragraph 6.)

There is a fee of $18.00 per academic year to assist in defraying expenses for medical care and emergency hospitalization. (See page 147.) Each graduate student is required to make a general deposit of $25 to cover any loss of, or damage to Institute property used in connection with his work in regular courses of study. Upon completion of his graduate work, or upon withdrawal from the Institute, any remaining balance of the deposit will be refunded.

No degrees are awarded until all bills due the Institute have been paid.

In regard to *fellowships and assistantships,* see page 185 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 208-218) as well as in the schedule of the four-year course in science or in engineering, except that, in the case of students transferring from other institutions, equivalents will be accepted in subjects in which the student shows by examination or otherwise that he is proficient, and except in so far as substitutions may be approved by special vote of the committee in charge.

Senior students at the Institute desiring to return for a fifth year should consult with the faculty in the field in which they expect to do their major work, and apply for admission to work towards the master's degree on a form obtained from the Dean of Graduate Studies. Such students will be expected to present satisfactory scholarship qualifications, and to have demonstrated a capacity for doing advanced work.

All programs of study, and applications for admission to candidacy for the degree of Master of Science shall be in charge of the Committee on the Course in Science (in case the advanced work is to be astronomy, biology, chemistry, chemical engineering, geology, geophysics, mathematics, or physics), or of the Committee on the Course in Engineering (in case the work is to be in civil, mechanical or electrical engineering, 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 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, and make application to the committee in charge for acceptance as a

candidate for that degree. Application forms for admission to candidacy for these degrees may be obtained from the Registrar, and must be submitted not later than the sixth week of the academic year in which the degree is to be granted.

II. REGISTRATION

1. The regulations governing registration and student responsibilities as given for undergraduate students on pages 141-143 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 142) also apply to students working toward the master's degree. In meeting the graduation requirements as stated on page 143, 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 pages 141-143.

4. Students admitted to work toward the degree of Master of Science who have completed their undergraduate work at other institutions are subject to the scholastic regulations applying to new transfer students as listed on pages 141-143.

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 concerning basic sciences and field geology. Detailed information of these requirements may be obtained from the Division Secretary. A written placement examination is required of incoming graduate students in the Division of Geological Sciences Thursday and Friday of the week preceding registration for the first term of their graduate work. For further details concerning the examination, see page 180.

6. Candidates for the master's degree in the Division of Chemistry and Chemical Engineering are required to take placement examinations. See pages 210-211.

7. Candidates for the master's degree in the Division of Physics, Mathematics, and Astronomy are required to take placement examinations to be used as a guide in selecting the proper course of study. (See page 182, section 1a.)

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 Mathematics, a complete first draft of a thesis presented in partial fulfillment 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 171. Regulations governing registration will be found on page 170.

2. *Residence.* At least six terms of graduate residence (as defined on pages 162-163) subsequent to a baccalaureate degree equivalent to that given by the California Institute are required for an engineer's degree. Of these, at least the last three terms must be at the California Institute. It must be understood that these are minimum requirements, and students must often count on spending a somewhat longer time in graduate work.

To qualify for an engineer's degree a student must complete the work prescribed by his supervising committee with a grade point average of at least 1.90, considering the grade of P as being equivalent to C and excluding grades

for research. Work upon research and the preparation of a thesis must constitute no fewer than 55 units. More than 55 units may be required by certain departments and the student should determine the particular requirements of his department when establishing his program.

In the case of a student registered for work toward an engineer's degree, and holding a position as graduate assistant or other Institute employee, the actual number of hours per week required by his teaching or research services shall be deducted from the total number of units for which he might otherwise register. This number of units shall be determined by his department.

3. *Admission to Candidacy.* Before the end of the second week of the first term of the academic year in which the student expects to receive the degree he must file in the office of the Dean of Graduate Studies an application for admission to candidacy for the degree desired. Upon receipt of this application, the Dean, in consultation with the chairman of the appropriate division, will appoint a committee of three members of the faculty to supervise the student's work and to certify to its satisfactory completion. One of the members of the committee must be in a field outside of the student's major field of study. The student should then consult with this committee in planning the details of this work. The schedule of his work as approved by the committee shall be entered on the application form and shall then constitute a requirement for the degree. Changes in the schedule will not be recognized unless initialed by the proper authority. No course which appears on the approved schedule and for which the applicant is registered may be removed after the last date for dropping courses as listed in the 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 172.)

The use of "classified" research as thesis material for any degree will not be permitted. Exceptions to this rule can be made only under special circumstances, and then only when approval is given by the Dean of Graduate Studies before the research is undertaken.

Before submitting his thesis, the candidate must obtain written approval of it by the chairman of the division and the members of his supervising committee, on a form obtained from the office of the Dean of Graduate Studies.

5. *Examination.* At the option of the department representing the field in which the degree is desired a final examination may be required. This examination would be conducted by a board to be appointed by the candidate's supervising committee.

Special Requirements for the Degree of Chemical Engineer

Students admitted to work for the degree of Chemical Engineer are required to take placement examinations. See pages 175, 211.

Special Requirements for the Degree of Electrical Engineer

To be recommended for the degree of Electrical Engineer the applicant must pass the same subject requirements as listed for the doctor's degree on page 177. (A grade of C or better is required for all but Ph 131.)

Special Requirements for the Degree of Geological or Geophysical Engineer

Students admitted to work for the degree of Geological or Geophysical Engineer must take placement examinations on Thursday and Friday of the week preceding their first term of graduate residence (see page 180). Prior to admission to candidacy for the degree of Geological or Geophysical Engineer the student should have completed all requirements for the degree of Master of Science in his respective field.

Special Requirements for the Degree of Mechanical Engineer

Each student admitted to work for the degree of Mechanical Engineer shall be required to take an oral placement examination given by the faculty in mechanical engineering before his registration. The results will be used as a guide in planning the student's work.

Not less than a total of 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 ab	Engineering Laboratory
Ma 112	Elementary Statistics
and one of the following:	
AM 125 abc	Engineering Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ph 107 abc	Electricity and Magnetism
Ma 108 abc	Advanced Calculus
Ma 114 abc	Mathematical Analysis

A list of possible courses from which a program of study may be organized will be found on page 216.

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.

As soon as feasible after admission to graduate standing to the Ph.D. degree, a supervising committee shall be appointed for each graduate student by the Dean of Graduate Studies upon the recommendation of the major Division. This committee shall consist of three members, of whom one shall be a representative of the major field, and one a representative of the minor field. The committee shall be responsible for guiding the graduate student during his study and research for the Ph.D. degree and offering him counsel as needed.

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 or engineer's degree first. These degrees, however, are not general prerequisites for the doctor's degree. Students who have received the master's degree and wish to pursue further studies leading toward either the engineer's or the doctor's degree must file a new application to continue graduate work toward the desired degree. Students who have received an engineer's degree will not in general be admitted for the doctor's degree.

During the second or third term of work toward the engineer's degree, a student may apply for admission to work toward the doctor's degree. If this admission is granted, his admission for the engineer's degree will be cancelled.

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

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 his supervising committee, or with members of the department in which he is taking his major work if his committee has not yet been appointed, to determine the studies which he can pursue to the best advantage.

3. A student will not receive credit for a course unless he is properly registered. At the first meeting of each class he should furnish the instructor with a regular assignment card for the course, obtained on registration. *The student himself is charged with the responsibility of making certain that all grades to which he is entitled have been recorded.*

4. The number of units allowed for a course of study or for research is so chosen that one unit corresponds roughly to one hour a week of work throughout the term, for a student of superior ability.

5. In registering for research, students should indicate on their program card the name of the instructor in charge, and should consult with him to determine the number of units to which the proposed work corresponds. At the end of the term the instructor in charge shall decrease the number of units for which credit is given, in case he feels that the progress of the research does not justify the full number originally registered for.

6. Registration, with at least minimum tuition (see page 165), is required for the term or summer period in which the requirements for the Ph.D. degree are completed, including either the final examination or submission of thesis.

7. Graduate students studying for the doctor's degree who are devoting their whole time to their studies will be allowed to register for not more than 60 units in any one term. (See pages 165, 167 with reference to total work load of graduate students.)

IV. GRADES IN GRADUATE COURSES

1. Term examinations are held in all graduate courses unless the instructor, after consultation with the chairman of the division, shall arrange otherwise. No student taking a course for credit shall be exempt from these examinations when held.

2. Grades for all graduate work are reported to the Registrar's office at the close of each term.

3. The following system of grades is used to indicate class standing in graduate courses: "A" excellent, "B" good, "C" satisfactory, "D" poor, "E" conditioned, "F" failed, "Inc" incomplete. In addition to these grades, which are to be interpreted as having the same significance as for undergraduate courses, (see page 141) the grade "P," which denotes passed, may be used at the discretion of the instructor, in the case of seminar or other work which does not lend itself to more specific grading. In graduate research, only the grades "P" and "F" are given.

V. GENERAL REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

1. *Major and Minor 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, or in a branch of the humanities.

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 advanced subjects. An approval form for the minor subject may be obtained from the Graduate Office.

Advanced studies include courses with numbers of 100 or over. However, only in approved cases is graduate residence credit given for such courses when they are required in the undergraduate option corresponding to the student's major field. No residence credit is given for courses with numbers under 100 when they constitute prerequisites to the student's minor subject courses. Credit in amount to be determined by the Committee on Graduate Study may be allowed for other courses with numbers under 100 when they are outside the student's major field.

2. *Residence:* At least three academic years of residence subsequent to a baccalaureate degree equivalent to that given by the Institute are required for the doctor's degree. Of this at least one year must be in residence at the Institute. It should be understood that these are minimum requirements, and students must usually count on spending a somewhat longer time in residence. However, no student will be allowed to continue work toward the doctor's degree for more than 15 terms of graduate residence, or more than 18 registrations for full- or part-time academic work, except by special action of the Committee on Graduate Study. In either case graduate study taken elsewhere will be counted when residence credit at the Institute has been allowed. (See page 163 regarding summer registration fo rresearch.)

A graduate student who, by special arrangement made in advance, is permitted to conduct a portion of his research in the field, in government laboratories, or elsewhere off the campus, must file in advance a registration card for this work in the office of the Registrar, in order that it may count in fulfillment of residence requirements. This work must be carried out under the direct supervision of a member of the Institute staff. The number of units to be credited for such work shall be determined by the Dean of Graduate Studies in consultation with the Chairman of the Division in which the student is carrying his major work; and a recommendation as to the proportion of the full tuition to be paid for such work shall be made by the Dean to the 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 thereafter one term or more of residence at the Institute, 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 169), 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 Institute staff of rank higher than that of Assistant Professor are not admitted to candidacy for a higher degree. For special departmental regulations concerning admissions 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 which the degree is to be conferred, and must be followed by two terms of further residence (45 units per term; see pages 162-164) 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 written examinations, graduate students may fulfill the language requirements by receiving above average grades in the following language courses: L 1 ab in French, L 35 in German, or L 50 abc in Russian. With the approval of the department of languages, the requirements in French, German, or Russian may also be satisfied by the completion of a translation project. A knowledge of the fundamentals of the language is presupposed in such cases.

Graduate students are permitted to audit all courses in languages. No graduate credit is given for these courses. As soon as possible after beginning their graduate study, students are urged to consult with the department of languages to determine the best means of satisfying the language requirements. It is advisable that these requirements be fulfilled as long as possible before the student expects to file application for candidacy.

(b) During his course of study, every doctor's candidate shall be examined broadly and orally on his major field, his minor field or fields, the scope of his thesis, and its significance in relation to his major field. These examinations, subject to the approval of the Committee on Graduate Study, may be taken at such time after admission to candidacy as the candidate is prepared, except that they must take place at least two weeks before the degree is to be conferred.

The examinations may be written in part, and may be subdivided into parts or given all at one time at the discretion of the departments concerned. The student must petition for these examinations on a form obtained from the Dean of Graduate Studies. For special departmental regulations concerning candidacy and final examinations, see Section VI, page 173.

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 satisfac-

tory 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 167.

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 astronomy, 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 171), the various Divisions of the Institute have adopted the following supplementary regulations.

DIVISION OF BIOLOGY

1. *Admission.* Applicants are expected to have studied mathematics, physics, chemistry and biology to approximately the same extent as covered in the undergraduate option in biology at the California Institute of Technology (see Schedules of Undergraduate Courses). Students with deficient preparation in one or more of these basic sciences may be admitted and required to remedy their deficiencies during the first years of graduate training. No graduate credit will be granted for such remedial study. Applicants intending to specialize in fields bordering between biology and chemistry or between biology and physics may be admitted on the basis of a curriculum equivalent to that offered respectively in the chemistry or physics undergraduate options at the Institute. Applicants are urged to take the Graduate Record Examinations (Aptitude Test and Advanced Tests in Biology, Chemistry, Mathematics or Physics) and have their test scores submitted to the Institute. In exceptional cases, graduate work is offered to women.

2. *Student Conferences.* During the week preceding registration for the first term, each entering student confers with his *Advisory Committee.* The committee consists of the instructor likely to be in charge of his major subject work and three others representing diverse fields of biology. The committee will advise the student of deficiencies in his training and will be available for consultation and advice throughout his graduate study.

3. *Teaching Requirement for Graduate Fellows.* A graduate student who holds a fellowship to do graduate work in the Division of Biology will be assigned to assist in teaching undergraduate courses if his advisory committee considers it to be of value for him to gain teaching experience. The amount of teaching may vary, but it will not be more than 12 units for one term per year.

4. *Major Subjects of Specialization.* The fields within the Division of Biology in which a student may pursue major work leading to the doctor's degree consist at present of:—

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

5. *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 4, or he may select a minor in general biology, which will consist of at least 45 units of approved course work.

6. *Admission to Candidacy.* To be recommended by the Division of Biology for admission to candidacy for the doctor's degree, the student must have demonstrated his ability to carry out original research and have passed the appropriate candidacy examinations, *viz*:—

a. A student taking both major and minor studies in the Division of Biology is required to take four candidacy examinations, including one in the field of the major and one in the field of the minor; the two others may be general botany and general zoology, or one of these plus one of the subjects listed above in section 4.

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.

7. *Final Examination and Thesis.* A final oral examination covering principally the work of the thesis will be held at least two weeks before the degree is to be conferred. 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.

DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

1a. *Chemistry.* On the Monday and Tuesday preceding General Registration for the first term of graduate study, graduate students admitted to work for the Ph.D. degree will be required to take written placement examinations in the fields of inorganic chemistry, physical chemistry, and organic chemistry. These examinations will cover their respective subjects to the extent that these subjects are treated in the undergraduate chemistry option offered at this Institute and in general will be designed to test whether the student possesses an understanding of general principles and a power to apply these to concrete problems, rather than a detailed informational knowledge. It is expected of graduate students that they demonstrate a proficiency in the above subjects not less than that acquired by abler undergraduates. Students who have demonstrated this proficiency in earlier residence at this Institute may be excused from these examinations.

In the event that a student fails to show satisfactory performance in any of the placement examinations he will be required to register for a prescribed course, or courses, in order to correct the deficiency at an early date. In general no graduate credit will be allowed for prescribed undergraduate courses. If the student's performance in the required course or courses is not satisfactory he will not be allowed to continue his graduate studies except by special action of the Division of Chemistry and Chemical Engineering on receipt of his petition to be allowed to continue.

To be recommended for candidacy for the doctor's degree in chemistry the applicant, in addition to demonstrating his understanding and knowledge of the fundamentals of chemistry, must give satisfactory evidence of his proficiency, at a higher level, in that field of chemistry elected as his primary field of interest and approved by the Division of Chemistry and Chemical Engineering. In general the applicant will be required to pass an oral examination and to submit to his examining committee one week prior to his examination (1) a written progress report giving evidence of his industry and ability in research and of his power to present his results in clear, concise language and with discrimination as to what is essential in scientific reports, and (2) three propositions (as described in the following page) which the applicant is prepared to defend during his oral examination.

A student admitted to work for the Ph.D. degree in chemistry who fails to satisfy the Division's requirements for candidacy by the end of his fifth term of graduate residence at the Institute will not be allowed to register in a subsequent academic year except by special permission of the Division of Chemistry and Chemical Engineering.

1b. *Chemical Engineering.* The requirements in chemical engineering are

essentially the same as those in chemistry except that the placement examinations will be required in the fields of engineering thermodynamics of one-component systems (on the Wednesday before registration), the unit operations of chemical engineering (on Thursday), and either physical chemistry (on Monday) or industrial chemistry (on Friday). Those students who propose to register for Ch 166 abc need not take the examination in unit operations. Students who have in earlier residence at this Institute demonstrated proficiency in the subjects covered by the placement examinations may be excused from them.

The Division's requirements for candidacy in chemical engineering are in general to be completed by the end of the student's second term subsequent to receiving the master's degree or completing the requirements imposed on the basis of the placement examinations. The candidacy examination covers thermodynamics, chemical engineering unit operations, physical chemistry, and industrial chemistry.

2. It is expected that the applicant shall have studied mathematics and physics substantially to the extent that these subjects are covered in the first two years of the Institute undergraduate courses. In 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 Chairman of the Division of Chemistry and Chemical Engineering three copies of his thesis, in final form, at least two weeks before the date of his final examination. Two 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.

Three copies of the set of propositions in final form must be submitted to the Chairman of 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.

DIVISION OF ENGINEERING

1. *Civil Engineering.* To be recommended for candidacy for the doctor's degree in civil engineering the applicant must pass with a grade of C or better the subjects prescribed and selected for the fifth year, or equivalent substitution satisfactory to the department, and such other advanced subjects related to the contemplated direction of study as the department may require, and must pass special comprehensive oral or written examinations in the field covered by these subjects.

2. *Electrical Engineering.* To be recommended for candidacy the applicant must pass the following subjects with a grade of C or better:

Ph 131 abc	Electricity and Magnetism
EE 132 abc	Circuit Analysis

and either:

EE 170 abc	Instrumentation and Control Systems
or	
EE 120 abc	Advanced Power System Analysis

and one of the following subjects:

Ph 102 abc	Introduction to Mathematical Physics and Differential Equations
AM 115 ab, AM 116	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 one of the following:

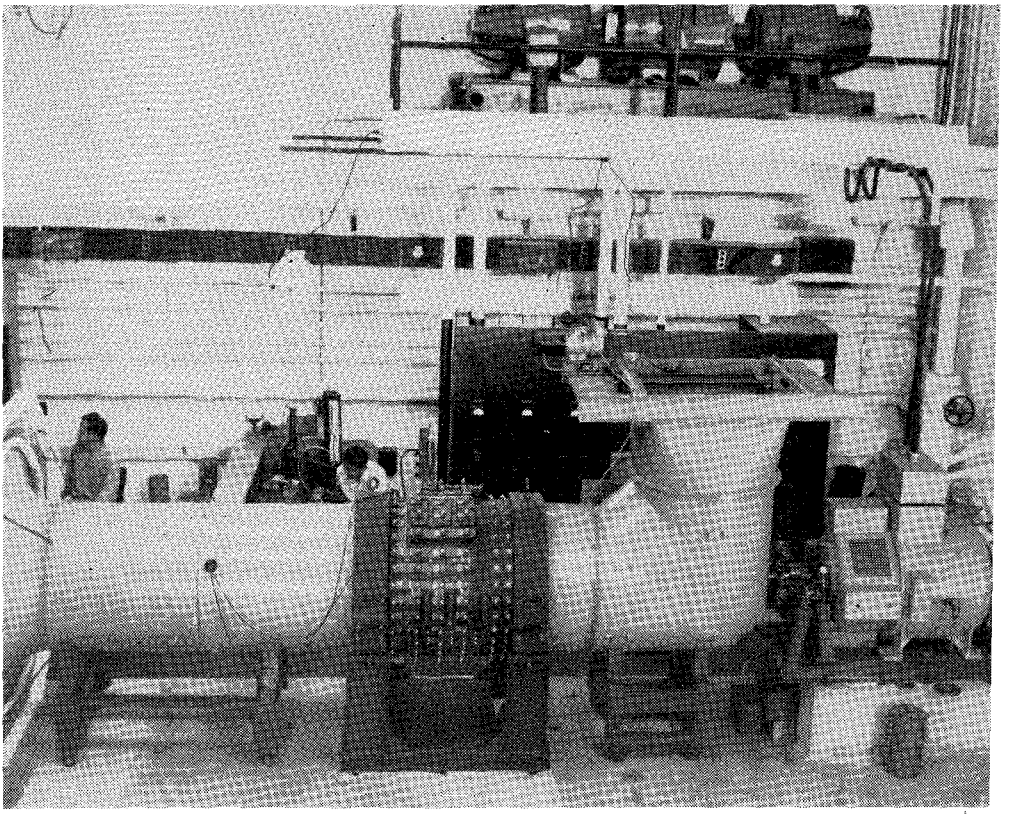
AM 126 abc	Applied Engineering Mathematics
Ph 129 abc	Methods of Mathematical Physics
Ma 114 abc	Mathematical Analysis

An applicant may also satisfy any of the course requirements described above by taking an examination in the subject with the instructor in charge. Every examination of this type will cover the whole of the course specified and the student will not be permitted to take it either in parts (e.g. term by term) or more than twice.

Students working toward the doctorate are required to take two oral examinations. One of these must be taken prior to admission to candidacy and covers broadly his major field and his minor field. The second, which is taken after admission, covers his doctorate thesis and its significance in and its relation to his major field.

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

3. *Mechanical Engineering.* Before being admitted to work for a doctor's degree in Mechanical Engineering, a graduate student will be admitted to



work toward the degree of Mechanical Engineer. After completion of at least 12 units of research in his chosen field, the student may apply for permission to work toward the doctorate. The required 12 units of research can usually be completed by the end of the first term of the sixth year. Permission to work toward the doctorate will be granted if the student's course work and research show that he is capable of carrying on work at the doctoral level. Notification of the action taken will be given to the applicant not later than the end of the second term. Upon being admitted to work toward the doctor's degree, the student's admission to work for the engineer's degree will be cancelled.

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

ME 125 ab	Engineering Laboratory
Ma 112	Elementary Statistics

and one of the following:

AM 125 abc	Engineering Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ma 108 abc	Advanced Calculus
Ma 114 abc	Mathematical Analysis
Ph 107 abc	Electricity and Magnetism

and, in addition, not fewer than 50 units of advanced courses arranged by the student in conference with his supervising committee and approved by the department. If any course submitted for candidacy was taken elsewhere than at the Institute, the candidate may be required to pass special examinations indicating an equivalent knowledge of the subject.

Candidates are required to take two oral examinations after admission to candidacy. The first, termed the general examination, must be taken not later than six weeks after admission to candidacy and shall cover the major and minor subjects. The second, or thesis examination, shall be a defense of the doctoral thesis and a test of the candidate's knowledge in his specialized field of research.

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 may then be admitted to work towards the doctor's degree. Whenever possible, notification of such admission will be given to the candidate by the middle of the second term. Upon being admitted to work towards the doctor's degree, his admission to work for the engineer's degree will be cancelled.

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

	AM 125 abc	Engineering Mathematical Principles
or		
	AM 126 abc	Applied Engineering Mathematics
or		
	Ma 114 abc	Mathematical Analysis
or		
	Ph 106 abc	Introduction to Mathematical Physics

and two of the following subjects:

Ae 107 abc	Elasticity Applied to Aeronautics	
Ae 201 abc	Hydrodynamics of Compressible Fluids	
Ae 204 abc	Theoretical Aerodynamics of Real and Perfect Fluids	
(JP 121 abc	Rocket	considered as one subject
(JP 130 abc	Thermal Jets	considered as one subject

If any of the above subjects was taken elsewhere than at the Institute, the candidate may be required to pass special examinations indicating an equivalent knowledge of the subject.

5. *Engineering Science.* The degree of Ph.D. is generally offered in Civil Engineering, Electrical Engineering, Mechanical Engineering and Aeronautics. The special requirements in these fields are described in the preceding sections. However, the Ph.D. degree in Engineering Science is also offered if specialization of the candidate does not lie primarily in any one of these fields. For instance, the degree of Ph.D. in Engineering Science may be conferred on candidates completing specified requirements in engineering and science fields, examples of which are applied mechanics, fluid mechanics, physical metallurgy. application of modern physics and chemistry to engineering, and guidance and control of engineering system. The requirements and the program of study leading to the Ph.D. in Engineering Science must be arranged and approved by the Division Doctorate Committee in Engineering Science. The

requirements for this degree will be similar to those described in the preceding sections, although not necessarily coinciding with those of any one option.

DIVISION OF GEOLOGICAL SCIENCES

The following statement summarizes the regulations governing the doctorate program. A circular which provides more detail on these matters is available upon request at the Division Office.

1. *Placement Examinations:* On Thursday and Friday of week preceding registration for his first term of graduate work, the student will be required to take written placement examinations covering basic aspects of the earth sciences and including elementary physics, mathematics, chemistry and biology. These examinations will be used to determine the student's understanding of basic scientific principles and his ability to apply these principles to specific problems. It is not intended that he possess detailed informational knowledge, but it is expected that he demonstrate a degree of proficiency not less than that attained by abler undergraduate students at the California Institute. A student who has demonstrated proficiency in earlier residence at the Institute may be excused from these examinations.

The student's past record and his performance in the placement examinations will be used to determine whether he should register for certain undergraduate courses. Any deficiencies must be corrected at the earliest possible date.

2. *Recommended Courses:* It is recommended, although not required, that the incoming graduate student take the following courses as early as possible in his program:

Ge 150	The Origin, Evolution, and Nature of the Earth.
Ge 151	Laboratory Techniques in the Earth Sciences.

These courses are designed to help orient the student and to acquaint him with pertinent problems, processes, and principles; with the kinds of tools employed in earth science studies, their limitations and potentialities; and with the interests and attitudes of mind of the staff.

3. *Field Requirement:* Many problems in the earth sciences require for their solution an understanding of field techniques and field relations. A student attempting to deal with these problems who lacks adequate or sufficiently varied field experience will be required to remove this deficiency by field work in prescribed courses, or in other ways approved by the Division.

4. *Major and Minor Fields:* The work for the doctorate in the Division of the Geological Sciences shall consist of advanced studies and of research in some branch of the geological sciences which will be termed the "major subject" of the candidate, and additional advanced studies in at least one other branch of science or engineering, which will be termed the "minor subject." The Division will accept as major subjects any of those subjects listed under the following fields, providing the number of students working under the staff member in that field does not exceed the limit of efficient supervision:

Geochemistry	Geophysics — General
Geomorphology	Glaciology
Geophysics — Applied	Invertebrate Paleontology

Mineralogy
Ore Deposits
Paleoecology
Petrology
Seismology
Sedimentation
Stratigraphy
Structural Geology

5. *Minor Requirement:* The purpose of the minor requirement is to give diversification of training and a broadening of outlook. It should involve basic approaches, techniques, and knowledge distinct from those of the major subject. The minor requirement can be satisfied by:

a. 45 units of advanced study in some other engineering or science division of the Institute. This is the method ordinarily preferred by the Division of the Geological Sciences, or

b. 45 units of advanced study in one of the fields listed below in the Division of Geological Sciences, other than the field of the major subject. Exceptions to this will be permitted only if the fields of concentration of the major and minor are, in the opinion of both the student's supervising committee and the staff, sufficiently distinct to satisfy completely the spirit of the minor requirement, stated above. The student is urged to take pertinent courses in other divisions of the Institute as part of the 45 units of work offered.

I. Geology

II. Geochemistry

III. Geophysics

6. *Admission to Candidacy:* An otherwise qualified student is eligible for admission to candidacy for the doctorate in the Division of the Geological Sciences as soon as he has passed his qualifying oral examination. This examination will consist of the defense of a set of propositions prepared by the candidate. The propositions should be 5 to 7 in number, and about half of them should relate to the branch of the earth sciences of major interest to the candidate. The remaining propositions should cover aspects of the science in fields other than that of the major interest, and at least one should lie in the candidate's proposed minor field. As prepared by the candidate himself, the propositions should display his originality, breadth of interest, and soundness of training. He will be judged both on his selection and formulation of the propositions and on his defense of them.

Three copies of the propositions should be filed in the office of the Division of the Geological Sciences, not later than midterm of the fifth term of graduate residence, for approval by the candidate's supervising committee (see page 169). An examining committee will then be appointed which generally, but not necessarily, will include all the members of the candidate's supervising committee, and a date will be set for the examination which is mutually agreeable to those concerned. The list of propositions, as approved by the supervising committee, must be filed by the candidate in the Division office at least two weeks in advance of the date set for the examination.

By approval of the Division of the Geological Sciences the candidate may obtain up to 15 units of graduate credit for his preparation of propositions, if these are adequately defended prior to midterm of his third term of graduate residence at the Institute.

A student admitted to work for the Ph.D. degree who fails to satisfy the Division's requirements for candidacy by the end of his fifth term of residence will not be allowed to register in a subsequent academic year except by special permission of the Division of the Geological Sciences. Successful completion of the qualifying examination is a necessary step in admission to candidacy. The remaining steps are outlined on page 171, item 3.

7. *Thesis and Paper for Publication:* The doctoral candidate must complete his thesis and submit it in final form by April 20 of the year in which the degree is to be conferred. The candidate must also prepare a paper for publication embodying the results of his thesis work in whole or in part. He should consult with the chairman of his supervising committee on the choice of subject and on the scope of the paper. This paper must either be accepted by an agency of publication or be in form such that the examining committee believes that it will be published.

8. *Final Examination:* The final oral examination for the doctorate will be scheduled following submission of the thesis and, in conformity with an Institute regulation, it must be scheduled at least two weeks before the degree is to be conferred.

DIVISION OF PHYSICS MATHEMATICS AND ASTRONOMY

1. PHYSICS

a. *Placement Examinations.* On the Thursday and Friday preceding the beginning of instruction for his first term of graduate study, a student admitted to work for an advanced degree in physics is required to take placement examinations to be used as a guide in selecting the proper course of study. These examinations will cover material treated in Introduction to Mathematical Physics; Electricity and Magnetism; Introduction to Atomic and Nuclear Physics, and Advanced Calculus approximately as covered in Ph 106, Ph 107, Ph 112; and Ma 108. In general, they will be designed to test whether the student possesses an understanding of general principles and a power to apply these to concrete problems, rather than detailed informational knowledge. In cases in which there is a clear basis for ascertaining the status of the entering graduate student, the placement examinations may be waived.

If the placement examinations reveal a need for courses prerequisite to those listed in section c, the student will be required to register for a prescribed course or courses. If he does not obtain grades of C or better in these courses he will be allowed to continue his graduate studies only by special permission of the Physics department graduate committee.

b. *Admission to Candidacy.* To be recommended for candidacy for the Ph.D. degree in physics the student must, in addition to the general Institute requirements, take at least 18 units of research, pass certain courses, either regularly or by special examination, and pass the oral candidacy examination. The courses required are those listed below in Group I, 36 units of those listed in Group II, 36 units of those listed in Group III, and 36 of the 45 units required for a minor. The requirement for 18 units of research may be waived if the student has clearly demonstrated his familiarity with research in a particular field. The oral examination will cover those subjects in physics and the minor field with which the student may be expected to have gained familiarity, either through his course work or preliminary research. A student, admitted

to work toward the Ph.D. degree, who fails to satisfy the Division's requirements for admission to candidacy by the end of his second year of graduate study at the Institute will not be allowed to register in a subsequent academic year without special permission of the Physics department graduate committee. When a student is required to take courses prerequisite to those listed in section c, this committee ordinarily will grant at that time a suitable extension of the time allowed to complete the candidacy requirements.

The student is expected to obtain a grade of C or better in each of his courses. If he obtains grades below C in the courses of Groups I and II or in the courses presented to fulfill the minor requirement, the Physics department graduate committee will scrutinize the student's entire record and, if it is unsatisfactory, will refuse permission for him to continue work for the Ph.D.

c. *Course Groups*—

		Units
	Group I	
Ph. 131 ab	Electricity and Magnetism	18
Ph 201 ab	Analytical Mechanics	18
	Group II	
Ph 129 ab	Methods of Mathematical Physics	18
Ph 205 ab	Principles of Quantum Mechanics	18
Ph 209 abc	Optics and Electron Theory	27
Ph 227 ab	Thermodynamics, Statistical Mechanics, and Kinetic Theory	18
	Group III	
Ph 203 ab	Nuclear Physics	18
Ph 207 ab	X- and Gamma-Rays	18
Ph 217	Spectroscopy	9
Ph 231 ab	Cosmic Rays and High Energy Physics	18
Ay 131 ab	Astrophysics I	18
or		
Ay 132 ab	Astrophysics II	18

d. *Further requirements for the Ph.D. degree.* In order to be recommended for the Ph.D. degree, each candidate must, in addition to the requirements for candidacy and the general Institute requirements for a Ph.D. degree, pass satisfactorily all remaining courses in Group II. In addition to these requirements, the student will normally take advanced courses, particularly in his field of specialization. In general a student will find it desirable to continue his graduate study and research for two years after admission to candidacy.

A final examination will be given not less than one month after the thesis has been presented in final form and subsequent to its approval. This examination will cover the thesis topic and its relation to the general body of knowledge of physics. This examination is not designed to cover the same material as the candidacy examination, although the candidate will be expected to answer general questions and in particular those that are related in one way or another to his field of specialization.

The candidate himself is responsible for completing his thesis early enough to allow the fulfillment of all Division and Institute requirements, having due regard for the impossibility of the scheduling by the Division of more than one final oral examination per day.

2. MATHEMATICS

a. Each new graduate student admitted to work for an advanced degree in Mathematics will be given an informal oral examination not later than the end of registration week. The purpose of this examination is to ascertain the preparation of the student and assist him in mapping out a course of study. The members of the examination committee will supervise the work of the student during the first year. This work will include independent reading and/or research.

b. To be recommended for candidacy for the degree of Doctor of Philosophy in Mathematics the applicant must satisfy the general requirements and pass an oral candidacy examination. This examination will be held at the end of the first term of the second year of graduate study. The student will choose two among the three major fields of mathematics (Algebra, Analysis, Geometry). The candidacy examination will cover (a) the fundamentals of the two chosen fields and (b) the independent work done by the candidate during his first year. At the discretion of the department this examination may be supplemented by a written examination. The department may in special cases change the date of the candidacy examination.

c. In the course of his studies the candidate for the degree of Doctor of Philosophy must pass the equivalent of a full year's course in each of the three major fields of Mathematics with a grade of C or better in each term (except that no grade requirements are made for a course taken in the last term of the last year). A candidate may satisfy any of these course requirements by passing an examination covering the full course in question.

d. On or before the first Monday in April of the year in which the degree is to be conferred, a candidate for the degree of Doctor of Philosophy must deliver a typewritten or printed copy of his completed thesis, in final form, to the chairman of his supervising committee. The department will assign to the candidate, immediately after the submission of his thesis, a topic of study outside his field of specialization. During the next four weeks the candidate is expected to assimilate the basic methods and the main results of the assigned topic with the aim of recognizing the direction of further research in this field.

e. The final oral examination in mathematics will be held as closely as possible four weeks after the date the thesis has been handed in. It will cover the thesis and fields related to it and the assigned topic of study.

f. It is the responsibility of the candidate to arrange for a final examination in his minor field of study. This examination should be held as soon as possible after admission to candidacy and completion of his courses in his minor subject. It will be given by the supervising committee of the candidate.

3. ASTRONOMY

The placement examinations, page 182, section 1 a, will be required of first-year students.

To be recommended for candidacy for the doctor's degree in astronomy, the applicant must complete satisfactorily 18 units of research, Ay 142, pass with

a grade of C or better or by special examination Ay 131 abc, Ay 132 abc, and a choice of 63 units of the following:

Ph 129 abc	Methods of Mathematical Physics
Ph 201 ab	Analytical Mechanics
Ph 203 abc	Nuclear Physics
Ph 205 ab	Principles of Quantum Mechanics
Ph 209 abc	Optics and Electron Theory
Ph 217	Spectroscopy
Ph 227 abc	Thermodynamics, Statistical Mechanics and Kinetic Theory

Special permission will be required for further registration if the candidacy course requirement is not satisfactorily completed by the end of the second year of graduate study. For admission to candidacy an oral examination will be given covering the major and minor fields of study.

A final draft of the thesis must be submitted at least six weeks before the commencement at which the degree is to be conferred. At least two weeks after submission of the thesis the student will be examined orally on the scope of his thesis and its relation to current research in astronomy.

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. Graduate assistants are eligible to be considered for scholarship grants.

Provision is made so that appointees may secure for themselves board in the Athenaeum (see page 92), 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.

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 class-

room and laboratory. The usual assistantship assignment calls for twelve hours per week and ordinarily 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 Fellowships: The income from the Cole Trust, established by the will of the late Mary V. Cole in memory of her husband, Francis J. Cole, is used to provide three fellowships annually, one in each of the following fields: electrical engineering, mechanical engineering, and physics. The recipients are designated as Cole Fellows.

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

4. Blacker Scholarships: The Robert Roe Blacker and Nellie Canfield Blacker Scholarship Endowment Fund, established by the late Mr. R. R. Blacker and Mrs. Blacker, provides in part for the support of graduate men engaged in research work. The recipients are designated as Blacker Scholars.

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

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

7. Meridan Hunt Bennett Scholarships. The scholarships for graduate students are granted from the Meridan Hunt Bennett Fund as stated on page 150.

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

*Fellows receiving grants equivalent to tuition and $600 or more per academic year are permitted to accept employment or other appointment from the Institute during the academic year only with special approval of the Dean of Graduate Studies.

Counselors, Inc., and other contributors. The fellowship is granted to a graduate student who undertakes some studies in industrial relations, as approved by the Director of the Industrial Relations Section.

12. Lucy Mason Clark Fellowship: This fellowship, in the field of plant physiology, is supported by a fund contributed by Miss Lucy Mason Clark.

13. Van Maanen Fellowship: One or more predoctoral or post doctoral fellowships are provided in the department of astronomy from the Van Maanen Fund . The recipients are known as Van Maanen Fellows.

(C). Special Fellowship and Research Funds

1. The following agencies contribute funds for the support of Graduate Fellowships which are administered by the Institute: Abbott Laboratories, AiResearch Manufacturing Company, Allied Chemical and Dye Corporation, California Research Corporation, Consolidated Engineering Corporation, Consumers Union, Corning Glass Works Foundation, Doherty Foundation, Douglas Aircraft Company, Dow Chemical Company, E. I. du Pont de Nemours and Company, Ethyl Corporation, Firestone Tire and Rubber Company, Fluor Foundation, General Electric Company, General Motors Corporation, General Petroleum Corporation-Socony-Vacuum Oil Company, D. Foster Hewett, Hoover Electric Company, Howard Hughes-Hughes Aircraft Company, International Business Machines Corporation, Kelman Electric and Manufacturing Company, Kennecott Copper Corporation, Lane-Wells Company, Paul E. Lloyd, Lockheed Leadership Fund, Arthur McCallum Fund, Newmont Exploration, Ltd., Nutrition Foundation, Inc., Olin Industries, Inc., Radio Corporation of America, The Rand Corporation, Richfield Oil Corporation, Schlumberger Foundation, Shell Fellowship Committee, Standard Oil Company of California, Stanolind Foundation, Union Carbide and Carbon Corporation, United States Rubber Company, Westinghouse Educational Foundation.

2. A number of governmental units, industrial organizations, educational foundations, and private individuals have contributed funds for the support of fundamental researches related to their interests and activities. These funds offer financial assistance to selected graduate students in the form of graduate research assistantships.

3. 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.

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, Bell Telephone Laboratories, E. I. du Pont de Nemours and Company, Merck and Company, Inc., American Cancer Society, the Atomic Energy Commission, the U. S. Public Health Service, the National Science Foundation, the National Foundation for Infantile Paralysis and other government agencies, as well as various foreign governments. Applications for such fellowships should in general be directed to the agency concerned.

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 course in mathematics. The stipend is $4000 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 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 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."

7. Millikan Fellowship: Established by the late Dr. Robert A. and Greta B. Millikan. Post-doctoral fellowship in the field of physical sciences, the recipients to be known as Millikan Fellows.

III. INSTITUTE GUESTS

Members of the faculties of other educational institutions and Research Fellows already holding the doctor's degree, who desire to carry on special investigations, may be invited to make use of the facilities of the Institute provided the work they wish to do can be integrated with the overall research program of the Institute and does not overcrowd its facilities. Arrangement should be made in advance with the chairman of the division of the Institute concerned. Such guests are given official appointment as Research Fellows, Senior Research Fellows, Research Associates, or Visiting Professors and thus have faculty status during their stay at the Institute.

PART THREE

Course Schedules and 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).[1]

Besides the subjects shown in the course schedules, students are required to take either military or physical education[2] in each term of the four school years. Students who continue their undergraduate work beyond four years continue to take physical education throughout their undergraduate course. Freshmen attend six orientation assemblies in addition to the general assemblies.

KEY TO ABBREVIATIONS

Aeronautics	Ae	English	En
Air Science	AS	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
Graphics	Gr	Philosophy	Pl
Economics	Ec	Physical Education	PE
Electrical Engineering	EE	Physics	Ph
Engineering Science	ES		

[1]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 5 on page 151.

[2]See page 146 for rule regarding excuses 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 (4-4-4)	12	12	12
En 1 abc	English: Reading, Writing and Speaking (3-0-3)	6	6	6
H 1 abc	History of European Civilization (2-0-3)	5	5	5
Gr 1 abc	Basic and Applied Graphics (0-3-0)	3	3	3
PE 1 abc[1]	Physical Education (0-3-0)	3	3	3
		53	53	53

SENIOR HUMANITIES ELECTIVES

Pl 1	Philosophy	H 4	The British Empire
Pl 2	Logic	H 7	Modern and Contemporary Germany
Pl 3	Current European Philosophies	H 8	The History of Russia
Pl 4	Ethics	H 15	The World Since 1914
Pl 6	Psychology	H 16	American Foreign Relations Since 1889
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	H 23	Modern War
En 19	Seminar in Literature	H 25	Political Parties and Pressure Groups
L 5	French Literature		
L 40	German Literature	H 124	Foreign Area Problems
Ec 48	Introduction to Industrial Relations		

[1]AFROTC students substitute 4 units of Air Science (AS 1 abc, 2-1-1) for Physical Education (PE 1 abc, 0-3-0).

AERONAUTICS OPTION

(For Aeronautics Option see page 205)

ASTRONOMY OPTION

(For First Year see page 194)
(For Second Year see Physics Option, page 206)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 143.

		Units per Term 1st	2nd	3rd
	THIRD YEAR			
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ph 106 abc	Introduction to Mathematical Physics (4-0-8)	12	12	12
Ph 107 abc	Electricity and Magnetism (2-0-4)	6	6	6
EE 4 abc	Basic Electrical Engineering (2-0-4)	6	6	6
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Electives (see below) to make[2]	6-10	6-10	6-10
		50-54	50-54	50-54
	FOURTH YEAR			
	Humanities Electives (3-0-6)[1]	9	9	9
Ec 4 ab	Economic Principles and Problems (3-0-3)	..	6	6
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ph 112 abc	Introduction to Atomic and Nuclear Physics (4-0-8)	12	12	12
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Electives (see below) to make[3]	20-27	18-20	18-20
		46-53	50-52	50-52
	ELECTIVES With Approval of Adviser			
L 32 abc	Elementary German (4-0-6)[4]	10	10	10
Ma 108 abc	Advanced Calculus (4-0-5)[4]	9	9	9
Ma 112	Elementary Statistics (3-0-6)	9	or	9
Ph 27 abc	Thermodynamics (2-0-4)[4]	6	6	6
Ph 115 ab	Optics (2-3-4)[4]	..	9	9
Ph 217	Spectroscopy (3-0-6)	..	..	9
Ge 2	Geophysics (3-0-6)	..	..	9
EE 160 abc	Electronics (2-3-4), (2-3-4), (2-3-4)	9	9	9
Ay 131 abc or Ay 132 abc	Astrophysics (3-0-6)[4]	9	9	9
Ay 141 abc	Astronomy Research Conference (1-0-1)	2	2	2

[1]Fourth year Humanities electives (the courses to be offered in any one term will be announced before the close of the previous term):

[2]AFROTC students substitute AS 3 abc for PE 3 abc and take electives to make 2-6 units per term.

[3]AFROTC students substitute AS 4 abc for PE 4 abc and take electives to make 15-22 units, first term; 13-15 units in second and third terms.

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

BIOLOGY OPTION

(For First Year see page 194)

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 143.

		Units per Term 1st	2nd	3rd
	SECOND YEAR			
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	Physical Geology (4-2-3)	9	..	..
Bi 1	Elementary Biology (3-3-3)	..	9	..
Bi 2	Genetics (3-3-3)	..	..	9
Bi 3	Plant Biology (2-6-2)	..	..	10
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	52	52
	SUMMER FOLLOWING SECOND YEAR			
Bi 4	Invertebrate and Vertebrate Zoology (5-10-5)			20 units
	THIRD YEAR			
En 7 abc	Introductory to Literature (3-0-5)	8	8	8
L 32 abc	Elementary German (4-0-6)	10	10	10
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10
Ch 41 abc	Organic Chemistry (3-0-5)	8	8	8
Ch 46 a	Organic Chemistry Laboratory (0-6-0)	6	..	..
Bi 5	Advanced Plant Biology (3-6-3)	..	..	12
Bi 20	Mamalian Anatomy and Histology (2-6-4)	..	12	..
	Biology Electives [5]	6	..	..
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
		51	51	51
	FOURTH YEAR			
	Humanities Electives (3-0-6) [4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	..
Bi 106	Embryology (2-6-4)	12	..	..
Bi 107 ab	Biochemistry (3-3-5; 3-4-8)	..	11	15
Bi 115	Plant Physiology (3-6-3)	..	12	..
Bi 116 ab	Animal Physiology (2-3-3)	8	8	..
Bi 117	Psychobiology (3-2-3)	..	..	9
	Biology Electives[5]	9	..	12
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		49	51	50

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1), for Physical Education (PE 2 abc, 0-3-0).

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

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

[4]For list of Humanities electives, see page 194.

[5]The following subjects are offered as fourth year Biology electives:

First Term

Bi 22	Special Problems (0-0-9)	units by arrangement
Bi 108	Advanced Genetics (2-0-4)	6 units
Bi 109	Advanced Genetics Laboratory	units by arrangement
Bi 114	Immunology (2-4-3)	9 units
Bi 125	Advanced Plant Biology (3-3-6)	12 units
Bi 129	Problems in Biophysics (2-0-4)	6 units
Ma 112	Elementary Statistics (3-0-6)	9 units

Second Term

Bi 22	Special problems (0-0-0)	units by arrangement

Third Term

Bi 22	Special Problems (0-0-9)	units by arrangement
Bi 110	Microbiology (3-3-3)	9 units
Bi 126	Genetics of Microorganisms (3-0-6)	9 units
Bi 127	Chemical Genetics Laboratory (0-6-0)	6 units
Bi 128	Advanced Microtechnique (1-4-1)	6 units
Ma 112	Elementary Statistics (3-0-6)	9 units
Ch 46 b	Organic Chemistry Laboratory (0-6-0 or 0-9-0)	6 or 9 units

CHEMISTRY OR APPLIED CHEMISTRY OPTIONS

(For First Year see page 194)

Any student of the Chemistry or Applied Chemistry Option whose grade point average in the required chemistry subjects of any year is less than 1.9 will be admitted to the required chemistry subjects of the following year only with the special permission of the Division of Chemistry and Chemical Engineering.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	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	Physical Geology (4-2-3)	9	..	..
Bi 1	Elementary Biology (3-3-3)	..	9	..
Bi 2	Genetics (3-3-3)	..	..	9
	or			or
Ay 1	Introduction to Astronomy (3-1-5)	..	..	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	52	52

THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	..
Ch 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
Ch 90	Oral Presentation (1-0-1)	..	..	2
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
		51	51	51

CHEMISTRY OPTION

FOURTH YEAR

	Humanities Electives (3-0-6)[4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ch 13 ab	Inorganic Chemistry (2-0-4)	6	6	..
Ch 16	Instrumental Analysis (0-6-2)	8	..	..
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	..	8	8
Ch 123	Thermodynamic Chemistry (2-0-4)	..	6	..
Ch 129	Surface and Colloid Chemistry (3-0-5)	..	..	8
L 35	Scientific German (4-0-6)	10	..	..
	Elective Subjects[5]	13	17	21
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		51	51	51

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

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

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

[4]For list of Humanities electives, see page 194.

[5]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 Ph 106 abc, Biochemistry Bi 107 ab.

APPLIED CHEMISTRY OPTION

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Elective (3-0-6)[2]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ch 16	Instrumental Analysis (0-6-2)	8	..	..
Ch 26 ab	Physical Chemistry Lab. (0-6-2; 0-3-1)	..	8	4
Ch 61	Industrial Chemistry (4-0-8)	12	..	..
Ch 63 ab	Chemical Engineering Thermodynamics (4-0-8)	..	12	12
Ch 129	Surface and Colloid Chemistry (3-0-5)	..	..	8
AM 2 abc	Applied Mechanics (3-0-5)	8	8	8
EE 1 a	Basic Electrical Engineering (3-0-6)	9	..	..
EE 4 cb	Basic Electrical Engineering (2-0-4)	..	6	6
EE 2 b	Basic Electrical Engineering Laboratory (0-3-0)	..	3	..
PE 4 abc[1]	Physical Education (0-3-0)	3	3	3
		51	51	52

[1]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

[2]For the list of Humanities electives, see page 194.

CIVIL ENGINEERING OPTION

(For First Year see page 194)

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 143.

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
Ec 2 ab	General Economics and Economic Problems (3-0-6)	9	9	..
Ec 18	Industrial Organization (3-0-4)	..	..	7
	or			or
Ec 25	Engineering Law (3-0-4)	..	..	7
ME 1	Empirical Design (0-9-0)	9	or 9	or 9
ME 3	Materials and Processes (3-3-3)	9	or 9	or 9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3; Ay 1, 3-1-5)	9	or 9	or 9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		51	51	49

THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
AM 1	Statics (3-0-6)	9	..	..
AM 4 ab	Strength of Materials (3-0-6)	..	9	9
AM 5 ab	Dynamics (3-0-6))	9	9	..
CE 1	Surveying (2-6-4)	..	..	12
CE 5	Hydrology (2-0-4)	..	6	..
EE 1 a	Basic Electrical Engineering (3-0-6)	9	..	..
EE 4 bc	Basic Electrical Engineering (2-0-4)	..	6	6
EE 2 ab	Basic Electrical Engineering Lab. (0-3-0)	..	3	3
Hy 2 ab	Hydraulics (4-0-8) (2-0-4)	12	6	..
ME 20	Heat Engineering (3-0-6)	..	..	9
PE 3 abc	Physical Education (0-3-0)	3	3	3
		50	50	50

FOURTH YEAR

	Humanities Elective (3-0-6)[4]	9	9	9
Ec 2 ab	General Economics and Economic Problems (3-0-6)	..	9	9
Ec 25	Engineering Law (3-0-4)	..	7	..
H 5 abc	Public Affairs (1-0-1)	2	2	2
Hy 11	Fluid Mechanics Laboratory (0-6-0)	..	6	..
ME 20	Heat Engineering (3-0-6)	9	..	..
CE 4	Highways and Airports (2-4-4)	10	..	..
CE 10 abc	Theory of Structures (3-3-6; 3-0-6)	12	12	9
CE 12	Reinforced Concrete (3-3-6)	..	..	12
CE 14 abc	Engineering Conference (1-0-1; 1-0-0)	2	2	1
CE 15	Soil Mechanics (2-0-4)	6	..	..
CE 20	Introduction to Sanitary Engineering[5] (2-0-4)	..	..	6
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		53	50	51

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

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

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

[4]For list of Humanities electives, see page 194.

[5]Students may substitute AM 15 c or Ge 110 for CE 20 in the third term of the fourth year.

ELECTRICAL ENGINEERING OPTION

(For First Year see page 194)

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 143.

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
Ec 2 ab	General Economics and Economic Problems (3-0-6)	9	9	..
Ec 18	Industrial Organization (3-0-4)	..	..	7
	or			or
Ec 25	Engineering Law (3-0-4)	..	..	7
ME 1	Empirical Design (0-9-0)	9	or 9	or 9
ME 3	Materials and Processes (3-3-3)	9	or 9	or 9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3; Ay 1, 3-1-5)	9	or 9	or 9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		51	51	49

THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
AM 1	Statics (3-0-6)	9	..	..
AM 4 a	Strength of Materials (3-0-6)	..	9	..
AM 5 a	Dynamics (3-0-6)	..	..	9
EE 1 abc	Basic Electrical Engineering (3-0-6)	9	9	9
EE 2 ab	Basic Electrical Engineering Lab. (0-3-0)	..	3	3
AM 15 abc	Engineering Mathematics (3-0-6)	9	9	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5)	10	10	10
PE 3 abc	Physical Education (0-3-0)	3	3	3
		48	51	51

FOURTH YEAR

	Humanities Elective (3-0-6)[4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 1 abc	General Economics and Economic Problems (3-0-3)	6	6	6
Ec 25	Engineering Law (3-0-4)	7	..	..
EE 6 ab	Electrical Machinery (2-0-4; 3-0-6)	..	6	9
EE 7	Electrical Machinery Laboratory (0-3-3)	..	..	6
EE 12	Electrical Circuits (4-0-8)	12	..	..
EE 15	Electromagnetism (2-0-4)	6	6	6
EE 16	Electrical Measurements (2-3-1)	..	6	..
EE 70 ab	Engineering Conference (1-0-1)	..	2	2
EE 160 abc	Electron Tubes (2-3-4)	9	9	9
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		54	49	52

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

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

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

[4]For list of Humanities electives, see page 194.

GEOLOGICAL SCIENCES OPTION

(For First Year see page 194)

Attention is called to the fact that any student whose grade-point average in freshman physics, chemistry and mathematics is less than 1.9, may, at the discretion of the Division of the Geological Sciences, be refused permission to register in the Geological Sciences Option. Furthermore, any student whose grade-point average is less than 1.9 in the subjects in the Division of Geological Sciences may, at the discretion of the Division, be refused permission to continue in the Geological Sciences Option.

SECOND YEAR[3]

		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 a	Analytical Chemistry (2-6-2)	10	..	..
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	..	..
Bi 1	Elementary Biology (3-3-3)	..	9	..
Ge 2	Geophysics (3-0-6)	..	..	9
Ge 3	Materials of the Earth's Crust (3-0-6)	..	9	..
Ge 5	Geobiology (3-0-6)	..	..	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	51	51

THIRD YEAR[4]

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	..	6
Ge 20 abc	Field Geology (4-5-1; 0-8-2; 0-6-4)	10	10	10
Ge 102	Oral Presentation (1-0-0)	..	1	..
Ge 176[7]	Elementary Seismology (3-0-3)	..	..	6
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Geology and Geochemistry[5] Options[6]			
Ge 4 a	Petrology, Igneous (3-3-2)	8	..	..
Ge 4 b	Petrology, Sedimenary (3-4-3)	..	10	..
Ge 4 c[7]	Petrology, Metamorphic (2-3-2)	..	..	7
Ge 9[7]	Techniques of Structural Geology (1-3-2)	6	..	..
Ge 104[7]	Introduction to Geochemistry (2-0-4)	..	..	6
Ch 24 ab	Physical Chemistry for Geologists (4-0-6)	10	10	..
	Electives[7]	..	6-9	..
		51	48-51	46
	Geophysics Option			
Ph 106 abc	Introduction to Mathematical Physics (4-0-8)	12	12	12
		39[8]	34[8]	45[8]

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

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

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

[4]Spring Field Trip, GE 122, 1 unit, required in junior and senior years.

[5]In general, the Geochemistry and Geophysics Options are recommended only for those students who anticipate continuing their training at the graduate level.

[6]Summer Field Geology, Ge 123, 20 units, required after third year in Geology and Geochemistry Options.

[7]Electives may be substituted for the courses so marked with the advice and permission of the student's advisor. Attention is called to the following courses as possible and desirable electives, but others may be acceptable if consistent with the student's interests and program of study: Ma 10, Ma 112, Ph 20, Ay 1, Bi 2, Ch 27, Ch 123, Ch 129, CE 5, CE 15, CE 134, CE 155, Hy 210 ab, Am 1, Am 4 ab, Am 5 ab, Am 110 a, L 1 ab, Ge 174, Ge 175, Ge 151.

[8]Add electives to bring unit load up to a minimum of 45 units, but not to exceed the allowable limit, selected from any of the following courses for which prerequisites have been completed: Any Ge course, Ay 1, Ch 21 abc, Ch 24 ab, Gr 5, EE 4 abc, EE 2 ab, Ma 3, Ma 10, Ma 16, Ma 108 abc, L 32 abc, Ph 107 abc. Special attention is called to the opportunity to take L 32 abc.

GEOLOGICAL SCIENCES OPTION

FOURTH YEAR[1]

		1st	2nd	3rd
		Units per Term		
	Humanities Elective (3-0-6)[2]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
L 32 abc	Elementary German (4-0-6)	10	10	10
Ge 100	Geology Club (1-0-0)	1	1	1
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Geochemistry Option			
Ch 13 abc[4]	Inorganic Chemistry (2-0-4)	6	6	6
Ch 27 ab[4]	Radioactivity and Isotopes (2-0-4)	6	6	..
Ch 129[4]	Surface and Colloid Chemistry (3-0-5)	..	..	8
Ge 105[4]	Optical Mineralogy (2-8-2)	12	..	..
Ge 106 ab[4]	Petrography (2-6-1; 2-4-3)	..	9	9
Ge 151 b	Laboratory Techniques in the Earth Sciences (0-5-0)	..	5	..
		49	51	48
	Geology Option			
Ge 121 abc	Advanced Field Geology (4-8-2; 0-8-2; 0-3-4)	14	10	7
	Electives to be selected from any advanced courses in the Division of Geological Sciences or courses in other Science or Engineering Divisions. The elective courses must be approved by the student's advisor	9-12	12-15	15-18
		48-51	47-50	47-50
	Geophysics Option			
Ph 107 abc	Electricity and Magnetism (2-0-4)	6	6	6
	Geology Electives	7-10	7-10	7-10
		38-41[5]	38-41[5]	38-41[5]

[1]Spring Field Trip, Ge 122, 1 unit required in junior and senior years.

[2]For list of Humanities electives, see page 194.

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

[4]Electives may be substituted for these courses with the advice and permission of the student's advisor.

[5]Add other electives in Physics, Mathematics, Chemistry, Astronomy, or Engineering to bring unit load to a minimum of 45 units, but not to exceed the allowable limit.

MATHEMATICS OPTION

(For First Year see page 194)

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 143.

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
Ma 3	Theory of Equations (4-0-6)	10	..	..
Ma 16	Matrices and Quadratic Forms (4-0-6)	..	10	..
Ma 10	Ordinary and Partial Differential Equations (4-0-6)	..	..	10
Ge 1	Physical Geology (4-2-3)	9	..	..
Bi 1	Elementary Biology (3-3-3)	..	9	..
Ay 1	Introduction to Astronomy (3-1-5)	..	..	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	52	52

THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ma 108 abc	Advanced Calculus (4-0-5)	9	9	9
Ph 106 abc	Introduction to Mathematical Physics (4-0-8)	12	12	12
	Elective in Mathematics[4]	9	9	9
	Elective in Languages[2,5]	10	10	10
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
		51	51	51

FOURTH YEAR

	Humanities Elective (3-0-6)[6]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab[3]	Economics	6	6	..
	Elective in Languages (4-0-6)[5]	10	10	10
	Electives in Mathematics[4]	18	18	27
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		48	48	51

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

[2]Junior AFROTC students take Ec 4 ab in the first two terms. They drop the junior language elective. They take AS 3 abc instead of PE 3 abc.

[3]Senior AFROTC students drop Ec 4 ab. They take AS 4 abc instead of PE 4 abc.

[4]Elective courses in Mathematics are:—Ma 61, 62, 63, 64, 67, 68, 91, 112 and all graduate courses in Mathematics with the exception of Ma 108. Courses in a cognate field may be chosen with the approval of the department.

Seniors intending to proceed to graduate work in Mathematics are expected to choose at least one full year's graduate course in Mathematics among their electives.

[5]Elective in Languages: German, Scientific German, French, Russian. A student who has taken languages in high school can be relieved of some or of all language requirements upon approval of the departments of languages and of mathematics. Any course can be elected to replace a language course from which the student has been excused.

[6]For list of Electives in the Humanities, see page 194.

MECHANICAL ENGINEERING OPTION

(For First Year see page 194)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of the faculty in Mechanical Engineering, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 143.

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
Ec 2 ab	General Economics and Economic Problems (3-0-6)	9	9	..
Ec 18	Industrial Organization (3-0-4)	..	..	7
	or			or
Ec 25	Engineering Law (3-0-4)	..	..	7
ME 1	*Empirical Design* (0-9-0)	9 or	9 or	9
ME 3	Materials and Processes (3-3-3)	9 or	9 or	9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3; Ay 1, 3-1-5)	9 or	9 or	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		51	51	49

THIRD YEAR

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

FOURTH YEAR

	Humanities Elective (3-0-6)[4]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 2 ab	General Economics and Economic Problems (3-0-6)	..	9	9
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 (0-3-5)	..	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	Fluid Mechanics Laboratory (0-6-0)	..	6	..
ME 50 ab	Engineering Conference (1-0-1)	..	2	2
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		53	54	50

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

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

[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

[4]For list of Humanities electives, see page 194.

MECHANICAL ENGINEERING (AERONAUTICS)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)[1]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 2 ab	General Economics and Economic Problems (3-0-6)	..	9	9
Ec 18	Industrial Organization (3-0-4)	..	..	7
ME 10	Metallurgy (3-3-6)	12	..	..
AM 3	Testing Materials Laboratory (0-3-5)	..	8	..
ME 50 abc	Engineering Conference (1-0-1)	..	2	2
Ae 101 abc	Introductory Mechanics and Thermodynamics of Fluids (3-0-6)	9	9	9
Ae 102 abc	Aircraft Structural Analysis (3-0-6)	9	9	9
Ae 105	Wind Tunnel Operation and Technique (1-3-2)	6	..	..
PE 4 abc[2]	Physical Education (0-3-0)	3	3	3
		50	51	50

[1]For list of Humanities electives, see page 194.

[2]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

PHYSICS OR ASTRONOMY OPTION

(For First Year see page 194)

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 more complete statement of this regulation will be found on page 143.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus, and Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Electrostatics, Electrodynamics and Optics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	..	..
Bi 1	Elementary Biology (3-3-3)	..	9	..
Ay 1	Introduction to Astronomy (3-1-5)	..	..	9
	Electives	6-11	6-11	6-11
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		48-53	48-53	48-53

Electives

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

THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5)	8	8	8
EE 4 abc	Basic Electrical Engineering (2-0-4)	6	6	6
Ph 106 abc	Introduction to Mathematical Physics (4-0-8)	12	12	12
Ph 107 abc	Electricity and Magnetism (2-0-4)	6	6	6
	Electives[2]	15-19	15-19	15-19
PE 3 abc[3]	Physical Education (0-3-0)	3	3	3
		50-54	50-54	50-54

Suggested Electives

(subject to approval of advisor)

L 32 abc	Elementary German (4-0-6)	10	10	10
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5)	10	10	10
Ma 108 abc	Advanced Calculus (4-0-5)[2]	9	9	9
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
Ph 27 abc	Thermodynamics, Statistical Mechanics, and Kinetic Theory (2-0-4)	6	6	6
Ch 27 abc	Radioactivity and Isotopes (2-0-4)	6	6	6
Ge 2	Geophysics (3-0-6)	..	..	9
Bi 2	Genetics (3-3-3)	..	..	9
EE 2 b	Electronics Laboratory (0-3-0)	..	3	..
	Or other subjects			

[1]AFROTC students substitute 4 units of Air Science (AS 2 abc, 2-1-1) for Physical Education (PE 2 abc, 0-3-0).

[2]Students should note that Ma 108 abc is prerequisite to most advanced mathematics courses.

[3]AFROTC students take AS 3 abc (4-3-1), and drop PE 3 abc (0-3-0), and 6 units of electives.

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities elective[1]	9	9[7]	9
Ec 4 ab	Economic Principles and Problems (3-0-3)	..	6	6
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ph 112 abc	Introduction to Atomic and Nuclear Physics (4-0-8)	12	12	12
	Laboratory Course	6-9	..	..
	Electives	18-21	18-21	18-21
PE 4 abc[2]	Physical Education (0-3-0)	3	3	3
		50-56	50-53	50-53

LABORATORY COURSES[3]

EE 16	Electrical Measurements (2-3-1)	6		
Ph 77	Special Problems in Experimental Physics[4] (units as arranged with instructor)	9-12		
Ph 172	Research (units as arranged with instructor)[4,5]	..		

SUGGESTED ELECTIVES[5,6]
(subject to approval of advisor)

Ph 115 ab	Geometrical and Physical Optics (2-3-4)	..	9	9
Ph 129 abc	Methods of Mathematical Physics (3-0-6)	9	9	9
Ph 131 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 201 ab	Analytical Mechanics (3-0-6)	9	9	..
Ph 202	Topics in Classical Physics (3-0-6)	..	..	9
Ph 217	Spectroscopy (3-0-6)	..	..	9
EE 160 abc	Electronics and Circuits (3-0-6) (2-3-4) (2-3-4)	9	9	9
Ch 21 abc	Physical Chemistry (4-0-6)	10	10	10
Ma 112	Elementary Statistics (3-0-6) (first or third term)	9	or	9
L 35	Scientific German (4-0-6)	10	..	..
L 1 ab	Elementary French (4-0-6)	..	10	10

[1]For list of Humanities electives, see page 194.

[2]To qualify as a Physics Laboratory course, physics research must be of an experimental nature.

[3]Students may register for Ph 77 or Ph 172 only *after* making arrangements with supervising instructor.

[4]Students who expect employment at the B.S. level should elect EE 160 abc.

[5]Only those courses most commonly taken are listed. Other courses in Physics, Mathematics, and Engineering may be substituted if approved by the Science Course Committee.

[6]AFROTC students will substitute 8 units of Air Science (As 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

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)[1]	9 or 10	9 or 10	9 or 10
Ae 101 abc[2]	Introductory Mechanics and Thermodynamics of Fluids (3-0-6)	9	9	9
Ae 102 abc[2]	Aircraft Structural Analysis (3-0-6)	9	9	9
Ae 103 abc[2]	Aerodynamics of the Airplane (3-0-6)	9	9	9
Ae 104 abc	Design of Aircraft Components (2-0-4)	6	6	6
AM 125 abc	Engineering Mathematical Principles (3-0-6)[3]	9	9	9
Ae 150 abc	Aeronautical Seminar (1-0-0)	1	1	1
		52-53	52-53	52-53

[1]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.)

[2]For those students who have previously had the equivalent of these courses at CIT or elsewhere, courses in Jet Propulsion, other courses in Aeronautics, or advanced courses in related fields may be substituted with the approval of the departmental advisor.

[3]Students who have not previously had AM 15 (AM 115), or Advanced Calculus and Differential Equations should take AM 115 ab and AM 116 in place of AM 125 abc. AM 126 abc may be substituted for AM 125 with the approval of the departmental advisor.

GRADUATE HUMANITIES ELECTIVES

H 100 abc	Seminar in History and Government
En 100 abc	Seminar in Literature
Pl 100 abc	Seminar in Philosophy
Pl 101 abc	History of Thought
Ec 100 abc	Business Economics
Ec 110	Industrial Relations
Ec 111	Business Cycles and Fiscal Policy
Ec 112	Modern Schools of Economic Thought
Ec 120 abc	Money, Income, and Employment
Ec 126 abc	Economics Analysis and Policy (Seminar)

AERONAUTICS

SIXTH YEAR

(Leading to the degree of Aeronautical Engineer)

		Units per Term 1st	2nd	3rd
Ae 106 abc	Experimental Methods in Aeronautics (1-3-2)	6	6	6
Ae 150 abc	Aeronautical Seminar (1-0-0)	1	1	1
Ae 200 abc	Aeronautics Research	20	20	20
	Electives (not less than)	18	18	18
		45	45	45

Elective subjects are to be selected from Aeronautics courses (pages 219-222) or advanced courses in other fields, as approved by the Aeronautics department.

AERONAUTICS (JET PROPULSION OPTION)

SIXTH YEAR

(Leading to the degree of Aeronautical Engineer)

Ae 150 abc	Aeronautical Seminar (1-0-0)	1	1	1
Ae 201 abc	Hydrodynamics of Compressible Fluids (3-0-6)	9	9	9
JP 280 abc	Jet Propulsion Research	18	18	19
	Electives (not less than)[1]	17	17	16
		45	45	45

[1]The electives are to be chosen from the list of Jet Propulsion subjects on pages 277-278 with the approval of the Goddard Professor of Jet Propulsion.

ASTRONOMY

FIFTH YEAR

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

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

Elective subjects program, to be approved by the department, from advanced subjects in astronomy and physics. Placement examination will be required (See page 182, section (a). Ay 112, Ma 108, Ph 106, Ph 107, Ph 113 may be required of those students whose previous training proves to be 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)

On the Monday and Tuesday preceding General Registration for the first term of graduate study, graduate students admitted to work for the M.S. degree will be required to take written placement examinations in the fields of inorganic chemistry, physical chemistry, and organic chemistry. These examinations will cover their respective subjects to the extent that these subjects are treated in the undergraduate chemistry option offered at this Institute and in general will be designed to test whether the student possesses an understanding of general principles and a power to apply these to concrete problems, rather than a detailed informational knowledge. It is expected of graduate students that they demonstrate a proficiency in the above subjects not less than that acquired by abler undergraduates. Students who have demonstrated this proficiency in earlier residence at this Institute may be excused from these examinations.

In the event that a student fails to show satisfactory performance in any of the placement examinations he will be required to register for a prescribed course, or courses, in order to correct the deficiency at an early date. In general no graduate credit will be allowed for prescribed undergraduate courses. If the student's performance in the required course or courses is not satisfactory he will not be allowed to continue his graduate studies except by special action of the Division of Chemistry and Chemical Engineering on receipt of his petition to be allowed to continue.

[1]For list of Humanities electives, see footnote page 208.

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 208. Candidates who have not had a course substantially equivalent to surface and Colloid Chemistry, Ch 129, must take this course. In addition not fewer than 30 units of courses of science subjects chosen from advanced courses and not fewer than 40 units of Chemical Research must be offered for the master's degree. Two copies of a satisfactory thesis describing this research, including a one-page digest or summary of the main results obtained, must be submitted to the Chairman of the Division at least ten days before the degree is to be conferred. The copies of the thesis should be prepared according to the directions formulated by the Dean of Graduate Studies, and should be accompanied by a statement approving the thesis, signed by the staff member directing the research and by the Chairman of the Committee on Undergraduate and Fifth-Year Study of the Division.

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

CHEMICAL ENGINEERING

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)[1]	9 or 10	9 or 10	9 or 10
Ch 166 abc	Chemical Engineering (3-0-9)	12	12	12
Ch 166 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 pages 166 and 175). 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.

[1]For list of Humanities electives, see footnote page 208.

CIVIL ENGINEERING

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
AM 115 ab	Engineering Mathematics (3-0-6)	..	9	9
CE 120 a	Statically Indeterminate Structures (3-3-6)	12	..	..
CE 125	Water Supply, Irrigation and Drainage (3-0-6)	..	..	9
CE 129	Spring Field Trip (0-1-0)	..	..	1
CE 130 abc	Civil Engineering Seminar (1-0-0; 0-4-0)	1	1	4
Hy 103 a	Advanced Hydraulics (3-0-6)	..	9	..
Ma 112 a	Elementary Statistics (3-0-6)[2]	9	..	..
	Electives as below (minimum)[3]	15	18	18
	Totals (Minimum)	46	46	50

Electives

AM 105	Advanced Strength of Materials (2-0-4)	6	..	..
AM 106	Problems in Buckling (2-0-4)	..	6	..
AM 107	Properties of Materials (2-0-4)	..	..	6
AM 110 a	Introduction to 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
CE 106	Soil Mechanics Laboratory (0-3-3)	..	6	..
CE 115 ab	Soil Mechanics (2-3-4)	9	9	..
CE 120 bc	Statically Indeterminate Structures (2-0-4)	..	6	6
CE 121 ab	Structural Design (0-9-0)	9	9	..
CE 121 c	Civil Engineering Design (0-9-0)	..	..	9
CE 126	Masonry Structures (2-3-4)	..	9	..
CE 127	Theory of Water and Waste Treatment (2-3-4)	9	..	..
CE 131	Design of Water and Waste Treatment Plants (2-3-4)	..	9	..
CE 132	Water Power Engineering (2-3-4)	..	9	..
CE 134	Ground Water Hydraulics (3-0-6)	..	..	9
CE 150	Foundations (3-0-6)	..	..	9
CE 155	Hydrology (3-0-6)	9	..	..
CE 156	Industrial Wastes (3-0-6)	..	..	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9
Hy 103 b	Hydraulic Structures (3-0-6)	..	..	9

SIXTH YEAR

(Leading to the degree of Civil Engineer)

Programs are selected from a comprehensive list of available subjects and are arranged by the student in consultation with members of the Civil Engineering faculty.

[1]For list of Humanities electives, see footnote page 208.
[2]AM 116 may be taken as an alternate for Ma 112.
[3]Electives must be approved by the Civil Engineering faculty.

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)[1]	9 or 10	9 or 10	9 or 10
EE 132 abc	Circuit Analysis (3-0-6)	9	9	9
EE 220 abc	Research Seminar in Electrical Engineering	2	2	2
	Two or more of the following electives:			
EE 120 abc	Advanced Power System Analysis			
EE 150 abc	Electromagnetic Fields			
EE 164 abc	Physical Electronics and Circuits			
EE 170 abc	Feedback Control Systems			
EE 180 abc	Methods of Machine Computation	18 or 21	18 to 24	18 to 24
	Other electives as approved by Electrical Engineering Faculty			

SIXTH YEAR

(Leading to the degree of Electrical Engineer)

AM 126 abc	Applied Engineering Mathematics (3-0-9)[3]	12	12	12

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.

[1]For list of Humanities electives, see footnote page 208.
[2]Required unless comparable work done elsewhere.
[3]This course is also required for the doctor's degree in electrical engineering

GEOLOGICAL SCIENCES

FIFTH YEAR

Option leading to degree of Master of Science in Geology

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
Ge 100	Geology Club	1	1	1
Ge 102	Oral Presentation	1	or 1	or 1
Ge 121 abc	Advanced Field Geology[2]	14	10	7
Ge 123	Summer Field Geology (20 units, in summer)[2]	..	..	..
Ch 124 ab	Physical Chemistry for Geologists	6	6	..
	Elective units from Group A or B below to total 140 units.			

Option leading to degree of Master of Science in Geophysics

	Humanities Electives (3-0-6; 4-0-6)[1]	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 123	Summer Field Geology (20 units, in summer)[2]	..	..	..
Ge 150	The Nature and Evolution of the Earth (any 24 units)	8	8	8
Ge 175	Introduction to Applied Geophysics	..	..	6
Ge 176	Elementary Seismology	..	6	..
Ge 282 abc	Geophysics—Geochemistry (Seminar)	1	1	1
Ph 106 abc	Introduction to Mathematical Physics	12	12	12
	Elective units to be chosen from advanced courses in the Geological Sciences, physics, mathematics, or electrical engineering to total 140 units.			

[1]For list of Humanities electives, see footnote, page 208.

[2]Students with limited experience in geological field work may be required to take all or a portion of Ge 20 abc as a prerequisite to Ge 121 abc or Ge 123. By approval of the Committee on Field Geology the field geology requirements may be satisfied by evidence of equivalent training obtained elsewhere.

A. Geology

FIFTH AND SIXTH YEARS

(Leading to the degree of Geological Engineer)[1]

		Units per Term 1st	2nd	3rd
Ge 100	Geology Club	1	1	1
Ge 102	Oral Presentation	1	or 1	or 1
Ge 103	Paleontology	9	..	..
Ge 104	Introduction to Geochemistry	..	..	6
Ge 105	Optical Mineralogy	12	..	..
Ge 106 ab	Petrography	..	9	9
Ge 107	Stratigraphy[3]	..	..	10
Ge 109	Techniques in Structural Geology	14	..	..
Ge 111 ab	Invertebrate Paleontology	..	10	10
Ge 121 abc	Advanced Field Geology	14	10	7
Ge 122	Spring Field Trip	..	..	1
Ge 123	Summer Field Geology (20 units, in summer)	..	..	..
Ge 126	Geomorphology	10	..	..
Ge 150 abc	The Nature and Evolution of the Earth[2]	8	8	8
Ge 150 def	The Nature and Evolution of the Earth[4]	8	8	8
Ge 151 abc	Laboratory Techniques in the Earth Sciences (5 unit minimum, additional units by arrangement)	5	5	5
Ge 200	Mineragraphy	15	..	..
Ge 202	Ore Deposits	..	15	..
Ge 209	Sedimentary Petrology[2]	..	10	..
Ge 210	Metamorphic Petrology[4]	..	..	10
Ge 212	Nonmetalliferous Deposits	..	..	10

Ge 213	Mineralogy (Seminar)	5	..	..
Ge 214	Petrology (Seminar)	..	5	..
Ge 215	Ore Deposits (Seminar)	..	..	5
Ge 228	Geomorphology of Arid Regions[2]	..	10	..
Ge 229	Glacial Geology[4]	..	10	..
Ge 230	Geomorphology (Seminar)	..	5	..
Ge 237	Tectonics	..	..	8
Ge 238	Structural Geology (Seminar)	5	..	..
Ge 244 abc	Paleozoology (Seminar)	5	5	5
Ge 245	Vertebrate Paleontology (Seminar)[3]	..	5	..
Ge 250	Invertebrate Paleontology and Paleoecology (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)	..	..	..

[1]Courses required for the degree of Master of Science in Geology are also required for the degree of Geological Engineer.
[2]1955-56.
[3]Not offered in 1955-56.
[4]1956-57.

B. Geophysics

FIFTH AND SIXTH YEARS

(Leading to the degree of Geophysical Engineer)

		Units per Term 1st	2nd	3rd
Ge 150 abc	The Nature and Evolution of the Earth[2,4]	8	8	8
Ge 150 def	The Nature and Evolution of the Earth[1,4]	8	8	8
Ge 151 abc	Laboratory Techniques in the Earth Sciences (5 units minimum, additional units by arrangement)[4]	5	5	5
Ge 167	Propagation of Elastic Waves in the Atmosphere[1]	..	3	..
Ge 174	Well Logging[1]	..	5	..
Ge 175	Introduction to Applied Geophysics	..	..	6
Ge 176	Elementary Seismology	..	..	6
Ge 261	Theoretical Seismology[2]	6	..	..
Ge 262	Interpretations of Seismograms of Teleseisms[2]	..	4	..
Ge 264	Propagation of Elastic Waves in Layered Media	8	8	..
Ge 268 ab	Selected Topics in Theoretical Geophysics	..	6	6
Ge 272	Applied Geophysics I[2]	..	10	..
Ge 273 ab	Applied Geophysics II[1]	..	5	5
Ge 274 ab	Applied Geophysics III[2]	..	5	6
Ge 282 abc	Geophysics-Geochemistry (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 160 abc	Electronics and Circuits	9	9	9
Ma 112	Elementary Statistics	9	or	9
Ph 106 abc	Introduction to Mathematical Physics	12	12	12
Ph 107 abc	Electricity and Magnetism	6	6	6
Ph 129 abc	Methods of Mathematical Physics	9	9	9
Ph 131 abc	Electricity and Magnetism	9	9	9
Ph 201 ab	Analytical Mechanics	9	9	..
Ph 202	Topics in Classical Physics	..	..	9

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 2 ab	Basic Electrical Engineering Laboratory	..	3	3
EE 4 abc	Basic Electrical Engineering	6	6	6
EE 16	Electrical Measurements	..	6	..

[1]1956-57.
[2]1955-56.
[3]Not offered in 1955-56.
[4]Ge 150 and Ge 151 are not acceptable toward a minor in Geophysics if the major is within the division. Majors outside the division will be credited with 5 units toward a minor in Geophysics for Ge 150 a.

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)[1]	9 or 10	9 or 10	9 or 10
ME 125 ab	Engineering Laboratory (1-6-2)	9	..	9
Ma 112	Elementary Statistics (3-0-6)	..	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			
AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 101 abc	Advanced Machine Design (1-6-2)	9	9	9
ME 110	Physical Metallurgy I (3-0-6)	9	..	..
ME 111 a	Metallography Laboratory (0-9-0)	..	9	..
ME 111 b	Industrial Physical Metallurgy (0-9-0)	..	..	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

JET PROPULSION, MECHANICAL ENGINEERING OPTION

FIFTH YEAR

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

	Humanities Electivies (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
JP 121 abc	Rocket (2-0-4)	6	6	6
JP 130 abc	Thermal Jets (3-0-6)	9	9	9
JP 200 abc	Chemistry Problems in Jet Propulsion (3-0-6)	9	9	9
ME 152 ab	Engineering Laboratory (1-6-2)	9	..	9
Ma 112	Elementary Statistics (3-0-6)	..	9	..
	Electives	6	6	6
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
		50 or 51	50 or 51	50 or 51
	ELECTIVES			
AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 101 abc	Advanced Machine Design (1-6-2)	9	9	9
ME 110	Physical Metallurgy I (3-0-6)	9	..	..
ME 111 a	Metallography Laboratory (0-9-0)	..	9	..
ME 111 b	Industrial Physical Metallurgy (0-9-0)	..	..	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

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 ab and AM 116 among the elective units.

NOTE: Students who plan advanced study past the fifth year, and who have had AM 115 ab and AM 116 or an equivalent course in their undergraduate work may substitute one of the following courses for one of the professional courses listed above, subject to the approval of the faculty in Mechanical Engineering:

AM 125 abc Engineering Mathematical Principles
AM 126 abc Applied Engineering Mathematics
Ph 107 abc Electricity and Magnetism

[1]For list of Humanities electives, see footnote page 208.

MECHANICAL ENGINEERING

SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

Specific requirements for the degree of Mechanical Engineer are given on page 169. The following list will suggest possible subjects from which a program of study may be organized:

ME 200	Advanced Work in Mechanical Engineering
ME 208 ab	Crystal Structure of Metals and Alloys
ME 209 ab	X-ray Metallography
ME 210 abc	Physical Metallurgy II
ME 211 ab	Advanced Metallography Laboratory
ME 214 ab	Mechanical Behavior of Metals
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 163 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 227 ab	Thermodynamics, Statistical Mechanics, and Kinetic Theory

JET PROPULSION, MECHANICAL ENGINEERING OPTION

SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

		Units per Term		
		1st	2nd	3rd
JP 220 abc	Theory of Stability and Control (2-0-4)	6	6	6
JP 280 abc	Jet Propulsion Research (Thesis)	18	18	18
ME 15 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
	Electives	24	24	24
		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)[2]	9 or 10	9 or 10	9 or 10
	Electives as below	39	39	39
		48 or 49	48 or 49	48 or 49
Ph 106 abc	Introduction to Mathematical Physics (4-0-8)[1]	8	8	8
Ph 107 abc	Electricity and Magnetism (2-0-4)[1]	4	4	4
Ph 110 ab	Kinetic Theory of Matter (3-0-6)	..	9	9
Ph 112 abc	Introduction to Atomic and Nuclear Physics[1]	8	8	8
Ph 115 ab	Geometrical and Physical Optics	..	6	6
Ph 129 abc	Methods of Mathematical Physics (3-0-6)	9	9	9
Ph 131 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 203 abc	Nuclear Physics (3-0-6)	9	9	9
Ph 205 abc	Principles of Quantum Mechanics (3-0-6)	9	9	9
Ph 207 abc	X- and Gamma-Rays (3-0-6)	9	9	9
Ph 217	Spectroscopy (3-0-6)	..	..	9
Ma 108 abc	Advanced Calculus (4-0-5)[3]	9	9	9
Ma 114 abc	Mathematical Analysis (4-0-8)	12	12	12

[1]Prerequisite for most other fifth-year courses. Two-thirds credit allowed physics graduate students.
[2]For list of Humanities electives, see footnote, page 208.
[3]Prerequisite for Ma 114.

NOTE: With the department's approval, students who have the proper preparation may substitute other graduate courses in Electrical Engineering, Mathematics or Physics for some of those listed above. Students who have received credit for Ph 131 abc as undergraduates may use these credits towards a master of science degree provided they replace them with undergraduate credits in L 32 abc (4-0-6) earned during the fifth year.

SUBJECTS OF INSTRUCTION

AERONAUTICS

ADVANCED SUBJECTS

Ae 101 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: *Foundations of Aerodynamics,* Kuethe and Schetzer; *Introduction to Compressible Fluids,* Liepmann and Puckett.

Instructor: Liepmann.

Ae 102 abc. Aircraft Structural Analysis. 9 units (3-0-6); 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. A modern airplane is considered and key structural elements are proportioned to support the dynamic and static loads arising from gust, maneuver, and landing loads. Special emphasis is placed on the analysis monocoque structures in compression, bending, shear, and torsion. Energy methods are applied in the analysis of landing gears, fuselage frames, and wings with cut-outs. Problems concerning manufacture, choice of materials, sandwich and other special construction are briefly discussed.

Texts: *Airplane Structural Analysis and Design,* Sechler and Dunn, *Elasticity in Engineering,* Sechler.

Instructor: Sechler.

Ae 103 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 and dynamic stability and control. Determination of response characteristics.

Texts: *Aerodynamics of the Airplane,* Millikan; *Airplane Performance, Stability, and Control,* Perkins and Hage.

Instructor: Royce.

Ae 104 abc. Design of Aircraft Components. 6 units (2-0-4); 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 visiting lecturers from the aircraft industry.

Ae 105. Wind Tunnel Operation and Techniques. 6 units (1-3-2); one term.

A one-term course covering pressure and velocity measuring instruments, balances, model suspensions, wind tunnel calibration and correction factors, data reduction and presentation, extrapolation of model results to full scale. Experiments on various aerodynamic phenomena are carried out by the students in a special wind tunnel constructed for instruction purposes.

Text: *Wind Tunnel Testing,* Pope.

Instructor: Bowen.

Ae 106 abc. Experimental Methods in Aeronautics. 6 units (1-3-2); each term.

Prerequisites: Ae 101, Ae 102, Ae 103, Applied Mechanics.

One term is devoted to a study of experimental techniques in the field of aircraft structures and applied elasticity; methods of reducing and correlating experimentally obtained data; and a study of sources of error in experimentation. A second term is concerned with the problems of the design and use of instrumentation and the fundamental principles involved in making precision measurements. A third term is devoted to experimental techniques in the field of fluid mechanics and aerodynamics. Statistical methods; analogs; hot-wire measurements; and boundary layers are among the problems discussed from an experimental standpoint.

Texts: Numerous reference works on experimental methods.

Instructors: Sechler, Klein, Liepmann.

Ae 107 abc. Elasticity Applied to Aeronautics. 9 units (3-0-6); each term.

Prerequisites: Applied Mechanics, Strength of Materials, AM 125 (may be taken concurrently).

Fundamental stress, strain, and displacement relationships in elastic bodies. Exact and approximate methods of solution of elasticity problems. Theories of bending and torsion. Fundamentals of plate and shell theory. Elastic stability of columns, plates, and shells. Thermal stresses.

Text: *Elasticity in Engineering*, Sechler.

Instructor: Fung.

Ae 108. Flight Test Techniques. 6 units (2-0-4); one term.

Prerequisite: Ae 103.

A classroom course covering the instrumentation and calibration of the test vehicle for performance, stability, or strength evaluation. Methods of data reduction for conventional or jet aircraft and missiles.

Instructor: Williams.

Ae 150 abc. Aeronautical Seminar. 1 unit (1-0-0); each term.

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

Ae 200 abc. Research in Aeronautical Seminar. Units to be arranged.

Theoretical and experimental investigations in the following fields: aerodynamics, compressibility, fluid and solid mechanics, supersonics, aeroelasticity, structures, thermoelasticity, fatigue, photoelasticity.

Instructors: Staff

Ae 201 abc. Hydrodynamics of Compressible Fluids. 9 units (3-0-6); each term.

Prerequisites: Ae 101, Ae 103.

One dimensional gasdynamics; subsonic and supersonic channel flow, normal and oblique shockwaves; shock propagation condensation phenomena. Potential flow and linearization techniques; the hodograph method and Karman-Tsien treatment. Method of characteristics, exact solutions and numerical calculation methods, nozzle design. Linearized potential flow, method of sources, Evvard's theory for lifting wings, conical flow wing theory. Similarity concepts, transonic and hypersonic flow fundamentals.

Text: Class notes and reference material.

Instructor: Lees.

Ae 202 abc. Advanced Problems in Airplane and Missile Structural Analysis. 6 units (2-0-4); each term.

Prerequisites: AM 125, Ae 107 (may be taken concurrently), Ae 102, Ae 104.

The application of basic and advanced mathematical methods of structural problems encountered in the design of modern aircraft and missiles. Analysis methods for high solidarity wing construction with and without sweep. Fuselage and shell design. Optimum combined aerodynamic and structural efficiency from weight standpoint. Practical aspects of fatigue and plasticity. Transient stress analysis. The effect of blast and impact loads. Aerodynamic heating, properties of materials at elevated temperatures, thermal stress analysis.

Instructor: Structures Staff.

Ae 203 abc. Advanced Problems in Aerodynamics. 6 units (2-0-4); each term.

Prerequisites: Ae 101, AM 125, Ae 103.

Introduction to theory of servo-mechanisms and application to stability and control. Helicopter aerodynamics, propeller theory, boundary layer theory, and internal aerodynamics. Aerodynamics of high speed flight including the effects of compressibility on stability and control. Fundamentals of aeronautical electronics.

Instructor: Staff.

Ae 204 abc. Theoretical Aerodynamics of Real and Perfect Fluids. 9 units (3-0-6); each term.

Prerequisites: Ae 101, AM 125, Ae 103.

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.

Instructors: Stewart, Coles.

Ae 205 abc. Statistical Problems in Gas Dynamics. 9 units (3-0-6); each term. Offered in alternate years beginning in 1953-54.

Prerequisites: Ae 101, Ae 201, AM 125, 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. Special applications such as buffeting, gust loads, noise problems.

Instructors: Lagerstrom, Liepmann.

Ae 206 abc. Advanced Problems in Fluid Mechanics. 9 units (3-0-6); each term. Offered in alternate years beginning 1954-55.

Prerequisites: Ae 101, Ae 201, Ae 204, or consent of instructor.

Selected topics in fluid mechanics and related fields of mathematics: Advanced problems in linearized theory with applications to airplanes and missiles for example, nonlinear theory of compressible fluids, elliptic and hyperbolic equations, and applications to supersonic and transonic flow. Viscous incompressible fluids, general theory, exact solutions, Stokes' and Oseen equations, and boundary layer theory. Viscous heat-conducting compressible fluids.

Instructors: Lagerstrom, Lees.

Ae 207 abc. Aeroelasticity. 9 units (3-0-6); each term.

Prerequisites: Ae 103, AM 125 or equivalent.

Aeroelastic oscillations of cylinders, transmission lines, and suspension bridges. Steady-state problems: divergence, loss of control and lift-distribution. Flutter: general characteristics, physical causation, method of analysis, effect of structural parameters, and methods of raising critical speeds. Dynamic stresses: landing and gust loads, statistical concepts, stochastic processes, distribution of extreme values. Buffeting. Stall flutter. General formulation of aeroelastic problems, including systems with automatic controls. Applications of Laplace transformation. Small variations of parameters. Prevalence of non-self-adjoint equations in aeroelasticity. Approximate methods of solution. Linearized theory of oscillating airfoils, in an incompressible fluid, and in compressible subsonic and supersonic flows. Comparison of the unsteady airfoil theory with experimental results.

Texts: Class notes and reference material.

Instructor: Fung.

Ae 208 abc. Seminar in Fluid Mechanics. 1 unit (1-0-0); each term.

A seminar course in modern fluid dynamics.

Instructor: Liepmann.

Ae 209 abc. Seminar in Solid Mechanics. 1 unit (1-0-0); each term.

A seminar course for students whose interests lie in the general field of advanced elasticity. Recent (theoretical and experimental) developments and original research in the field as reviewed for possible application to the current problems in the aircraft and related industries.

Instructor: Sechler.

JET PROPULSION

(For Jet Propulsion see page 277)

AIR SCIENCE

AS I abc. Air Science I. 4 units (2-1-1).

A study of a series of short courses including the following: Introduction to AFROTC, Introduction to Aviation, Fundamentals of Global Geography, International Tensions and Security Structures, and Instruments of National Military Security. One hour each week is devoted to Leadership Training Laboratory—Basic Military Training.

Text: Government Manuals furnished by the Air Force will be issued to the students.

Instructor: AFROTC Staff.

AS II abc. Air Science II. 4 units (2-1-1).

A study of the Elements of Aerial Warfare including Targets, Weapons, Delivery Aircraft, the Air Ocean, Bases, and People. One hour each week is devoted to Leadership Training Laboratory—Cadet Non-Commissioned Officer Training.

Text: Government Manuals furnished by the Air Force will be issued to the students.

Instructor: AFROTC Staff.

AS III abc. Air Science III. 8 units (4-3-1).

A study of a series of short courses including the following: The Air Force Commander and Staff, Problem Solving Techniques, Communicating in the Air Force, Instructing in the Air Force, Military Justice System, Applied Air Science, and Air Force Base Functions. One hour each week is devoted to Leadership Training Laboratory—Cadet Officer Training.

Text: Government Manuals furnished by the Air Force will be issued to the students.

Instructor: AFROTC Staff.

AS IV abc. Air Science IV. 8 units (4-1-3).[1]

A study of a series of short courses including the following: Principles of Leadership and Management, Military Aspects of World Political Geography, and Military Aviation and Evolution of Warfare. One hour each week is devoted to Leadership Training Laboratory—Cadet Officer Training.[1]

Text: Government Manuals furnished by the Air Force will be issued to the students.

Instructor: AFROTC Staff.

APPLIED MECHANICS

UNDERGRADUATE SUBJECTS

AM 1. Applied Mechanics—Statics. 9 Units (2-3-4); first 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, Vreeland, and Assistants.

AM 4 ab. Applied Mechanics—Strength of Materials. 9 Units (3-0-6); second and third terms.

Prerequisite: AM 1.

Theory of elasticity applied to engineering problems involving tension and compression, bending of beams, torsion of shafts, buckling of columns, etc.; determination of the stresses, strains, and deformations in typical structures; theory of statically indeterminate structures; properties of materials of construction; determination of safe loads for engineering structures and machines.

Text: Elements of Strength of Materials, Timoshenko & MacCullough.

Instructors: Housner, Hudson, Vreeland, and Assistants.

AM 5 ab. Applied Mechanics—Dynamics. 9 Units (3-0-6); first and second terms; (third and first terms for EE students).

Prerequisite:AM 1.

Principles of dynamics; dynamics of a particle; dynamics of rigid bodies; Lagrange's equations; applications to engineering problems involving dynamic characteristics of machine parts, mechanical and structural vibrations, impact, momentum transport, etc.

Text: Applied Mechanics-Dynamics, Housner and Hudson.

Instructors: Housner, Hudson, Vreeland, and Assistants.

AM 3. Testing Materials Laboratory. 8 Units (0-3-5); first, second or third terms.

Prerequisite: AM 4a.

Experimental techniques for determining the mechanical behavior of engineering materials. Measurements of elastic limit, yieldpoint, ultimate strength, modulus of elasticity, etc. Experimental verification of theoretical solutions of problems in elastic deformations.

Instructors: Wood and Assistants.

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[1]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC must take H 23 (Modern War) as their humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the humanities elective requirement for this term.

AM 15 abc. Engineering Mathematics. 9 units (3-0-6); first, second, third terms.

Prerequisites: Ma 1 abc, Ma 2 abc.

A course in the mathematical treatment of problems in engineering and physics. Emphasis is placed on the setting up of problems as well as their mathematical solution. The topics studied include: vector analysis with emphasis on its application to deriving the differential equations of classical field theory in generalized form; the solution of ordinary differential equations by standard techniques and by power series; problems leading to special functions such as Bessel function; and partial differential equations and boundary value problems, with emphasis on techniques applying series of orthogonal functions.

Instructors: Wayland, DePrima and Assistants.

ADVANCED SUBJECTS

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

AM 105. Advanced Strength of Materials. 6 units (2-0-4); first term.

Prerequisite: AM 1 bcd.

Analysis of problems of stress and strain that are described by ordinary differential equations, such as beams on elastic foundation, curved bars, combined bending and axial loading of beams, combined bending and torsion of beams. Energy methods of solution.

Instructors: Housner, Lurie.

AM 106. Problems in Buckling. 6 units (2-0-4); second term.

Prerequisite: AM 1 bcd.

Analysis of problems dealing with the elastic instability of columns, beams, arches and rings, and the inelastic buckling of columns.

Instructors: Housner, Lurie.

AM 107. Mechanical Properties of Engineering Materials. 6 units (2-0-4); third term.

Prerequisite: AM 3.

A study of the various aspects of the mechanical properties of engineering materials that are of importance in design. Elastic deformation, plastic deformation, creep and other temperature properties, fatigue, brittle fracture, and internal friction are discussed.

Instructor: Wood.

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 ab. Engineering Mathematics. 9 Units (3-0-6); second and third terms.

Prerequisites: Ma 1 abc, Ma 2 abc or equivalent.

A course in the mathematical treatment of problems in engineering or physics, primarily for fifth year students who have not had a course in advanced engineering mathematics as undergraduates. The mathematical content is similar to that of AM 15 abc, but less emphasis is placed on ordinary differential equations.

Instructors: DePrima, Wayland and Assistants.

AM 116. Complex Variables and Applications. 9 units (3-0-6); first term.

Prerequisites: Ma 1 abc, Ma 2 abc or equivalent.

A basic introduction to analytic functions of a complex variable. Emphasis is placed on application of conformal mapping to boundary value problems and on techniques of contour integration.

Text: Churchill, Introduction to Complex Variables and Applications.

Instructors: DePrima, Wayland and Assistants.

AM 125 abc. Engineering Mathematical Principles. 9 units (3-0-6); each term.

Prerequisites: AM 15, AM 115 ab and AM 116, Ma 108, or equivalent.

Topics from ordinary and partial differential equations with applications to vibrations, elasticity, theory of sound, fluid mechanics, and diffusion.

AM 126 abc. Applied Engineering Mathematics. 12 units (3-0-9); each term.

Prerequisites: AM 15, AM 115 ab and AM 116, Ma 108, or equivalent.

A problem and lecture course in engineering mathematics. Preparation of approximately six reports per term on problems taken from all branches of engineering. First term lectures cover topics in ordinary differential equations including: LaGrange's equations, normal modes of vibration, and nonlinear systems. Second and third term lectures cover topics in partial differential equations including: characteristics, vibration theory, Rayleigh-Ritz method, conformal mapping, La Place transform, difference equations, relaxation methods.

Instructors: Lindvall and MacNeal.

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

Prerequisites: AM 1 bcd, AM 115 ab, AM 116.

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,* Karman 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 measurements of strains, accelerations, frequencies, etc., in vibrating systems, and the interpretation of the results of such measurements. Consideration is given to the design, calibration and operation of the various types of instruments used for the experimental study of dynamics problems.

Instructor: Hudson.

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

Prerequisites: AM 125, 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 abc. Nuclear Engineering and Reactor Theory. 9 units (3-0-6); first, second, and third terms.

Prerequisites: Ph 112 abc, or equivalent.

The fission process. Neutron diffusion theory. Reactor equations and their solution. Stability and control problems. Radiation shielding. Heat transfer and material problems.

AM 205 abc. Theory of Solids. 9 units (3-0-6); first, second, and third terms.

Theory of specific heats. Free electron theory of metals and semi-conductors. Thomas-Fermi and Hartree-Fock approximations. Theory of cohesion, conductivity, and optical properties.

Instructor: Plesset.

AM 250 abc. Research in Applied Mechanics.

Research in the field of Applied Mechanics. By arrangements with members of the staff, properly qualified graduate students are directed in research. Hours and units by arrangement.

ASTRONOMY

UNDERGRADUATE SUBJECTS

Ay 1. Introduction to Astronomy. 9 units (3-1-5); third term.

This course is intended to give the student sufficient familiarity with general astronomy to enable him to read with profit all but the more technical books and articles dealing with this subject.

Instructor: Greenstein.

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

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

The planets, the sun and solar-terrestrial relations. Physical properties of the stars and the spectral sequence. Binary and variable stars. Dynamics of the galaxy, extragalactic nebulae.

Instructors: Osterbrock, Munch.

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.

Instructors: Osterbrock, Munch.

Ay 131 abc. Astrophysics I. 9 units (3-0-6); first, second and third terms.

Prerequisites: Ay 2 abc, Ph 112 abc.

The masses, luminosities and radii of the stars. The sun. Atomic spectrascopy. Stellar spectra. The theory of radiative equilibrium in stellar atmospheres. The continuous absorption by atoms and the production of the continuous spectrum of the stars; the line absorption coefficient and the formation of spectral lines. Determination of the abundances of the elements. Offered in alternate years with Ay 132. Not given in 1955-56.

Instructors: Greenstein, Munch.

Ay 132 abc. Astrophysics II. 9 units (3-0-6); first, second, third terms.

Prerequisites: Ay 2 abc, Ph 112 abc or their equivalents.

Stellar dynamics, velocity distribution, and galactic rotation. Structure of the galaxy; interstellar matter. Introduction to the study of stellar interiors; polytropes; opacity and energy generations. Stellar models. Red giants, white dwarfs. Stellar evolution. Pulsating stars.

Instructors: Munch, Osterbrock.

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

Discussions on the large scale distribution of matter in the Universe, statistics of the distribution of nebulae and clusters of nebulae. Hydrodynamic and statistical mechanical analysis of the morphology of nebulae. Theory and discussion of observational data obtained from observations on stars of special interest, such as supernovae, novae, white dwarfs, variable stars, and emission line stars. Theory and practice of new types of telescopes and other observational devices. Practical work of reduction of data obtained with the Schmidt telescopes on Palomar Mountain. Only students, assistants, faculty members, and visiting research personnel are admitted to the seminar who have the time, inclination and ability to engage in active, constructive work on problems which will be formulated in this seminar.

Meetings throughout the year according to agreement.

Instructor: Zwicky.

Ay 141 abc. Research Conference in Astronomy. 2 units; first, second and third terms.

Meets weekly to discuss work in progress in connection with the staff of the Mount Wilson and Palomar Observatories.

Ay 142. Research in Astronomy and Astrophysics. Units in accordance with the work accomplished.

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

Ay 202. The Solar Atmosphere. 6 Units (2-0-4); first term.

Admission to qualified students.

The observational data of solar surface and envelope activity. Sunspots, solar rotation. The corona.

Instructor: Nicholson.

Ay 212. Extragalactic Nebulae. 6 units (2-0-4); second term.

Admission to qualified students.

The contents of extragalactic nebulae, and the spatial distribution of various types of objects. The kinematics and distribution of stars in our Galaxy. The distance and age scales.

Instructor: Baade.

Ay 214. Theoretical Cosmology. 6 units (2-0-4); third term.

Admission to qualified students.

Cosmological theories of the large-scale distribution of matter. The steady-state theory. Observational tests. Theories of formation and evolution.

Instructor: Hoyle.

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 the Planetary System.

Ay 203. Stellar Electromagnetism.

Ay 204. Stellar Spectroscopy.

Ay 205. Spectra of Emission-line Stars.

Ay 206. Stellar Radial Velocities.

Ay 207. Stellar Absolute Magnitudes.

Ay 208. Photometry.

Ay 209. Planetary and Diffuse Emission Nebulae.

Ay 210. Interstellar Matter.

Ay 211. Structure and Dynamics of the Galaxy.

Ay 213. The Observational Approach to Cosmology.

BIOLOGY

UNDERGRADUATE SUBJECTS

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

A study of the organism as a structural and functional entity, and of the relation of biological problems to human affairs.

Instructors: Galston, Beadle.

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

Prerequisite: Bi 1.

A course presenting the fundamentals of genetics and their relation to general biological problems.

Instructor: Lewis.

Bi 3. Plant Biology. 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); summer.

Prerequisite: Bi 1.

A course dealing with the taxonomy, comparative anatomy, and ecology of the more important animal phyla.

(Students taking the Biology option are required to take this course at the Marine Laboratory for six weeks, starting the Monday following the end of their sophomore year. This course is taken without payment of additional tuition. Living quarters are provided at the Laboratory at a nominal charge.)

Bi 5. Advanced Plant Biology. 12 units (3-6-3); third term.

Prerequisite: Bi 3.

A study of the nutrition, growth, and development of green plants. Emphasis is placed on an understanding of the basic physical and chemical processes regulating the lives of plants.

Instructor: Galston.

Bi 18. Review in Botany. 3 units (1-0-2). No graduate credit. This course is given when convenient for professors and students.

A short review of general botany and plant physiology. Required of graduate students who take a minor in plant physiology but have had no previous courses in botany.

Instructor: Went.

Bi 20. Mamalian Anatomy and Histology. 12 units (2-6-4); second term.

Prerequisite: Bi 4.

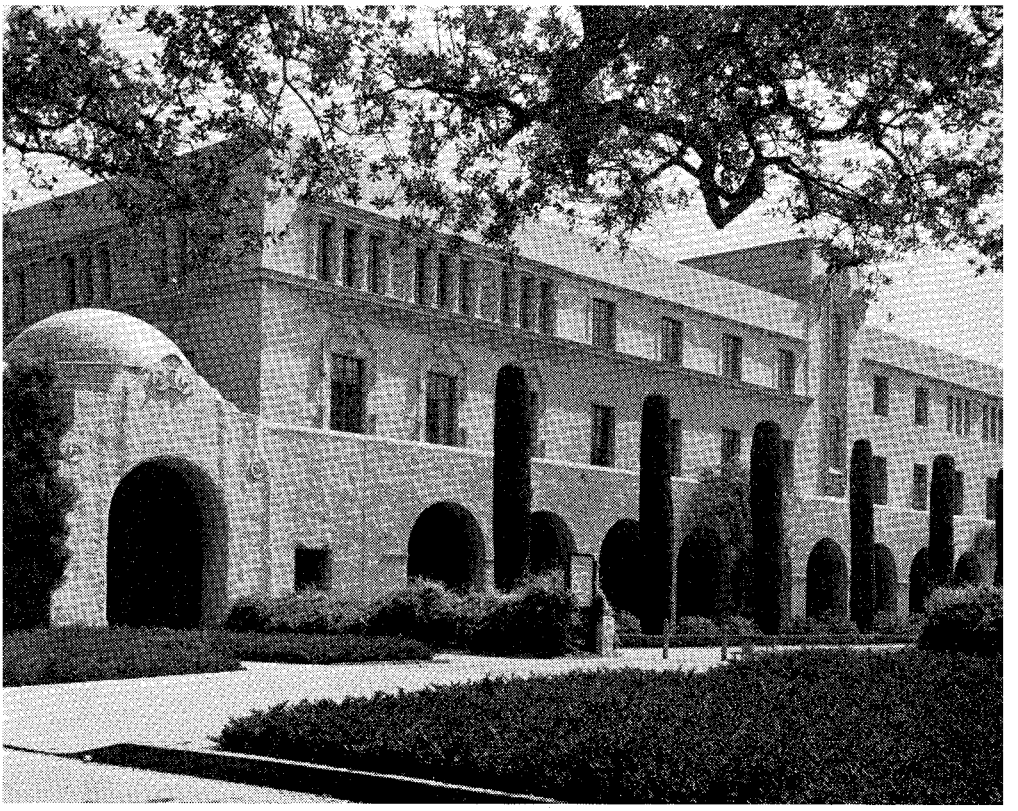
Macroscopic and microscopic structure of a mammal, including elementary instruction in preparation of tissue for microscopic inspection.

Instructors: Van Harreveld, Keighley.

Bi 22. Special Problems. Units to be arranged: first, second, and third terms.

Special problems in one of the fields represented in the undergraduate biology curriculum; to be arranged with instructor before registration.

Instructors: The Biology teaching staff.



Kerckhoff Laboratories of the Biological Sciences.

ADVANCED SUBJECTS

A. Subjects open to graduate students, but not to be counted toward a major for the degree of Doctor of Philosophy.

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

Prerequisite: Bi 4.

The subject deals mainly with vertebrate embryology and includes some invertebrate, experimental and cytological material.

Instructor: Tyler.

Bi 107 ab. Biochemistry. 11 units (3-3-5) second term; 15 units (3-4-8) third term.

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 or 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: Beadle.

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

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

Instructor: Lewis.

Bi 110. General Microbiology. 9 units (3-3-3); third term.

Prerequisites: Bi 2, Bi 107 a.

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: Bertani.

Bi 114. Immunology. 9 units (2-4-3); first term.

Prerequisites: Bi 2, Ch 41 abc.

A course on the principles and methods of immunology and their application to various biological problems.

Instructor: Owen.

Bi 115. Plant Physiology. 12 units (3-6-3); second term.

A study of physiological and biochemical processes in higher plants.

Instructor: Bonner.

Bi 116 ab. Animal Physiology. 8 units (2-3-3); first and second terms.

Prerequisites: Bi 4, Bi 20, Ch 41 to be taken simultaneously or previously.

A survey of comparative and mammalian physiology.

Instructors: Wiersma, Van Harreveld, Sperry.

Bi 117. Psychobiology 1. 9 units (3-3-3); third term.

Prerequisites: Bi 1.

An introduction to the biology of behavior with correlated laboratory study of the vertebrate nervous system. Offered in 1954-55 and alternate years.

Instructor: Sperry.

Bi 120. Mammalian Anatomy and Histology. 9 units; first term.

Prerequisite: Bi 4.

This subject is the same as Bi 20 but with reduced credit for graduate students. Graduate students majoring in Biology receive no credit for this subject.

Instructors: Van Harreveld, Keighley.

Bi 125. Topics in Plant Biology. 12 units (3-3-6); first term.

Special topics in plant physiology, plant biochemistry, and plant ecology.

Instructors: Bonner, Galston, Went.

Bi 126. Genetics of Microorganisms. 9 units (3-0-6); third term.

Prerequisites: Bi 107 and Bi 108.

A course dealing with the general genetics and biochemical genetics of Neurospora, bacteria, and viruses. Required of all graduate students majoring or minoring in genetics.

Instructors: Horowitz, Delbrück, and Staff.

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

A laboratory course dealing especially with Neurospora, to be taken concurrently with Bi 126. Given in alternate years. Not offered 1954-55.

Instructor: Horowitz.

Bi 128. Advanced Microtechnique. 6 units (1-4-1); third term.

Theory and practice of preparing biological material for microscopic examination; histochemical methods; phase contrast microscopy; methods in electron microscopy.

Instructor: Tyler.

Bi 129. Problems in Biophysics. 6 units (2-0-4); first term.

Effects of ionizing and ultraviolet radiation on vital functions; photoreactivation; photosynthesis; active transport; excitation.

Instructor: Delbrück.

B. Subjects primarily for graduate students.

Bi 201. General Biology Seminar. 1 unit; all terms.

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

In charge: Bonner, Lewis, Van Harreveld.

Bi 202. Biochemistry Seminar. 1 unit; all terms.

A seminar on selected topics and on recent advances in the field.

In charge: Mitchell.

Bi 204. Genetics Seminar. 1 unit; all terms.

Reports and discussion on special topics.

In charge: Anderson.

Bi 205. Experimental Embryology Seminar. 1 unit; all terms.

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

In charge: Tyler.

Bi 206. Immunology Seminar. 1 unit; all terms.

Reports and discussions; meets twice monthly.

In charge: Owen, Tyler.

Bi 207. Biophysics Seminar. 1 unit; all terms.

A seminar on the application of physical concepts to selected biological problems. Reports and discussions. Open also to graduate students in physics who contemplate minoring in Biology.

Instructor: Delbrück.

Bi 214 abc. Chemistry of Bio-Organic Substances. 3 units (1-0-2); first, second, and third terms.

Prerequisite: Ch 41 ab.

A series of lectures on selected topics of organic chemistry which have special interest from a biological viewpoint.

Instructor: Haagen-Smit.

Bi 217. Quantitative Organic Microanalysis. Units to be arranged; second term.

Laboratory practice in the methods of quantitative organic microanalysis required for structure determination of organic compounds. Students must obtain permission from the instructor before registering for this subject as the enrollment is necessarily limited.

Instructor: Haagen-Smit.

Bi 218. General Virology. 10 units (2-4-4); second term.

Prerequisites: Bi 1, Bi 2, Bi 110, and permission of instructor.

Structure of the viruses, biochemical processes involved in their synthesis, genetic properties of viruses and relationship of the genetic material of the viruses to the genetic material of the host cell.

Instructors: Dulbecco, Watson.

Bi 220 abc. Experimental Embryology. 6 units (2-0-4); first, second, and third terms.

Lectures and discussion of the problems of embryonic development, including such topics as growth of the ovary, breeding habits of animals, fertilization, cleavage, organ formation, metamorphosis, regeneration, tissue culture, embryonic metabolism, etc. The subject may be taken for two consecutive years since the subject matter will be duplicated only in alternate years.

Instructor: Tyler.

Bi 221. Experimental Embryology Laboratory. Units to be arranged; all terms.

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

Instructor: Tyler.

Bi 225. 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 two terms.

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

Bi 230. Psychobiology II. 9 units (3-3-3); third term.

Prerequisite: Bi 103 or equivalent.

An advanced course on the neural organization of behavior including laboratory study of the mammalian central nervous system. Offered in alternate years. Not offered in 1954-55.

Instructor: Sperry.

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

Reading and discussion of the problems of plant physiology.

Instructors: Went, Bonner, Galston.

Bi 241 abc. Advanced Biochemistry. 6 units (2-0-4); first, second, and third terms.

A survey of the biochemistry of higher plants.

Instructor: Bonner.

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

Prerequisites: Bi 5, Bi 115.

Discussion of the effects of 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 course in the methods of physiology, with special reference to nerve and muscle, with opportunity for research.

Instructors: Wiersma, Van Harreveld.

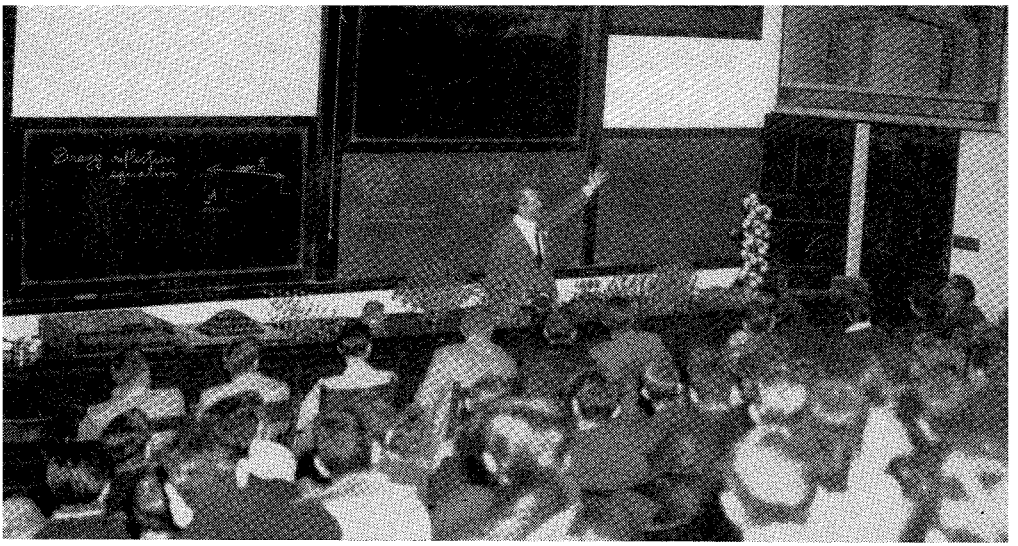
Bi 270. Special Topics in Biology. Units to be arranged. First, second and third terms.

Students may register with permission of the responsible faculty member.

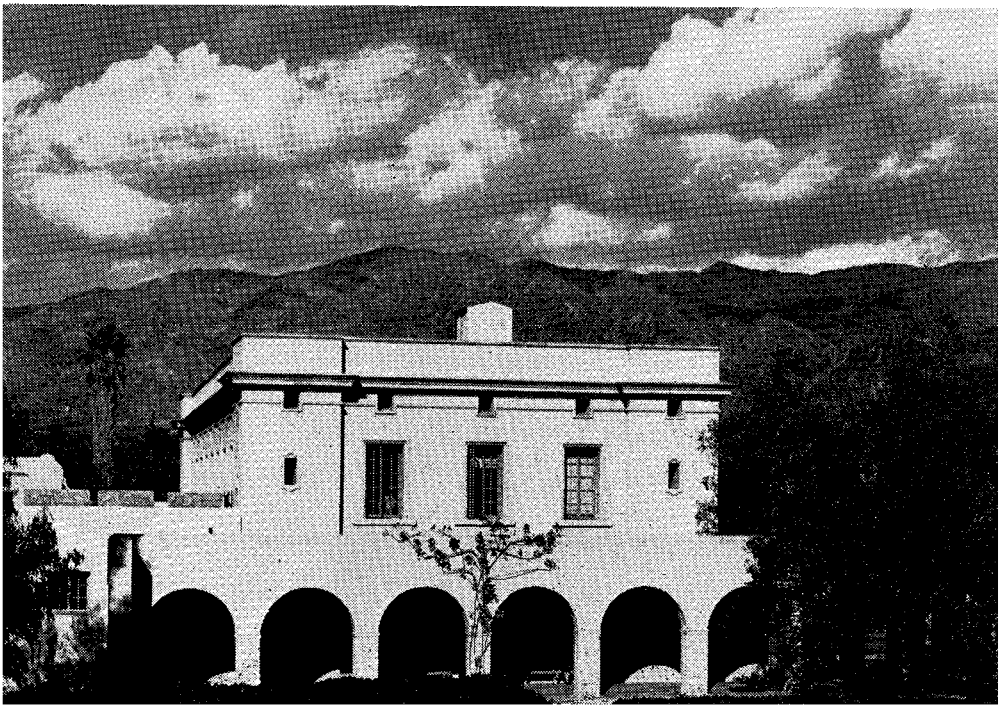
Bi 280-288. Biological Research. Units to be arranged. First, second, and third terms.

Students may register for research in the following fields after consultation with those in charge:

Animal physiology (280), biochemistry (281), bio-organic chemistry (282), embryology (283), genetics (284), immunology (285), marine zoology (286), plant physiology (287), biophysics (288).



A demonstration lecture in chemistry, and the Gates Laboratory of Chemistry.



CHEMISTRY AND CHEMICAL ENGINEERING

UNDERGRADUATE SUBJECTS

Ch 1 abc. Inorganic Chemistry, Qualitative Analysis. 12 units (4-4-4); 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 substances 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, Bergman, and Assistants.

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 and control and for research.

Instructor: Sturdivant.

Ch 20. Electric and Magnetic Properties of Molecules. 9 units (3-0-6); third term.

This course is designed especially for members of the sophomore honor section. Topics to be discussed include introduction to atomic and molecular structure; index of refraction and birefringence of substances in relation to the electronic polarizability of molecules; dielectric constant, diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism, Kerr effect, and other properties of substances in relation to electric dipole moments, magnetic moments, and other molecular properties.

Instructors: Pauling, Bergman.

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

Prerequisites: Ch 12 ab; 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 for Geologists. 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 abc. Radioactivity and Isotopes. 6 units (2-0-4); first, second, third 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.

Instructor: Yost.

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

Prerequisite: Ch 12 ab.

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: Roberts.

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

Prerequisite: Ch 12 ab.

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: Roberts 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.

Instructor: Corcoran.

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

Ch 90. Oral Presentation. 2 units (1-0-1); third term.

Training in the technique of oral presentation of chemical topics. Practice in the effective organization and delivery of reports before groups.

Instructors: Pauling, Thomas.

ADVANCED SUBJECTS

Ch 113 abc. Inorganic Chemistry. 4 units (2-0-2); first, second, third terms.

Selected groups of inorganic compounds will be considered from modern physicochemical 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; 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.

Prerequisites: 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 124 ab. Physical Chemistry for Geologists. 6 units (4-0-2); first, second terms.

This course is the same as Ch 24.

Instructor: Hughes.

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

This course is the same as Ch 27.

Instructor: Yost.

Ch 129. Surface and Colloid Chemistry. 8 units (3-0-5); third term.

Prerequisite: Ch 21 abc or equivalent.

Classroom exercises with outside reading and problems, devoted to the properties of surfaces and interfaces, and the general principles relating to disperse systems with particular reference to the colloidal state.

Instructor: Badger.

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

Prerequisite: Ch 21 abc.

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 132. Physical Chemistry in the Characterization of Proteins. 6 units (2-0-4); first term.

Prerequisite: Ch 21 abc, or equivalent.

A discussion of the principles and methods employed in the determination of the size, shape, charge, and thermodynamic properties of proteins. The methods considered are acid-base titrations, equilibrium dialysis, osmotic pressure, light scattering, sedimentation, diffusion, viscosity, and electrophoresis. The use of instruments will be demonstrated.

Instructor: Vinograd.

Ch 148 abc. Advanced Organic Chemistry. 4 units (2-0-2); first, second, third terms.

Prequisites: Ch 41 abc, Ch 46 abc.

Lectures and recitations emphasizing the analytical methods of organic chemistry. Consideration of the general problem of the characterization of organic compounds by qualitative and quantitative procedures.

Instructor: Niemann.

Ch 149 abc. Advanced Organic Chemistry Laboratory. 6 units (0-6-0); first, second, third terms.

Prerequisites: Ch 41 abc, Ch 46 abc, and consent of instructor.

Laboratory exercises to accompany Ch 148. The isolation, purification, and identification of organic compounds with special reference to the manipulation of milligram and decigram quantities. Qualified students may pursue research work.

Instructors: Niemann and Assistant.

Ch 163 ab. Chemical Engineering Thermodynamics. 8 units; second, third terms.

Prerequisite: Ch 21 abc or Me 15 abc.

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 quantitative problems involved in carrying out chemical reactions efficiently on a commercial scale. The unit operations of chemical industry (such as materials transfer, heat transfer, evaporation, filtration, distillation, drying) are studied both as to principle and practice.

Text: *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 abc, Ch 61, Ch 63 ab.

A laboratory course providing fundamental training in the methods and technique of engineering measurements and in research encountered by the chemical engineer.

Instructors: Sage, Reamer.

Ch 168 ab. Mechanics of Fluid Flow. 6 units. (2-0-4); second, third terms.

Prerequisite: Ch 166 a.

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

Instructor: Sage.

Ch 169. Advanced Industrial Chemistry. 6 units (2-0-4); first term.

Prerequisites: Ch 61, Ch 63 ab.

An extension of Ch 61 with emphasis on quantitative approaches to industrial chemical problems. Consideration is given to the more important chemical reactions of industrial interest. Chemical kinetics and material and energy balances are treated.

Instructor: Corcoran.

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 190. Oral Presentation. 2 units (1-0-1); first term.

Training in the technique of oral presentation of chemical topics; graduate teaching assistants in chemistry are required to take this course, unless excused for demonstrated proficiency.

Instructors: Thomas, Davidson.

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

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

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

In Charge: Pauling.

Ch 223 abc. Statistical Mechanics. 9 units (3-0-6); first, second, third terms.

After a survey of the principles of classical and quantum mechanics and of the theory of probability, the equilibrium theory of statistical mechanics is developed and used to interpret the laws of thermodynamics from the molecular standpoint. A detailed study of the relationships between the thermodynamic functions of gases, liquids, and solids and their structure on the molecular scale follows.

Given in alternate years. Offered in 1955-56.

Instructor: Davidson.

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

Prerequisite: Ch 21 abc or the equivalent.

Basic concepts and the laws of thermodynamics are reviewed. The theories of heterogeneous equilibrium and chemical equilibrium are developed according to the methods of Willard Gibbs. Methods of calculation of the thermodynamic functions of pure chemical substances and of components of real gas mixtures and liquid solutions are treated in a systematic manner. Heterogeneous equilibrium is interpreted analytically by means of the differential equations of the equilibrium lines and surfaces in phase diagram space. Chemical equilibrium in homogeneous real gas reactions, and in reactions in liquid solutions, is treated in detail. Attention is given to the important application of thermodynamics to electrochemical systems, surface phases, and to systems under the influence of external gravitational, electric, and magnetic fields. Problems.

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 in alternate years. Offered in 1955-56.

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

Instructor: Schomaker.

Ch 227 abc. The Structure of Crystals. 9 units (3-0-6); first, second, third terms.

The following topics are discussed.

The nature of crystals and x-rays and their interaction. The various experimental methods of investigation—Bragg, Laue, oscillation, Weissenberg, etc. The theory of space groups and the use of symmetry in the determination of the structures of crystals. The detailed study of representative structure investigations. The quantitative treatment of x-ray diffraction. Fourier-series methods of structure investigation.

Given in alternate years. Offered in 1955-56.

Instructor: Sturdivant.

Ch 228. Electron-Diffraction Method of Determining the Structure of Molecules. 6 units (2-0-4); first term.

The topics discussed are the interaction of electrons with atoms, molecules, and crystals, and the techniques of determining the structure of molecules by the electron-diffraction method.

Given in alternate years. Offered in 1956-57.

Instructor: Schomaker.

Ch 229 ab. X-Ray Diffraction Methods. 6 units (2-0-4); second, third terms.

Prerequisite: Ch 227 abc or equivalent.

An advanced discussion of the techniques of structure analysis by x-ray diffraction.

Given in alternate years. Offered in 1956-57.

Instructors: Hughes, Schomaker, Sturdivant.

Ch 233 ab. The Metallic State. 6 units (2-0-4); first, second terms.

The physical, electrical, and magnetic as well as the structural, chemical, the thermodynamic properties of metals and alloys considered from modern viewpoints.

Instructor: Yost.

Ch 234. Introduction to the Spectra of Molecules. 6 units (2-0-4); first term.

The theory of the structure of the spectra of both the diatomic and 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 1955-56.

Instructor: Badger.

Ch 235 abc. Chemical Kinetics. 6 units (2-0-4); first, second, third terms.

The mechanisms of the chemical reactions, as revealed by various methods, especially rate measurements and photochemical experiments, are discussed. Both theoretical and experimental aspects of the subject are studied. Topics include the transition state theory and the collision theory, unimolecular reactions, ionic reactions, modern experimental approaches to the nature of transient intermediates and elementary reactions, molecular structure and reactivity, catalysis, tracer studies, hydrodynamics and kinetics, combustion and detonation. In its later stages, the course is of the seminar type.

Instructor: Davidson.

Ch 245 ab. The Synthesis of Organic Compounds. 6 units (2-0-4); first, second terms.

A discussion of factors involved in preparative studies; followed by a consideration of the synthesis of organic compounds by classes. The assigned problems are designed, in part, to familiarize the student with the use of the literature.

Given in alternate years. Offered in 1956-57.

Instructor: Buchman.

Ch 246 abc. Theories of the Structures and Reactions of Organic Compounds. 4 units (2-0-2); first, second, third terms.

Prerequisites: Ch 41 abc, Ch 21 abc.

Theoretical organic chemistry with emphasis on methods for determination of reaction mechanisms and the application of the molecular orbital approach to problems of structure and reactivity.

Given in alternate years. Offered in 1955-56.

Instructor: Roberts.

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

Topics considered have included chromatography, fats, steroids, sex hormones, simple heterocyclic compounds and alkaloids, chlorophyll, carotenoids, anthocyanins, flavones, pterins, bile pigments; natural products with quinoid structure; structure and physiological action; chemistry of the chemotherapeutics and of the insecticides; detoxification processes, nitrogen metabolism, carbohydrate metabolism, sugar phosphates, nucleotides, 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 abc, Ch 46 abc.

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

Given every third year. Offered in 1956-57.

Instructor: Niemann.

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

Prerequisites: Ch 41 abc, Ch 46 abc.

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

Given every third year. Offered in 1955-56.

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 262 abc. Thermodynamics of Multi-Component Systems. 8 units (2-0-6); first, second, third terms.

Prerequisite: Ch 166 abc, AM 15 ab, Ch 63 ab or equivalent.

A presentation of the background necessary for a working knowledge of multi-component open systems from the engineering viewpoint. A discussion of the volumetric and phase behavior of pure substances, and of binary, ternary, and multi-component fluid systems at physical and chemical equilibrium is included as a part of this thermodynamic treatment. The solution of numerous problems relating to the application of these principles to industrial practice constitutes a part of this course.

Texts: *Volumetric and Phase Behavior of Hydrocarbons,* Sage and Lacey; *Thermodynamics of Multi-component Systems,* Sage.

Instructor: Sage.

Ch 263 abc. Transfers in Fluid Systems. 12 units (2-2-8); first, second, third terms.

Prerequisites: Ch 166 abc, AM 15 ab, Ch 168 ab or equivalent.

A consideration of thermal and material transfers in fluid systems under conditions encountered in practice. Emphasis is placed upon point conditions and upon the analogies between momentum, thermal, and material transfers in turbulent flow. The greater part of the effort in the course is devoted to the solution of transfer problems many of which require the use of graphical or numerical methods for solution of the nonlinear differential equations involved. A two hour computing period is provided during one afternoon each week in order to familiarize the students with these mathematical methods. Limited use is made of automatic computing equipment.

Given in alternate years. Offered in 1956-57.

Instructor: Sage.

Ch 266 abc. Applie dChemical Kinetics of Homogeneous and Heterogeneous Reactions. 8 units (2-0-6); first, second, third terms.

Prerequisite: Ch 166, and Ch 262 is desirable.

Kinetics of various reactions, considering especially the behavior of catalysts and the characteristics of systems at elevated pressures. Primary emphasis will be placed upon predicting the course of chemical reaction under the conditions encountered in processing operations. The third term will deal in part with combustion processes and flames. Offered to third or fourth year graduate students in chemical engineering.

Given in alternate years. Offered in 1956-57.

Instructor: Corcoran.

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 inorganic analytical methods.

The kinetics of chemical reactions including photochemical reactions.

The determination of the structure of crystals and gas molecules by the 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 nature of the metallic bond and the structure of metals and intermetallic compounds.

Studies of radioactivity.

Investigation of the properties of the transuranic elements.

Microwaves and nuclear resonance.

(In organic chemistry)

Studies of the mechanism of organic reactions in relation to electronic theory.

Kinetics and equilibria of addition reactions of unsaturated compounds.

Coordination reactions of unsaturated compounds.

Sulfinyl and phosphinyl chlorides.

Isolation of alkaloids and determination of their structure.

The synthesis of substances related to cyclobutadiene.

Studies of the mechanism of the Walden inversion.

The chemistry of amino acids and peptides.

The constitution of the phosphatides and cerebrosides.

The chemistry of carotenoids and other plant pigments.

The use of chromatographic methods of analysis and separation of stereoisomers.

Diphenylpolyenes.

Chemistry of small-ring carbon compounds.

Application of isotopic tracer techniques to problems in organic chemistry.

Relation of structure to reactivity of organic compounds.

(In immunochemistry and other fields of application of chemistry to biological and medical problems)

The study of the mechanism of antigen-antibody reactions and the structure of antibodies.

The functional significance of antibodies.

The chemical and physical properties of blood.

Investigation of plasma substitutes.

The isolation and characterization of cellular antigens.

Studies on the enzymatic cleavage and formation of amide bonds.

Chemical analysis of proteins and determination of the order of amino-acid residues in polypeptide chains.

The crystal structure of amino acids, peptides, and proteins.

Correlation of Vitamin A potency with molecular configuration.

Investigation of fluorescent compounds in plants and animals, including microorganisms.

The study of plant hormones and related substances of physiological importance.

Investigation of mammalian and bacterial polysaccharides including the blood-group specific substances.

The chemistry of protozoa.

Chemotherapy of parasitic diseases.

The nature of sickle cell anemia and other hemolytic 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.

Studies of non-equilibrium behavior of fluid systems at elevated pressure.

Reaction kinetics.

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.

Ch 291 abc. Chemical Engineering Seminar. 2 units (1-0-1); first, second, third terms.

Oral presentations of industrial chemistry and chemical engineering problems of current interest.

Instructor: Corcoran.

CIVIL ENGINEERING

UNDERGRADUATE SUBJECTS

CE 1. Surveying. 12 units (2-6-4); third term.

A study of the elementary operations employed in making surveys for engineering work, including the use, care, and adjustment of instruments, linear measurements, angle measurements, note keeping, stadia and plane table surveys, calculation and balancing of traverses, topographic mapping and field methods. Triangulation, base line measurements, determination of latitude and a true meridian by sun and circumpolar star observations, stream gauging. Route location of highways.

Text: *Surveying,* Breed.

Instructor: Michael.

CE 4. Highways and Airports. 10 units (2-4-4); first 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 Engineering,* Ritter and Paquette.

Instructor: Michael.

CE 5. Hydrology. 6 units (2-0-4); second term.

Fundamental to an understanding of water supply, irrigation, flood control, drainage, water power, river and harbor regulation and many other phases of civil engineering, this subject deals with the forces and factors that control the occurrence of water in nature, including precipitation, evaporation, transpiration, infiltration, percolation, ground water, and flood flows.

Instructor: Brooks.

CE 7. Curves and Earthwork. 6 units (2-0-4); third 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: *Railroad Curves and Earthwork,* Allen.

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.

Instructors: Martel, McCormick.

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.

Instructor: McKee.

CE 15. Soil Mechanics. 6 units (2-0-4); first term.

A study of the physical characteristics of soil, including origin, methods of classification and identification, permeability, seepage forces, consolidation, and one-dimensional settlement.

Text: *Fundamentals of Soil Mechanics,* Taylor.

Instructor: Converse.

CE 20. Introduction to Sanitary Engineering. 6 units (2-0-4); third term.

Prerequisite: Hy 2 ab.

An introduction to the problem of supply, treatment and distribution of water for municipal use and irrigation purpose; and to the problems of collection, treatment, and disposal of municipal sewage and liquid industrial wastes.

Instructor: McKee.

ADVANCED SUBJECTS

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

Prerequisite: CE 115 a.

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.

CE 115 a. Soil Mechanics. 9 units (2-3-4); first term.

Prerequisite: AM 1 abcd.

A study of the physical characteristics of soil, including origin, methods of classification and identification, permeability, seepage forces, consolidation, and one-dimensional settlement. Basic laboratory tests of soils will be performed.

Text: *Fundamentals of Soil Mechanics,* Taylor.

Instructor: Converse.

CE 115 b. Soil Mechanics. 9 units (3-0-6); second term.

Prerequisite: CE 115 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 footing, piles, stability of slopes, earth dams, highways and airport runways.

Instructor: Converse.

CE 120 a. Statically Indeterminate Structures. 12 units (3-3-6); first term.

Prerequisites: CE 10 abc, CE 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.

Instructor: Martel.

CE 120 bc. Statically Indeterminate Structures. 6 or more units as arranged (2-0-4); any term.

A continuation of the study of indeterminate structures as begun in CE 120 a with the use of analytical and instrumental methods of solution.

Instructor: Martel.

CE 121 a. Structural Design. 9 units (0-9-0); first term.

Prerequisites: CE 10 abc, CE 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); second term.

Prerequisites: CE 10 abc, CE 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); third 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. 6 or more units as arranged; any term.

A comparison of the analytical study and the experimental effects of vibrations on simple structures with the actual effects of earthquakes upon buildings.

Instructor: Martel.

CE 125. Water Supply, Utilization, and Drainage. 9 units (3-0-6); third term.

Prerequisites: Hy 2 ab; Hy 11; CE 20.

A study of the principles involved in the collection, storage, and distribution of water for municipal use and irrigation, and the removal of storm waters, municipal sewage, and excess irrigation waters; design, construction, and operation of systems; dams, reservoirs, canals; water rights and stream administration; the economic aspects of projects.

Instructor: McKee.

CE 126. Masonry Structures. 9 units (2-3-4); second term.

Prerequisite: CE 12.

Theory of design and methods of construction of masonry structures; foundations, dams, retaining walls, and arches.

Instructors: Martel, McCormick.

CE 127. Theory of Water and Waste Treatment. 9 units (2-3-4); first term.

Prerequisite: CE 20.

A study of the chemical, physical, and biological phenomena involved in the treatment of water, sewage, and liquid industrial wastes; water quality criteria, testing procedures, coagulation, flocculation, sedimentation, disinfection, softening, corrosion control, biological oxidation, and miscellaneous treatment.

Instructor: McKee.

CE 129. Spring Field Trip. 1 unit (0-1-0); week between second and third terms.

An inspection tour of the waterworks structures of the lower Colorado River basin, including the Regional Salinity Laboratory of the Department of Agriculture, Imperial Irrigation District and Dam, Parker Dam and pumping facilities of the Metropolitan Water District, Davis Dam, Hoover Dam, and the work of the USBR River Control Section.

Required of all graduate students in Civil Engineering.

CE 130 ab. Civil Engineering Seminar. 1 unit (1-0-0); first, second terms: 4 units (0-4-0); third term.

Conferences participated in by faculty and graduate students of the Civil Engineering department. The discussions cover current developments and advancements within the fields of civil engineering and related sciences, with special consideration given to the progress of research being conducted at the Institute. Inspection trips.

CE 131. Design of Water and Waste Treatment Plants. 9 units (2-3-4); second term.

Prerequisite: CE 127.

Application of the theories of water and waste treatment to the functional design of treatment works; screening, settling basins, flocculators, filters, chemical application, activated sludge processes, trickling filters, oxidation ponds, sludge digestion and disposal, and the design of discharge structures.

Instructor: McKee.

CE 132. Water Power Engineering. 9 units (2-3-4); second term.

Prerequisite: CE 5 or CE 155.

The applications of hydraulics and hydrology to the development of hydroelectric power. Determination of firm and secondary power from available streamflow. Design of power reservoir. Hydraulic turbines, penstocks, draft tubes, governors. Water hammer and cavitation problems. Design of power plant at a particular site.

Instructor: Brooks.

CE 134. Ground Water Hydraulics. 9 Units (3-0-6); third term.

Prerequisite: AM 15 ab or AM 115 ab.

A systematic study of the mechanics of ground water flow, with applications to various engineering problems, including seepage through earth dams and levees, uplift on foundations, flow toward wells, natural and artificial ground water recharge, and dewatering for excavations. Emphasis is placed on flow net analysis and mathematical methods.

Instructor: Brooks.

CE 135. Geodesy and Precise Surveying. 6 or more units as arranged; 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 141. Structural Engineering Research. 6 or more units as arranged; any term.

Selected problems and investigations to meet the needs of advanced students.

Instructor: Martel.

CE 142. Sanitation Research. 6 or more units as arranged; 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. 6 or more units as arranged; 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. 6 or more units as arranged; 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. 9 units (3-0-6); third term.

Prerequisite: CE 115 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 pneumatic caissons, cofferdams, underpinning, methods of exploration.

Instructor: Converse.

CE 155. Hydrology. 9 units (3-0-6); first term.

Prerequisite: CE 125.

Detailed studies of climatology, precipitation, run-off, transpiration, flood flows and flood forecasting, with special emphasis on statistical analysis.

Instructor: Brooks.

CE 156. Industrial Wastes. 9 units (3-0-6); third 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.

CE 300. Civil Engineering Research.

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 problem they present. Subjects studied include production, exchange, distribution, money and banking, the economic activities and policies of government, and international trade.

Instructor: Brockie.

Ec 2 ab. General Economics and Economic Problems. 9 units (3-0-6).

The same course as Ec 1 abc, given in two terms instead of three.

Instructors: Brockie, Grey.

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.

Instructor: Sweezy.

Ec 13. Reading in Economics. Units to be determined for the individual by the department.

Ec 18. Industrial Organization. 7 units (3-0-4); 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.

Instructor: 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: Chaitkin.

Ec 48. Introduction to Industrial Relations.* 9 units (3-0-6).

Senior Elective.

This course stresses the personnel and industrial relations functions and responsibilities of supervisors and executives. The history, organization, and activities of unions and the provisions of current labor legislation are included. The relationships of a supervisor or executive with his employees, his associates, and his superiors are analyzed, and the services which he may receive from the personnel department are examined. The course also discusses the use of basic tools of supervision.

Instructor: Gray.

ADVANCED SUBJECTS

Ec 100 abc. Business Economics. 10 units (4-0-6); first, second, third terms.

Open to graduate students.

This course endeavors to bridge the gap between engineering and business, especially industry. It is intended for two groups of technically trained students: 1) those who wish sooner or later, to take advantage of opportunities in industry beyond their strict technical fields, and 2) those who will be engaged in teaching and in scientific research, but who wish to get an understanding of industry in both its technical and philosophical aspects.

*The 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 contributons to the improved functioning of the economy.

The principal divisions of the subject matter of the courses are: 1) business organization, 2) industrial promotion and finance, 3) factory management, 4) industrial sales, and 5) business economic topics, especially the business cycle. This treatment provides a description of the industrial economy about us and of the latest management techniques. The points of most frequent difficulty are given special study. The case method of instruction is used extensively in the course.

Instructor: Gilbert.

Ec 106 abc. Business Economics (Seminar). Units by arrangement; first, second, third terms.

Open to graduate students.

This seminar is intended to assist the occasional graduate student who wishes to do special work in some part of the field of business economics or industrial relations. Special permission to register for this course must be secured from the instructors.

Instructors: Gilbert, Gray.

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.

Instructor: Gray.

Ec 111. Business Cycles and Governmental Policy. 9 units (3-0-6); second term.

A study of the nature, causes, and possible control of economic fluctuations with special emphasis on the interrelationship of business cycles and such fiscal matters as national debt control, national budgetary control, and the maintenance of high levels of employment, production, and purchasing power. The course also integrates the international problems of war, reconstruction, trade, and investment with the analysis of business cycles and internal fiscal policies in order to provide a unified theory of national and international economic equilibrium. May be taken as a senior elective.

Instructor: Brockie.

Ec 112. Modern Schools of Economic Thought. 9 units (3-0-6); third term.

A study of economic doctrine in transition, with particular emphasis on the American contribution. Against a background of Marshall and Keynes, a critical examination will be made of the institutional, collective, quantitative, social, experimental, and administrative schools of economics.

Ec 120 abc. Dynamics of the American Economy. 9 units (3-0-6); first, second, third terms.

A study of the causes of high productivity, fluctuations in prices and business volume, the expansion of the economic role of government, and the dominant position of the United States in the world economy. Special attention to scientific and technological advance, population growth, and war or defense spending as they affect the American economy.

Instructor: Sweezy.

Ec 126 abc. Economic Analysis and Policy (Seminar). Six units or more as arranged; first, second, third term.

Open to students who have taken Ec 120 or to other qualified students with the consent of the instructor.

This seminar is designed to give students who already have some training in economics an opportunity to discuss and analyze selected problems of economic policy, both national and international.

Instructor: Sweezy.

ELECTRICAL ENGINEERING

UNDERGRADUATE SUBJECTS

EE 1 abc. Basic Electrical Engineering. 9 units (3-0-6); EE 1 a 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 and Assistants.

EE 2 ab. Basic Electrical Engineering Laboratory. 3 units (0-3-0); second, third terms.

Prerequisites: Ma 2 abc; Ph 2 abc.

This course is the laboratory for 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 and Assistants.

EE 4 ab. Basic Electrical Engineering. 6 units (2-0-4); EE 4 a first term only, EE 4 bc second or third terms.

Equivalent to EE 1 abc with reduced units for non-engineering students.

Instructor: Maxstadt.

EE 6 ab. Electro-Mechanical Devices. 6 units (2-0-4); second term; 9 units (3-0-6) third term.

Prerequisites: EE 1 abc; EE 2 abc and EE 12.

A general study of electromechanical energy conversion methods and devices, including typical rotating machinery and various transducers. Brief study of transformers and of power transmission lines. Emphasis is upon physical principles rather than upon details of design.

Text: *Electric Machinery*, Fitzgerald and Kingsley

Instructor: McCann.

EE 6 ab. Electro-Mechanical Devices. 6 units (2-0-4); second term; 9 units

Prerequisites: EE 1 abc; EE 2 abc; and enrollment in EE 6.

Laboratory experiments with energy conversion devices of various types to illustrate the principles studied in EE 6.

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.

Instructor: McCann.

EE 15 abc. Electromagnetism. 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. Topics covered include electrostatics, magnetostatics, Maxwell's equations, waveguides, cavity resonators, and antennas.

Text: Course Notes.

Instructor: Langmuir.

EE 16. Electrical Measurements. 6 units (2-3-1); first term.
Prerequisites: Ph 2 abc; EE 1 abc.

Advanced course in precision electrical measurements and their accuracy. Theory and practice of the treatment of errors; sources of error, Gaussian and other distributions, probable errors and confidence intervals, least-squares curve fitting. Laboratory experiments illustrating the use of precision measuring equipment and the estimation of errors.

Text: Class and Laboratory Notes.

Instructors: Martel 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.

Instructor: McCann.

ADVANCED SUBJECTS

EE 120 abc. Advanced Electric Power System Analysis. 9 units (3-0-6). Three terms.

This course is devoted to the study of electric circuit theory as applied to the basic problems encountered in the design and operation of modern power transmission and distribution systems.

Texts: *Electrical Transmission and Distribution Reference Book* and Course Notes.

Instructors: McCann, Lindvall.

EE 120 a. 9 units (3-0-6); 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. 9 units (3-0-6); 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. 9 units (3-0-6); 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 lighting. 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 122. Power Distribution. 6 units, supervised reading course by assignment.

Basic elements of modern distribution system; unit substations, underground distribution, switchgear and protective devices. Application of fireproof equipment in hazardous areas.

Instructor: Maxstadt.

EE 124. Specifications and Design of Electrical Machinery. Units to be arranged.

Prerequisites: EE 7, and preceding subjects.

Preparation of specifications and design calculations for alternating and direct current machinery.

Text: *Electrical Machine Design*, Gray.

EE 132 abc. Circuit Analysis. 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 12; EE 60.

Transient analysis of linear networks; Laplace transform methods; generalized network analysis.

Instructor: Pickering.

EE 140. Electric Communication. 6 units (2-0-4); first term.

Prerequisites: EE 12; EE 60.

A study of selected topics in communication with special emphasis on recent developments.

Instructors: Pickering and Martel.

EE 141. Communications Laboratory. 6 units (0-3-3); first term.

Prerequisite: Must be taking or have taken EE 140.

Laboratory assignments in advanced communication problems.

Instructors: Pickering and Martel.

EE 150 abc. Electromagnetic Fields. 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 160; EE 15.

An advanced course in classical electromagnetic theory and its application to guided waves, cavity resonators, antennas, artificial dielectrics, propagation in ionized media, propagation in anisotropic media, magnetohydrodynamics, and to other selected topics of research importance.

Text: Course Notes.

Instructor: Papas.

EE 160 abc. Electronics and Circuits. 9 units (3-0-6) first term; 9 units (2-3-4) second and third terms.

Prerequisite: EE 1 abc. (EE 4 abc for Physics majors.)

Physical electronics and introduction to theory of solid state. Fundamental theory of electron tubes and applications to communication and control circuits.

Instructor: Langmuir.

EE 164 abc. Physical Electronics and Circuits. 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 60; Ph 7 or EE 15.

Electron optics of electrostatic and magnetic fields, space charge effects including waves, beam spread, production and focussing, plasma oscillations, space charge and kinematic analysis of klystrons, reflex tubes, and slow wave interaction systems. The Llewellyn-Peterson equations and their application to high frequency and microwave diodes and multigrid tubes. The analysis and relation of transient and steady state response in amplifiers by Laplace Transform techniques. Brillouin flow beam systems and magnetron relations. Generalized energy exchange theorems for stream to stream, and stream to wave interactions. Thermal noise energy in streams and general thermal noise considerations. Streams in the presence of a generalized impedance wall. The electromagnetic theory of slow wave propagating wave guides and helical systems. The design of amplifiers and amplifier interstages by complex frequency techniques and the potential analogy.

Texts: *Vacuum Tubes.* Spagenberg; *Electron Beam and T.W. Tubes,* Pierce; *Vacuum Tube Amplifiers,* Valley and Wallman; and Course Notes on interaction theory.

Instructor: Field.

EE 165 a. Ultra High Frequency Laboratory. 6 units (0-3-3); third term.

Prerequisites: EE 150 and EE 164, or be enrolled for them; EE 15.

Covering experiments on microwave generation, bridges, precise impedance measurement, nodal shift methods, and the properties of microwave circuit elements such as matched T's, directional couplers and antennas.

Instructor: Field.

EE 170 abc. Instrumentation and Control Systems. 9 and 12 units (3-0-6) (3-3-6) (3-3-6).

EE 170 abc. Feedback Control Systems. 9 units (3-0-6); first term; 12 units (3-3-6); second and third terms.

A study of automatic feedback control systems. Basic theory and methods of analysis and synthesis; the Nyquist criterion, root locus methods, and analog computer techniques. Multiple loop systems. Non-linear systems with emphasis on phase plane and describing function techniques. Statistical methods and noise problems. Practical electrical, mechanical and hydraulic components. The laboratory experiments are designed to acquaint the student with characteristics of practical components, but emphasis is placed on a correlation of observed response with predictions based on the various theoretical methods.

EE 180 abc. Methods of Machine Computation in Engineering Analysis. 12 units (3-3-6); first, second, third terms.

General survey of the basic principles of analog and digital computing techniques. Development and application of electronic differential analyzer principles. Development and application of direct analogy computer principles. Methods of general circuit synthesis for systems of active and passive form. Analog techniques for non-linear mechanics. Methods of instrumentation and requirements for computer components. Development and application of digital machine methods of numerical analysis. Basic principles of logical design and instrumentation for digital computers. Application of machine computing methods to complex system analysis.

Instructors: McCann, Wilts.

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; electrical Engineering Problems relating to physical electronics, electronic devices and their application; Engineering Analysis problems requiring large scale computer techniques, A.C. network techniques, Analog and Transient studies, etc. Problems relating to the distribution and uses of electric power for lighting and industrial uses; studies of light sources and illumination.

EE 220. Research Seminar in Electrical Engineering. 2 units.

Meets once a week for discussion of work appearing in the literature and in industry. All advanced students in electrical engineering and members of the electrical engineering staff are expected to take part.

In charge: Electrical Engineering Faculty.

EE 240 abc. Communication and Information Theory. 9 units (3-0-6).

Prerequisite: EE 132 abc.

Basic theory of communication of information; probability; random phenomena; entropy and channel capacity; coding and modulation methods; correlation functions and harmonic analysis; spectral density; effects of linear and non-linear circuits; noise, its origins and mathematical models; design of optimum linear circuits (based mainly on Wiener's work).

Text: Mimeographed Notes.

Instructors: Ramo, Martel.

EE 250 abc. Advanced Electromagnetic Field Theory. 9 units (3-0-6); first, second, third terms.

This course covers the applications of Maxwell's equations to problems involving antennas, waveguides, cavity resonators, and diffraction. It includes the solution of problems by the classical methods of retarded potentials and orthogonal expansions and lectures in the modern techniques of Schwinger that employ the calculus of variations and integral equations.

Text: *Static and Dynamic Electricity*, Smythe; *Randwertprobleme der Mikrowellenphysik*, Borgnis and Papas.

Instructors: Smythe, Papas.

EE 260 abc. Advanced Course in Physical Electronics. Units to be arranged.

Prerequisite: EE 164.

Aberrations in focussing systems. Oscillations around Brillouin Flow conditions. Space charge waves at Brillouin and Intermediate Flow. The exact analysis of the klystron and reflex tubes. The large signal analysis (non-linear) of micro-wave tubes. Cyclotron resonance forms of interaction. Cherenkow and other relativistic interaction mechanisms. Effects on interaction devices of loss, space charge, high gain per wavelength, finite transverse dimensions, and finite magnetic fields.

Instructor: Field.

EE 262 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 60 abc; Ph 7; 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.

Offered 1956-57.

Instructor: Ramo.

EE 264 abc. Radio Engineering. 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 15 ab; EE 60 abc, 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.

EE 280 abc. Advanced Course in Electrical Computing Methods. 9 units (2-3-4); first, second, third terms.

Prerequisite: EE 180.

A continuation of EE 180 with emphasis on advanced theory of electrical analogies.

Instructors: Wilts, MacNeal, McCann.

EE 290 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.

ENGINEERING GRAPHICS

Gr 1 a. Engineering Graphics. Basic Graphics. 3 units (0-3-0); first term.

The study of geometrical forms and their representation by means of freehand orthographic and perspective drawings. Instruction includes the techniques of freehand pencil rendering, lettering forms, analysis of the elements of three-dimensional shapes and their proportional relationships, introduction to the principles of orthographic and perspective projection, principal views, visualization, shading techniques, sections and conventions. Problems are given involving the drawing of basic geometrical forms, machine parts and scientific apparatus. Emphasis is placed on a constructive approach, careful observation and accuracy.

Text: *Graphics in Engineering and Science,* Levens.

Instructors: Welch, Wilcox.

Gr 1 b. Applied Graphics. 3 units (0-3-0); second term.

Prerequisite: Gr 1 a.

This course is a continuation of Gr 1 a and is designed to give the student a general knowledge of the most important types of technical drawings, to develop further his ability to visualize in three-dimensions and to give him an introduction to descriptive geometry. Subjects of instruction include single, double auxiliary and axiometric projection, sections and theory of dimensioning. Most of the work is done with the aid of instruments, but the ability of the student to do freehand construction and to use other abbreviated methods is taken advantage of as a time-saving device. Assigned problems represent fields of interest in both science and engineering.

Text: *Graphics in Engineering and Science,* Levens.

Instructors: Welch, Wilcox.

Gr 1 c. Applied Graphics. 3 units (0-3-0); third term.

Prerequisite: Gr 1 ab.

The course is designed to supplement the material given in Gr 1 ab, and to extend the work in descriptive geometry as a means of solving more difficult three-dimensional space relationships. Instruction is given in directional determination and true lengths of lines, parallelism and perpendicularity, point to line and line to line measurements, determination of angles, relationships between points, lines and planes; projection, rotation, and the development of ruled surfaces. Problems are from the various fields of engineering and science.

Text: *Graphics in Engineering and Science,* Levens.

Instructors: Welch, Wilcox.

Gr 5. Descriptive Geometry. 6 units (0-6-0); third term.

Prerequisite: Gr 1 abc.

The course is primarily for geology students and is designed to supplement the study of shape description as given in Gr 1 abc and to present a graphical means of solving the more difficult three-dimensional problems. The student reviews geometrical relationships of straight lines and planes, then advances to curved lines, single and double curved surfaces, warped surfaces and intersections. Methods of combining the analytical solution of the simpler problems with the graphical solution are discussed and applied. Emphasis is placed throughout the course on practical problems in mining and earth structures and on the development of an ability to visualize in three dimensions.

Instructors: Tyson, Wilcox.

Gr 7. Advanced Graphics. Maximum of 6 units. Elective; any term.

Prerequisite: Gr 1 abc; ME 1.

Further study in the application of graphics to the solution of engineering problems and in the basic elements of design for production. Emphasis is placed on one of the following subjects to be selected as the need requires: analysis of the more complex machine mechanisms; basic elements of product design; graphical solution of vector problems, graphical calculus; nomography.

Instructors: Tyson, Welch.

ME 1. Empirical Design. 9 units (0-9-0); first, second or third terms.

See page 285.

ENGLISH

English composition is prescribed for all students in the freshman year, and an introduction to literature is prescribed for all students in the junior year. In the senior year the students are offered a number of options in English, American, and European literature.

The instruction in composition is intended to give a thorough training in both writing and speaking. The instruction in literature is intended to provide an appreciate acquaintance with some of the chief works of major authors, past and present, and to foster the habit of self-cultivation in books.

The regular courses in English do not exhaust the attention given at the Institute to the student's use of the language; all writing, in whatever department of study, is subject to correction with regard to English composition.

UNDERGRADUATE SUBJECTS

En 1 abc. 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, Mayhew, Stanton, Piper.

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, Mayhew, Piper, Smith, Stanton.

En 8. Contemporary English and European Literature.* 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

A survey of English and Continental literature from 1859 to the present time. Emphasis is placed on the influence of science, particularly biological and psychological theory, on content and techniques.

Instructor: Eagleson.

En 9. American Literature.* 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

A study of major literary figures in the United States from Whitman and Mark Twain to those of the present time. The larger part of the course is concerned with contemporary writers. An emphasis is placed on national characteristics and trends as reflected in novel and short story, biography, poetry and drama.

Instructor: Langston.

En 10. Modern Drama.* 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

A study of leading European, British, and American dramatists from Ibsen to writers of the present time. Special attention is given to dramatic technique, and to the plays both as types and as critical comments upon life in the late nineteenth and twentieth centuries.

Instructors: Huse, Stanton.

En 11. Literature of the Bible.* 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

A study of the Old and New Testaments, and the Apocrypha, exclusively from the point of view of literary interest. The history of the English Bible is review, and attention is brought to new translations. Opportunity is offered for reading modern fiction, poetry, and drama dealing with Biblical subjects.

Instructors: Smith, Huse.

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

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: Thomas.

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.

Instructor: Hutchings.

En 16. Spelling. No credit.

This subject may be prescribed for any student whose spelling is unsatisfactory.

En 17. Technical Report Writing.* 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

Practice in writing reports and articles in engineering, science, or business administration. The course includes some study of current technical and scientific periodicals. The major project is the preparation of a full-length report.

Instructor: Piper.

En 18. Modern Poetry.* 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

A study of three or four major poets of the twentieth century, such as Yeats, T. S. Eliot and W. H. Auden. Modern attitudes toward the world and the problem of Belief. Some consideration of recent theories of poetry as knowledge.

Instructors: Smith, Clark.

En 19. Seminar in Literature.* 9 units (3-0-6); second term.

Senior elective. Prerequisite: En 7.

The subject matter of this course arises from the interest of the students registered in any given term. Each student is required to give a long oral report to the class on some humanistic subject selected by himself with the approval of the instructor. The number registered for the course in any term is strictly limited and is by permission of the instructor. Hours by arrangement.

Instructor: Eagleson.

En 20. Summer Reading. Units to be determined for the individual by the department. Maximum 8 units. Elective.

Reading in literature, history, philosophy, and other fields during summer vacation, books to be selected from a recommended reading list, or in consultation with a member of the staff. Critical essays on the reading will be required.

ADVANCED SUBJECTS

En 100 abc. Seminar in Literature. 9 units (2-0-7); first, second, third terms.

A survey of recent critical methods, from I. A. Richards to the present time, and the application of these methods to the work of such major writers as Joyce, Yeats, Eliot and Mann. The influence of modern psychology and anthropology on creative writing and criticism.

Instructor: Smith.

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

FRENCH

(See under Languages)

GEOLOGICAL SCIENCES

UNDERGRADUATE SUBJECTS

Ge 1. Physical Geology. 9 units (4-2-3); first term.

Prerequisites: Ch 1 abc, Ph 1 abc.

An introduction to the basic principles of the earth sciences. Geology, geochemistry, and geophysics in relation to materials and processes acting upon and within the earth's crust. Consideration is given to: rocks and minerals, structure and deformation of the earth's crust, earthquakes, volcanism, and the work of wind, running water, ground water, the oceans and glaciers upon the earth's surface with the aim of stimulating the students' interest in the geological aspects of the environment in which he will spend his life.

Text: *Principles of Geology*, Gilluly, Waters, and Woodford.

Instructors: Allen, Sharp, and Teaching Fellows.

Ge 2. Geophysics. 9 units (3-0-6); third term.

Prerequisites: Ge 1, Ma 2 ab, Ph 2 ab.

A selection of topics in the field of geophysics using, as fully as possible, the prerequisite background. Included are consideration of the earth's gravity and magnetic fields, geodesy, seismology, and the deformation of solids, tides, thermal properties, radioactivity, age determinations, the continents, the oceans, and the atmosphere. Observations followed by their analysis in terms of physical principles.

Instructor: Press.

Ge 3. Materials of the Earth's Crust. 9 units (3-0-6); second term.

Prerequisites: Ge 1, Ch 1, Ph 1.

A study of the fundamental structure of minerals, rocks and other earth materials and of their behavior under the varying physical conditions of the earth's crust. Topics discussed include crystallography, stability relations of minerals, solid-state transformations, and mechanisms of material transfer with strong emphasis on the basic atomistic relations. This course is intended to provide fundamental information needed for subsequent studies in mineralogy, petrology, and structural geology.

Text: *Crystal Chemistry*, Evans.

Instructor: Wasserburg.

Ge 4 a. Igneous Petrology. 8 units (3-3-2); first term.

Prerequisite: Ge 3 ab.

A study of the origin, occurrence, and classification of the igneous rocks, with training in the megascopic identification, description and interpretation of these rocks and their constituent minerals. Problems of genesis are considered mainly in the light of chemical equilibria and features of geologic occurrence.

Instructor: Silver.

Ge 4 b. Sedimentary Petrology. 10 units (3-4-3); second term.

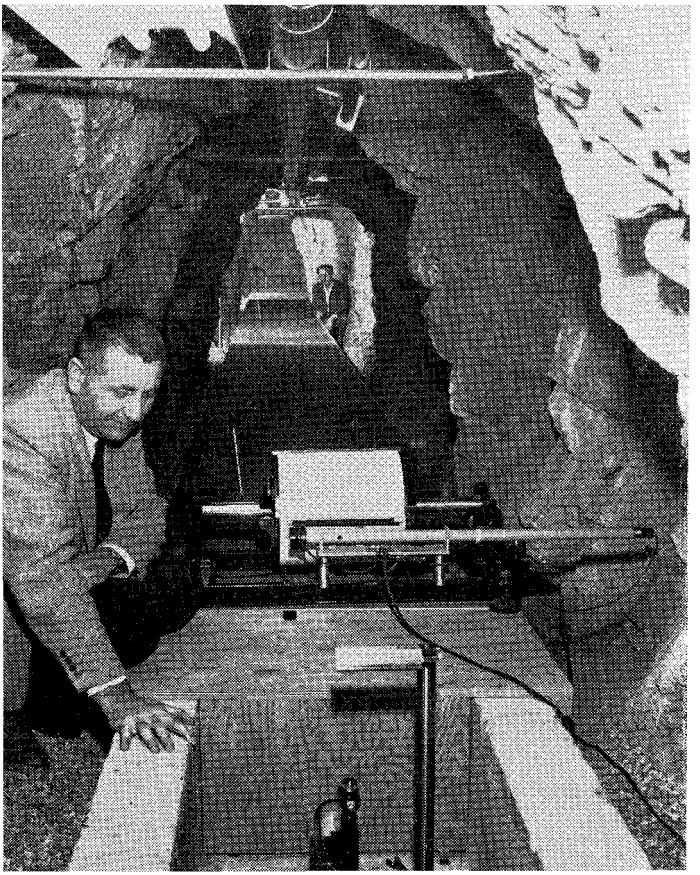
Prerequisites: Ge 1, Ge 3.

A study of the origin, occurrence, and classification of the sedimentary rocks, training in the identification, description, and interpretation of these rocks, using megascopic methods and the binocular microscope; consideration of the chemical, physical, and biologic processes involved in the origin, transport, and deposition of sediments, and their subsequent diagenesis. Field trips supplement the laboratory study.

Text: *Sedimentary Rocks*, Pettijohn; *Principles of Geochemistry*, Mason.

Instructor: Pray.

Researches on the Malaspina Glacier in Alaska are being carried on as a part of an investigation of the problem of solid flow in geologic bodies. Here a Caltech field party is shown using geophysical instruments to measure the thickness of the glacier.



The Seismological Laboratory's newest and largest instrument, a fuzed quartz earth strain meter, is installed in a tunnel in the mountains north of Monrovia, California

Ge 4 c. Metamorphic Petrology. 7 units (2-3-2); third term.

Prerequisite: Ge 3, Ch 24 ab.

A study of the origin, occurrence, and classification of the principal metamorphic rocks, with training in the megascopic identification, description, and interpretation of these rocks. Emphasis is placed upon problems of genesis, which are viewed mainly in the light of chemical equilibria and features of geologic occurrence.

Text: *Igneous and Metamorphic Petrology*, Turner and Verhoogen.

Instructor: Engel.

Ge 5. Geobiology. 9 units (3-0-6); third term.

Prerequisites: Ge 1, Ch 1, Bi 1.

An examination, chiefly in biological terms, of processes and environments governing the origin and differentiation of secondary materials in the crust throughout the span of earth history. Consideration is given to the environmental influence of the change from a reducing to an oxidizing atmosphere upon the evolution of life processes and to the subsequent progression of organisms and organic activity throughout the oxidizing era as recorded in the sedimentary rocks of the earth's crust. Special attention is devoted to organic progression and differentiation in time and space in terms of environment.

Instructors: Lowenstam, Brown.

Ge 9. Techniques of Structural Geology. 6 units (1-3-2); first term.

Prerequisites: Ge 1, Ge 2, Ge 3.

An introduction to the techniques of describing and interpreting structural features of geologic systems. Laboratory studies include the use of descriptive geometry and the stereographic projection in the solution of geologic problems, and the application of contrasting techniques to the presentation of geologic data.

Text: *Structural Geology*, Billings.

Instructor: Allen.

Ge 20 abc. Field Geology. 10 units (4-5-1) first term; 10 units (0-8-2) second term; 10 units (0-6-4) third term.

Prerequisites: Ge 1, Ge 3 ab.

An introduction of the interpretation of geologic features in the field, and to the fundamental principles and techniques of geologic mapping. Classroom and field studies include the interpretation of geologic maps, megascopic investigation of rock types, the solution of field problems in structure and stratigraphy, geologic computations, and an introduction to the use of aerial photographs for field mapping. To these ends, small areas are mapped in great detail and reports are prepared in professional form.

Text: *Field Geology*, Lahee.

Instructors: Jahns (21 a); Pray and Stehli (21 b); Allen (21 c).

ADVANCED SUBJECTS

Courses given in alternate years are so indicated. Courses in which the enrollment is less than five may, at the discretion of the instructor, not be offered.

Ge 100. Geology Club. 1 unit (1-0-0); all terms.

Presentation of papers on research in geological science by the students and staff of the Division of the Geological Sciences and by guest speakers.

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.

Instructor: Jones.

Ge 103. Paleontology. 9 units (2-3-4); first term.

Covering basic concepts of evolution and ecology.

Instructor: Lowenstam.

Ge 104. Introduction to Geochemistry. 6 units (2-0-4); third term.

Prerequisites: Ch 12 a, Ch 24 ab, Ma 2 abc, Ph 2 abc.

The applications of chemical principles to the study of the origin and evolution of the earth.

Text: *Principles of Geochemistry*, Mason.

Instructors: Brown and Epstein.

Ge 105. Optical Mineralogy. 12 units (2-8-2); first term.

Prerequisite: Ge 3.

The principles of optical crystallography; training in the use of the petrographic microscope in identification of crystalline substances, especially natural minerals, both in thin section and as unmounted grains.

Text: *Optical Crystallography*, Wahlstrom.

Instructor: Jahns.

Ge 106 ab. Petrography. 9 units (2-6-1) second term; 9 units (2-4-3) third term.

Prerequisite: 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: *Petrography*, Williams, Turner, and Gilbert.

Instructor: Campbell.

Ge 107. Stratigraphy. 10 units (3-2-5); third term; not offered 1955-56.

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.

Ge 109. Deformation of Rocks. 4 units; first term.

This subject is the same as Ge 9 but with reduced credit for graduate students.

Ge 111 ab. Invertebrate Paleontology. 10 units (2-6-2); second, third terms.

Prerequisite: Ge 1.

Morphology and geologic history of the common groups of the lower invertebrates, with emphasis on their evolution and adaptive modifications. Second term: consideration of the higher invertebrates groups; preparation of fossils and problems of invertebrate paleontology.

Instructor: Stehli.

Ge 121 abc. Advanced Field Geology. 14 units (4-8-2), first term; 10 units (0-8-2), second term; 7 units (0-3-4), third term.

Prerequisites: Ge 3, Ge 21 abc.

Interpretation of geologic features in the field, with emphasis on problems of the type encountered in professional geologic work. Advanced techniques of investigation are discussed. The student investigates limited but complex field problems in igneous, sedimentary, and metamorphic terrain. Individual initiative is developed, principles of research are acquired, and practice gained in field techniques, including the use of the plane table in geologic mapping. The student prepares reports interpreting the results of his investigations.

Instructors: Jahns, Silver (121 a); Pray, Stehli (121 b); Silver (121 c).

Ge 122. Spring Field Trip. 1 unit (0-1-0); week between second and third terms.

Field study 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; and to the mining districts and other localities of geologic significance in central and southern Arizona.

Required of junior and senior students, and strongly recommended for all graduate students in the Division of the Geological Sciences.

Instructors: The Geology Staff.

Ge 123. Summer Field Geology. 20 units.

Prerequisites: Ge 4 abc, Ge 21 abc.

Intensive field study of a 10-15 square mile area from a centrally located, temporary camp. Emphasis is placed on stratigraphic and structural interpretation, and on detailed mapping techniques, including the use of aerial photographs. Each student prepares a geologic map, stratigraphic and structural sections, and a complete geologic report. The work is performed under close supervision of regular staff members.

The area chosen generally lies in a part of the Rocky Mountains, or the Basin and Range Province. The course is designed to complement the field training in southern California afforded by the regular school year courses, Ge 21 and Ge 121.

The course begins the Monday following commencement (about June 12) and lasts for six weeks. It is required at the end of the junior year of candidates for the bachelor's degree in the geology and geochemistry options; of candidates for the Master of Science degree; and, at the discretion of the staff, of candidates for other advanced degrees in the Division of Geological Sciences. Registration is limited to students regularly enrolled in the California Institute of Technology or to those entering the following term.

Text: *Suggestions to Authors,* Wood and Lane.

Instructors: Pray (in charge), and other members of the staff.

Ge 126. Geomorphology. 10 units (4-0-6); first term.

Prerequisite: Ge 9.

Primarily a consideration of dynamic processes acting on the surface of the earth, and the genesis of landforms.

Instructor: Sharp.

Ge 150 abcdef. The Nature and Evolution of the Earth. 8 units (3-0-5). Ge 150 abc offered in 1955-56; Ge 150 def offered in 1956-57.

Discussions at an advanced level of problems of current interest in the earth sciences. The course is designed to give graduate students in the geological sciences and scientists from other fields an integrated picture of the earth and the processes that occur on its surface, together with a broad sampling of data and thought concerning current problems. The lectures are given by members of the staff of the Division of the Geological Sciences. Staff members from other divisions and visiting lecturers from the outside also will participate in the instruction. Students may enroll for any or all terms of this course without regard to sequence. The subjects to be discussed include:

150 a. The compositions and structures of galaxies, stars and planets; the interior of the earth; the physics of the earth's crust; terrestrial magnetism.

150 b. The chemistry of silicate systems; the origin and crystallization of magmas; petrology and geochemistry of rocks.

150 c. Metamorphic phenomena; ore genesis; the determination of geologic time; orogeny and volcanism; crustal deformation; tectonic and volcanic earthquakes.

150 d. The physics and chemistry of the atmosphere and ocean; geomorphology; weathering and geochemical cycles; coastal and deep sea sedimentation.

150 e. Sedimentary geology; isotope fractionations in geologic processes; life and life processes; genetic aspects of evolution.

150 f. Morphologic basis of evolution; extinction; paleoecology; geology and man.
Instructors: Brown (in charge), and other members of the staff.

Ge 151 abc. Laboratory Techniques in the Earth Sciences. 5 units (0-5-0); first, second, and third terms.

The course is designed to give students a first hand introduction to instruments and laboratory technique utilized in research in the earth sciences and to permit some evaluation of the limitations and potentials of the techniques, as well as of the precision and accuracy of the data obtained. Insofar as is possible and practicable the actual operation of the instruments, as well as recording and processing of data are done by the students under supervision of the staff. Any or all three terms of the course may be elected, but many students will find their principal need is for the introduction to techniques and instruments employed in the fields outside of their major. The course carries a minimum of 5 units, each term. By arrangement with the staff, the course may be available in other terms than designated, and additional units may be elected.

151 a. Geology: Introductory training in the use of the polarizing microscope using transmitted and reflected light, the refractometer, universal stage and interpretation of the data obtained; also tools and techniques employed and problems encountered in polishing and thin sectioning of rocks and minerals rock and mineral separations, preparation of geologic maps, and the sampling of rocks and ores.
Instructors: Epstein and Silver.

151 b. Geochemistry: Introductory training in the use of the emission spectrograph, mass spectrometer, alpha and beta counters, x-ray spectrometer, and those tools and techniques employed in wet chemical analyses of minerals, rocks, and meteorites and interpretation of data obtained.
Instructors: Epstein and Silver.

151 c. Geophysics: Introductory training in the operation of seismographs, gravity meters, magnetometers, and other geophysical instruments and the interpretation of the data obtained.
Instructors: Benioff (in charge), and other members of the staff.

Ge 167. Propagation of Elastic Waves in the Atmosphere. 3 units (1-0-2); second term, 1956-57.

A study of the propagation of sound waves through the troposphere and the stratosphere and comparison with elastic waves through the ocean and the solid earth.
Instructor: Gutenberg.

Ge 174. Well Logging. 5 units (3-0-2); second term, 1956-57.

Physical principles of various methods of well logging and their applications. Electrical, radioactive, chemical, fluoroscopic and mechanical methods will be studied.
Instructor: Potapenko.

Ge 175. Introduction to Applied Geophysics. 6 units (3-0-3); third term.

A survey of pure and applied geophysics designed mainly for geological, engineering, and other students who do not expect to enroll in specialized subjects in this field.
Text: *Introduction to Geophysical Prospecting*, Dobrin.
Instructor: Potapenko.

Ge 176. Elementary Seismology. 6 units (3-0-3); third term.

Prerequisites: Ge 1, Ma 2 ab.
A survey of the geology and physics of earthquakes.
Instructor: Richter.

GEOLOGY

Ge 200. Mineragraphy. 15 units (3-10-2); first term.

Prerequisite: See Instructor.

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. 15 units (3-9-3); second term.

Prerequisite: 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, 1955-56.

Prerequisite: Ge 105.

A study of the processes and products of sedimentation in relation to their geologic environment. Emphasis is given to major lithologic facies and their interpretation. The laboratory work affords an introduction to techniques of sedimentary analysis. Occasional field trips.

Instructor: Pray.

Ge 210. Metamorphic Petrology. 10 units (2-4-4); third term, 1956-57.

Prerequisites: Ge 106 ab, Ch 124 ab.

A study of metamorphic processes.

Text: *Origin of Metamorphic and Metasomatic Rocks,* Ramberg.

Instructors: Engel and Epstein.

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 interests among members of the group.

In charge: Jahns and Engel.

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.

Prerequisite: See Instructor.

Discussion of problems and current literature concerning ore deposits.

In charge: Noble.

Ge 228. Geomorphology of Arid Regions. 10 units (3-0-7); second term, 1955-56.

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.

Instructor: Sharp.

Ge 229. Glacial Geology. 10 units (3-0-7); second term, 1956-57.

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 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: Allen

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: Allen

PALEONTOLOGY

Ge 244 abc. Paleozoology (Seminar). 5 units; first, second and third terms.

This course is designed to present the current status of paleozoology and explore its major problems. Topics for discussion include the following: Effects of burial environment and diagenesis on fossil distribution and preservation; reconstruction of the environmental framework from morphology, skeletal mineralogy and physical and chemical sedimentary expression; morphologic and crystal compositional expressions of ecologic adaptations and their relations to evolution; environmental history and its possible evolutionary effects; evolution as exemplified by the fossil record and interpreted by means of modern biologic theory; problems and approaches of modern systematics. Marine biology and recent bioclastic sedimentation as well as fossil situations will be interpreted in the field, the laboratory and through the literature.

Instructors: Lowenstam and Stehli.

Ge 245. Vertebrate Paleontology (Seminar). 5 units; second term. Not offered in 1955-56.

Discussion of progress and results of research in vertebrate paleontology.

Critical review of current literature.

Ge 250. Invertebrate Paleontology and Paleoecology (Seminar). 5 units; first term.

Critical review of classic and current literature in paleoecology, biogeochemistry and invertebrate paleontology. Study of paleontologic principles and methods.

Instructors: Lowenstam and Stehli.

GEOPHYSICS

Ge 261. Theoretical Seismology. 6 units (2-0-4); first term, 1955-56.

Prerequisites: Ma 108, or Ma 10, or Ph 106 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, 1955-56.

Prerequisite: Ge 261.

Instructor: Gutenberg.

Ge 264 ab. Propagation of Elastic Waves in Layered Media. 8 units (4-0-4); first and second terms.

Prerequisites: Ph 106 abc.

Experimental and theoretical aspects of elastic wave progragation in a layered half space, in plates, cylinders, and spheres, with application of seismic waves and underwater acoustics.

Instructor: Press.

Ge 268 ab. Selected Topics in Theoretical Geophysics. 6 units (3-0-3); second and third terms. Not offered 1955-56.

Prerequisite: Ph 106 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 272. Applied Geophysics, I. 10 units (4-0-6); second term, 1955-56

Prerequisite: Ph 106 abc or equivalent.

Theory of potential including the background necessary for interpretation and planning of gravity, magnetic and electrical prospecting. Gravity methods of prospecting.

Instructor: Dix.

Ge 273 ab. Applied Geophysics, II. 5 units (2-0-3); second and third terms, 1956-57.

Prerequisite: Ph 106 abc or equivalent.

Methods of seismology applied to geological problems and prospecting. Theory and practice.

Text: *Seismic Prospecting for Oil,* Dix.

Instructor: Dix.

Ge 274 ab. Applied Geophysics, III. 5 units (2-0-3), second term; 6 units (2-1-3), third term; 1955-56.

Prerequisite: Ph 107 abc or equivalent.

Magnetic and electric methods applied to geological problems and to prospecting, mainly to mining. Theory and practice.

Instructor: Potapenko.

Ge 282 abc. Geophysics-Geochemistry (Seminar). 1 unit; first, second, third terms.

Prerequisite: At least two subjects in geophysics or geochemistry.

Discussion of papers in geochemistry, general and applied geophysics.

In charge: Brown, Dix, Epstein, Gutenberg, Potapenko.

GENERAL

Ge 295. Master's Thesis Research. Units to be assigned. Listed as to field according to the letter system under Ge 299.

Ge 297. Advanced Study.

Students may register for 8 units or less of advanced study in fields listed under Ge 299. Occasional conferences; final examination.

Ge 299. Research.

Original investigation, designed to give training in methods of research, to serve as theses for higher degrees, and to yield contribution to scientific knowledge. These may be carried on in the following fields.

(E) engineering geology,
(F) petroleum geology
(G) ground water geology,
(H) metalliferous geology,
(I) nonmetalliferous geology,
(J) geochemistry,
(M) mineralogy,
(N) areal geology,
(O) stratigraphic geology,
(P) structural geology,
(Q) geomorphology,
(R) petrology,
(S) vertebrate paleontology,
(T) invertebrate paleontology,
(U) seismology,
(W) general geophysics,
(X) applied geophysics,
(Y) geophysical instruments,
(Z) glacial geology.

GERMAN

(See under Languages)

HISTORY AND GOVERNMENT

UNDERGRADUATE SUBJECTS

H 1 abc. History of European Civilization. 5 units (2-0-3); first, second, third terms.

In introduction to the history of Europe from 1648 to the present. The course will include discussions of political, social, and economic problems, and of the more important theoretical concepts of the period.

Instructors: Ellersieck, Elliot, Fay.

H 2 abc. History and Government of the United States. 6 units (2-0-4); first, second, third terms.

The United States since the Revolution. Particular attention will be given to the great questions of domestic and foreign policy which the United States has faced in recent times. The course will include a study of the Constitution and form of government of the United States and the State of California, and will trace the evolution of national and local political institutions and ideas.

Instructors: J. Davies, Piper, Thompson.

H 4. The British Commonwealth of Nations.* 9 units (3-0-6).

Senior elective.

A study in imperial relationships.

Instructor: Elliot.

H 5 abc. Public Affairs. 2 units (1-0-1); first, second, third terms.

In this course a selection of important contemporary problems connected with American political and constitutional development, economic policies, and foreign affairs will be considered.

Instructors: Elliot, Sweezy; occasional lectures by other members of the department.

H 7. Modern and Contemporary Germany.* 9 units (3-0-6).

Senior elective.

A study of what is sometimes called "The German Problem." Attention will be focused on the rise of Prussia, on Prussian leadership in the unification and direction of Germany, and on the place of Germany in the economy of Europe. Particular stress will be placed upon the German experience since the first World War.

H 8. Modern and Contemporary Russia.* 9 units (3-0-6).

Senior elective.

An attempt to discover and interpret the major recurring characteristics of Russian history and society, with attention particularly to developments in the Soviet period.

Instructor: Ellersieck.

H 15. Europe Since 1914.* 9 units (3-0-6).

Senior elective.

Since 1914 the world has felt the impact of two great wars and powerful revolutionary ideas. This course will analyze these upheavals of the twentieth century and their effect on domestic problems and international organization.

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

H 16. American Foreign Relations.* 9 units (3-0-6).

Senior elective.

How American foreign policy has been formed and administered in recent times: the respective roles of the State Department, Congress, and the President, of public opinion and pressure groups, of national needs and local politics.

Instructor: Paul.

H 17. The Far West and the Great Plains.* 9 units (3-0-6).

Senior elective.

A study of the development of the great regions that compose the western half of the United States. Especial attention will be paid to the influence of the natural environment on the men who settled the West, from pioneer days to the present time, and the exploitation of natural resources, through such industries as mining, ranching oil, and farming.

Instructor: Paul.

H 19. Modern America.* 9 units (3-0-6).

Senior elective.

An experimental course in which the main theme will be the conflict between government regulation and private enterprise in Twentieth-Century America. Classes will be conducted as discussions under the joint leadership of an historian and an economist.

Instructors: Paul, Sweezy.

H 22. Modern Britain.* 9 units (3-0-6).

Senior elective.

A study of Britain's recent past with particular emphasis upon the development of the working class movement.

Instructor: Elliot.

H 23. Modern War.* 9 units (3-0-6).

Senior elective.

The course will trace the major developments within the military establishment, such as the growth of the general staff and mass armies. It will discuss the major strategic concepts of the nineteenth and twentieth centuries and the problems of modern war, with some consideration of the political, economic, and social aspects of waging war.

Instructor: Tanham.

H 24. The Dynamics of Political Behavior.* 9 units (3-0-6).

Senior elective.

An examination of general behavior patterns and tendencies of individuals as related to their political behavior and to appropriate types of political institutions. Relevant psychological and sociological theory and research will be discussed in an effort to find the kinds of government suitable to people living in modern technological and industrial society.

Instructor: J. Davies.

H 25. Political Parties and Pressure Groups.* 9 units (3-0-6).

Senior elective.

A study of those institutions through which individuals and groups seek to control governmental policy and administration. Particular attention will be focussed on parties as formulators of individuals' political wants, fears, and expectations and as transmitters of these programs to government.

Instructor: J. Davies.

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.

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

H 41. Summer Reading. Units to be determined for the individual by the department. Maximum, 8 units.

Elective.

Reading in history and related subjects during summer vacation. Topics and books to be selected in consultation with members of the department. A brief written report will usually be required.

ADVANCED SUBJECTS

H 100 abc. Seminar in History and Government. 9 units (2-0-7).

A study of recent developments in national 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: G. Davies.

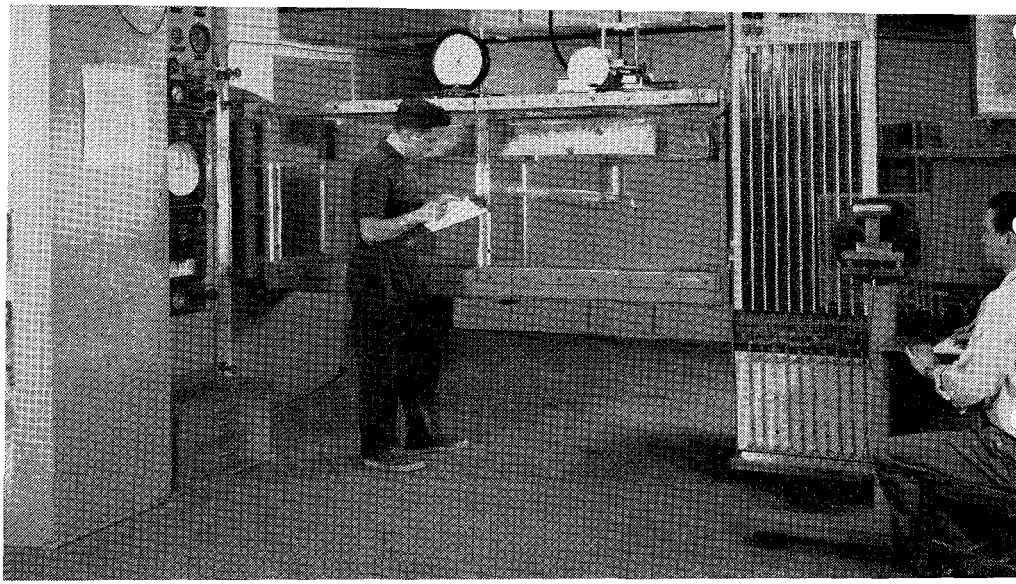
H 124. Seminar in Foreign Area Problems.* 9 units (3-0-6); second term.

Senior elective.

The object of this course is to give students an opportunity to study in some detail problems current in certain selected foreign areas. Three or four areas will be considered each time the course is given, and the selection will normally vary from year to year. Instruction will be given mainly by area specialists of the American Universities Field Staff.

Instructors: Elliot and members of AUFS.

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



The free-surface water tunnel in the Hydrodynamics Laboratory.

HYDRAULICS

UNDERGRADUATE SUBJECTS

Hy 1. Hydraulics. 9 units (3-0-6); first term.

Prerequisites: AM 1, AM 4 ab, 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.

Instructor: Daugherty.

Hy 2 ab. Hydraulics. 12 units (4-0-8); first term; 6 units (2-0-4); second term. (For Civil Engineers.)

Kinematics and dynamics of fluid motion with emphasis on liquids. Hydrostatics, fluid similitude, flow measurements, flow in pipes and open channels; flow about immersed bodies; hydraulic turbines; centrifugal pumps and fluid power transmission.

Instructor: Brooks.

Hy 11. Fluid Mechanics Laboratory. 6 units (0-6-0); second term.

Prerequisite: AM 1, AM 4 ab, AM 5 a.

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. Fluid Mechanics. 9 units (3-0-6); first, second, third terms.

Prerequisites: Hy 1 or Hy 2 ab and Hy 11 or equivalent.

Continuity, momentum and energy equations for viscous, compressible fluids; circulation and the production of vorticity; potential flow and applications to flow around bodies; gravity waves; laminar flow; laminar boundary layers; turbulence and turbulent shear flow; transport of sediment; introduction to fluid mechanics of turbomachines.

Instructor: Rannie.

Hy 103 a. Advanced Hydraulics. 9 units (3-0-6).

Prerequisite: Hy 2 ab.

Ideal fluid flow, turbulence and diffusion, boundary layer, dimensional analysis, theory and use of hydraulic models, resistance of flow, steady flow in open channels, hydraulic jump, backwater curves and flood routing.

Instructor: Vanoni.

Hy 103 b. Hydraulic Structures. 9 units (3-0-6).

Prerequisite: Hy 103 a.

High velocity flow in open channels, sediment transportation, theory and design of hydraulic structures, water hammer, surface waves and coastal engineering.

Instructor: Vanoni.

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 fields 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 faculty in Mechanical Engineering.

Instructor: Daugherty.

Hy 200. Advanced Work in Hydrodynamics or Hydraulic Engineering. Units to be based upon work done; any term.

Special courses on problems to meet the needs of students beyond the fifth year.

Hy 201 abc. Hydraulic Machinery. 6 units (2-0-4); first, second, third terms.

A study of such rotating machinery as turbines, pumps, and blowers, and their design to meet specific operating conditions. This course will be given in seminar form led by members of the Hydrodynamics and Mechanical Engineering staffs.

Hy 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 flow in open channels, wave phenomena in enclosed bodies of fluids such as lakes and oceans, density currents, and water hammer.

Instructor: Vanoni.

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 hydraulic machinery and also for bodies moving in a stationary fluid.

Instructor: Knapp.

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.

HISTORY OF SCIENCE

HS 100 abc. History of Science.[1] 9 units (2-0-7); first, second, third terms.

A detailed study of selected events in the history of scientific research. Aim of the course is to analyse how important concepts have been discovered and established, how mathematics, hypothesis, experiment and other elements of the scientific method have brought about advances of scientific knowledge in historic instances, and how rigorous scientific concepts have been related to broader social ideas in the history of thought.

Instructor: T. Smith.

[1]This course is open to graduate students only, but not toward the fifth year option in Humanities (see page 207).

JET PROPULSION

ADVANCED SUBJECTS

JP 121 abc. Rocket. 6 units (2-0-4); each term.

Prerequisites: AM 15, ME 15.

Study of flow through rocket nozzle; over- and under-expanded nozzles. Combustion chamber and grain proportions for solid propellant rocket motors; properties and burning characteristics of solid propellants. Combustion and combustion instability in solid propellant rockets. Combustion chamber, propellant supply, and injection system for mono- and bipropellant rocket motors. Turbopump powerplants for liquid rocket propellant supply. Low and high frequency instability in liquid rocket motors. Problems of heat transfer and cooling in rocket motor injectors, combustion chambers and nozzles. Exterior ballistics and performance analysis of rocket propelled vehicles.

Instructors: Marble, Zukoski.

JP 130 abc. Thermal Jets. 9 units (3-0-6); each term.

Prerequisites: AM 15, ME 15.

Analysis of ramjet performance; detailed study of subsonic and supersonic ramjet diffuser performance and stability, combustion and flame stabilization in ramjet combustors, off-design performance, transient operation and starting. Operating principles of pulsejet, ducted rocket, and thrust augmentors.

Performance cycle analysis of turbojet, turbopropeller, and ducted fan or by-pass engines. Operating principles, design, and performance of compressor, turbine, and combustion chamber and afterburner components. Component matching, engine-diffuser matching, and calculation of complete engine performance; problems of starting and off-design operation. Study of turbine cooling, liquid injection, regenerative systems, and other modifications to basic cycles. Performance analysis of thermal jet propelled aircraft and vehicles.

Instructor: Marble.

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.

JP 200 abc. Chemistry Problems in Jet Propulsion. 9 units (3-0-6); each term.

Descriptive discussions on atomic and molecular structure. Systematics of organic chemistry. Chemistry of propellants. Thermodynamics of combustion. Quantitative evaluation of rocket propellants. Combustion of liquid propellants, ignition delay, evaporation in rocket motors. Principles of chemical kinetics. Chemical reactions during nozzle flow. Detonation, flame propagation, mechanism of burning of solid propellants, heterogeneous combustion.

Instructors: Aroeste, Penner.

JP 201 abc. Physical Mechanics. 9 units (3-0-6); each term.

Prerequisites: JP 200, ME 115 or equivalent.

Relation between molecular parameters and observable physical properties. Use of statistical methods for the calculation of thermodynamic functions, transport properties, equations of state, and chemical reaction rates. Theoretical calculations of gas emissivity, applications to combustion spectroscopy.

Instructor: Penner.

JP 202 abc. Engineering Spectroscopy. 6 units (2-0-4) (0-6-0) (2-0-4).

Principles of atomic and molecular spectroscopy. Industrial spectroscopic instruments. Analytical spectroscopy, including quantitative analysis of isothermal fluid mixtures. Optical methods for the measurement of flame and furnace temperatures. Quantitative spectroscopy of flames and shocks. Optical methods in fluid-flow studies.

Instructor: Penner.

JP 210. High Temperature Design Problems. 6 units (2-0-4); third term.

Prerequisites: ME 3, ME 10, and Ae 107 a or AM 110 a.

Temperature distribution and thermal stress under non-uniform and unsteady conditions. Applications to thermal shock analysis and high temperature designs. General survey of the physical and the mechanical properties of metals, ceramels, and ceramics with reference to high temperature applications.

Instructors: Duwez, Tsien.

JP 220 abc. Theory of Stability and Control. 6 units (2-0-4); each term.

Prerequisites: AM 125 or AM 126.

Stability and control of systems with constant coefficients, principles of feed-back servomechanisms, automatic control of propulsion systems. Stability and control of system with time lag, Satche diagram. Stability of systems with time varying coefficients. Ballistic disturbance theory, applications to the problem of control and guidance of ballistic vehicles. Control design by specified criteria. Reliability and control of error.

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: 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.

Instructors: Staff Members.

LANGUAGES

The subjects in languages are arranged primarily to meet the needs of science students who find it necessary to read books, treatises, and articles in French, German and Russian. In the study of these languages correct pronunciation and the elements of grammar are taught, but the emphasis is laid upon the ability to translate from them into English.

UNDERGRADUATE SUBJECTS

L 1 ab. Elementary French. 10 units (4-0-6); second, third terms.

A subject in grammar, pronunciation, and reading that will provide the student with a vocabulary and with a knowledge of grammatical structure sufficient to enable him to read at sight French scientific prose of average difficulty. Accuracy and facility will be insisted upon in the final tests of proficiency in this subject. Students who have had French in the secondary school should not register for this subject without consulting subject without consulting the department of 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, Wayne.

L 32 abc. Elementary German. 10 units (4-0-6); first, second, third terms.

This subject is presented in the same manner as the Elementary French. Students who have had German in the secondary school or junior college should not register for this subjects without consulting the department of 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. Reading 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.

ADVANCED SUBJECTS

L 105. Same as L 5. For graduate students.

L 140. Same as L 40. For graduate students.

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

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 geometery.

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 course. Ma 2 a and Ma 2 b cover partial differentiation, multiple integration, vectors and solid analytic geometry. Ma 2 c deals with ordinary differential equations.

Texts: *Analytic Geometry and Calculus,* Phillips; *Differential Equations,* Agnew.

Professor in charge: Apostol.

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.

Instructor: Ward.

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, and an introduction to partial differential equations.

Text: *Differential Equations,* Agnew.

Instructor: Spitzer.

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: Ward, Dilworth.

Ma 61.* Algebra. 9 units (3-0-6); third term.

Prequisites: Ma 3, Ma 16.

An introduction to modern algebra. Discussion of quadratic fields, factorization and ideal theory. Given in 1956-57 and alternate years.

Instructor: Dilworth.

Ma 62.* Differential Geometry. 9 units (3-0-6); first term.

Selected topics in metrical differential geometry. Given in 1956-57 and alternate years.

Instructor: Calabi.

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*Graduate students who wish to take the courses Ma 61, 62, 63, 64, 67, 68, 91 should register for them under the numbers Ma 161, 162, . . . , 191. These courses carry a credit of 6 units towards a minor in mathematics.

**The topic of this course may be changed next year as a result of a reorganization of the curriculum in the mathematics option.

Ma 63.* Theory of Sets. 9 units (3-0-6); second term.

The basic concepts of the theory of sets. Cardinal and ordinal numbers. Introduction to point set topology. Discussion of real numbers. Gicen in 1956-57 and alternate years.

Instructor: Calabi.

Ma 64.* Projective and Algebraic Geometry. 9 units (3-0-6); first term.

Homogeneous coordinates, projective group. Duality principle. Singular points of curves. Birational transformations. Given in 1955-56 and alternate years.

Text: *Analytic and Projective Geometry,* Struik.

Instructor: Erdélyi.

Ma 67. Ordinary Differential Equations. 9 units (3-0-6); first term.

Geometrical and quantitative analysis of first order systems. Nature of solutions in the phase plane. Stability. Periodic solutions. Introduction to the Sturm-Liouville theory for linear second order equations.

Instructor: DePrima.

Ma 68. Operational Calculus. 9 units (3-0-6); second term.

Introduction to operational calculus based on the Laplace integral. Applications to ordinary and partial differential equations.

Text: *Modern Operational Mathematics in Engineering,* Churchill.

Instructor: Erdélyi.

Ma 91.* Special Course. 9 units (3-0-6); third term.

Each year, during the third term, a course will be given in one of the following topics:

(a) Some field of complex number theory.
(b) Some field of algebra or logic. (Given in 1953-54).
(c) Combinatorial Topology. (Given in 1952-53).
(d) Game Theory. (Given in 1955-56).
(e) Development of Mathematics. (Given in 1951-52).

Ma 98. Reading. 3 units or more by arrangement.

Occasionally a reading course under the supervision of an instructor will be offered. Topics, hours, and units by arrangement. Only qualified students will be admitted after consultation with the instructor in charge of the course.

ADVANCED SUBJECTS

A. These courses are open to undergraduate and graduate students. They count fully towards a minor, but carry no credit towards a major for the degree of Doctor of Philosophy. See also Ma 61, 62, 63, 64, 67, 68, and 91 which, under the numbers Ma 161, etc., carry a partial credit of 6 units toward a minor in Mathematics.

Ma 108 abc. Advanced Calculus. 9 units (4-0-5); three terms.

Prerequisites: Ma 1, Ma 2.

This course is an introduction to advanced methods in analysis. Each year the course will include a discussion of functions of a complex variable; line, surface, volume integrals and their inter-relations; applications of the differential calculus of functions of several variables; functions defined by infinite series and integrals. In addition the course will contain topics selected from: Fourier series and integrals; special functions, such as the gamma and beta functions, Bessel functions, error function; Stieltjes integrals. The aim of this course is to provide a thorough understanding of basic principles, a facility in the use of techniques and a familiarity with applications. This course, or its equivalent, is a prerequisite to graduate mathematics courses in analysis.

Instructors: Ward, Fuller, Spitzer.

*Graduate students who wish to take the courses Ma 61, 62, 63, 64, 67, 68, 91 should register for them under the numbers Ma 161, 162, . . . , 191. These courses carry a credit of 6 units towards a minor in mathematics.

Ma 112 a. Elementary Statistics. 9 units (3-0-6); first and third terms.
Prerequisites: Ma 1, Ma 2.

This course is intended for anyone interested in the application of statistics to science and engineering. The topics treated will include the preparation and systematization of experimental data, the fundamental statistical concepts; population, sample, mean and dispersion, curve fitting and least squares, significance tests and problems of statistical estimation.

Text: *Introduction to Mathematical Statistics,* Hoel.

Instructors: Karlin and Truax.

B. These courses are intended primarily for graduate students. They count fully towards a major or a minor for the degree of Doctor of Philosophy.

Ma 114 abc. Mathematical Analysis. 12 units (4-0-8); three terms.

Prerequisite: Ma 108 abc.

Theory of analytic functions of a complex variable and topics selected from: asymptotic and divergent series, Fourier series, orthogonal polynomials and functions, differential and integral equations, special functions.

Text: *Functions of a Complex Variable,* Copson.

Instructor: Erdélyi.

Ma 117 abc. Set Theory and Theories of Integration. 9 units (3-0-6); three terms.

Prerequisite: Ma 108 abc.

Beginning with the theory of sets the course consists of a detailed study of the integration and differentiation of functions of one real variable. It includes a modern treatment of Lebesgue and of Lebesgue-Stieltjes integrals, the theory of functions of bounded variation, applications to measure theory. Given in second and third term only.

Instructor: Dilworth

Ma 120 abc. Abstract Algebra. 9 units (3-0-6); three terms.

Prerequisites: Ma 3, Ma 10.

Abstract treatment of groups, rings and fields including topics chosen from: structure theory of groups and rings, Galois theory, and valuation theory of fields.

Text: *Modern Algebra,* Volume 1, Van der Waerden.

Instructor: Dean.

Ma 130 abc. Riemannian and Non-Riemannian Geometry. 9 units (3-0-6); three terms.

Prerequisites: Ma 62 or Ma 111 a.

The first term, Ma 130 a, emphasizes the postulational approach to modern geometries discussing specifically the case of euclidean and other elementary coordinate geometries. Riemannian geometry. Topics of the second and third term: Non-Riemannian geometry. Theory of parallel displacement of tensors. Affine differential geometry. Projective differential geometry. Continuous groups and their applications to geometry. Infinite dimensional differential geometry. Contemporary researches in differential geometry.

Not given in 1955-56.

Ma 140 abc. Combinatorial Topology. 9 units (3-0-6); three terms.

Introduction to combinatorial topology. The course covers homology and co-homology theory with applications to fixed point theorems and homotopy theory. Selected topics from the theory of fibre bundles.

Not given in 1955-56.

Ma 152. Mathematical Logic. 9 units (3-0-6); three terms.

A survey of classical and modern applications of mathematical logic.

Not given in 1955-56.

Ma 160 abc. Theory of Numbers. 9 units (3-0-6); three terms.

Prerequisites: Ma 108 and Ma 114 ab for the last two terms.

The first term, Ma 160 a, is an introduction to the elementary theory of numbers including divisibility, numerical functions, elementary theory of primes, quadratic residues. The second and third terms, Ma 160 bc, include topics selected from: Dirichlet series, distribution of primes, additive number theory.

Instructor: Apostol.

Ma 170 abc. Theory of Probability. 9 units (3-0-6); three terms.

Prerequisites: Ma 65 and Ma 108 abc.

An introduction to the classical theory of probability leading to the limit theorems and the theory of infinitely divisible distributions. The theory of Markoff processes.

Instructor: Spitzer.

Ma 172 a. Intermediate Statistics. 9 units (3-0-6); second term.

Prerequisites: Ma 112 a, Ma 108 a or equivalent, an elementary knowledge of the theory of matrices and quadratic forms is desirable.

The topics dealt with include a more complete study of analysis of variance, the general linear hypothesis, multivariate analysis and sequential analysis.

Not given in 1955-56.

Ma 180 abc. Mathematical Methods in Physics. 9 units (3-0-6); three terms.

Prerequisites: Ma 108 abc, Ma 10.

Topics selected from matrices and bilinear forms, spectral analysis in Hilbert space, Fourier series and integrals, expansions in orthogonal function systems, integral equations, introduction to the calculus of variations, partial differential equations, characteristic value problems, perturbation methods.

Instructor: DePrima. Given in second and third term only.

Ma 190 abc. Elementary Seminar. 9 units; three terms.

This seminar is restricted to first year graduate students and is combined with independent reading. The topics will vary from year to year.

In charge: Bohnenblust and Karlin.

C. The following courses and seminars will be offered according to demand. They are intended for graduate students sufficiently advanced to take an active interest in contemporary fields of research. The courses and seminars to be offered and the topics to be covered will be announced at the beginning of each term.

Ma 210 abc. Advanced Topics in Analysis. 9 units; three terms.

Topics selected from: the theories of functions of one and of several complex variables, quasi-analytic functions, asymptotic expansions; transform theories with applications; orthogonal expansions and almost periodic functions; topological methods in analysis; calculus of variations; analytic number theory.

Not given in 1955-56.

Ma 211 abc. Topics in Functional Analysis. 9 units; three terms.

Topics selected from: the theory of topologized algebraic structures (topological groups, normed linear spaces and rings); the abstract differential calculus; applications to analysis and geometry.

Not given in 1955-56.

Ma 215 abc. Seminar in Analysis. 6 units; three terms.

Ma 216 abc. Seminar in Functional Analysis. 6 units; three terms.

Ma 220 abc. Topics in Contemporary Algebra. 9 units; three terms.

Selected topics of current interest in algebra, such as the theory of partially ordered sets, lattice theory, representation theory of groups and rings.

Not given in 1955-56.

Ma 225 abc. Seminar in Algebra. 6 units; three terms.

Ma 230 abc. Advanced Topics in Geometry. 9 units; three terms.

Topics selected from the theories of modern Riemannian, non-Riemannian geometry, projective differential geometry, infinite dimensional differential geometry, topology and applications to analysis.

Not given in 1955-56.

Ma 235 abc. Seminar in Geometry. 6 units; 3 terms.

Ma 262 abc. Seminar in Number Theory. 6 units; three terms.

Ma 274 abc. Topics in Probability and Statistics. 9 units; three terms.

Topics selected from: advanced decision theory including methods of game theory; advanced multivariate analysis and the general linear hypothesis; general stochastic processes.

Not given in 1955-56.

Ma 275 abc. Seminar in Probability and Statistics. 9 units; three terms.

Ma 280 abc. Advanced Topics in Applied Mathematics. 9 units; three terms.

Topics selected from: non-linear mechanics; mathematical problems in fluid mechanics; mathematical theory of diffraction and scattering; probability methods in analysis with applications; singular integral equations with applications; abstract space methods in applied mathematics.

Not given in 1955-56.

Ma 285 abc. Seminar in Applied Mathematics. 6 units; three terms.

Ma 290. Reading.

Occasionally advanced work is given by a reading course under the direction of an instructor. Hours and units by arrangement.

Ma 291. Research.

By arrangement with members of the staff, properly qualified graduate students are directed in research. Hours and units by arrangement.

Ma 292. Research Conference in Mathematics. 2 units.

Reports on current literature or their own work will be presented at regular intervals by members of the staff, graduate students or visitors.

APPLIED MATHEMATICS COURSES OFFERED BY OTHER DEPARTMENTS

AM 15 Engineering Mathematics—See Applied Mechanics section, for description.

AM 115 Engineering Mathematics—See Applied Mechanics section, for description.

AM 116 Complex variables and applications—See Applied Mechanics section, for description.

AM 125 Engineering Mathematical Principles — See Applied Mechanics section, for description.

AM 175 Non-linear Vibrations—See Applied Mechanics section, for description.

Ph 106 Introduction to Mathematical Physics—See Physics section, for description.

Ph 129 Methods of Mathematical Physics—See Physics section, for description.

MECHANICAL ENGINEERING

UNDERGRADUATE SUBJECTS

ME 1. Empirical Design. 9 units (0-9-0); first, second or third term.

Prerequisite: GR 1 abc.

This course is planned to supplement first year graphics with more advanced application of graphical techniques to spatial problems and problems in kinematics. Emphasis is placed on creative ingenuity and a rational approach to new design problems as well as on development of the student's ability to recognize fundamental principles in analyzing existing machines. The following subjects are introduced for study through a coordinated series of lecture discussions and laboratory problems; displacements, velocities and accelerations in linkages; cam design, gearing, selection of standard fastenings, couplings, seals and bearings in relation to design.

Instructors: Tyson, Welch.

ME 3. Materials and Processes. 9 units (3-3-3); first, second or third term.

Prerequisites: Ph 1 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 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: Buffington, Clark.

ME 5 abc. Machine Design. 9 units (2-6-1); first, second, third terms.

Prerequisite: ME 1, AM 1 abcd.

Application of the mechanics of machinery and strength of materials 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. Laboratory work is design analysis of significant devices and machines which involves dynamic problems of some complexity, such as high-speed link motions, valve gear, shock absorbers, hydraulic coupling uses, high-speed rotors, electric motor applications, elementary servomechanisms and controls, hydraulic circuits and applications.

Text: *Design and Production,* Kent.

Instructor: Morelli.

ME 10. Metallurgy. 12 units (3-3-6); first term.

Prerequisite: ME 3.

A study of the properties of ferrous and non-ferrous metals and alloys with respect to their application in engineering; the principles of heat treatment for a proper understanding by engineers for application in specification of alloys for design. The microstructures of ferrous and non-ferrous metals and alloys are studied in the laboratory.

Text: *Physical Metallury for Engineers,* Clark and Varney.

Instructors: Buffington, Clark.

ME 15 abc. Thermodynamics and Fluid Mechanics. 10 units (3-2-5); first, second, third terms.

Prerequisites: Ph 2 abc, Ma 2 abc.

First term: A study of the basic principles of fluid mechanics, the continuity equation, Euler's equations of motion, the Bernoulli equation, and the momentum theorem. Emphasis is placed on incompressible fluids. The effects of friction are studied and applications of the principles to problems of hydraulics are considered. A brief introduction of potential flow theory and to bounary layer theory is included.

Second and Third Terms: A study of the first and second laws of thermodynamics, with applications to flow and non-flow processes. Basic power cycles for vapors and gases and their suitability for engineering purposes. Properties of fluids and the use of standard tables. An introduction to the flow of a compressible fluid and some elements of turbine and compressor design. Elementary principles of combustion.

Instructors: Acosta, 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, gas and vapor mixture, advanced treatment of second law, Joule-Thomson effect, Chemical thermodynamics. Internal combustion engines (piston and turbine).

Instructor: 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: *Elements of Thermodynamics and Heat Transfer,* Obert.

Instructor: Kyropoulos.

ME 25. Mechanical Laboratory. 9 units (0-6-3); third term.

Prerequisite: ME 15 abc.

Principles of engineering measurements.

Instructor: Kyropoulos.

ME 50 ab. Engineering Conferences. 2 units (1-0-1); second, third terms.

A course in public speaking for engineers, on engineering topics.

Instructor: Daugherty.

ADVANCED SUBJECTS

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 undergraduate 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 construction, 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: Morelli.

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 all fields except Ae, CE, and ME. No graduate credit is given for this subject to students in Ae, CE, and ME, except by special approval of the faculty in Mechanical Engineering.

ME 110. Physical Metallury I. 9 units (3-0-6); first term.

Prerequisite: ME 10.

A study of phase equilibria of metallic systems, recrystallization, grain growth, precipitation hardening, the heat flow in heating and cooling metals, the mechanics of transformations in steel.

Text: Lecture notes and references.

Instructor: Buffington.

ME 111 a. Metallography Laboratory. 9 units (0-9-0); second term.

Prerequisite: ME 10.

Technique of metallographic laboratory practice including preparation of specimens by mechanical and electrolytic means, etching reagents and their use, photomicrography, in connection with ferrous and nonferrous materials.

Text: *Principles of Metallographic Laboratory Practice,* Kehl.

Instructor: Clark.

ME 111 b. Industrial Physical Metallurgy. 9 units (0-9-0); third term.

Prerequisite: ME 111 a.

Application of the principles of physical metallurgy and the techniques of metallographic laboratory practice to the solution of problems concerning the cause of failure of commercial parts. Typical cases are used as problems to be solved by the student and presented and discussed before the class in the form of reports.

Instructor: Clark.

ME 114. Metallurgy. 9 units (3-3-6); first term.

Prerequisite: ME 3.

This subject is the same as ME 10, but with reduced credit for graduate students in all fields except Ae and ME. No graduate credit is given for this subject to students in Ae and ME, except by special approval of the faculty in Mechanical Engineering.

ME 115 abc. Thermodynamics and Heat Transfer. 9 units (3-0-6); first, second, and third terms.

Prerequisites: ME 15 abc, ME 16 ab.

Macroscopic thermodynamics and the elements of microscopic thermodynamics with applications to engineering processes; the transport of energy by conduction, convection, and radiation; the thermodynamics of flow systems.

Instructor: Sabersky.

ME 124 ab. Thermodynamics. 7 units (3-0-6), first term; 4 units (2-0-4) second term.

Prerequisite: ME 15 abc.

This subject is the same as ME 16 ab, but with reduced credit for graduate students in all fields except Ae, ChE, and ME. No graduate credit is given for this subject to students in Ae, ChE, and ME, except by special approval of the faculty in Mechanical Engineering.

ME 125 ab. Engineering Laboratory. 9 units (1-6-2); first and third terms.

The techniques of making measurements encountered in engineering practice and research, with the use of special and standard measuring instruments, and the recognition of precision and accuracy of data secured. The planning of tests and research, and the analysis of data.

Instructors: ME Staff.

ME 150 abc. Mechanical Engineering Seminar. (2 units, 1-0-1); first, second, third terms.

Attendance required of graduate students in mechanical engineering. Conference on research work and reviews of new developments in engineering.

Instructors: ME Staff.

ME 200. Advanced Work in Mechanical Engineering.

The staff of the mechanical engineering department will arrange special courses on problems to meet the needs of students beyond the fifth year.

ME 208 ab. Crystal Structure of Metals and Alloys. 9 units (3-0-6); first and second terms.

Prerequisite: ME 110.

Atomic structure of metals, free atoms, assembly of atoms, physics of x-rays, elementary crystal structure. Methods of analysis of x-ray diffraction applied to metals and alloys. General principles of alloying. Structure of alloys, solid solutions, intermetallic compounds, electron compounds. During the latter part of the course, topics are assigned from the literature.

Instructor: Duwez.

ME 209 ab. X-ray Metallography. 6 units (0-6-0); second and third terms.

Prerequisite: ME 208 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 210 abc. Physical Metallurgy II. 9 units (3-0-6); first, second, and third terms.

Prerequisite: ME 110.

The modern theory of solids and applications to conductivity, magnetic properties, and cohesive energy of metals. Kinetics and mechanism of phase changes in the solid state. Long-range and short-range order in metals.

Text: References.

Instructor: Buffington.

ME 211 ab. Advanced Metallography Laboratory. 6 units (0-6-0); first and second term.

Prerequisites: ME 110, ME 111 ab.

Experimental studies of heat-treatment, grain size, hardenability, structures of ferrous and nonferrous materials, structure of welded and brazed joints, recrystallization, and special problems.

Text: *Principles of Metallographic Practice*, Kehl.

Instructor: Clark.

ME 214 ab. Mechanical Behavior of Metals. 9 units (3-0-6); second and third terms.

Prerequisite: ME 110 and AM 110 a.

A study of the nature and physical theory of the deformation of metals under the influence of applied forces. Elasticity of single crystals, anelasticity and internal friction, permanent deformation by slip and twinning. Theory of dislocation and its application to problems of the deformation of metals. Discussion of other selected topics in the mechanical behavior of metals, such as creep, fatigue, and fracture.

Instructor: Wood.

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: Kyropoulos.

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); first, second, third terms.

Prerequisites: Hy 101 abc or Ae 101 abc or equivalent.

The fluid mechanics of turbomachines; potential flow through two-dimensional cascades of airfoils; the theory of three-dimensional rotational flow in axial turbomachines; stall propagation in compressors; tip clearance flow and losses; boundary layer and other secondary flows in turbomachines; applications of the above to the design of turbomachines.

Instructor: Rannie.

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: Notes and original papers.

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 behavior in the engine, corrosion, sludge formation.

Bearing metals; tin, lead, silver, etc.

Texts: *Analysis and Lubrication of Bearings*, M. C. Shaw and E. F. Macks (McGraw-Hill, 1949); *Motor Oils and Engine Lubrication*, C. W. Georgi (Reinhold Publ. Co., 1950).

Instructor: Kyropoulos.

ME 300. Thesis Research.

For Subjects in Jet Propulsion see page 277.

PALEONTOLOGY

(See under Geological Sciences)

PHILOSOPHY AND PSYCHOLOGY

UNDERGRADUATE SUBJECTS

Pl 1. Introduction to Philosophy.* 9 units (3-0-6).

Senior elective.

A study of the major problems of philosophy in terms of the most influential contemporary world views, including naturalism, idealism, theism, pragmatism and positivism.

Instructors: Mead, Bures.

Pl 2. Logic.* 9 units (3-0-6).

Senior elective.

A study of modern and traditional logic. An analysis of knowledge into basic symbolic forms. Detailed consideration of such logical concepts as: proposition, truth, variable, definition, implication, inference, class, syllogism, logical law, deductive system. Emphasis on the fundamental role of logical methods in the rational approach to knowledge.

Instructor: Bures.

Pl 3.* 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 (30-6).

Senior elective.

A study of ethical values in relation to human nature and culture. Among the major topics considered are: the moral systems of some representative cultures; the development of personality and values in these cultures; the possibility of a rational basis for ethics; competing views of human nature; ethical conflicts in American culture.

Instructor: Bures.

Pl 6. General Psychology.* 9 units (3-0-6).

Senior elective.

An introduction to modern psychological theory and practice. The principal topics studied are: the response mechanisms and their functions, emotion; motivation; the nature and measurement of intelligence; learning and retention; sensation and perception; personality and personal adjustment.

Instructors: Mead, Bures, Weir.

Pl 7. Human Relations. 9 units (1-2-6); third term.

An introduction to the principles of human relations with major emphasis on the development of groups. Psychological and emotional factors influencing group behavior, group leadership and group co-operation will be explored.

Instructors: Coffey, Ferguson.

Pl 13. Reading in Philosophy. Units to be determined for the individual by the department. Elective, with the approval of the Registration Committee, in any term.

Reading in philosophy, supplementary to, but not substituted for, courses listed; supervised by members of the department.

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

ADVANCED SUBJECTS

Pl 100 abc. Philosophy of Science. 9 units (2-0-7).

A full-year sequence. The relation between science and philosophy. The functions of logical analysis in knowledge and the analysis of the language of science. A study of the nature of formal science (logic and mathematics) and of factual science, their methods and interrelationships. Concept formation in the sciences. Analysis of some basic problems in the philosophy of science: measurement, casuality, probability, induction, space, time, reality. Scientific method and social problems.

Instructor: Bures.

Pl 101 abc. History of Thought. 9 units (2-0-7).

A full-year sequence. A study of the basic ideas of Western Civilization in their historical development. The making of the modern mind as revealed in the development of philosophy and in the relations between philosophy and science, art and religion. The history of ideas in relation to the social and political backgrounds from which they came.

Instructor: Mead.

PHYSICS

UNDERGRADUATE SUBJECTS

Ph 1 abc. Mechanics, Molecular Physics, Heat and Sound. 12 units (3-3-6); first, second, third terms.

Prerequisites: High school physics, algebra and trigonometry.

The first year of a general college course in physics extending through two years. The course work consists of class recitations in which the basic material of physics is presented largely by means of analytical solutions to problems. A bi-weekly demonstration lecture by staff members from various departments illustrates some of the more interesting applications of physics. The weekly laboratory allows some choice of problem on the part of the student. In addition to many standard experiments, some material is provided for original experiments.

Text: *Mechanics, Molecular Physics, Heat and Sound*, Millikan, Roller, and Watson.

Instructors: Cowan, Strong, Watson, and Graduate Assistants.

Ph 2 abc. Electrostatics, Electrodynamics, and Optics. 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: *Introduction to Electricity and Optics*, Frank.

Instructors: T. Lauritsen, and Graduate Assistants.

Ph 20. Experimental Basis of Modern Physics. 9 units (3-0-6); second term.

This course is offered primarily as a sophomore elective for physics majors. The material includes such topics as electron physics, heat radiation, spectroscopy, x-rays, nuclear physics and cosmic rays, emphasizing those fundamental experiments on which present theories of the physical world are based. The subject matter overlaps that of Ph 112 to a considerable extent, but is treated at a more elementary level. Collateral reading in selected topics is emphasized.

Text: *Atomic Physics*, Semat.

Instructor: Whaling.

Ph 27 abc. Thermodynamics, Statistical Mechanics, and Kinetic Theory. 6 units (2-0-4); first, second, third terms.

Prerequisite: Ph 106 abc (may be taken concurrently).

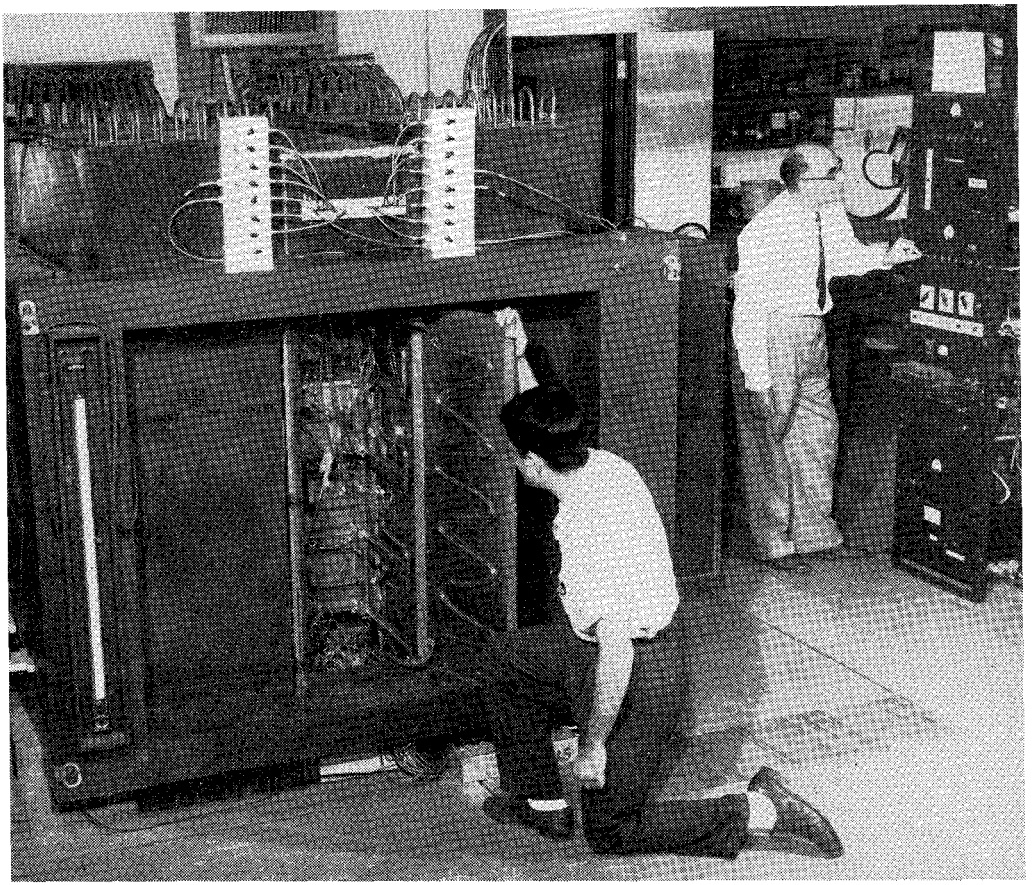
An introductory course covering the fundamental concepts of thermodynamics, statistical mechanics, and kinetic theory, with emphasis upon the physical principles involved.

Text: *Thermodynamics*, Sears.

Ph 77. Special Problems in Experimental Physics. 9-12 units (subject to arrangement with instructor). First term.

A laboratory course organized on a project basis, open to a limited number of senior physicists each year. Students will set up and perform experiments of their choice related to some field of modern physics. The emphasis will be upon developing the experimental ability and the initiative of the student, and upon familiarizing him with procedures of current importance in experimental physics.

Instructor: Whaling.



Cosmic ray cloud chamber, with the access door opened to show four cloud chamber sections which are mounted in the center of a 35-ton electromagnet.

ADVANCED SUBJECTS

Ph 106 abc. Introduction to Mathematical Physics. 12 units (4-0-8); 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 the solution of problems in physics. The emphasis will be primarily upon topics from the general field of mechanics, such as particle mechanics, the Euler-Lagrange and Hamilton equations, damped vibrations, coupled vibrating systems, the vibration of continuous systems, orthogonal functions, rigid body dynamics, and special relativity. Graduate students majoring in physics or astronomy will be given only 8 units credit for this course.

Text: *Mechanics*, Slater and Frank.

Instructors: Anderson, Peterson, Trilling.

Ph 107 abc. Electricity and Magnetism. 6 units (2-0-4); first, second, third terms.

Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc; Ph 106 abc or AM 15 (may be taken concurrently).

A course in theoretical electricity and magnetism, with an introduction to the solution of boundary value problems in electricity. Topics covered will include electrostatics, magnetostatics, and current flow; electromagnetic induction; electromagnetic radiation, including plane waves, spherical waves, dipole radiation; electromagnetic field energy and momentum. The emphasis will be upon the more general aspects of the subject, and upon physical principles. Graduate students majoring in physics or astronomy will be given only 4 units credit for this course.

Text: *Electromagnetism,* Slater and Frank.

Instructor: Tollestrup.

Ph 110 bc. Kinetic Theory of Matter. 9 units (3-0-6); second and third terms.

Prerequisites: Ph 1 abc, Ma 2 abc.

A lecture course in kinetic theory and its basic applications (and limitations) to the equilibrium and "steady" state phenomena in gases. Specific discussion of transfer, surface and low pressure phenomena, Brownian movement and kinetics of aerosols.

Text: *Kinetic Theory of Gases,* Kennard, Loeb and selected chapters from literature.

Instructor: Goetz.

Ph 112 abc. Introduction to Atomic and Nuclear Physics. 12 units (4-0-8)); first, second, third terms.

Prerequisites: Ph 106 abc and Ph 107 abc, or the equivalent.

An introductory problem and lecture course in the experimental and theoretical foundations of modern atomic and nuclear physics. Subjects include electromagnetic radiation, heat radiation, photoelectricity, atomic structure and the quantum theory, spectroscopy, quantum distribution laws, electrons in solids, x-rays, radioactivity and nuclear structure, nuclear reactions, elementary particles and high energy physics. Graduate students majoring in physics or astronomy will receive only 8 units credit for this course.

Instructor: Leighton.

Ph 115 ab. Geometrical and Physical Optics. 9 units (2-3-4); second and third terms.

Prerequisite: Ph 2 abc.

An intermediate lecture, problem, and laboratory course dealing with the fundamental principles of geometrical optics, of interference, of diffraction and other topics of physical optics. Graduate students majoring in physics or astronomy will receive only 6 units credit for this course.

Instructor: King.

Ph 129 abc. Methods of Mathematical Physics. 9 units (3-0-6); first, second, third terms.

Prerequisites: Ph 106 abc and Ma 108 abc or the equivalents.

Aimed at developing familiarity with the mathematical tools useful in physics, the course discusses practical methods of summing series, integrating, and solving differential equations, including numerical methods. The special functions (Bessel, Elliptic, Gamma, etc.) arising in physics are described, as well as Fourier series and transforms, partial differential equations, orthogonal functions, eigenvalues, calculus of variations, integral equations, matrices and tensors, and non-commutative algebra. The emphasis will be toward applications, with special attention to approximate methods of solution.

Instructor: Christy.

Ph 131 abc. Electricity and Magnetism. 9 units (3-0-6); first, second, and third terms.

Prerequisite: An average grade of C in Ph 107 abc.

A problem course in electricity, magnetism and electromagnetic waves for students who are doing or plan to do graduate work. The first two terms cover potential theory as applied to electrostatics, magnetostatics and current flow in extended mediums; and the laws of electromagnetic induction as applied to linear circuits. The third term covers eddy currents, electromagnetic waves and the motion of charged particles in electromagnetic fields.

Text: *Static and Dynamic Electricity,* Smythe.

Instructor: Smythe.

Ph 172. Research in Physics. Units in accordance with the work accomplished. Approval of the department must be obtained before registering.

Ph. 201 ab. Analytical Mechanics. 9 units (3-0-6); first and second terms.

Prerequisites: Ph 106 abc or AM 15 abc; Ph 129 ab is desirable.

A problem and lecture course dealing with the various formulations of the laws of motion of systems of particles and rigid bodies, and with both exact and approximate solutions of the resulting equations. Topics considered include Lagrange's equations, canonical transformations, vibrations about equilibrium and steady motion, and the non-linear oscillator.

Instructor: Pellam.

Ph. 202. Topics in Classical Physics. 9 units (3-0-6); third terms.

The content of this course will vary from year to year. Typical topics: Elasticity, Hydrodynamics, potential theory, a study of mechanical wave motions.

Instructor: Davis.

Not given in 1955-56.

Ph. 203 abc. Nuclear Physics. 9 units (3-0-6); first, second, and third terms.

Prerequisite: Ph 112 abc or equivalent.

A problem and lecture course in nuclear physics. Subjects include fundamental properties and structure of nuclei, nuclear forces, nuclear reactions, and particle accelerators.

Instructor: Fowler.

Ph 205 abc. Principles of Quantum Mechanics. 9 units (3-0-6); first, second and third terms.

Prerequisites: Ph 112 abc or equivalent; Ph 129 abc is desirable.

First and second terms: A basic course in quantum mechanics. Subjects include superposition of amplitudes, Schroedinger equation, hydrogen atom, perturbation theory, H-molecule ion, helium atom, operators, spin, complex atoms, particle scattering and radiation. Third term: Relativistic quantum mechanics, Dirac equation and quantum electrodynamics.

Instructor: Feynman.

Ph 207 abc. X- and Gamma-rays. 9 units (3-0-6); first second, and third terms.

Prerequisite: Ph 112 abc, or equivalent.

Covers the generation of x-rays and gamma-rays and the various interactions of these with matter both in practical applications to research physics and in theory. The first term is devoted to a descriptive general survey of the subject. The second term deals with nuclear gamma-ray and x-ray emission spectra, the mean lives of excited states, elementary theory of multipole radiation, theories of the generation and intensities of characteristic x-ray line spectra and also of the continuous x-ray spectrum covering briefly under the latter topic the theories of Sommerfield and of Heitler and their experimental verifications. The third term covers in considerable detail the scattering of these radiations by matter, both coherent and incoherent processes being considered, and presents the resulting physical conclusions regarding the structure of atoms, molecules, liquids, solids and the Compton effect with its manifold implications. Other interactions between radiation and matter are also treated. Solution of a moderate number of illustrative problems required in all three terms.

Instructor: DuMond.

Not given in 1955-56.

Ph 209 abc. Optics and Electron Theory. 9 units (3-0-6); first, second, and third terms.

Prerequisites: Ph 107 abc; and Ph 131 ab is desirable.

The first term is devoted to selected topics in geometrical and physical optics. The remaining terms take up electromagnetic waves in vacuum and in matter, dispersion and absorption, special relativity, the classical theory of electrons, including retarded potentials, radiation of a point charge, theory of dielectrics and of magnetism.

Instructor: Sands.

Not given in 1955-56.

Ph 212 ab. Mechanics of Continuous Media. 9 units (3-0-6); second and third terms.

Prerequisite: Ph 201 ab.

Hydrodynamics of nonviscous fluids; Euler and Lagrange equations; general integrals and special problems. Hydrodynamics of viscous fluids; applications of the Navier-Stokes equations to special problems. Theory of supersonic flow and shock waves. Fundamental equations of the theory of elasticity.

Instructor: Plesset.

Ph 217. Spectroscopy. 9 units (3-0-6); third term.

Prerequisite: Ph 112 abc or the equivalent.

A discussion of observed spectra in terms of atomic structure theory.

Instructor: King.

Ph 218 ab. Electronic Circuits and their Application to Physical Research. 9 units (3-0-6); first and second terms.

Permission of the instructor is required in order to register for this course.

A course on electronic circuits with primary emphasis on basis factors entering into the design and use of electronic instruments for physical research. Topics considered will include the theory of response of linear networks to transient signals, linear and nonlinear properties of electron tubes and practical circuit components, basic passive and active circuit combinations, cascade systems, amplifiers, feedback in linear and nonlinear systems, statistical signals, noise, and practical construction. Particular examples will be taken from commonly used research instruments.

Instructor: Sands.

Given in alternate years. Offered 1955-56.

Ph 219 abc. Advanced Electromagnetic Field Theory. 9 units (3-0-6); first, second, and third terms.

This course covers the applications of Maxwell's equations to problems involving antennas, waveguides, cavity resonators, and diffraction. It includes the solution of problems by the classical methods of retarded potentials and orthogonal expansions and lectures in the modern techniques of Schwinger that employ the calculus of variations and integral equations. (Identical with EE 250 abc.)

Texts: *Static and Dynamic Electricity*, Smythe; Course Notes.

Instructors: Smythe and Papas.

Ph 227 abc. Thermodynamics, Statistical Mechanics, and Kinetic Theory. 9 units (3-0-6); first, second and third terms.

Prerequisites: Ph 201 ab, 205 ab (may be taken concurrently) or the equivalent.

The fundamental concepts and laws of thermodynamics. Entropy and other characteristic functions. Nernst's theorem. Kinetic theory of gases. Classical and quantum statistical mechanics. The relation between statistical mechanics and thermodynamics. Illustrative applications of thermodynamics and statistical mechanics.

Instructor: Davis.

Ph 231 ab. Cosmic Rays and High Energy Physics. 9 units (3-0-6); second and third terms.

The properties of high-energy particles and radiation as determined from experiments with cosmic rays and from experiments with electronuclear machines. Topics included are electromagnetic interactions, nuclear interactions, and the production and properties of mesons and V-particles.

Instructors: Anderson and Bacher.

Not given in 1955-56.

Ph 234 abc. Topics in Theoretical Physics. 9 units (3-0-6); first, second, and third terms.

Prerequisite: Ph 205 ab or equivalent.

The content of this course will vary from year to year. Topics presented will include: General methods in quantum mechanics such as operator calculus, group theory and its application; theory of meson and electromagnetic fields; atomic and molecular structure; theory of solids; theoretical nuclear physics.

Instructor: Gell-Mann.

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 235a may be taken separately by students who are interested only in the principles and applications of the special theory of relativity.

Offered in alternate years. Not given in 1955-56.

Instructor: Robertson.

Ph 238 abc. Seminar on Theoretical Physics. 4 units; first, second, and third terms.

Recent developments in theoretical physics for specialists in mathematical physics.

In charge: Christy, Feynman, and Gell-Mann.

Ph 241. Research Conference in Physics. 4 units; first, second, and third terms.

Meets once a week for a report and discussion of the work appearing in the literature and that in progress in the laboratory. Advanced students in physics and members of the physical staff take part.

In charge: Bacher.

Ph 300. Research in Physics. Units in accordance with work accomplished. Approval of the Department must be obtained before registering.

Ph 300 is elected in place of Ph 172 when the students has progressed to the point where his research leads directly toward the thesis of the degree of Doctor of Philosophy.

PSYCHOLOGY

(See under Philosophy)

RUSSIAN

(See under Languages)

PART FOUR

Degrees, Honors, and Awards, 1954-55

DEGREES CONFERRED JUNE 10, 1955

Doctor of Philosophy

Douglas Einar Applequist (Chemistry and Biology). B.S., University of California, 1952.

George Myron Arcand (Chemistry and Physics). B.S., California Institute of Technology, 1950.

Michel Bader (Physics and Mathematics). B.S., California Institute of Technology, 1952.

Sune Bertil Berndt (Aeronautics and Mathematics). C.E., Swedish Royal Institute of Technology, 1947; Tecn. Licent., 1951.

Richard Allan Bernard (Chemistry and Plant Physiology). B.S., Stanford University, 1950.

Dwight Winton Berreman (Physics and Mathematics). B.S., University of Oregon, 1950; M.S., California Institute of Technology, 1952.

Egil Kristoffer Björnerud (Physics and Astronomy). B.S., University of Washington, Angeles, 1951.

John Doyle Britton (Chemistry and Mathematics). B.S., University of California, Los Angeles, 1951.

John Warren Brookbank (Embryology and Animal Physiology). B.A., University of Washington, 1949; M.S., 1952.

Odus Roy Burggraf (Aeronautics and Physics). B.Ae., Ohio State University, 1952; M.S., 1952.

C. Wayne Burnham (Geochemistry and Petrology). B.A., Pomona College, 1951; M.S., California Institute of Technology, 1953.

Douglas Dean Campbell (Metalliferous Geology and Mineralogy). B.A.Sc., University of British Columbia, 1946.

John Arthur Carlson (Mechanical Engineering and Physics). B.S., Illinois Institute of Technology, 1951; M.S., California Institute of Technology, 1952.

Robert Apperson Chase (Aeronautics and Mathematics). B.S., Stanford University, M.S., 1951.

Robert Norman Clayton (Chemistry and Mathematics). B.Sc., Queen's University, 1951; M.Sc., 1952.

Duane Herbert Cooper (Physics and Mathematics). B.S., California Institute of Technology, 1950.

Eugene Floyd Cox (Chemistry and Plant Physiology). B.S., Georgia Institute of Technology, 1950; M.S., 1951.

Stephen Franklin Crumb (Electrical Engineering and Physics). B.S., University of Texas, 1943; M.S., 1948.

Milford Hall Davis (Physics and Mathematics). B.S., Yale University, 1949; M.S., California Institute of Technology, 1950.

Joseph Myers Denney (Engineering Science and Physics). B.S., California Institute of Technology, 1951; M.S., 1952.

Saul Feldman (Mechanical Engineering and Mathematics). B.S., University of California, Los Angeles, 1951; M.S., 1953.

Gary Felsenfeld (Chemistry and Biology). A.B., Harvard College, 1951.

Arthur W. Fort (Chemistry and Literature). B.S., University of Chicago, 1949; S.M., 1951.

Edwin Jean Furshpan (Animal Physiology and Embryology). B.A., University of Connecticut, 1950.

George Jay Gleghorn, Jr. (Electrical Engineering and Mathematics). B.S., University of Colorado, 1947; M.S., California Institute of Technology, 1948.

Martin Goldsmith (Mechanical Engineering and Physics). B.S., University of California, 1951; M.S., California Institute of Technology, 1952.

Juris Hartmanis (Mathematics and Physics). B.A., University of Marburg, 1949; M.A., University of Kansas City, 1951.

Ray Alden Hefferlin (Physics and Astronomy). B.A., Pacific Union College, 1951.

Albert Roach Hibbs (Physics and Mathematics). B.S., California Institute of Technology, 1945; S.M., University of Chicago, 1947.

Robert Ross Jennings (Chemistry and Biology). B.S., California Institute of Technology, 1950.

JOHN BEVERLEY JOHNSTON (Mathematics and Physics). B.S., California Institute of Technology, 1951.

ARMIN DALE KAISER (Biophysics and Chemistry). B.S., Purdue University, 1950.

STANLEY LEONARD KAMENY (Physics and Mathematics). B.S., Queens College, Flushing, New York, 1948; M.S., California Institute of Technology, 1949.

WILLIAM JAMES KARZAS (Physics and Mathematics). B.S., California Institute of Technology, 1949.

SHANKAR LAL (Aeronautics and Mathematics). B.Sc., Benares Hindu University, 1944; D.I.I.Sc., Indian Institute of Science (Bangalore), 1946; D.I.C., Imperial College of Science and Technology (London), 1947; M.S., London University, 1949.

JOHN IRVIN LAURITZEN, JR. (Physics and Mathematics). B.A., Miami University, 1949.

DAVID ARTHUR LIBERMAN (Physics and Mathematics). B.S., California Institute of Technology, 1949.

CINNA LOMNITZ (Geophysics and Civil Engineering). C.E., University of Chile, 1948; M.S., Harvard University, 1950.

RALPH LUTWACK (Chemistry and Physics). B.S., California Institute of Technology, 1950.

RICHARD JEFFREY MAGNUS (Aeronautics and Mathematics). B.Ae., University of Minnesota, 1944; M.S., 1947; AeE., California Institute of Technology, 1948.

JOSEPH DAVID MANDELL (Virology and Genetics). B.S., Rutgers University, 1950; M.S., Oklahoma Agricultural and Mechanical College, 1951.

DAVID TREADWAY MANNING (Chemistry and Biology). B.S., California Institute of Technology, 1950.

KOICHI MANO (Physics and Mathematics). B.S., Tokyo University, 1945.

CRAIG MARKS (Mechanical Engineering and Chemistry). B.S., California Institute of Technology, 1950; M.S., 1951.

ROYAL RICHARD MARSHALL (Chemistry and Geology). B.S., University of Minnesota, 1950.

JOHN WILLIAM MCKEE (Physics and Biology). B.S., Iowa State College, 1949.

WILLIAM RAYMOND MILLS, JR. (Physics and Mathematics). B.A., The Rice Institute, 1951.

DAVID CHARLES OAKLEY (Physics and Mathematics). B.S., California Institute of Technology, 1950; M.S., 1952.

ALLEN IVES ORMSBEE (Aeronautics and Mathematics). B.S., University of Illinois, 1946; M.S., 1949.

DONALD RALPH PETERSEN (Chemistry and Physics). B.A., Lawrence College, 1951.

CORNELIUS JOHN PINGS, JR. (Chemical Engineering, Chemistry and Mathematics). B.S., California Institute of Technology, 1951; M.S., 1952.

RODRIGO ALVARO RESTREPO (Mathematics and Physics). B.A., Lehigh University, 1951.

BRUCE JOSEPH ROGERS (Plant Physiology and Bio-organic Chemistry). B.S.F., University of California, 1949; M.S.F., 1950.

JOHN JAMES WILLIAM ROGERS (Petrology and Geochemistry). B.S., California Institute of Technology, 1952; M.S., University of Minnesota, 1952.

ROY MONROE SACHS (Biology and Invertebrate Paleontology). B.S., Massachusetts Institute of Technology, 1951.

FRANK BOYER SALISBURY (Plant Physiology and Geochemistry). B.S., University of Utah, 1951; M.S., 1952.

KAZUHIKO SATO (Chemical Engineering and Chemistry). B.S., California Institute of Technology, 1951; M.S., 1952.

ALFRED DALE SCARBROUGH (Electrical Engineering and Physics). B.S., California Institute of Technology, 1945; M.S., 1947.

DOROTHY ANN SEMENOW (Chemistry and Biology). B.A., Mount Holyoke College, 1951.

SEDAT SERDENGECTI (Mechanical Engineering and Mathematics). B.S., Syracuse University, 1951; M.S., California Institute of Technology, 1952.

LEON THEODORE SILVER (Structural Geology and Petrology and Geochemistry). B.S., University of Colorado, 1945; M.S., University of New Mexico, 1948.

GEORGE TOLMIE SKINNER (Aeronautics and Physics). B.S., University of St. Andrews, 1948; M.S., California Institute of Technology, 1949; AeE., 1951.

WILLIAM GLENN SLY (Chemistry and Physics). B.S., San Diego State College, 1951.

GERALD SPEISMAN (Physics and Mathematics). B.S., City College of New York, 1951.

EDWARD ABRAHAM STERN (Physics and Mathematics). B.S., California Institute of Technology, 1951.

JOHN CHARLES STEWART (Astronomy and Physics). B.S., University of the South, 1951; Sc.M., Brown University, 1952.

ARNOLD ADOLPH STRASSENBURG (Physics and Mathematics). B.S., Illinois Institute of Technology, 1951; M.S., California Institute of Technology, 1953.

GEORGE WALTER SUTTON (Mechanical Engineering and Physics). B.M.E., Cornell University, 1952; M.S., California Institute of Technology, 1953.

GEORGE HENRY TRILLING (Physics and Mathematics). B.S., California Institute of Technology, 1951.

DAVID RICHARD VIGLIERCHIO (Bio-organic Chemistry and Plant Physiology). B.S., California Institute of Technology, 1950.

THEODORE STRATTON WEBB, JR. (Physics and Mathematics). B.S., University of Oklahoma, 1951.

TRUMAN OWEN WOODRUFF (Physics and Mathematics). A.B., Harvard College, 1947; B.A., Oxford University, 1950.

WILLIAM VALE WRIGHT, JR. (Mechanical Engineering and Physics). B.S., California Institute of Technology, 1951.

HSUN-TIAO YANG (Aeronautics and Mathematics). B.S., National Central University, 1946; M.S., University of Washington, 1950.

STANLEY ALAN ZWICK (Physics and Mathematics). B.S., California Institute of Technology, 1950.

ENGINEER'S DEGREES

Aeronautical Engineer

LAWRENCE CLOYD BALDWIN, Lt., U.S.N., B.S., United States Naval Academy, 1945; B.S., United States Naval Postgraduate School, 1954.

WILLIAM CURTIS BENTON, Major, U.S.M.C., B.S., United States Naval Postgraduate School, 1954.

CARL BIRDWELL, JR., Lt., U.S.N., B.S., United States Naval Postgraduate School, 1954.

ROY STRIBLING CORNWELL, Lt. Comdr., U.S.N., B.Ae.Eng., North Carolina State College, 1943; B.S., United States Naval Postgraduate School, 1954.

THOMAS HUSTON CROWE, Lt. U.S.N., B.S., University of South Carolina, 1945; B.S., United States Naval Postgraduate School, 1954.

ROBERT FRANKLIN DOSS, Lt., U.S.N., B.S., United States Naval Postgraduate School, 1954.

ALVIN LYONE FEHRMAN, Capt., U.S.A.F., B.E., Vanderbilt University, 1947.

WESTON MORGAN HOWARD, B.S., University of Washington, 1953.

GEORGE THOMAS JAMES, JR., Capt., U.S.A.F., B.S.M.E., Purdue University, 1949.

DONALD WALTER KILEY, Lt., U.S.N., B.S., United States Naval Postgraduate School, 1954.

HAROLD CECIL LARSEN, B.S., University of Utah, 1941; M.S., California Institute of Technology, 1946.

ROBERT MCCLELLAN, B.S., California Institute of Technology, 1948; M.S., 1949.

JAMES FOSTER REX, Lt., U.S.N., B.S., United States Naval Postgraduate School, 1954.

PEHR HARALD BENEDICTUS SCHALIN, B.S., Finland Institute of Technology, 1946; M.S., California Institute of Technology, 1954.

OSCAR SEIDMAN, B. Sc., Rutgers University, 1929; M. Sc., 1931.

GEORGE STALK, Capt., U.S.A.F., B.S., Purdue University, 1949.

WILLIAM JEFFRIS WILLIAMSON, B.S., California Institute of Technology, 1948; M.S., 1949.

Mechanical Engineer

RAY DEVERLE BOWERMAN, B.S., California Institute of Technology, 1951; M.S., 1952.

RICHARD WILSON FLYGARE, B.S., University of Utah, 1949; M.S., California Institute of Technology, 1953.

MASTER OF SCIENCE IN SCIENCE

Astronomy

WILLIAM GEARY MELBOURNE, A.B., University of California, 1954.
RAY LEON NEWBURN, JR., B.S., California Institute of Technology, 1954.

Biology

TOYOO TOMITA, M.S., Tohoku University, 1952.

Chemistry

JAMES KING, JR., B.S., Morehouse College, 1953.

Chemical Engineering

PAUL LINCOLN ARMSTRONG, JR., B.S., California Institute of Technology, 1951.
JIMMIE RONALD BOWDEN, B.S., University of Kansas, 1949.
RONALD TAYLOR CALDWELL, B.S., California Institute of Technology, 1951.
MANUEL JESÚS CRESPO, B.S., California Institute of Technology, 1951.
JEAN GARCIN, Dipl. Eng., École Centrale des Arts et Manufactures (Paris), 1954.
ROBIN NEAL HUNTLEY, B.S., California Institute of Technology, 1954.
DAVID SWARNER KOONS, B.S., California Institute of Technology, 1952.
MOISES LEVY, B.S., California Institute of Technology, 1952.
ROBERT FREDERICK MELDAU, B.S., University of California, 1950.
GORDON BRUCE MUNN, B.S., California Institute of Technology, 1954.
ROBERT GENE RINKER, B.S., Rose Polytechnic Institute, 1951.
GORDON W. WHITAKER, B.S., Purdue University, 1951.
WARREN CARL WINDHAM, B.S., Lamar State College of Technology, 1954.

Geology

LLOYD EARL BEST, Geoph. Eng., Colorado School of Mines, 1952.
DONALD G. BRYANT, B.S., University of Arizona, 1954.
THOMAS B. HOWES, A.B., Knox College, 1943.
ARTHUR E. LEWIS, B.S., St. Lawrence University, 1950.
BRUCE OWEN NOLF, B.A., State University of Iowa, 1954.
BIMALENDU RAYCHAUDHURI, B.Sc., Calcutta University, 1948; M.Sc., 1951.
ARTHUR WILLIAM ROSE, B.S., Antioch College, 1953.
DAVID MCLEAN WILSON, B.S.E., Princeton University, 1953.
DONALD UNDERKOFLER WISE, B.S., Franklin and Marshall College, 1953.

Geochemistry

HENRY PHILIP SCHWARCZ, A.B., University of Chicago, 1952

Geophysics

DONALD JAMES MARSHALL, B.S., Massachusetts Institute of Technology, 1954.
CLIFTON RICHARD SMITH, B.S., California Institute of Technology, 1954.

Physics

ARTHUR H. MUIR, JR., B.A., Williams College, 1953.
HENRY RICHARD MYERS, B.S., Massachusetts Institute of Technology, 1954.
PHILIP R. SNELGROVE, B.S., Brigham Young University, 1953.
TERENCE CHRISTOPHER TERMAN, B.S., Stanford University, 1952.
WALTER D. WALES, B.A., Carleton College, 1954.

MASTER OF SCIENCE IN ENGINEERING

Aeronautics

DAVID HARRIS CAMPBELL, B.S., Queens University, 1954.
LUCIANO CAVALCANTE, B.S., Rensselaer Polytechnic Institute, 1953.
BERNARD ANTOINE DARRIEUS, Ing. Civil de Ae., École Nationale Superieure de l'Aeronau tique, 1954.
ALVIN LYONE FEHRMAN, Capt., U.S.A.F., B.E., Vanderbilt University, 1947.
TERRELL WALLACE FEISTEL, B.S., California Institute of Technology, 1954.
CHARLES ROBERT HAMILTON, Dipl. Ae., University of Bucharest, 1952.
KEITH LARSEN HENRIE, B.S., University of California, 1954.
ARTHUR CHARLES HEYMAN, B.A.E., New York University, 1954.
HOMER HARVEY HOWELL, JR., B.S., U.S.A.F. Institute of Technology, 1951.
GEORGE THOMAS JAMES, JR., Capt., U.S.A.F., B.S., Purdue University, 1949.
PETER BARRY STUART LISSAMAN, B.S., Natal University of South Africa, 1951.
ROBERT MARTIN PEDRAGLIA, B.S., California Institute of Technology, 1948.
SIGMUND MARVIN REDELSHEIMER, B.Ae.E., Alabama Polytechnic Institute, 1951.
KENNETH WILLIAM ROGERS, B.S., University of Wyoming, 1950.
GEORGE STALK, Capt., U.S.A.F., B.S., Purdue University, 1949.

Civil Engineering

LELAND DEAN ANDERSON, B.S., California State Polytechnic College, 1954.
JAMES MELVIN BELL, B.S., Colorado Agricultural and Mechanical College, 1954.
JOSEPH DUTCHER BENNETT, B.S., University of Colorado 1954.
J. M. ROGER DE WIEST, C.E., University of Ghent, 1949.
HARRY AUGUSTUS GRIFFITH, Capt., U.S.A., B.S., United States Military Academy, 1949.
HASHIM HUSSAIN HAMZAWÍ, C.E., College of Engineering, Bagdad, 1951.
MCGLACHLIN HATCH, Lt. Col., U.S.A., B.S., United States Military Academy, 1943.
WILLIAM EDWARD HUBER, Capt., U.S.A., B.S., United States Military Academy, 1949.
DENNIS VERNON LONG, B.S., California Institute of Technology, 1949.
ROLAND SEBA MILLER, B.S., California Institute of Technology, 1954.
WILLIAM THORNTON MOORE, Capt., U.S.A., B.S., United States Military Academy, 1949.
MANUEL MORDEN, B.S., California Institute of Technology, 1954.
WILLIAM ADDISON RANK, Capt., U.S.A., B.S., United States Military Academy, 1949.
MANLEY EATON ROGERS, Capt., U.S.A., B.S., United States Military Academy, 1950.
HOWARD LYNN STROHECKER, Capt., U.S.A., B.S., United States Military Academy, 1949.

Electrical Engineering

GARY DELANE BOYD, B.S., California Institute of Technology, 1954.
ALAIN BRÈTHES, Eng. École Nationale Superieure des Télécommunications, 1954.
VINCENZO MARIA CESTARI, B.S., California Institute of Technology, 1955.
JAMES COLBATH CROSBY, B.S., California Institute of Technology, 1954.
WALTER FRANK EICHWALD, B.S., University of Pennsylvania, 1954.
ROGER MORSE GOLDEN, B.S., California Institute of Technology, 1954.
NELSON NEWCOMB HOFFMAN, B.S., Drexel Institute of Technology, 1954.
HSUNG-CHENG HSIEH, B.A., Dartmouth College, 1954.
CURTIS CARL JOHNSON, B.S., California Institute of Technology, 1954.
WALTER ADOLPH JOHNSON, B.E.E., The Cooper Union, 1954.
MACROBIO LIM, B.S., University of the Philippines, 1950.
RICHARD PHILIP MATHISON, B.S., Purdue University, 1952.
ARTHUR EDWARD MILLER, JR., B.S., California Institute of Technology, 1954.
WILLIAM ROBERT MORELAND, B.S., Illinois Institute of Technology, 1954.

RICHARD FRANCIS OKADA, B.S., Drexel Institute of Technology, 1954.
ROBERT KEITH PETERSON, B.S., University of Colorado, 1951.
PHILIP DAVIS POTTER, B.S., California Institute of Technology, 1954.
WILLARD VAN TUYL RUSCH, B.S.E., Princeton University, 1954.
TAKESHI SATO, B.S., California Institute of Technology, 1954.
JERRY LEON STUART, B.S., University of Tulsa, 1953.
ALVIN WILLIAM TRIVELPIECE, B.S., California State Polytechnic College, 1953.
THEODORE VAN DER WAETEREN, E.M.Eng., University of Louvain (Belgium), 1954.

Mechanical Engineering

GUNNAR ERIK BROMAN, Cert., Royal Institute of Technology (Sweden), 1949.
DANIEL JOSEPH COLLINS, B.A., Lehigh University, 1954.
ALLEN EUGENE FUHS, B.S., University of New Mexico, 1951.
ROBERT OREN GOSE, B.S., University of Wyoming, 1947.
RICHARD ELDON HYDE, B.S., California Institute of Technology, 1954.
JOHN THOMAS LLOYD, B.S., California Institute of Technology, 1954.
REGIS EARL NEUMAN, B.S., Carnegie Institute of Technology, 1951.
JOHN STANLEY NIEWIEROSKI, B.S., University of Connecticut, 1954.
JERRY ALAN ORR, B.S., University of Miami, 1954.
ROBERT VIDAL RAGSAC, B.S., San Jose State College, 1954.
HERBERT SCHWARTZ, B.M.E., New York University, 1949.
ROBERT LOUIS SMITH, B.S., California Institute of Technology, 1954.
STEPHEN LOUIS STAMM, B.S., University of Pennsylvania, 1954.
SALVATORE PHILIP SUTERA, B.E., Johns Hopkins University, 1954.
SIMON TAMNY, B.S., California Institute of Technology, 1954.

BACHELOR OF SCIENCE IN SCIENCE

JOHN PHILIP ANDELIN, Jr., *Physics, Academic Honor, Honor Key.*
MERVYN LEE BARMAN, *Physics.*
ALFRED ANGEL BARRIOS, *Applied Chemistry.*
GILBERT LAWRENCE BEEBOWER, *Applied Chemistry.*
WILLIAM ARNOLD BERG, JR., *Physics.*
EDWARD MICHAEL BOUGHTON, JR., *Physics, Academic Honor, Honor Key.*
CARL O. BOWIN, *Geology.*
CHARLES JACOB BROKAW, *Biology, Academic Honor.*
CHALON LUCIUS CARNAHAN, *Chemistry, Academic Honor.*
DAVID LESTER CROWTHER, *Physics, Academic Honor.*
ERNEST AARON DERNBURG, *Biology.*
JOHN JACOB DOMINGO, *Physics, Academic Honor.*
ERNEST DZENDOLET, *Biology.*
LEWIS FRANCIS ELLMORE, *Physics.*
EUGENE ENGELS, JR., *Physics, Academic Honor.*
GEORGE EPSTEIN, *Mathematics.*
PHILIP JOSEPH FERRELL, *Physics.*
BERN DONALD FOLKMAN, *Applied Chemistry.*
HARVEY S. FREY, *Physics.*
HORACE WATARU FURUMOTO, *Physics.*
GARY S. GAYRON, *Physics, Academic Honor.*
JAY ARTHUR GLASEL, *Chemistry, Academic Honor.*
STANLEY LAWRENCE GROTCH, *Applied Chemistry, Academic Honor.*
WALTER HAENGGI, *Geology.*
WILLIAM RUBECK HAGEMEIER, *Physics.*

JOHN LEONARD HONSAKER, *Physics, Academic Honor.*
CONRAD HOUSLEY, *Geology.*
RICHARD MILTON JALI, *Physics.*
MARION ALAN JONCICH, *Physics, Academic Honor.*
ALBERT JOHN LIEBER, *Physics.*
WILLIAM BRECKENRIDGE LINDLEY, *Physics, Academic Honor.*
ORESTE WOODBURY LOMBARDI, *Geochemistry.*
STANLEY LAWRENCE MANATT, *Chemistry, Academic Honor.*
VINCENT ANTHONY MARINKOVICH, *Physics, Honor Key.*
FREDERICK MARTIN, *Physics.*
THEODORE KERNER MATTHES, *Mathematics, Academic Honor.*
EDWIN JAMES MEACHAM, *Chemistry.*
ROBERT FRANCIS MEADE, *Geology.*
WALTER RICHARD MENETREY, *Physics, Academic Honor.*
JOHN JAY MERRILL, *Physics, Academic Honor, Honor Key.*
F. CURTIS MICHEL, *Physics, Academic Honor.*
RALPH FRALEY MILES, JR., *Physics, Academic Honor.*
MARCO ROLAND NEGRETE, *Physics, Academic Honor.*
RICHARD LEROY NIELSEN, *Geology.*
THOMAS WYATT NOONAN, *Physics, Academic Honor.*
HENDRICK HUNTER PAALMAN, *Applied Chemistry, Academic Honor.*
ROY WILMER PAUL, JR., *Mathematics.*
RICHARD JOHN PICCOLINI, *Chemistry, Academic Honor.*
RICHARD BRADLEY READ, *Physics, Academic Honor.*
DONALD BRUCE ROBERTS, *Physics, Academic Honor, Honor Key.*
JACK WILBUR ROCCHIO, *Physics.*
CHARLES SPENCER ST. CLAIR, *Geology.*
BERNARD PAUL SCHWEITZER, *Physics, Honor Key.*
EDWIN BURT SEIDMAN, *Chemistry.*
SAMUEL JOHN SIMS, *Geology.*
DONALD JAMES TAYLOR, *Physics.*
THOMAS TRILLING, *Physics.*
JAMES STEPHEN TYLER, *Applied Chemistry.*
DONALD ARTHUR VOGEL, *Biology.*
MARTIN VOGEL, *Chemistry, Academic Honor.*
RICHARD FRANKLIN WEBBER, *Physics, Academic Honor.*
JOHN DAVID WEISNER, *Physics.*
JOHN HARMON WOLFE, *Mathematics.*
ALVA FUMIHIKO YANO, *Physics.*
KENNETH ZIEDMAN, *Physics.*

BACHELOR OF SCIENCE IN ENGINEERING

JAMES LOWELL ADAMS, *Mechanical Engineering, Academic Honor, Honor Key.*
JOHN EDWIN AMES, JR., *Mechanical Engineering, Aeronautics.*
FRANCESCO GALLATIN BEUF, *Mechanical Engineering, Honor Key.*
WALTER D. BIGGERS, *Mechanical Engineering.*
DELANO ALEXANDER BROUILLETTE, *Electrical Engineering, Academic Honor*
JOHN ARTHUR BRYANT, *Mechanical Engineering.*
JOHN DANIEL BUSH, *Mechanical Engineering.*
VINCENZO MARIA CESTARI, *Electrical Engineering.*
WILLIAM HAROLD CHAMBERS, JR., *Mechanical Engineering.*
ROBERT DALE CHRISTIAN, *Mechanical Engineering.*
RONALD ROBERT COCHRAN, *Mechanical Engineering.*
JOHN WILLIAM CONVERSE, *Mechanical Engineering.*
PAUL WILLIAM CRAMER, JR., *Electrical Engineering.*
LAWRENCE S. CRANE, *Electrical Engineering.*
WILLIAM JAMES CREIGHTON, *Mechanical Engineering, Academic Honor.*
BENJAMIN EDGAR CUMMINGS, *Aeronautics, Academic Honor.*
RONALD WAYNE DANKLEFS, *Mechanical Engineering.*
EUGENE HUNTER DRYDEN, *Electrical Engineering, Academic Honor.*
ALFRED MYNDERSE GOLDMAN, JR., *Aeronautics.*
JOSEPH ERNEST GRAETCH, *Mechanical Engineering.*
RAYMOND GEORGE GRIESER, *Electrical Engineering, Honor Key.*
DANIEL J. GRIFFIN, JR., *Electrical Engineering.*
WILLIAM BRUCE HAIGLER, *Mechanical Engineering.*
LEIGHTON D. HANON, JR., *Mechanical Engineering.*
PAUL LEROY HARRISON, *Electrical Engineering.*
ALAN LEE HELGESSON, *Electrical Engineering, Academic Honor, Honor Key.*
GERALD EUGENE HOOPER, *Electrical Engineering.*
CARL WESLEY JOHNSON, *Electrical Engineering.*
LOUIS URS KILCHENMAN, *Electrical Engineering.*
HAROLD ROBERT KRAMER, *Electrical Engineering.*
ROGER EDWIN LAGERQUIST, *Mechanical Engineering.*
WILLIAM FRANK LAPSON, *Mechanical Engineering.*
HUGH GATSON LENEY, *Electrical Engineering, Academic Honor.*
JAMES PETTIS LEWIS, *Mechanical Engineering, Honor Key.*
GERALD ZEE LIPPEY, *Aeronautics, Academic Honor.*
GEORGE EVERETTE MADSEN, *Civil Engineering, Academic Honor, Honor Key.*
RICHARD ADDISON MANLEY, *Mechanical Engineering.*
FRANK RAYMOND MASTROLY, JR., *Mechanical Engineering.*
JAMES MCCLOUD, *Mechanical Engineering.*
GEORGE HOBART MCDONALD, JR., *Civil Engineering, Academic Honor, Honor Key.*
CHARLES NEAL MCKINNON, JR., *Aeronautics.*
MILES ALBIN NESMAN, *Aeronautics.*
ALBERT LOYD NICHOLS, JR., *Mechanical Engineering.*
EARL VERN NOGLE, *Electrical Engineering.*
STANLEY FRASER PARKILL, *Mechanical Engineering.*
RUDOLPH CARL PARZL, *Electrical Engineering.*
ROBERT VERNON POWELL, *Electrical Engineering.*
JAMES GORDON ROBINS, *Electrical Engineering.*
JERROLD ALLEN ROYCE, *Civil Engineering.*
RICHARD R. SCHMID, *Civil Engineering.*
CHARLES PAUL SHUMATE, *Mechanical Engineering.*

RODNEY WILLIAM SUPPLE, *Mechanical Engineering, Honor Key.*
THOMAS GEORGE TAUSSIG, *Electrical Engineering.*
ALAN J. TEAGUE, *Mechanical Engineering.*
JAMES PHILIP WADE, *Electrical Engineering.*
RICHARD NIELER WAGENSELLER, *Mechanical Engineering, Honor Key.*
VAN IAN WALKLEY, *Civil Engineering.*
FRANK BLAKSLEE WALLACE, JR., *Mechanical Engineering, Honor Key.*
PAUL KENG CHIEH WANG, *Electrical Engineering, Academic Honor.*
DONALD E. WELCH, *Mechanical Engineering.*
WALTER LEE WHIRRY, *Electrical Engineering, Academic Honor.*

CANDIDATES FOR COMMISSIONS UNITED STATES AIR FORCE RESERVE OFFICERS TRAINING CORPS

James L. Adams
Gilbert L. Beebower
William A. Berg, Jr.
Edward M. Boughton, Jr.
William H. Chambers, Jr.
Robert D. Christian
Benjamin E. Cummings
Eugene H. Dryden
Eugene Engels, Jr.
Philip J. Ferrell
Horace W. Furumoto
Jay A. Glasel
Alfred M. Goldman, Jr.
Joseph E. Graetch
Paul L. Harrison
John L. Honsaker
Gerald E. Hooper
Roger E. Lagerquist
Hugh G. Leney
Gerald Z. Lippey
Richard A. Manley
George H. McDonald, Jr.
Charles N. McKinnon, Jr.
John J. Merrill
F. Curtis Michel
Ralph F. Miles, Jr.
Miles A. Nesman
Richard B. Read
Donald B. Roberts
James G. Robins
Jack W. Rocchio
Donald J. Taylor
Martin Vogel
Van I. Walkley
Richard F. Webber

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 1954-55:

Class of 1956

Berg, H. C.
Bergeman, T. H.
Black, Jr., M. W.
Bodeen, C. A.
Bradford, R. E.
Chapple, W. M.
DiLoreto, A. G.
Eiselen, E. T.
Fretwell, Jr., L. J.
Goldenberg, H. M.
Hahne, G. E.
Hershberger, E. E.
Kalm, A.
McCune, D. C.
McHorney, P. E.
Orbach, R. L.
Peters, R. B.
Rockey, R. J.
Rogers, J. D.
Small, Jr., H. W.
Spence, W. N.
Weymann, R. J.
Young, J. E.

Class of 1957

Allen, D. A.
Anderson, C. H.
Barston, E. M.
Brandow, B. H.
Brust, D.
Hundley, R. O.
Jordon, P. C. H.
Klaz, G.
Lubliner, J.
Marshall, J. H.
Moore, R. T.
Moretti, P. M.
Petersen, W. A.
Rapaport, S. A.
Rauch, H. E.
Richert, A. S.
Rumsey, Jr., H. C.
Specht, Jr., W. A.
Tangora, M. C.
Thomas, J. R.
Wildey, R. L.

Class of 1958

Albini, F. A.
Byles, D. G.
Cowley, R. T.
Fineman, J. C.
Gunckel, II, T. L.
Harrington, T. M.
Holtzman, S. F.
Kern, W. M.
Klement, Jr., W.
Konrad, M. W.
Leeson, D. B.
Minning, P.C.
Neville, R. C.
Oetzel, G. N.
Rusch, M. R.
Stone, C. J.
Sturgis, H. E.
Thiebaux, M. L.
Wagner, W. G.
Zeilenga, J. H.

Conger Peace Prize Oration

First Prize: Donald F. Meyer

Second Prize: Robert K. Tucker

Mary A. Earle McKinney Prize in English

First Prize: Alan Poisner

Second Prize: Jay Glasel

Third Prize: Peter Gottlieb

Frederic W. Hinrichs, Jr., Memorial Award

Rodney W. Supple

Thomas Hunt Morgan Memorial Award

Edwin J. Furshpan

SIGMA XI AWARD

Douglas Applequist

GENERAL INDEX