CATALOG

1958-1959

CALIFORNIA INSTITUTE OF TECHNOLOGY

1958

SEPTEMBER

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BULLETIN OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY

Volume 67 Number 3

The California Institute of Technology Bulletin is printed quarterly

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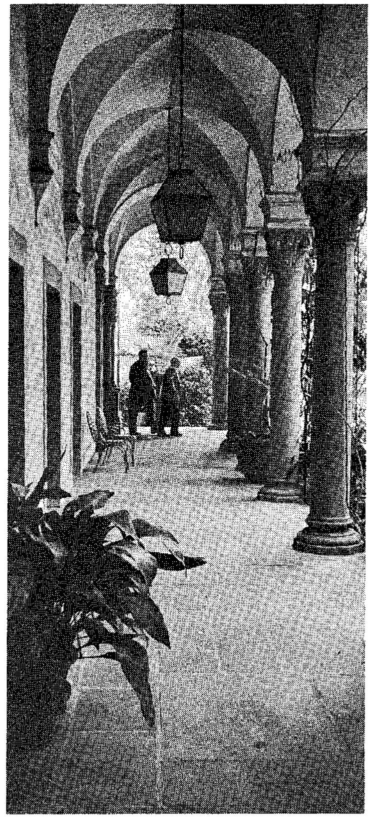
CATALOG
1958-1959



CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA · CALIFORNIA

CONTENTS

ACADEMIC CALENDAR

1958-59

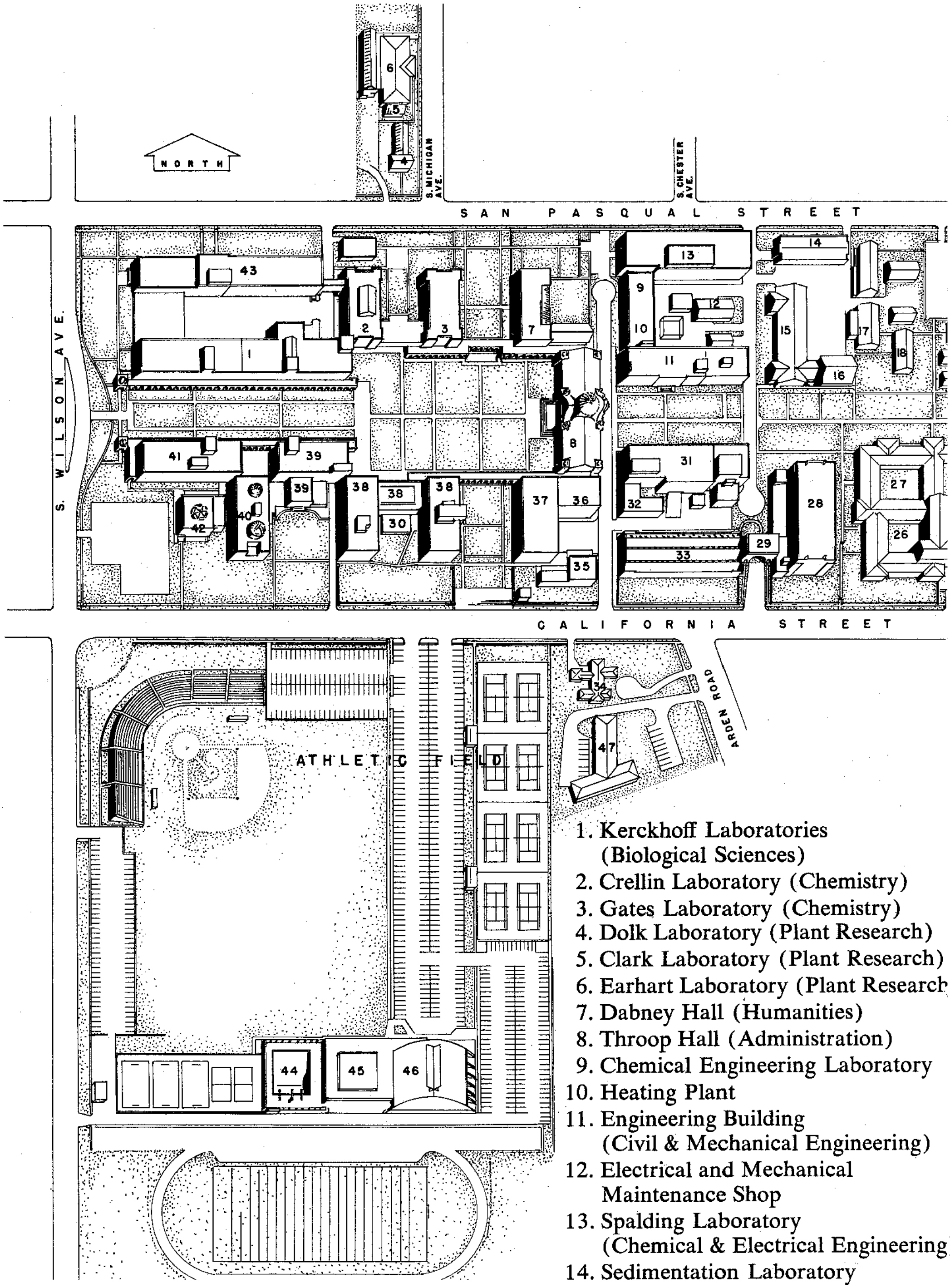
1958	FIRST TERM
September 25	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 25	Registration of students transferring from other colleges—8:00 a.m. to 12 noon.
September 25-27	Student Camp.
September 29	General Registration—8:30 a.m. to 3:30 p.m.
September 30	Beginning of instruction—8:00 a.m.
October 17	Last day for adding courses.
October 18	Examinations for the removal of conditions and incompletes
October 25	Parents' Day.
November 3-8	Mid-Term Week.
November 8	MID-TERM.
November 10	Mid-Term deficiency notices due—9:00 a.m.
November 14	Last day for dropping courses.
November 21	French and German examinations for admission to candidacy for degree of Doctor of Philosophy.
November 24-28	Pre-registration for second term, 1958-59.
November 27-30	Thanksgiving recess.
November 27-28	Thanksgiving holidays for employees.
December 6	College Entrance Board examinations for admission to the freshman class, September 1959.
December 6	Students' Day.
December 15-19	Final examinations—first term, 1958-59.
December 19	Last day for admission to candidacy for the degree of Doctor of Philosophy in June 1959.
December 20	End of first term, 1958-59, 12M.
December 20-January 5	Christmas vacation.
December 25-26	Christmas holidays for employees.

1959	SECOND TERM
January 1	New Year's holiday for employees.
January 3	Registration Committee—9:00 a.m.
January 5	General Registration—8:30 a.m. to 3:30 p.m.
January 6	Beginning of instruction—8:00 a.m.
January 23	Last day for adding courses.
January 24	Examinations for the removal of conditions and incompletes.
February 2-7	Mid-Term Week.
February 7	MID-TERM.
February 9	Mid-Term deficiency notices due—9:00 a.m.
February 13	Last day for dropping courses.
February 14	Last acceptable date for taking college board aptitude test for freshman admission in September, 1959.
February 20	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
February 23-27	Pre-registration for third term, 1958-59.
March 14	Last acceptable date for taking college board achievement tests for admission in September, 1959.
March 16-20	Final examinations—second term, 1958-59.
March 21	End of second term, 1958-59, 12M.
March 27	Registration Committee—9:00 a.m.
March 21-29	Spring Recess.

1959	THIRD TERM
March 30	General Registration—8:30 a.m. to 3:30 p.m.
March 31	Beginning of instruction—8:00 a.m.
April 17	Last day for adding courses.
April 18	Examinations for the removal of conditions and incompletes.
April 27-May 2	Mid-Term Week.
May 2	Last day for obtaining admission to candidacy for Engineers' degrees.
May 2	MID-TERM.
May 4	Mid-term deficiency notices due—9:00 a.m.
May 8	Last day for dropping courses.
May 15	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
May 18-22	Pre-registration for first term, 1959-60.
May 29	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy.
May 29	Last day for presenting theses for Engineers' degrees.
May 30	Memorial Day holiday.
June 1-5	Final examinations for senior and graduate students, third term, 1958-59.
June 5-6	Examinations for admission to upper classes, September 1959.
June 8-12	Final examinations for undergraduate students, third term, 1958-59.
June 10	Meetings of committees on Courses in Science and Engineering, 10:00 a.m.
June 10	Faculty meeting—2:00 p.m.
June 11	Class Day.
June 12	Commencement.
June 13	End of third term, 1958-59, 12M.
June 19	Registration Committee—9:00 a.m.
July 3-4	Independence Day holiday for employees.

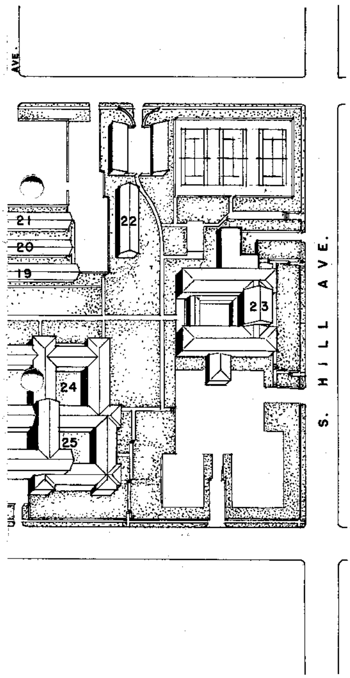
1959	FIRST TERM, 1959-60
September 7	Labor Day holiday for employees.
September 24	Registration of entering freshmen—8:00 a.m. to 12 noon.
September 24	Registration of students transferring from other colleges—8:00 a.m. to 12 noon.
September 24-26	Student Camp.
September 28	General Registration—8:30 a.m. to 3:30 p.m.
September 29	Beginning of instruction—8:00 a.m.

CAMPUS · CALIFORNIA



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)
9. Chemical Engineering Laboratory
10. Heating Plant
11. Engineering Building (Civil & Mechanical Engineering)
12. Electrical and Mechanical Maintenance Shop
13. Spalding Laboratory (Chemical & Electrical Engineering)
14. Sedimentation Laboratory
15. Coffee Shop and Dormitory
16. Throop Club

INSTITUTE OF TECHNOLOGY

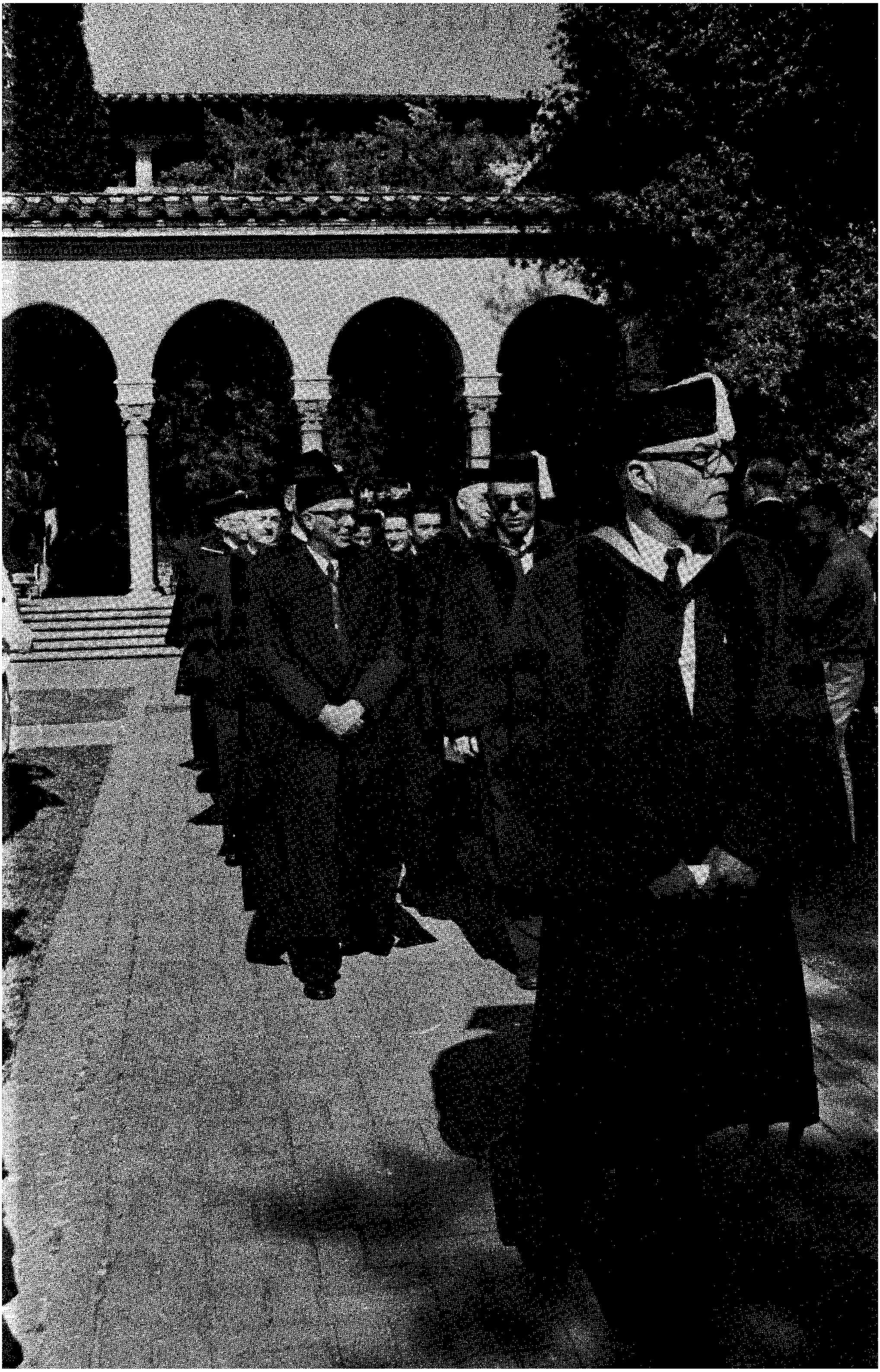


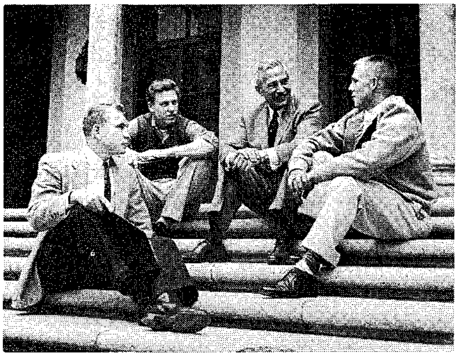
THE CAMPUS of the California Institute is in a residential section of Pasadena, about a mile from the central business district. The area bounded by East California Street, South Hill Avenue, San Pasqual Street, and South Wilson Avenue is the central campus of about thirty acres, the first twenty-two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

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: eight tennis courts; three outdoor basketball and two volleyball courts; a football practice field; a quarter-mile track with a 220-yard straightaway; two baseball diamonds, one with a grandstand seating 5000; and a gymnasium and swimming pool.

17. 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. Building T-3
22. Building T-4
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 Aeronautical Laboratory
32. Hydrodynamics Laboratory
33. Central Engineering Machine Shop
34. Arden House
35. Physical Plant Office; Receiving Room & Central Warehouse
36. Kellogg Laboratory (Electrical Engineering; Physics)
37. High Voltage Research Laboratory
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
46. Scott Brown Gymnasium
47. Archibald Young Health Center





President Lee A. DuBridge and students

CALIFORNIA INSTITUTE OF TECHNOLOGY

THE primary purpose of the undergraduate school of the California Institute of Technology, as stated by the Trustees, is "to provide a collegiate education which will best train the creative type of scientist or engineer so urgently needed in our educational, governmental, and industrial development." It is believed that this end will be more readily attained at the Institute because of the contacts of its relatively small group of undergraduate students with the members of its relatively large research staff. Advancement in understanding is best acquired by intimate association with creative workers who are, through research and reflection, extending the boundaries of knowledge.

The Institute offers two four-year undergraduate courses, one in Engineering and the other in Science, both leading to the degree of Bachelor of Science and both planned so that interchange between them is not unduly difficult. For the first year, the work of all undergraduates is identical. Differentiation between these two courses begins with the second year. The Engineering course is of a general, fundamental character, with a minimum of specialization in the separate branches of engineering. It includes an unusually thorough training in the basic sciences of physics, chemistry, and mathematics, as well as the professional subjects common to all branches of engineering. With minor exceptions, the student does not concentrate in his chosen field until the fourth year. The Engineering course also includes a large proportion of cultural studies, time for which is secured by eliminating the more narrowly particularized subjects commonly included in undergraduate engineering courses. Such a curriculum, it is hoped, will provide a combination of the fundamental scientific training with a broad human outlook. This is, in fact, the type of collegiate education endorsed by leading engineers—a training which avoids on the 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, 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 portion (about forty percent) of the total student body. Engaged themselves on research problems of varying degrees of complexity, and taught by faculty members who are also actively engaged in research, they contribute materially to the general atmosphere of intellectual curiosity and creative activity which is engendered on the Institute campus.

In order to utilize Institute resources most effectively, two general lines of procedure are followed. First, the Institute restricts the number of fields in engineering and science in which it offers undergraduate instruction and graduate study, believing that it is better to provide thoroughly for a limited number than to risk diffusion of personnel, facilities, and funds in attempting to cover a wide variety of fields. Second, and in line with this policy of conservation of resources, the student body is strictly limited to that number which can be satisfactorily provided for. The size of the undergraduate group is limited by the admission, at present, of 180 Freshmen each September. Admission is granted, not on the basis of priority of application, but on a careful study of the merits of each applicant, including the results of competitive entrance examinations, high school records, and interviews by members of the Institute Staff. Applicants for admission with advanced standing from other institutions and for admission to graduate study are given the same careful scrutiny. These procedures result, it is believed, in a body of students of very exceptional high ability. A high standard of scholarship is also maintained, as is appropriate for students of such high competence.

Pasadena, at the foot of the San Gabriel Mountains. In the foreground, the Caltech campus.

HISTORICAL SKETCH

The California Institute of Technology, as it has been called since 1920, developed from a local school of arts and crafts, founded in Pasadena in 1891 by the Honorable Amos G. Throop and named, after him, Throop Polytechnic Institute. It had at first been called Throop University, but the title was soon considered too pretentious. The Institute 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."

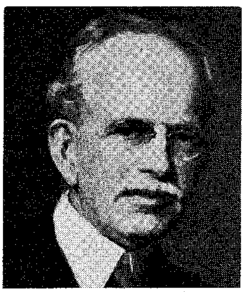
These larger plans were the vision of George Ellery Hale, astronomer and first director of the Mount Wilson Observatory, who foresaw the development in Pasadena of a distinguished institution of engineering and scientific research. Hale well knew that a prime necessity was modern, well-equipped laboratories, 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 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 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."

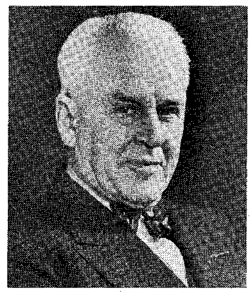
It would have surprised Roosevelt to know that within a decade the little College of Technology would have again raised its sights, leaving to others the training of mere efficient technicians and concentrating its own efforts on Roosevelt's "hundredth men." On November 29, 1921, the Trustees declared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

Perhaps some causes of this change are the rapid growth of southern California between 1911 and 1921, the springing up everywhere of high schools and vocational schools which relieved Throop of some of its responsibilities, and the increasing public interest in scientific research as the implications of modern physics became better known. But the immediate causes of the change in the Institute at Pasadena were men. George Ellery Hale still held to his dream. Arthur Amos Noyes, Professor of Physical Chemistry and former Acting President of the Massachusetts Institute of Technology, served part of each year as Professor of General Chemistry and Research Associate from 1913 to 1919, when he resigned from M.I.T. to devote full time to Throop as Director of Chemical Research. In a similar way Robert Andrews Millikan began, before the war, to spend a few months a year at Throop as Director of Physical Research. In 1921, when Dr. Norman Bridge agreed to provide a research laboratory in physics, Dr. Millikan resigned from the University of Chicago and became administrative head of the Institute as well as director of the Norman Bridge Laboratories.



HALE

NOYES



MILLIKAN

The great period of the Institute's life began, then, under the guidance of three men of vision—Hale, Noyes, and Millikan. They were all distinguished research scientists, and they soon attracted graduate students. In 1920 the enrollment was 9 graduate students and 359 undergraduates under a faculty of 60; a decade later there were 138 graduate students, 510 undergraduates, and a faculty of 180. At the present time there are about 600 undergraduates, 425 graduate students, and a faculty of about 350.

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

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

CALTECH'S NOBEL LAUREATES

Robert A. Millikan, Thomas Hunt Morgan, Carl D. Anderson, Linus Pauling, and Edwin M. McMillan

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 came from the University of California to lead the work in the new division. Later gifts, especially from Mr. and Mrs. Allan C. Balch, and the gift of the Arms and Mudd laboratories, contributed further to the establishment of the geological sciences at Caltech.

In 1928 the California Institute began its program of research and instruction in biology. There had been a chair of biology, named for Charles Frederick Holder, in the old Throop Institute, but it was not until the efforts of the C.I.T. trustees, the General Education Board, the Carnegie Institution of Washington, and William G. Kerckhoff were combined that a program of research and teaching at the highest level was inaugurated. Thomas Hunt Morgan became the first chairman of the new Division of Biology and a member of the Executive Council of the Institute. Under Morgan's direction the work in biology developed rapidly, especially in genetics and biochemistry. Morgan received the Nobel Prize in 1933.

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

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

Although the emphasis upon the humanities or liberal arts as an important part of the education of every scientist and engineer was traditional even in the Throop College days, a reiterated insistence upon this principle was made when Hale, Noyes, and Millikan created the modern Caltech. In 1942, when a five-year engineering course leading to the M.S. degree was offered, the humanities requirement was included. In 1925 William Bennett Munro, Chairman of the Division of History, Government, and Economics at Harvard, joined the Institute Staff, and he soon became a member of the Executive Council. In 1928 Mr. and Mrs. Joseph B. Dabney gave the Dabney Hall of Humanities, and friends of the Institute provided an endowment of $400,000 for the support of instruction in humanistic subjects. Later Mr. Edward S. Harkness added a gift of $750,000 for the same purpose.

Largely on the initiative of Henry M. Robinson the California Institute Associates were organized in 1925. These men and women, now numbering 240, are the successors of those early dedicated pioneers who saw in Throop College the potentiality of becoming a great and famous institution. The Institute Associates, by their continued support, have played a vital part in the Institute's progress. In 1949 the Industrial Associates Program was organized as a mechanism for providing corporations with the opportunity of supporting fundamental research at the Institute and of keeping in touch with new developments in science and engineering.

For the five years beginning with the summer of 1940, the Institute devoted an increasingly large part of its personnel and facilities to the furthering of national defense and the war effort. The Institute's work during this period fell for the most part into two main categories: special instructional programs, and research on the development of the instrumentalities of war. The first included participation in the Engineering, Science, and Management War Training Program, in which a total of over 24,000 students were enrolled in Institute-supervised courses; advanced meteorology for Army Air Force cadets; advanced work in aeronautics and ordnance for Army and Navy officer personnel; and the provision of instruction (as well as housing and subsistence) for a unit of the Navy V-12 Engineering Specialists. The research and development work was carried on for the most part under nonprofit contracts with the 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. The Jet Propulsion Laboratory in the upper Arroyo Seco continues under Institute management a large-scale program of research in this field for the Defense establishment.

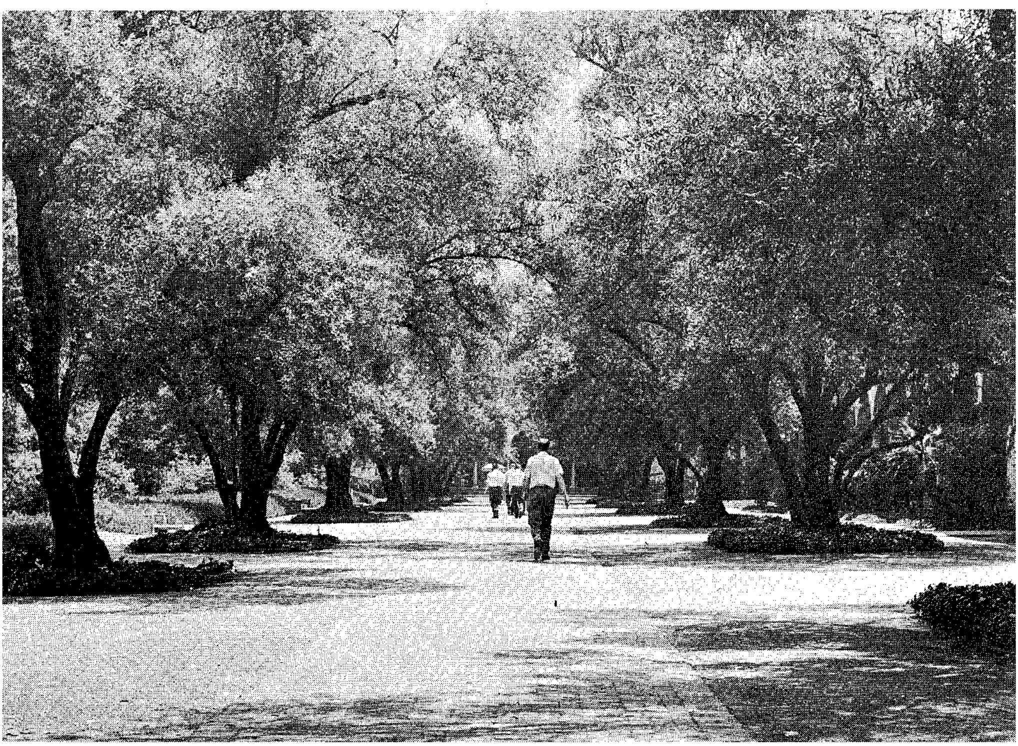
In 1945 R. A. Millikan retired as chairman of the executive committee; he served as vice-chairman of the Board of Trustees until his death in 1953. Dr. Lee A. DuBridge became President of the California Institute on September 1, 1946.

In recent years new developments have taken place in all of the divisions. In 1948 the Palomar Observatory and the 200-inch Hale telescope were dedicated. In 1949 the Earhart Plant Research laboratory was completed and in 1950 a new engineering building. In 1951 a cosmic ray laboratory was built and in the next year a synchrotron was constructed for the study of atomic nuclei. In 1954 the generosity of the alumni, and of the late Scott Brown, a member of the Associates, provided a gymnasium and swimming pool. In 1955 the completion of the Norman W. Church Laboratory for Chemical Biology pointed to new activities in an important field of science. 1957 saw the completion of the Eudora Hull Spalding Laboratory of Engineering, an important addition to the facilities available for instruction and research in chemical and electrical engineering, and a new student health center, the gift of Mrs. Archibald Young in memory of her late husband, who was long an Institute Associate.

Today the California Institute has over 7632 alumni scattered all over the world, many eminent in their fields of engineering and science. Four of them have received Nobel prizes: Carl D. Anderson (B.S. '27, Ph.D. '30), Edwin M. McMillan (B.S. '27, M.S. '29), Linus Pauling (Ph.D. '25), and William Shockley (B.S. '32).

As the Institute has developed in effectiveness and in prestige it has attracted a steady flow of gifts for buildings, for endowment, and for current operations. The gifts invested in plant now total over $23,000,000 and those invested in endowment over $40,000,000. Present and future needs will require a continuance of this generosity on the part of individual foundations and corporations.

Olive Walk, which bisects the central campus



THE INDUSTRIAL RELATIONS SECTION

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

The Section has developed a five-fold program of activities and service for companies, unions, associations, and individuals: (1) a reference library of books, pamphlets, magazines, and other materials related to industrial relations; (2) specialized courses or series of meetings without academic credit for representatives of companies and unions; (3) periodic conferences of business executives and of union and government officials for the discussion of current labor problems; (4) surveys and research studies on problems of industrial relations; and (5) a series of bulletins and circulars which are the product of these activities.

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

The Benefits and Insurance Research Center

In recognition of the growing importance of employee benefit and insurance programs in industrial relations, the Benefits and Insurance Research Center was established in 1955 as a part of the Industrial Relations Section. The Center is financed through special gifts from a large number of companies interested in supporting a program of objective research and instruction in this field. In its special area the work of the Center parallels closely the program of activities and services developed by the Industrial Relations Section.

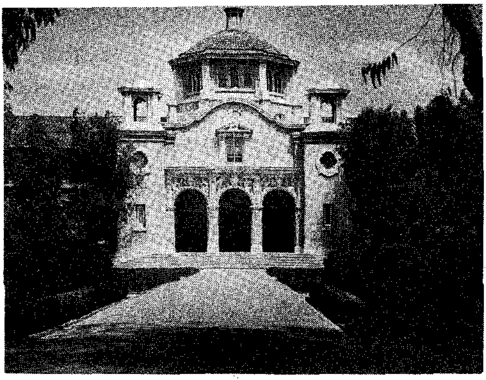
Detailed information about the specific activities and services of the Center can be secured from the Director of the Industrial Relations Section or the Research Director of the Benefits and Insurance Research Center, Culbertson Hall.

The Management Development Center

The increasing complexity of business operations has emphasized the fact that a manager must not only know how to do the work being supervised but must also know how to supervise—a separate and distinct function. The expanding demand for training in the knowledge and skills required for supervision caused the establishment of the Management Development Center in 1957 as a part of the Industrial Relations Section.

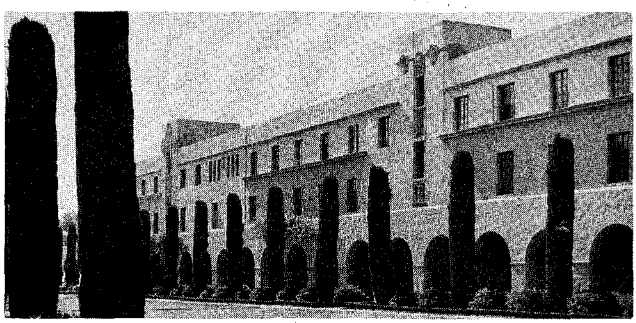
This Center offers training in the field of management in general and in the specialized field of personnel administration. A wide range of courses is presented with various methods and combinations of methods: on campus or off campus, full-time or part-time, for representatives of a variety of companies or specially designed for the management of a specific company. The courses do not carry academic credit.

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

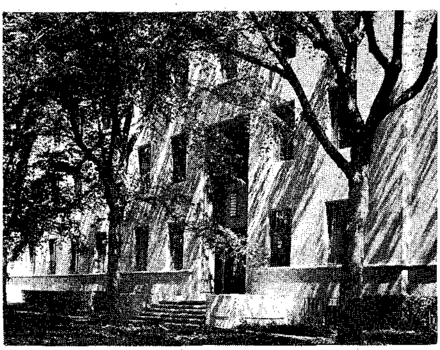


Throop Hall

Church Laboratory for Chemical Biolog.

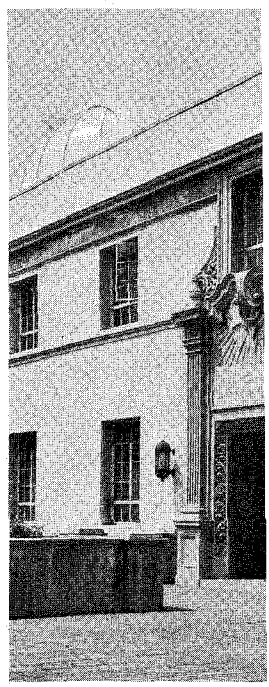


Kerckhoff Laboratories
of the Biological Sciences



Spalding Laboratory
of Engineering

Athenaeum



Robinson Laboratory
of Astrophysics

BUILDINGS AND FACILITIES

THROOP HALL, 1910. The administration building; erected with funds supplied by a large number of donors, and named for the Honorable Amos G. Throop, founder of Throop Polytechnic Institute, from which California Institute developed.

GATES AND CRELLIN LABORATORIES OF CHEMISTRY: first unit, 1917; second unit, 1927; third unit, 1937. The first two units were the gift of the late Messrs. C. W. Gates and P. G. Gates, of Pasadena; the third unit was the gift of the late Mr. and Mrs. E. W. Crellin, of Pasadena.

CULBERTSON HALL, 1922. The Institute auditorium; named in honor of the late Mr. James A. Culbertson of Pasadena 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.

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, 1939; annex, 1948. The gift of the late Mr. and Mrs. William G. Kerckhoff, of Los Angeles.

DOLK PLANT PHYSIOLOGY LABORATORY (of the Division of Biology), 1930. Named in memory of Herman E. Dolk, Assistant Professor of Plant Physiology from 1930 until his death in 1932.

ATHENAEUM, 1930. The gift of the late Mr. and Mrs. Allan C. Balch, of Los Angeles, President of the Board of Trustees of the Institute, 1933-1943. A clubhouse for the use of the staffs of the California Institute, the Huntington Library, and the Mt. Wilson Observatory; and the California Institute Associates.

STUDENT HOUSES, 1931.

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

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

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

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

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

W. K. KELLOGG LABORATORY 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 of the Institute.

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

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

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

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

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

PHYSICAL PLANT 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.

COSMIC RAY LABORATORY, 1952.

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

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

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

EUDORA HULL SPALDING LABORATORY OF ENGINEERING, 1957. Erected with funds allocated from the Eudora Hull Spalding Trust.

ARCHIBALD YOUNG HEALTH CENTER, 1957. The gift of Mrs. Archibald Young, of Pasadena, in memory of her husband, a member and director of the California Institute Associates.

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

LIBRARIES

The General Library, as the center of the Institute library system, houses the administrative office, which serves nine departmental libraries located in as many buildings on the campus. The departmental libraries house the collection of books, periodicals, and basic reference works in aeronautics, astronomy and astrophysics, biology, chemistry, chemical engineering, geology, humanities, industrial relations, and physics. The General Library houses the collections in mathematics and engineering, as well as the master catalog for the entire system. The bookstacks throughout the libraries are open to all readers. The collections constitute strictly a working library, including subscriptions to more than 3000 periodicals.

OFF-CAMPUS FACILITIES

KRESGE SEISMOLOGICAL LABORATORY, 1928, and DONNELLEY SEISMOLOGICAL LABORATORY (of the Division of the Geological Sciences), North San Rafael Avenue, 1957.

The second laboratory was the gift of Mr. and Mrs. C. Pardee Erdman, of Pasadena, The Kresge Foundation of Detroit, Michigan, and The James Irvine Foundation of San Francisco; and named in honor of Mrs. Erdman's father, Mr. Reuben H. Donnelley.

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

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

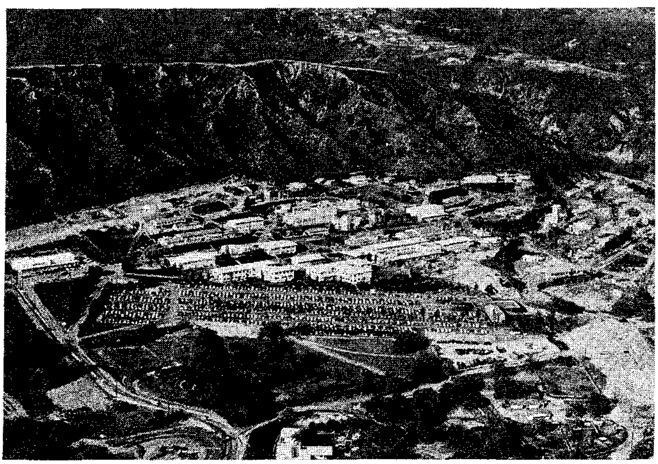
JET PROPULSION LABORATORY, 4800 Oak Grove Drive, 1944. Owned and sponsored by the Department of Defense and operated by the Institute.

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

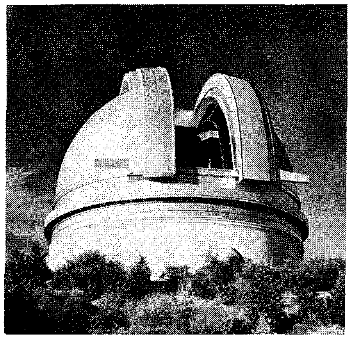
SOUTHERN CALIFORNIA COOPERATIVE WIND TUNNEL, 950 South Raymond Avenue, 1945. Owned by five cooperating aircraft companies and operated under a management agreement by the Institute.

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

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



The Jet Propulsion Laboratory, operated by Caltech for the Department of Defense



The 200-inch telescope at the Palomar Observatory

STUDY AND RESEARCH AT THE CALIFORNIA INSTITUTE

1. THE SCIENCES

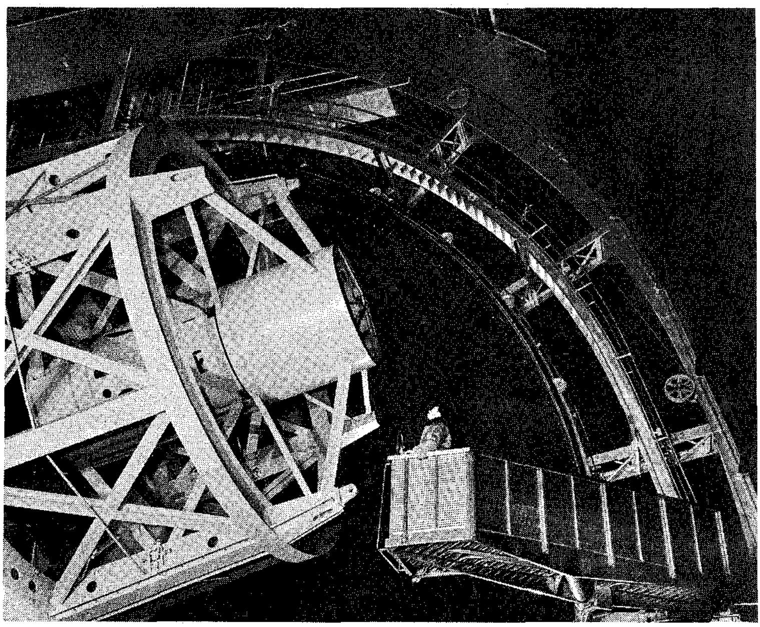
ASTRONOMY

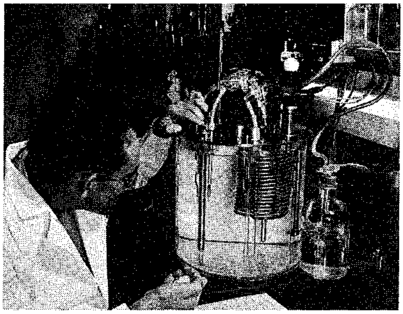
The Rockefeller Boards provided in 1928 for the construction by the Institute of an astronomical observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, 48-inch and 18-inch schmidt wide-angle telescopes and other auxiliary instruments, together with an astrophysical laboratory, on the Institute campus. The purpose of this observatory is to supplement, not to duplicate, the facilities of the Mount Wilson Observatory of the Carnegie Institution of Washington, which, while not a part of the California Institute, is located even closer to Pasadena than is Palomar Mountain. The increased light-collecting power of the 200-inch telescope permits further studies of the size, structure, and motion of the galactic system; of the distance, motion, radiation, composition, and evolution of the stars; and the interstellar gas of the spectra of the brighter stars under very high dispersion; of the distance, motion, and nature of remote nebulae; and of many phenomena bearing directly on the constitution of matter. The 48-inch schmidt 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 field of physics and mathematics. The California Institute of Technology and the Carnegie Institution of Washington have recognized the advantages implicit in the creation of a great astronomical center in which a unitary scientific program would be pursued under highly favorable circumstances, that would attract distinguished investigators to collaborate with the staff of the observatories in scientific matters, and that would draw young men of great ability to graduate studies where they might enjoy the inspiration of leading minds and familiarize themselves with powerful tools of exploration. For this purpose a plan for the unified operation of the two observatories, in which they function as a single scientific organization under the direction of Dr. I. S. Bowen, was approved by the Trustees of the two institutions. Under this plan all the equipment and facilities of both observatories are made available for the astronomical investigations of the staff members of the combined observatories and the unified research program is paralleled by undergraduate and graduate training in astronomy and astrophysics in which members of the Staff of Mount Wilson Observatory join with the Institute Faculty.

In 1956 work started in radio astronomy, and advanced study and research in this field is now under way. A 32-foot paraboloid for 21 cm research has been in operation and a large interferometric radio telescope, consisting of two 90-foot diameter steerable paraboloids, is approaching completion near Bishop. This will be one of the most advanced installations in this new and rapidly growing field.

As a result of the cooperation possible over a broad range of astronomy, astrophysics, and radio astronomy unusual opportunities exist at the California Institute for advanced study and research. The instructional program is connected with a broad and thorough preparation in physics, mathematics, and relevant subjects, as well as instruction in astronomy, radio astronomy, and astrophysics.





Graduate student studies size and shape of protein molecules

Biological Sciences

UNDERGRADUATE WORK 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 either 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.

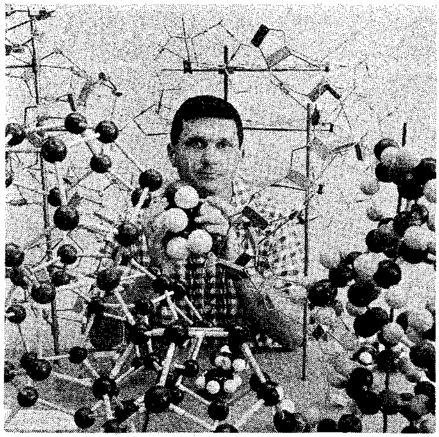
Adjacent to the campus there are the Plant Physiology Laboratories, with several air-conditioned greenhouses, and the Earhart Plant Research Laboratory. The Earhart Laboratory is a unique instrument for the study of plant growth under complete weather control. All the elements of climate, such as light, 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 aquaria for keeping them. The proximity of the marine station to Pasadena makes it possible to supply the biological laboratories with living material for research and teaching. The fauna at Corona del Mar and at Laguna Beach, which is nearby, is exceptionally rich and varied, and is easily accessible.

Planned for construction in 1958-1959 is the Campbell Plant Research Laboratory—a new greenhouse adjacent to the Earhart, Clark, and Dolk Laboratories. Work is scheduled to be started about the same time on the Gordon A. Alles Laboratory for Molecular Biology—a laboratory that will link the existing Kerckhoff and Church Laboratories at all floor levels.



Molecular models used in investigation of protein structures

Chemistry and Chemical Engineering

The Gates and Crellin Laboratories of Chemistry consist of three adjacent units. The first two are the gift of the late Messrs. C. W. Gates and P. G. Gates. The third unit, which was completed in 1937 and affords space approximately equal to that of the first two units, is the gift of the late Mr. and Mrs. E. W. Crellin. In addition, the Division of Chemistry and Chemical Engineering occupies the East half of the new Norman Church Laboratory of Chemical Biology.

These four units include laboratories used for undergraduate instruction in inorganic, analytical, physical, and organic chemistry; they also include classrooms, lecture rooms, and a chemistry library. The remaining space in these buildings is largely devoted to facilities for research. There are numerous laboratories for inorganic, physical, and organic research, providing space for about one hundred research fellows and advanced students. The laboratories in the Norman W. Church Laboratory of Chemical Biology are used for research in immunochemistry and on the application of chemistry to biological and medical problems.

The Chemical Engineering Laboratory is located in the new Eudora Hull Spalding Engineering Building and in the adjoining Engineering Building. This laboratory is well equipped for making the accurate measurements needed in engineering investigations of quantitative character. It is especially well provided with equipment for determination of the phase relations and thermodynamic properties of fluids at moderately high pressures. Research equipment is available for intensive study of reaction kinetics and transfers of matter and energy in systems involving fluids.

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

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

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

The chemical subjects of the junior year consist of courses in physical, analytical, and a wide variety of elective subjects, as described on page 204. A substantial number of elective courses in closely related fields are accepted for credit in the chemistry option. Relatively few of the advanced courses in chemistry are primarily descriptive in nature; most of them are presented largely as series of problems to be solved by the students.

The supervision of the research work of graduate students is distributed among the members of the staff of the Division of Chemistry and Chemical Engineering. Some of the many fields in which researches are being actively prosecuted are listed on pages 170-171.

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 other fields of science or engineering. The lines of research being pursued in chemical engineering include engineering thermodynamics, phase equilibrium of fluids at elevated pressures, thermal transfer, fluid flow, diffusional processes, reaction kinetics, applied mathematics, and combustion.

Geological Sciences

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

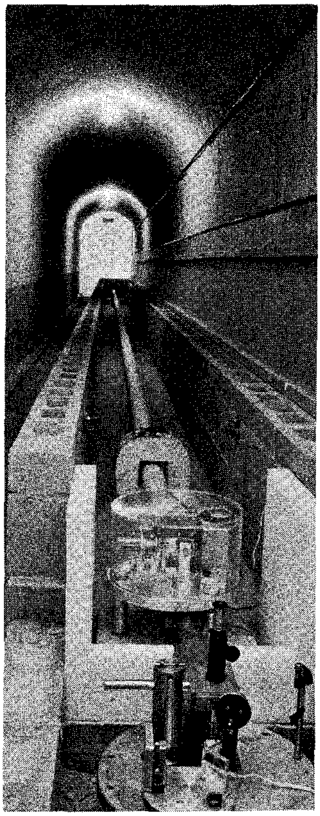
Physical facilities, both natural and man-made, are excellent. All the classroom instruction and most of the laboratory research in geology and geochemistry, as well as part of that in geophysics, are carried on in the Arms and Mudd Laboratories. These are modern, five-story buildings which were specifically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

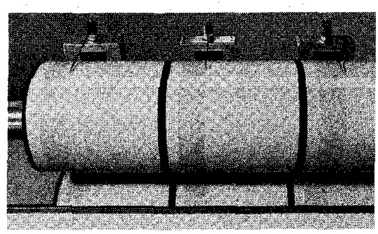
Extensive facilities are available for the application of techniques of nuclear chemistry to problems in the earth sciences. These facilities include chemical laboratories for trace-element studies, a silicate analysis laboratory, and mass spectrometric and counting facilities for isotopic work. Available equipment includes mass spectrometers, emission counters, an induction furnace, and extensive mineral separation facilities in addition to the usual geological and chemical items.

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

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

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





The Seismological Laboratory

The student body is purposely kept small and usually consists of 40 to 50 graduate students and 20 to 30 undergraduates. The small size of the student group and large size of the staff give a highly favorable ratio of students to staff and result in close associations and contacts which enhance the value of the educational program.

UNDERGRADUATE WORK

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

The Geochemistry and Geophysics options are recommended only for those students who anticipate continuing their training at the graduate level.

Men trained in the earth sciences find employment in research, teaching, and a wide variety of other professional activities. Many work for the petroleum industry both in the field and in the laboratory on theoretical as well as applied problems. Some eventually become administrators and executives. Mining companies, railroads, large utilities, and other organizations engaged in development of natural resources, employ men trained in the geological sciences, as do a number of Federal and state bureaus, such as the U. S. Geological Survey and the Bureau of Reclamation.

GRADUATE WORK

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

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

MATHEMATICS

UNDERGRADUATE WORK

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

Since the more interesting academic and industrial positions open to mathematicians require training beyond a Bachelor's degree, the man who expects to make mathematics his profession must normally plan to continue either here or elsewhere, with graduate work leading to the degree of Doctor of Philosophy.

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

Requirements. Unless a student has done exceptionally well in his freshman and sophomore years, he should not contemplate specializing in mathematics. 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

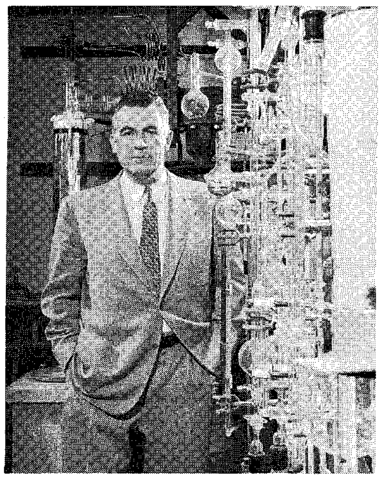
Graduate work in mathematics is planned to give the student a broad knowledge of classical and modern mathematics and to train him to do creative independent work. The normal course of study leads to the Ph.D. degree and requires three or four years. Exceptional ability and graduate work done elsewhere may shorten this time.

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

Requirements. The general requirements for the degree of Ph.D. are listed and pages 97-101; additional requirements for mathematics are found on pages 112-113. The special prerequisites for the course requirements in a minor subject are listed under the separate departments. In particular those for physics are listed on pages 216-220.

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

Master's degree. Students initially planning to take only a master's degree are accepted only under very special circumstances. When the complete Ph.D. requirements cannot be met, a master's degree may be awarded upon passing at least five courses listed under B or C on pages 205-207, 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.



Dr. John Pellam in his low-temperature physics laboratory

Physics

UNDERGRADUATE WORK

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

Since the best education is that which comes from the contact of youth with creative and resourceful minds, the members of the staff of the Norman Bridge Laboratory of Physics have been from the beginning productive physicists rather than merely teachers. The instruction is done by the small group method, twenty to a section, save for one demonstration lecture every other week throughout the freshman and sophomore years. Most of the members of the staff participate in these lectures. The entering freshman thus makes some contact in his first year with many senior members of the staff, and he has the opportunity to maintain that contact throughout his four undergraduate years, and his graduate work as well, if he elects to go on to the higher degrees.

In order to provide the thorough training in physics required by those who are going into scientific or engineering work, two full years of general physics are required of all students. Those who desire to major in physics take during their junior and senior years intensive courses that provide a more than usually thorough preparation for graduate work. Elective courses during the junior and senior years provide flexibility which enables the student to select a program to fit his individual requirements. Students who do not expect to go into graduate work are advised to choose electives from among the engineering subjects. Many of the undergraduate students who elect physics are given also an opportunity to participate in some of the thirty to sixty research projects which are always underway and the graduate seminars are open to undergraduates at all times.

GRADUATE WORK

Graduate students working toward the Ph.D. degree should complete the requirements for admission to candidacy for the doctor's degree as soon as possible. (See page 100.) The courses required to be passed either regularly or by examination provide an unusually thorough grounding in the fundamentals of physics, and the student learns to use these principles in the solution of problems. After the first year of graduate work, students with special technical training will find it comparatively easy to obtain part-time work during the summer on one or another research projects in physics. Students so employed are also expected to register for 15 or more units of research.

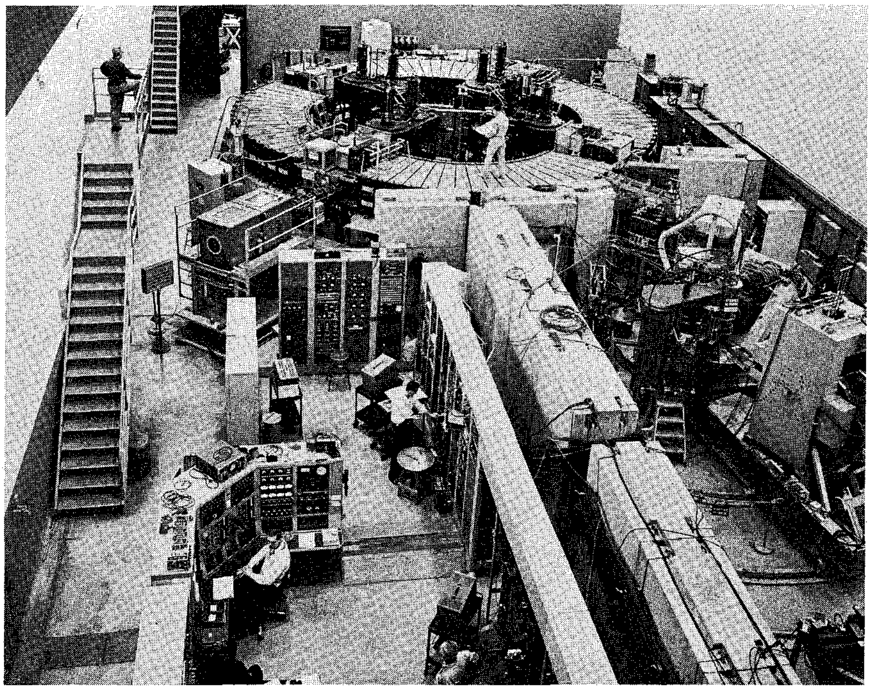
The Norman Bridge Laboratory of Physics is equipped to carry on research in most of the principal fields of physics. An addition to this laboratory has been especially constructed for the work in cosmic rays and the study of elementary particles. Special facilities for research in nuclear physics are also provided in the W. K. Kellogg Radiation Laboratory—which is equipped with three electrostatic generators and auxiliary equipment which make the facilities especially good for precision work in the field of light nuclei. The Synchrotron Laboratory houses an electron accelerator which is now operating at energies up to 1.2 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 that precision investigation of X-rays and gamma rays and the study of beta ray spectra. Liquid helium is available and there is a laboratory for work in low-temperature physics. Opportunities for study in theoretical physics in any one of a number of fields are particularly good for a limited number of students whose ability and background qualify them for theoretical work.

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

There is a general seminar or research conference each week which is regularly attended by all research workers and graduate students. In addition, there are 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.



With the billion-volt synchrotron Caltech investigators can produce and examine some of the most fundamental particles in nature

2. ENGINEERING

UNDERGRADUATE WORK

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

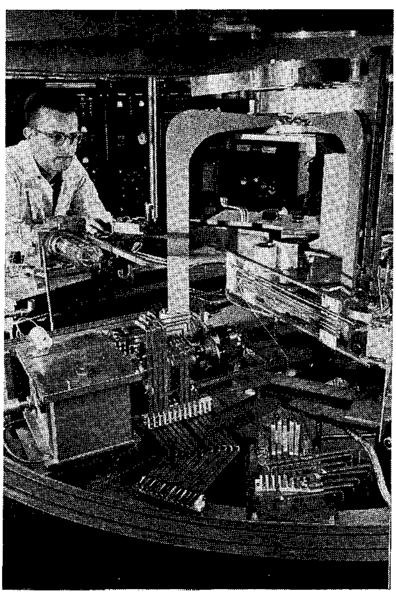
The plan of instruction in engineering embodies a four-year course for the degree of Bachelor of Science in Engineering. The three undergraduate curricula of civil, electrical, and mechanical engineering* have a core of basic science and the engineering sciences essentially common throughout three years.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

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

*See pages 27-28 for chemical engineering.

Graduate study and research opportunities in Engineering exist in aeronautics, civil, mechanical, electrical, and chemical engineering, with courses broadly outlined, leading to the degree of Master of Science. These courses normally require one year of work following the Bachelor's degree and are designed to prepare the engineer for professional work of more specialized and advanced nature. A sixth year leads to the degree of Aeronautical Engineer, Chemical Engineer, Civil Engineer, Electrical Engineer, or Mechanical Engineer. In addition, advanced work is offered in Aeronautics, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, and Engineering Science leading to the degree of Doctor of Philosophy. In all phases of the graduate program students are encouraged to include in their courses of study a considerable amount of work outside of their specialized fields, particularly in mathematics and physics.

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



A graduate student in mechanical engineering uses a high temperature spectrometer to study the X-ray diffraction patterns from metals

AERONAUTICS

The graduate school of Aeronautics and the Guggenheim Aeronautical Laboratory, widely known as the GALCIT, were established in 1928 at the California Institute with the aid of the Daniel Guggenheim Fund for the Promotion of Aeronautics. In 1948, a Jet Propulsion Center, to provide facilities for study in that field, was established by the Daniel and Florence Guggenheim Foundation (see page 45). The staffs of these three facilities are actively engaged in the fields of Aeronautics and the allied sciences. The following program of instruction at the postgraduate level and of advanced research is now in progress:

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

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

3. Experimental and theoretical researches on:

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

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

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

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

e. Problems in jet propulsion with special emphasis on the underlying fluid mechanics, thermodynamics, dynamics, and chemistry. (See page 45.)

The campus laboratory houses a wind tunnel of the closed circuit type with a working section 10 feet in diameter. A 750 horsepower motor and propeller produce test section wind velocities in excess of 200 miles per hour. A complete set of balances permits the rapid testing of aircraft models as well as the undertaking of many types of scientific investigation in this tunnel. A fluid mechanics laboratory contains several smaller wind tunnels and a considerable amount of auxiliary apparatus especially suitable for the study of the basic problems connected with turbulent flows. The problems of transonic, supersonic, and hypersonic flows may be investigated in other wind tunnels specifically designed for such purposes. In these tunnels, flow velocities up to approximately 10 times the velocity of sound may be studied. These tunnels are equipped with optical apparatus which can be used for the study of shock wave phenomena. A structures laboratory is equipped with standard and special testing machines for research in the field of aircraft structures. Fatigue machines are also available for investigating the fatigue properties of materials. Photoelastic equipment is available for the study of stress distribution by optical methods. The laboratory is also equipped with excellent shop facilities for the manufacture of testing equipment, an extensive reference library of books and periodicals on aeronautical and allied topics and research instrumentation.

The Aeronautics department has developed a number of interests related to but not strictly included in its academic, on-campus activities. Two of these now have extensive research facilities with which the department maintains close contact, although they are not located on the Institute campus. The first is the Jet Propulsion Laboratory which consists of a group of about 1800 persons, of whom about 500 are professional engineers and scientists. The Laboratory is supported by the Department of Defense and is administered under the auspices of the Institute; and a number of key personnel share their time between Institute teaching and Laboratory duties. The purpose of the Laboratory is to do research on the fundamental problems of jet propulsion and guided missiles, with emphasis on supersonic aerodynamics, fuels and combustion, high-temperature materials, rocket motor design, and electronic instrumentation for telemetering and missile guidance. Among the experimental facilities are: two supersonic wind tunnels (a 20-inch tunnel capable of speeds of 4.8 times the velocity of sound and a 20-inch hypersonic wind tunnel capable of speeds of 8 to 9 times sound velocity); over a dozen rocket and thermal jet test cells, large laboratories devoted to refractory materials, hydraulics, instrumentation, chemistry, combustion, heat transfer; and a REAC electronic analog computer. The Laboratory extends the use of these facilities to properly accredited Institute students who are doing thesis work.

The second off-campus facility is the Southern California Cooperative Wind Tunnel which is owned by five aircraft companies. The Laboratory with its equipment was constructed and is operated by the Aeronautics department under a management agreement. This tunnel now has approximately 45,000 installed horsepower, with a number of interchangeable working sections, and is able to develop speeds up to 1.75 times the velocity of sound.

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

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

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

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

CHEMICAL ENGINEERING AND APPLIED CHEMISTRY

(See pages 27-28)

Civil Engineering

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

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

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

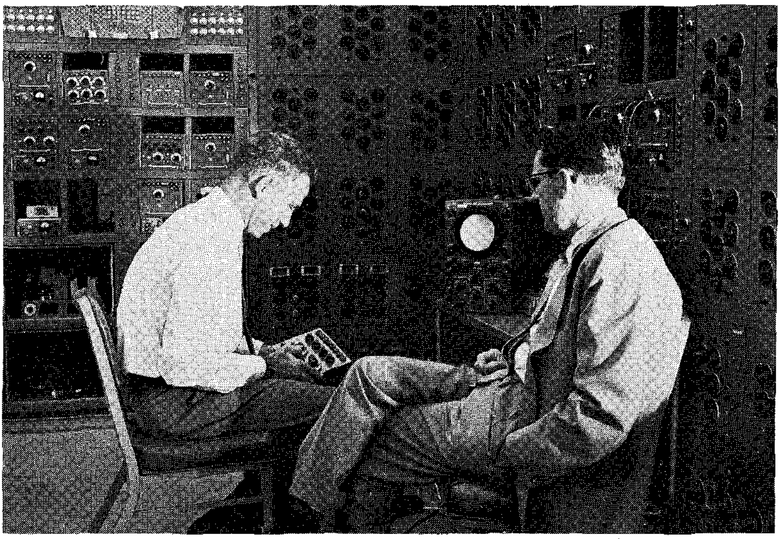
In some instances a student who has not specialized in civil engineering as an undergraduate will be admitted for graduate study in Civil Engineering if he intends to pursue a program of study leading toward the Civil Engineer or Ph.D. degree. As preparation for advanced study and research, a good four-year undergraduate program in mathematics and the sciences may be substituted for a four-year undergraduate engineering course with the approval of the department. The qualifications of each applicant will be considered individually, and, after being enrolled, the student will arrange his program in consultation with a member of the department. In some cases, the student may be required to make up deficiencies in undergraduate work. However, in every case the student will be urged to take some courses which will broaden his understanding of the overall field of civil engineering, as well as courses in his specialty. In addition, most graduate students are required to take further work in applied mathematics.

The general areas of civil engineering in which advanced work is offered are (1) structural engineering and applied mechanics, (2) soil mechanics and foundation engineering, (3) hydraulics (hydrodynamics, hydraulic engineering and hydrology), and (4) sanitary engineering. Emphasis is placed on the application of mathematics and basic scientific principles to the solution of civil engineering problems, and the student is discouraged from depending on handbooks and empirical formulas.

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

In recent years, graduate students and members of the staff have pursued a variety of research programs such as analysis of structures subjected to dynamic loadings (such as earthquakes); compaction of soil by vibration; design criteria for various hydraulic structures; investigation of laws of sediment transportation by streams and settling in sedimentation tanks; water quality criteria; and sterilization of sewage.

Field trips to many unusual civil engineering works in this region are a regular part of the fifth-year program. The annual 6-day trip along the lower Colorado River during the spring vacation provides an unusually fine opportunity to inspect large hydraulic projects and to study the problems of integrated multiple-purpose development of a large river basin.



Electrical engineers use the analog computer to simulate such problems as aircraft flutter or ship vibrations

Electrical Engineering

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

Electrical engineering affords opportunity for many choices of life work relating to design, research, production, operation, and management. Some phases of these activities and the commercial semi-technical phases of the electrical industry require only the preparation of the four-year course, but the better, or more normal, preparation for an electrical engineering career requires the completion of the five-year course leading to the degree, Master of Science.

The instruction pattern for electrical engineering is therefore designed on a five-year basis, the fifth year courses being open to qualified students who have completed the four-year electrical engineering option for the Bachelor of Science degree from the Institute, or have had substantially the same preparation in other colleges.

Other fields of endeavor call for a knowledge of mathematics, physics, and electrical engineering in excess of that obtainable in the five-year curricula. To meet this need the Institute has provided courses of graduate study and research in electrical engineering leading to the degrees of Electrical Engineer and Doctor of Philosophy. These courses provide for advanced work in the application of mathematical analysis and physical laws to mechanical and electrical problems and may be taken by a limited number of exceptional students who have completed the five-year electrical engineering course at the Institute, or less frequently by students from other colleges who have substantially the same preparation.

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

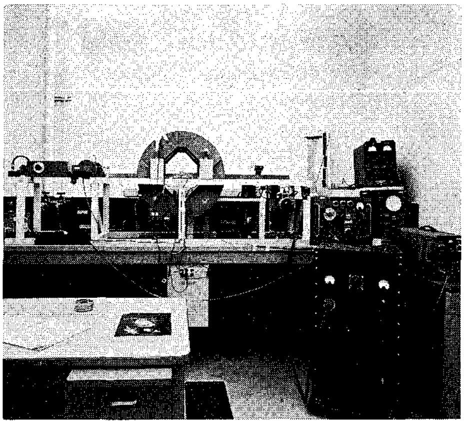
Of the several electrical engineering laboratories at the California Institute, the Computing Center, the Servomechanism Laboratory, and the Electron and Microwave Tube Laboratory are outstanding.

The *Computing Center* provides comprehensive facilities for research and instruction in the development and application of large scale machine computation to the solution of the more complex mathematical problems of science and engineering. The computers in the Laboratory include a large-scale direct analogy electric analog computer, a Datatron 205 general purpose digital computer, IBM 797 and LGP-30 digital computers, and several digital and analog computers developed by the Institute.

The Computing Center serves as a general service facility to all campus research requiring such mathematical aids.

The *Electron Tube and Microwave Laboratory* has special facilities for conducting research and instruction in the behavior of microwave electron tubes and broadly related fields. A small but complete laboratory for processing vacuum tubes of almost any kind is available. Microwave and low-frequency test equipment, which make it possible to conduct investigations in nearly any part of the frequency spectrum, are also available.

The *Antenna Laboratory* is devoted to theoretical and experimental studies of electromagnetic wave phenomena. It provides facilities for the investigation of basic problems arising principally, but not exclusively, from recent developments in antenna theory and design. A major part of the research program now in progress concerns the mathematical theory of diffraction, the propagation of waves in anisotropic inhomogeneous media, artificial dielectrics, broad-band antennas, and surface-wave antennas.



Microwave Research in Electrons

A *Servomechanism Laboratory* has been established for instruction and research on feedback control systems. The facilities of this laboratory provide excellent opportunities for research leading to all graduate degrees. One important feature is an electric analog computer suitable for general mathematical analysis and detailed studies of control system components in a complete system.

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

Other laboratories and equipment for research work in electronics, communications, information theory, and circuit synthesis are available. Facilities for research in dynamo-electric machinery are also available.

Engineering Science

Advanced programs of study leading to the degree of Doctor of Philosophy in Engineering Science are offered by the Division of Engineering. These programs are complementary to those leading to the degrees of Doctor of Philosophy in Civil, Mechanical, Electrical, and Aeronautical Engineering and are designed to meet the needs of currently developing fields of engineering that are not included in the already established engineering disciplines. The general requirements for the doctorate in Engineering Science are similar to those for the degree in the other fields of engineering, including the completion of satisfactory thesis research. The fields of study may include topics in engineering and science, such as applied mechanics, fluid mechanics, physical metallurgy, 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 with electives in the fourth year in aeronautics, general mechanical engineering, and physical metallurgy. The fifth year, therefore, is somewhat more specialized, with options in general mechanical engineering, jet propulsion, physical metallurgy, and nuclear engineering. A schedule of subjects is specified for each of the fifth-year options which may be modified by petition to the staff in mechanical engineering to satisfy the special interest of the student.

Greater specialization is provided by the work for the engineer's or doctor's degree. The student is allowed considerable latitude in selecting his course of subjects, and is encouraged to elect related course work of advanced character in the basic sciences. The engineer's degree of Mechanical Engineer is considered as a terminal degree for the student who wishes to obtain advanced training more highly specialized than is appropriate to the degree of Doctor of Philosophy. Research work leading to a thesis is required for the engineer's degree and for the doctor's degree.

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

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

GUGGENHEIM JET PROPULSION CENTER

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

The solution of the engineering problems in jet propulsion draws on the knowledge and practice of the older branches of engineering, in particular, mechanical engineering and aeronautics. Thus, it is proper that the program of instruction in jet propulsion include material from both of these engineering fields. Similarly, it is expected in general that students entering the course work in jet propulsion will have had their undergraduate preparation in mechanical engineering or aeronautics. Thus, the program of instruction in jet propulsion has two separate options, allowing men from both aeronautics and mechanical engineering to follow their previous inclinations and developments. The Mechanical Engineering option leads to the degree of Master of Science upon completion of the fifth-year program. For men in the Aeronautics Option, the degree of Aeronautical Engineer will be given upon completion of a sixth-year program. Similarly, the degree of Mechanical Engineer will be given to men upon the completion of the sixth-year program of the Mechanical Engineering Option.

Students from the Aeronautics Option may be admitted to work for the degree of Doctor of Philosophy in Aeronautics and a minor field. Students from the Mechanical Engineering Option may be admitted to work for the degree of Doctor of Philosophy in Mechanical Engineering and a minor field. No designation specifying the field of jet propulsion will be given.

The facilities of the Institute, in particular those in Aeronautics and in Mechanical Engineering, are available to students working towards advance degrees. Under the present regulations, students who wish to use the facilities of the Jet Propulsion Laboratory must, however, first obtain clearance from the Armed Services.

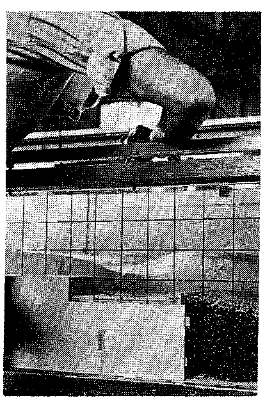
HYDRODYNAMICS

Hydrodynamics and hydraulic engineering represent subjects in Fluid Mechanics which complement other Institute work in Aerodynamics and in which a vigorous program of research and instruction is maintained. While no specific degree in Hydrodynamics is given, advanced students in any of the several options of the Engineering Division may elect to do a thesis problem in this field. The several specialized laboratories provide excellent facilities for graduate student research.

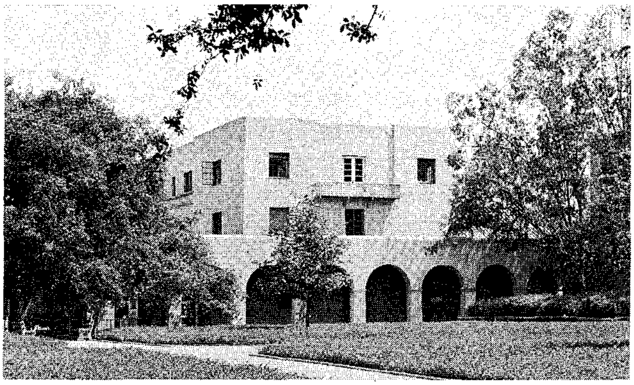
Hydraulic Machinery Laboratory. This laboratory is designed for carrying out basic and precise research studies in the hydrodynamics of centrifugal and propeller pumps, turbines, and allied flow problems. Dynamometers with precision speed controls are available up to 450 horsepower output or input, and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

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

Sedimentation Laboratory. This laboratory, originally operated for soil conservation studies, has become a center for basic investigations into the mechanism of entertainment, transportation, and deposition of solid particles by flowing fluids. The equipment includes (a) two closed circuit flumes for studying sediment transportation, (b) a sediment analysis laboratory, (c) a water tunnel for studying diffusion and turbulence, and (d) facilities for studying flow problems of the type found in hydraulic structures. Facilities of this installation are available to graduate students carrying out research required for the Engineer or Ph.D. degrees. Because these facilities are suitable for studying problems of interest to Civil Engineers they are used primarily by students in this group.



A small model of a dam is used for studies of soil conservation and erosion in the Hydraulics Laboratory



Dabney Hall of the Humanities

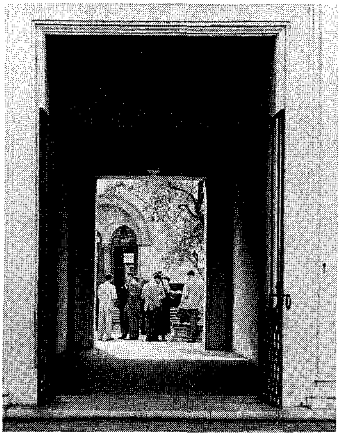
3. THE HUMANITIES

One of the distinctive features of the California Institute is its emphasis upon the humanistic side of the curriculum. The faculty is in thorough sympathy with this aim and gives full support to it. Every student is required to take, in each of his four undergraduate years, one or more humanistic courses. These courses in the Division of the Humanities include the subjects English and foreign literatures, European and American history, philosophy and social ethics, economics (including industrial relations), and government. All of them are so planned and articulated that the student obtains a solid ground and not merely the superficial acquaintance which is too often the outcome of a free elective system. The standards of intellectual performance in these studies are maintained on the same plane as in the professional subjects.

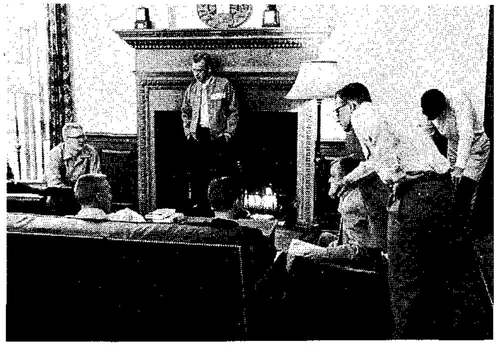
Ample quarters for the work in humanities are provided in Dabney Hall, which was given to the Institute by the late Mr. and Mrs. Joseph B. Dabney of Los Angeles as an evidence of their interest in the humanities program of the Institute and their desire to support it. Besides the usual class and lecture rooms, Dabney Hall of the Humanities contains a divisional library and reading room, offices for members of the humanities faculty, a Public Affairs Room, and a student lounge which opens upon a walled garden of olive trees.

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

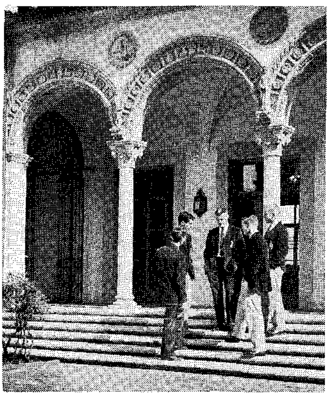
In addition to the regular staff of the Institute, scholars from other institutions give instruction or lectures in the Division of the Humanities. The proximity of the Huntington Library, with its unique opportunities for research in literature, history, and economics, is assurance that the instruction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



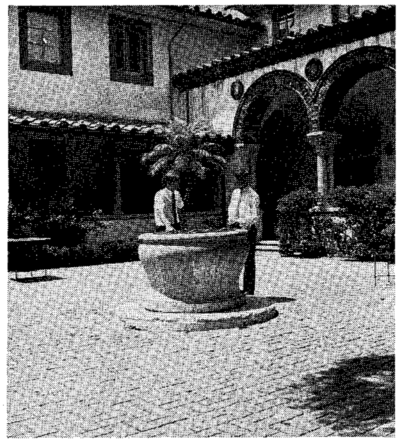
Blacker



Dabney

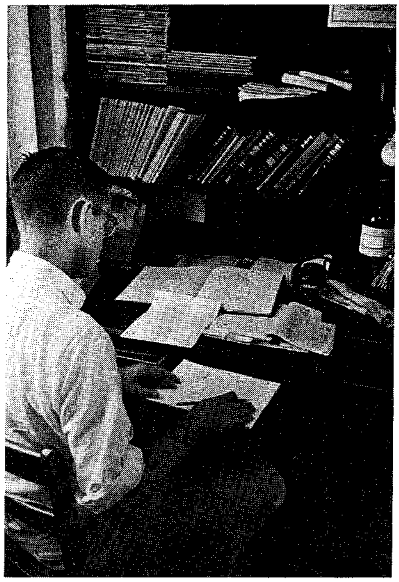


Fleming



Ricketts

The Student Houses are pleasantly located in the central campus



STUDENT LIFE

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

All four Houses have attractive inner courts surrounded by portales. More than half the rooms are 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 provide for resident students. Throop Club has its own elected officers and committees and carries on a full program of social and other activities. The Throop Club lounge, made possible by the generosity of a group of friends of the Institute, provides a convenient gathering place on the campus and is the center of Throop Club activities. For non-resident students, membership in the Throop Club greatly facilitates participation in undergraduate social life and intramural sports.

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

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

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

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

Board of Control. The Honor System is the fundamental principle of conduct of all students. More than merely a code applying to conduct in examinations, it extends to all phases of campus life. It is the code of behavior governing all scholastic and extra-curricular activities, all relations among students, and all relations between students and faculty. The Honor

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

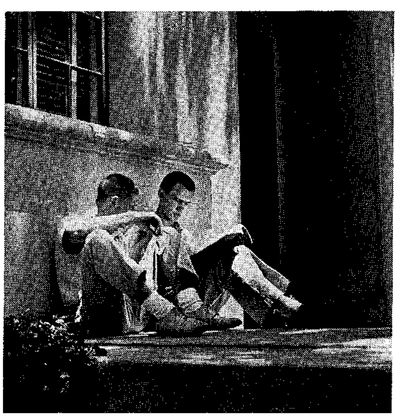
Faculty-Student Relations. Faculty-student coordination and cooperation with regard to campus affairs is secured through periodic joint meetings of the Faculty Committee on Student Relations and certain student body officers and elected representatives. These conferences serve as a clearing house for suggestions as to policy, organization, etc., originating with either students or faculty.

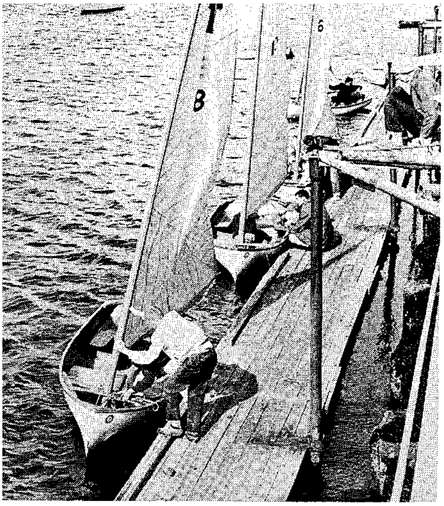
Departmental Advisers. Each member of the three undergraduate upper classes is assigned to a Department Adviser, a Faculty member in the option in which the student is enrolled. The adviser interests himself in the student's selection of optional courses, progress toward his degree, and, eventually, in assisting the student toward satisfactory placement in industry or in graduate school. Normally, the association between student and adviser, which is primarily professional, is established in the sophomore year and continues through graduation.

An informal discussion with a distinguished visitor to the campus

Dinner break at a weekend snow party

The Interhouse Dance

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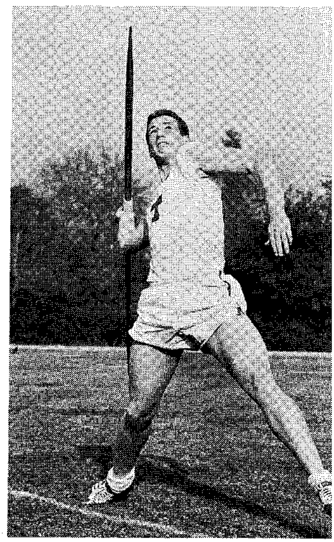

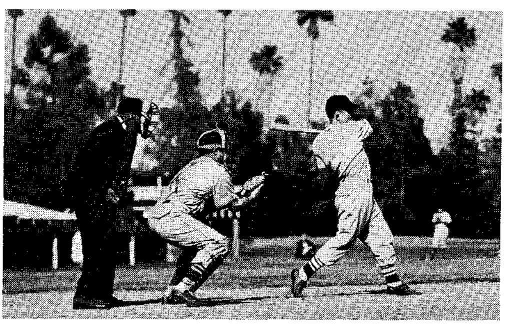

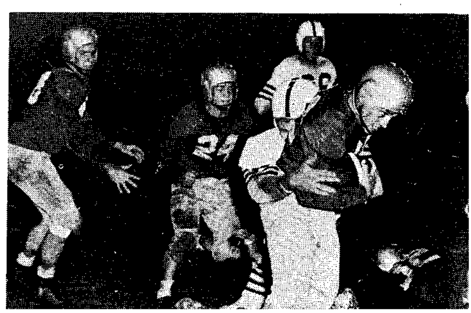

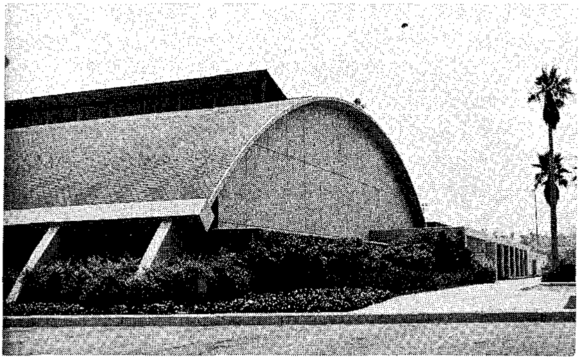

Scott Brown Gymnasium and
Alumni Swimming Pool

Athletics. The California Institute maintains a well-rounded program of athletics, and as a member of the Southern California Intercollegiate Athletic Conference, schedules contests in nine sports with the other members of the Conference—Occidental, Pomona, Redlands, and Whittier—as well as with many other neighboring colleges. In addition, the Caltech Sailing Club sails a fleet of Institute-owned dinghies based at Los Angeles Harbor.

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

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

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

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

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

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

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

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

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

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

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

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

AIR FORCE RESERVE OFFICERS TRAINING CORPS

THE California Institute has a unit of the Air Force ROTC. Membership in the unit is voluntary. Students may join only at the beginning of the freshman year. All freshmen may join the unit regardless of the option in engineering or science which they may eventually select. Except, and at discretion of Professor of Air Science, students with prior military service may be given credit for basic course towards Air Force ROTC requirements. Students who remain in the program through graduation may be commissioned as Second Lieutenants in the Air Force Reserve. Students may be enrolled in any of four Categories: Category I, flying training candidates; Category II, Technical and Scientific fields; Category III, non-flying and non-technical fields; Category IV, veterans only. No flight training will be given at the Institute. No test, either mental or physical, other than those necessary for entrance to the California Institute are required to enter the basic course which covers the first two years. During the middle of the sophomore year those in the basic course will be screened for aptitude and must pass the physical examination required for the Category they wish to enter before being admitted to the advanced course in the junior and senior year.

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

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

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

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

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

For AFROTC course requirements for the first year see page 120.

Section II

INFORMATION AND REGULATIONS FOR THE GUIDANCE OF UNDERGRADUATE STUDENTS

Requirements for Admission to Undergraduate Standing

THE California Institute is not coeducational and applications are accepted from men students only. The academic year consists of one twelve-week term and two eleven-week terms, extending from late September until the middle of June. There are no summer sessions, except that graduate students are permitted to register for summer research. Undergraduates are admitted only once a year—in September. All undergraduates at the California Institute are expected to carry the regular program leading to the degrees of Bachelor of Science in Science or Bachelor of Science in Engineering. Special students who wish to take only certain subjects and are not seeking a degree cannot be accepted.

Admission to the Freshman Class

Students are selected from the group of applicants on the basis of (a) high grades in certain required high school subjects (b) results of the College Entrance Examination Board tests, and (c) recommendation forms, and a personal interview when this is feasible. The specific requirements in each of these groups are described below. An application fee of $10 is due at the time an application for admission is submitted. No application will be considered until this fee is paid. The fee is not refundable whether or not the applicant is admitted or cancels his application, but it is applied on the first term bills of those who are admitted and who register in September.

APPLICATION FOR ADMISSION

Two applications are needed. One, for admission, is made on a form furnished by the California Institute on request, and is returned directly to the Institute together with an application fee of $10. The other, to take examinations, may be secured by writing to the College Entrance Examination Board either in Los Angeles or Princeton (see below).

Completed admission application blanks, the $10 application fee, and high school records including courses that may be in progress must reach the Admissions Office not later than March 2, 1959. (Application to take entrance examinations must be made directly to the College Board at an earlier date, for which see page 60.)

Applicants living outside of the United States must submit their credentials by December 1, 1958.

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

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

HIGH SCHOOL CREDITS

Each applicant must be thoroughly prepared in at least fifteen units of preparatory work, each unit representing one year's work in a given subject in an approved high school at the rate of five recitations weekly. Each applicant must offer all of the units in Group A and at least five units in Group B.

Group A:	English	3
	Mathematics	4
	Physics	1
	Chemistry	1
	United States History and Government	1
Group B:	Foreign Languages, Shop, additional English, Geology, Biology or other Laboratory Science, History, Drawing, Commercial subjects, etc.	5

The four-year program in mathematics should cover the principal topics of first-year algebra, intermediate algebra, trigonometry, and plane geometry, preferably including the basic notions of solid geometry. An introduction to elementary analytic geometry and the calculus is desirable but not necessary.

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

The Admissions Committee recommends that the applicant's high school course include at least two years of foreign languages, a year of geology or biology, basic elementary shop work, and as much extra instruction in English grammar and composition as is available in the high school curriculum.

ENTRANCE EXAMINATIONS

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

For admission in 1959 the Scholastic Aptitude Test must be taken no later than the February 14 College Board Test date and the Achievement Tests no later than the March 14 date. *It is important to note that no applicant can be considered with the original group to be admitted in 1959 who has not taken the Scholastic Aptitude Test by February 14 and the required Achievement Tests by March 14.* No exception can be made to the rule that all applicants must take these tests and no substitution of other tests for those listed above can be permitted.

Full information regarding the examinations of the College Entrance Examination Board is contained in the *Bulletin of Information* which may be obtained without charge by writing to the appropriate address given below. The tests are given at a large number of centers, but should any applicant be located more than 65 miles from a test center, special arrangements will be made to enable him to take the tests nearer home.

Applicants who wish to take the examinations in any of the following states, territories, or foreign areas should address their inquiries by mail to College Entrance Examination Board, P.O. Box 27896, Los Angeles 27, California:

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

Candidates applying for examination in any state or foreign area not given above should write to College Entrance Examination Board, P.O. Box 592, Princeton, New Jersey.

Each examination application submitted for registration must be accompanied by the examination fee of $16 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. The application fee of $10 is the only fee sent to the California Institute at the time an application is made.

For admission to the California Institute in 1959 a candidate has only two dates on which he can take the required Achievement Tests. These are December 6, 1958 and March 14, 1959. The Scholastic Aptitude Test may be taken on December 6 as well. Most applicants will find that they will be better prepared for the achievement tests if they wait until March 14. The College Board will offer the Scholastic Aptitude Test on January 10 and February 14 in addition, but no Achievement Tests will be offered on these latter dates. *The dates on which a candidate may take the College Board tests are thus*: *Scholastic Aptitude Tests—December 6, 1958, January 10, 1959, February 14, 1959*; *Achievement Tests—December 6, 1958, March 14, 1959.* He must be sure to put the California Institute's name in the appropriate blank on the College Board examination application form which he fills out for *each* of the dates he chooses.

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

	For examination centers located	
To take tests on	In the United States, Canada, the Canal Zone, Mexico, or the West Indies, applications must be received by	In Europe, Asia, Africa, Central and South America, and Australia, applications must be received by
Dec. 6, 1958	November 15	October 18
Jan. 10, 1959 (Aptitude Test only)	December 13	November 22
Feb. 14, 1959 (Aptitude Test only)	January 24	December 27
Mar. 14, 1959	February 14	January 24

Candidates are urged to send in their examination applications and fees to the Board as early as possible, preferably at least several weeks before the closing date, since early registration allows time to clear up possible irregularities which might otherwise delay the issue of reports. Under no circumstances will an examination application be accepted if it is received at a Board office later than one week prior to the date of examination. No candidate will be permitted to register with the supervisor of an examination center at any time. Only properly registered candidates, holding tickets of admission to the centers at which they present themselves, will be admitted to the tests. Requests for transfer of examination center cannot be considered unless these reach the Board office at least one week prior to the date of the examination.

Please note that requests to take the examinations and all questions referring exclusively to the examinations are to be sent to the College Entrance Examination Board at the appropriate address as given above, and not to the California Institute.

PERSONAL INTERVIEWS AND RECOMMENDATION FORMS

By March 2, recommendation forms will be sent out for each applicant who has an application on file. These forms are sent directly to the principal or headmaster of the school which the applicant is attending, with the request that they be filled out and returned directly to the California Institute. These recommendation forms provide valuable information on candidates. The College Board scores, the last of which will be received by about April 15, provide further important data. Since, however, there are many more applicants to the California Institute than our facilities can accommodate, as much information as possible is desired on each candidate for admission. Wherever preliminary information shows that an applicant has a chance of gaining admission, an attempt is made to hold a personal interview with him at the school he is attending. It is not possible to visit all of the schools involved; but if a personal interview cannot be held, this in no way prejudices an applicant's chances of admission. The applicant has no responsibility with regard to the personal interview unless and until he receives a notice giving the time and date when a representative will visit his school. These visits occur beween March 15 and May 1.

NOTIFICATION OF ADMISSION

Final selections will ordinarily be made and the applicants notified of their admission or rejection well before May 20, 1959 which is the date before which most College Board member colleges have agreed that they will not require any candidate to give final notice of acceptance of admission or of a scholarship. Upon receipt of a notice of admission an applicant should immediately send in the registration fee of $10. In the event of subsequent cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute. Places in the entering class will not be held after May 20, if the applicant could reasonably be expected to have received notice of acceptance at least ten days before this date. Otherwise, places will be held not more than ten days after notification. When the registration fee has been received, each accepted applicant will be sent a registration card which will entitle him to register, provided his physical examination is satisfactory. The registration card should be presented at the Dabney Hall Lounge on the date of registration.

Checks or money orders should be made payable to the California Institute of Technology.

ADVANCED PLACEMENT PROGRAM

A number of high schools and preparatory schools offer selected students the opportunity to accelerate and to take in the senior year one or more courses which are taught at the college level and cover the material of a first-year college course. The College Entrance Examination Board gives each year in May a set of Advanced Placement examinations covering this advanced work. The California Institute will allow credit and advanced placement for such work as follows. Credit for the second and third terms (En 1 bc) of freshman English on the basis of a one-year college-level course in English reading and composition and a high score on the College Board Advanced Placement examination in English; advanced placement in English in the second and third terms in English 6, "Literary Masterpieces." Credit for freshman mathematics on the basis of a one-year college-level course covering the topics of the first-year work at the Institute (see course description of Ma 1 abc, page 203) and a high score on the College Board Advanced Placement test in mathematics; advanced placement in sophomore mathematics (Ma 2 abc). Credit for freshman physics on the basis of a one-year college-level course covering the topics of the first-year work at the Institute (see course description of Ph 1 abc, page 216) and a satisfactory grade in the California Institute's transfer examination in physics taken by those applying for admission as sophomores (the College Board Advanced Placement test in physics is not adapted to the first-year work at the Institute and is, therefore, not accepted); advanced placement in sophomore physics (Ph 2 abc). Credit for certain portions of freshman chemistry on the basis of a one-year college-level course covering the topics of the first-year work at the Institute (see course description of Ch 1 abc, page 164. It is not anticipated that all of the topics of Ch 1 abc will have been covered. Those that are not must be taken in the regular way) and a high score on the College Board Advanced Placement test in chemistry; advanced placement for those entering options in which chemistry is required in the sophomore year. NOTE: The Advanced Placement tests are in no way a substitute for the College Board aptitude and achievement tests at the ordinary high-school level required for admission. The latter are the only tests considered in granting freshman admission. After admission those who offer advanced credits and examinations will be considered for credit and advanced placement in the subjects involved.

PHYSICAL EXAMINATION

Prior to final acceptance for admission, each applicant is required to submit a report of physical examination on a form which will be sent him at the time he is notified of admission. It is the applicant's responsibility to have this form filled out by a Doctor of Medicine (M.D.) of his own choosing. (See page 74.) 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 80-87. Note that there is a distinction between Honors at Entrance and scholarship grants and that the latter are awarded on the basis of financial need as well as high standing on the entrance examinations. No one can be considered for a scholarship grant who has not sent in a scholarship form according to the instructions on page 80. For information on tuition cost starting in September 1959 and on deferred tuition payment plans see page 79.

NEW STUDENT CAMP

All undergraduate students entering the Institute for the first time, either as freshmen or as transfer students, are required to attend the New Student Camp as part of the regular registration procedure. This meeting occupies three days of registration week preceding the fall term, and is usually held at Camp Radford, a large well-equipped camp owned by the city of Los Angeles and located in the San Bernardino mountains east of Redlands.

A large number of faculty members and student leaders attend the camp. During the three-day program the new students hear what life at the Institute is like. They learn what is expected of them and what aids are available to them to help them live up to these expectations. Because of the comparatively small student body and the pressure of work once academic activity starts, it is important both to the student and to the Institute that new students become, at the very beginning, part of a homogeneous group sharing a common understanding of purpose and a common agreement on intellectual and moral standards. The three days at the camp afford the best possible opportunity for achieving this necessary unity.

STUDENTS' DAY

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

AIR FORCE ROTC

For details of admission to the AFROTC see page 56.

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 57-63 or as upper classmen in the manner described below. Those who have pursued college work elsewhere, but whose preparation is such that they have not had the substantial equivalent of the following freshman subjects, English, mathematics, and physics, will be classified as freshmen and should apply according to the instructions on pages 57-63. They may, however, receive credit for the subjects which have been completed in a satisfactory manner.

An applicant for admission must write to the Office of Admissions, California Institute of Technology, Pasadena, California stating his desire to transfer, the branch of engineering or science he wishes to pursue, and the number of years of college he will have completed by the date of transfer. At the same time he must present a transcript of his record to date showing in detail the character of his previous training and the grades received both in high school and college. If the college transcript does not list subjects *and grades* for high school work, the applicant must see that his high school sends the Office of Admissions a transcript of this work. After the transcripts have been evaluated by the Admissions Office an application blank will be sent provided the grades and subjects on the transcripts meet the transfer requirements.

Please note that an application blank is not sent until the transcripts have been received and evaluated, and that the applicant must write a letter giving the information outlined in the preceding paragraph. Transcripts are held in the files until such a letter is received.

Application blanks must be on file in this office by April 15. Transcripts should, therefore, be sent no later than April 1. Applicants living in foreign countries must have applications and transcripts on file by March 1 at the latest and should understand that no information with regard to acceptance or rejection can be sent before June 20.

Applicants who are enrolled in a college at the time applications are made do not ordinarily complete the academic year until May or June. Such applicants should make sure that a list of subjects being taken during the final semester is included in the transcript sent for evaluation and that a supplementary transcript showing the grades for the final semester is sent at the end of the academic year as soon as these grades are available.

Before their admission to the upper classes of the Institute all students are required to take entrance examinations in mathematics, physics, and English composition covering the work for which they desire credit, except that in addition an examination in chemistry is required of those desiring to major in chemistry. Students must offer courses, both professional and general, substantially the same as those required in the various years at the Institute (see pages 120-136) or make up their deficiencies as soon as possible after admission.

It is not possible to answer general questions regarding the acceptability of courses taken elsewhere. The nature of the work at the Institute is such as to demand that all courses offered for credit be scrutinized individually. Even when a transcript of record is submitted it is not always possible to tell whether the courses taken are equivalent to the work at the Institute. In case the standard of the work taken elsewhere is uncertain additional examinations may be required before the question of credit is finally determined.

Applicants are advised to read the descriptions of the freshman and sophomore courses, particularly those in physics, mathematics, and chemistry, and to note that the work in freshman mathematics includes certain topics in differential and integral calculus. It is possible, however, for an able student to cover outside of classes, the necessary work in integral calculus and thus prepare himself for the entrance examination and the sophomore course in mathematics. Note also the references to freshman and sophomore chemistry on page 65.

Two examinations of a comprehensive character are offered in each of the three subjects, mathematics, physics, and chemistry. One examination in each subject covers the work of the first year, the other examination that of the first and second years. Representative examination papers will be sent to approved applicants upon request. The English examination covers composition only and is the same, regardless of the level at which the applicant is seeking admission. The Institute courses for which those admitted will receive credit will be determined by the Committee on Admission to Upper Classes and the departments concerned on the basis of the applicants' previous records and of the results of their examinations.

It is not possible to give definite assurance that a transfer student entering the sophomore year will graduate in three years or that one entering as a junior will graduate in two years. Much depends on the amount and nature of the credit granted at the time a student registers in September and on the possibility of fitting deficiency make-ups into the regular schedule.

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

The first-year chemistry course at the California Institute differs from those given at many other colleges because of the inclusion of a substantial amount of quantitative analysis in the laboratory work. A transfer student who has had a one-year college course in inorganic chemistry and qualitative analysis will be considered to have met the first year chemistry requirements provided, of course, that his grades have been satisfactory, except that those wishing to major in biology or chemistry will be required to take certain portions of freshman chemistry if they have not had the equivalent laboratory work elsewhere.

The transfer examination in chemistry is required only of those wishing to major in chemistry. For admission to the sophomore year this examination will cover general chemistry and qualitative analysis. The examination for admission to the third year is a comprehensive test covering general chemistry, qualitative and quantitative analysis. Transfer students entering the junior year in chemistry will be able to take the sophomore organic chemistry course during their first year at the Institute.

No application fee is charged in the case of transfer students, but only those whose records are good will be permitted to take the tests.

Applicants should not come to the Institute expecting to be admitted to the examinations, without first receiving definite permission to take them.

The schedule for the examinations for admission to upper classes September 24, 1959, is as follows:

Chemistry	(3 hours)	1:00 P.M.	June 5, 1959
English	(1 hour)	9:00 A.M.	June 6, 1959
Mathematics	(2 hours)	10:30 A.M.	June 6, 1959
Physics	(3 hours)	2:00 P.M.	June 6, 1959

No other examinations for admission to upper classes will be given in 1959.

Applicants residing at a distance may take the examinations under the supervision of their local college authorities, provided definite arrangements are made well in advance. Arrangements for examinations in absentia should include a letter to the Dean of Admissions from the person directing the tests stating that the required supervision will be given.

The attention of students planning to transfer to junior standing is called to the fact that, until they have satisfactorily completed three full terms of residence at the Institute, they are subject to the same scholastic requirements as are freshmen and sophomores. (See pages 69-73.) 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 71.)

Physical examinations and vaccination are required as in the case of students entering the freshman class. (See page 62.) 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 62.) 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 certain liberal arts colleges, whereby students enrolled in these liberal arts colleges may follow a certain prescribed course for the first three years and then transfer into the third year of one of the engineering options at the California Institute without further formality provided that they have the unqualified recommendation of the officials at the liberal arts college which they are attending. After satisfactorily completing in two years at the California Institute all remaining work required for a bachelor's degree in engineering they will be awarded a bachelor of arts degree by the college from which they transferred and a bachelor of science degree in engineering by the California Institute. Application for admission at the freshman level under this plan should be made to the liberal arts college.

The list of colleges with which these arrangements exist is as follows:

Bowdoin College, Brunswick, Maine

Brandeis University, Waltham, Massachusetts

Grinnell College, Grinnell, Iowa

Occidental College, Los Angeles, California

Ohio Wesleyan University, Delaware, Ohio

Pomona College, Claremont, California

Reed College, Portland, Oregon

Wesleyan University, Middletown, Connecticut

Whitman College, Walla Walla, Washington

REGISTRATION REGULATIONS

	Registration Dates	*Fees Payable*	*Instruction Begins*
Freshmen and Transfer Students......	Sept. 25, 1958	Sept. 25, 1958	Sept. 30, 1958
Upperclassmen and Graduate Students	Sept. 29, 1958	Sept. 29, 1958	Sept. 30, 1958

For Second and Third Term dates refer to the Institute Calendar.

FEES FOR LATE REGISTRATION

Registration is not complete until the student has personally turned in the necessary registration and class assignment cards for a program approved by his registration officer and has paid his tuition and other fees. A penalty fee of four dollars is assessed for failure to register on the scheduled date, and a similar fee is assessed for failure to pay fees within the specified dates. These requirements apply to all three terms.

SPECIAL STUDENTS

Applicants who wish to take a special program without working toward a degree are not accepted for undergraduate admission. Registered undergraduates who register for programs which make it appear that they are no longer candidates for a B.S. degree may be refused further registration by the Registration Committee.

CHANGES OF REGISTRATION

All changes in registration must be reported to the Registrar's Office by the student. Such changes are governed by the last dates for adding or dropping courses as shown on the Institute calendar. A grade of F will be given in any course for which a student registers and which he does not either complete satisfactorily or drop. A course is considered dropped only after the student has turned in to the Registrar's Office a drop card properly filled out and signed by the instructor concerned and any other required persons. A student may not at any time withdraw from a course which is required for graduation in his option without permission of one of the Deans. Senior students must also have the approval of the Registrar. A student may not withdraw from a course after the last date for dropping courses without, in addition to his instructor's consent, the approval of the Registration Committee. A student may, with the consent of the instructor concerned, add a course after he has completed his regular registration provided the addition does not bring the total units for which he is registered above 58 including Physical Education or ROTC. To carry excess units he must obtain the recommendation of his Departmental Adviser and the approval of the Registration Committee (see page 73). A student may not add a course after the last date for adding courses without, in addition to his instructor's consent, the approval of the Registration Committee. Registration for added courses is complete only after a student has turned in to the Registrar's Office an add card properly filled out and signed by the instructor concerned. No credit will be given for a course for which a student has not properly registered.

General Regulations

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

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

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

Auditing of Courses

Persons not regularly enrolled in the Institute may, with the consent of the instructor in charge of the course and the Chairman of the Division concerned, be permitted to audit courses upon payment of a fee in the amount of $15.00 per term, per lecture hour. Registration cards for auditing of courses may be obtained in the Registrar's office. Regularly enrolled students and members of the Institute staff are not charged for auditing. No grades for auditors are turned in to the Registrar's office and no official record is kept of the result of work done.

SCHOLASTIC GRADING AND REQUIREMENTS

Scholastic Grading

The following system of grades is used to indicate the character of the student's work in his various subjects of study:

A denotes Excellent, B denotes Good, C denotes Satisfastory,* D denotes Poor, E denotes Conditioned, F denotes Failed, inc denotes Incomplete.

In addition, grades of A+ and A−, B+ and B−, C+ and C−, and D+ may, where appropriate, be used for undergraduates only.

In certain designated courses, the grade of "P" indicating Pass may be given, but it is not counted in computing grade-point average of an undergraduate student. The grade of "H" is a grade given for satisfactory completion of freshman honor elective courses and is not used in computing the grade-point average.

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

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

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

Failed means that no credit will be recorded for the course, the units, however, count in the student's grade-point average. He may register to repeat the subject in a subsequent term and receive credit without regard to his previous grade, the new registration and units being counted as for any other course. In special cases the Registration Committee may, with the instructor's approval, authorize the completing of a *failed* course by three 3-hour examinations, the units and new grade being recorded as in the event of repeating the subject. The original "F" and units for the course remain on the record and are counted in computing the grade-point average.

Scholastic Requirements

All undergraduates and Master of Science candidates are required to meet certain scholastic standards as outlined below. In addition, students who have been reinstated to senior standing after having failed to make the required number of credits in the junior year are subject to these scholastic requirements in the senior year.

Each course in the Institute is assigned a number of units corresponding to the total number of hours per week devoted to that subject, including

*Excepting that C− is considered poor.

classwork, laboratory, and the normal outside preparation.* *Credits* are awarded on the basis of the number of units multiplied by four if the grade received is "A," three if "B," two if "C," and one if "D"; thus, a student receiving a grade of "B" in a twelve-unit course receives 36 credits for this course.†

Credits are not given for work in physical education.

Grade-point average is computed by dividing the total number of credits earned in a term or an academic year by the total number of units taken in the corresponding period. Units for which a grade of 'F" has been received are counted, even though the "F" may have subsequently been removed. (See above.) Units and credits in military subjects taken by Air Force ROTC students are counted in computing grade-point average. Physical education units, units in undergraduate and graduate research, and units for honor elective courses 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 1.3.

(b) If he fails to obtain a grade-point average of at least 1.9 for the academic year. A student who has completed at least three full terms of residence at the Institute and has been registered for his senior or Master's year shall no longer be subject to the requirement that he make a grade-point average of at least 1.9 for the academic year except that a student who is *reinstated* to enter the senior year is subject to this requirement during his senior year. Seniors and Master's candidates are subject to the requirement

TABLE OF CREDITS CORRESPONDING TO GRADE AND NUMBER OF UNITS

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

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

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

that they must receive a grade-point average of at least 1.3 each term to be eligible for subsequent registration. (Special note should be made of the graduation requirement described below.)

(c) Any undergraduate student who is *reinstated* and who fails to make a grade-point average of at least 1.9 for the following term is ineligible to register.

(d) An undergraduate student is ineligible to register for any term if he fails during the preceding term to remove a deficiency in physical education from an earlier term.

A student ineligible for registration because of failure to meet the requirements stated in the preceding paragraphs may, if he desires, submit immediately to the appropriate Dean a petition for reinstatement, giving any reasons that may exist for his previous unsatisfactory work and stating any new conditions that may lead to better results. Each such application will be considered on its merits. If this is the first such occurrence the Dean can, after consultation with the student and examination of his record, reinstate him or at the Dean's discretion refer special cases to the Registration Committee. A reinstated student who again fails to fulfill the scholastic requirements for registration must petition the Registration Committee through the appropriate Dean. In any case the student may, if he wishes, appear before the committee and may at the discretion of the Dean be required to appear. A second reinstatement will be granted only under very exceptional conditions.

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

Leave of Absence. Leave of absence involving non-registration for one or more terms must be sought by written petition. Such leave up to one year can be granted by the appropriate Dean for a student whose grade-point average is 2.3 or more. Other petitions should be addressed to the Registration Committee, and the student must indicate the length of time, and the reasons, for which absence is requested. In case of brief absences from any given exercise, arrangements must be made with the instructor in charge.

Departmental regulations. Any student whose grade-point average (credits divided by units) is less than 1.9 in the subjects listed under his division* may, at the discretion of his department, be refused permission to continue the 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

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

some other option provided permission is obtained, or from repeating courses to raise his average in his original option.

Graduation requirement: To qualify for graduation a student must complete the prescribed work in some one option of the course in engineering or of the course in science with a passing grade in each required subject and with a grade-point average of 1.90. A grade of "F" in an elective course need not be made up, provided the student has received passing grades in enough other accepted units to satisfy the minimum total requirements of his option. In addition to the above requirement, a member of the Air Force ROTC unit must satisfactorily complete the basic course unless relieved of this obligation by the Air Force. If a member of the AFROTC has entered the advanced course or if he has at any time at the California Institute secured deferment under Selective Service by reason of his membership in the AFROTC, he must satisfactorily complete the AFROTC course and must accept a commission in the Air Force if one is offered unless excused from these obligations by action of the Air Force.

Residence Requirement. All transfer students who are candidates for the Bachelor of Science degree must complete at least one full year of residence in the undergraduate school at the Institute immediately preceding the completion of the requirements for graduation. At least ninety of the units taken must be in subjects in professional courses. A full year of residence is interpreted as meaning the equivalent of registration for three terms of not less than 49 units each.

Honor standing. At the close of each academic year the Committee on Undergraduate Scholarships and Honors awards Honor Standing to fifteen or twenty students in each of three classes remaining in residence. These awards are based on the scholastic records of the students. A list of these students attaining Honor Standing on the basis of their academic records for 1957-58 appears on page 235.

Graduation with honor. Graduation *with honor* will be granted a student who has received on the average throughout his course 130 credits per term which result from grades of "A" and "B" exclusively, provided also that he achieves such an average in the senior year. In addition, a student may be graduated with honor under joint recommendation of his division and the Committee on Undergraduate Scholarships and Honors and approval of the Faculty.

Term examinations will be held in all subjects unless the instructor in charge of any subject shall arrange otherwise. No student will be exempt from these examinations. Permission to take a term examination at other than the scheduled time will be given only in the case of sickness or other emergency and upon the approval of the instructor in charge and of one of the Deans. A form for applying for such permission may be obtained in the Registrar's Office. Another form must be filled out when conflicts exist in a student's examination schedule. It is the student's responsibility to report the conflict to the instructor in charge of one of the conflicting examinations and to request the instructor to leave a copy of the examination in the Registrar's Office to be given at the time and place scheduled for conflict examinations.

Excess or fewer than normal units. Undergraduates who wish to register in any term for more than 56 units inclusive of Physical Education or Air Science must obtain the recommendation of the Departmental Adviser and the approval of the Registration committee. Master's candidates, see page 93.

Registration for fewer than 33 units must be approved by the Registration Committee. See page 91 for Graduate Students.

Freshman honor electives. A freshman with a grade-point average for the previous term greater than 1.9 may register in the second or third term for one "Honor Elective" (3 units) in one field, providing he earned at least a B— the previous term in the prescribed course in the chosen field or obtains the approval of the instructor in such course. Registration for an "Honor Elective" is entirely voluntary. If satisfactory work is done, a grade of "H" will be recorded and three units of credit will be allotted on the record; however, these units will not be included in the computation of grade-point average.

Selection of course and option. Students who wish to enter one of the options in science must select their options and notify the Registrar's Office thereof shortly before the close of the freshman year. Students who enter the engineering course may postpone selection of option until shortly before the close of the sophomore year.

Graduation in two different options. Students who wish to receive a second degree of Bachelor of Science in another option are required to have one additional year of residence (three terms of study involving at least 45 units per term) beyond the first Bachelor of Science degree.

Candidacy For The Bachelor's Degree

A student must file with the Registrar a declaration of his candidacy for the degree of Bachelor of Science on or before the first Monday of November preceding the date at which he expects to receive the degree. His record at the end of that term must show that he is not more than 21 units behind the requirement in the regular work of his course as of that date. All subjects required for graduation, with the exception of those for which the candidate is registered during the last term of his study, must be completed by the second Monday of May preceding commencement.

STUDENT HEALTH AND PHYSICAL EDUCATION

Physical Education

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

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

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

Student Health

PHYSICAL EXAMINATION AND VACCINATION

All admissions, whether graduate or undergraduate, are conditional until a report of physical examination and vaccination is received and approved by the Director of Student Health. See page 62.

THE DISPENSARY AND INFIRMARY

The new Archibald Young Health Center is located on Arden Road, 50 feet below California Street. The services offered by the dispensary are available to graduate students, undergraduate students, students' wives, and faculty. The service offered to employees and dependents is for emergencies only and not for continuing care. Only graduate and undergraduate students (and male employees for emergencies) are admitted to the infirmary. Students have priority on the available beds.

The staff consists of attending physicians, retained consultants, and nurses. A medical consultant in radiological safety is on the consulting staff. Diagnostic psychiatric care is available. The infirmary is operated twenty-four hours a day, seven days a week, during the academic year. The dispensary is open during the academic year from 9 a.m. to 5 p.m. from Monday through Friday, and 9 a.m. to 12 noon on Saturday. During the summer vacation, a somewhat restricted dispensary service is offered.

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

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 $30.00 per academic year. Ten dollars of this fee is paid into an Emergency Health Fund and the remaining portion of the health fee, consisting of $20.00, entitles a student to the services of the dispensary during the academic year. 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.

SUMMER HEALTH FEE

By action of the Board of Trustees, all graduate students registered for summer work will be charged a Health Fee of $1.00, beginning June 1957. This will make them eligible for benefits from the Emergency Health Fund to assist in defraying expenses contracted during the summer vacation period between Commencement Day in June and Registration Day in September for treatment and hospitalization necessitated by accidental bodily injury sustained while on the Institute campus or while participating in school activities.

During the summer vacation graduate and undergraduate students pay a fee of $2.00 per visit to the Health Center, plus cost of medicine and laboratory services.

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 student's health fee, $10.00 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 injuries incurred in connection with authorized intercollegiate athletics. However, 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 $500.00.

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

7. 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.

8. 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.

EXPENSES

ANNUAL EXPENSE SUMMARY

I. Undergraduate Students

*Registration Fee (freshmen and transfer students)		$ 10.00	
Tuition 1958-59 (3 terms)		900.00	
Tuition 1959-60 (3 terms)		1,275.00	
Health and Hospitalization Fee		30.00	
General Deposit		25.00	
Student Body Dues		19.00	
Subscription to California Tech		1.50	
Books and Supplies (approx.)		75.00	
Total for Academic Year			$1,060.50
Student House Living Expenses	Board $519.75		
	Room $259.00[2]	778.75	
	Dues	18.00	796.75
Total for Academic Year with Board and Room			$1,857.25

II. Graduate Students

Tuition 1958-59 (3 terms)	$ 900.00	
Tuition 1959-60 (3 terms)	1,275.00	
Health and Hospitalization Fee	30.00	
General Deposit	25.00	
Books and Supplies (approx.)	75.00	
Total for Academic Year		$1,030.00

*For freshmen and transfer students applying for admission in 1958-59, there will be a $5. Application Fee, not refundable, but applicable, upon registration to the Tuition Fee.

The following is a list of Student Expenses at the California Institute of Technology for the Academic Year 1958-59, together with the dates on which the various fees are due. These charges are subject to change at the discretion of the Institute.

Undergraduate Students

Date Due			*Fee*
Upon notification of admission	Registration Fee		$ 10.00[1]
Sept. 25, 1958: Freshmen and transfer students	General Breakage Deposit		25.00
	Tuition, 1st term		300.00
Sept. 29, 1958: All others	Board and Room, 1st term 21 meals per week		275.75[2]
	First Term Incidental Fees:		
	Associated Student Body Dues	5.50	
	Subscription to Calif. Tech for 1957-58	1.50	
	Health and Hospitalization Fee	30.00[3]	
	Total		37.00
	Locker Rent, 1st term		1.00[4]
	Parking Fee, 1st term		1.50[4]
	Student House Dues, 1st term		6.00
January 5, 1959	Tuition, 2nd term		300.00
	Board and Room, 2nd term 21 meals per week		255.00[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	6.00
March 30, 1959	Tuition, 3rd term	300.00
	Board and Room, 3rd term 21 meals per week	248.00[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	6.00

Graduate Students

	First Term:		
September 29, 1958	Tuition	300.00	
	Health and Hospitalization Fee	30.00[3]	
	General Deposit (see page 79)	25.00	
	Second Term:		
January 5, 1959	Tuition	300.00	
	Third Term:		
March 30, 1959	Tuition	300.00	
	*Summer Health Fee	1.00	
Total for Academic Year			956.00

Tuition Fees for fewer than normal number of units:

Over 32 units Full Tuition[5]
32 to 25 units .... $225.00 per term
24 to 10 units .... $9.00 per unit per term
Minimum per term .... $90.00[6]
Auditor's Fee .... $15.00 per term, per lecture hour

*A Health Fee of $1 will be charged to all graduates taking summer research.

Withdrawals: Students withdrawing from the Institute during the first three weeks of a term, for reasons deemed satisfactory to the Institute, are entitled to a refund of tuition fees paid, less a reduction of 20% and a pro rata charge for time in attendance.[7] No portion of the Health Fee, Student Body Dues, or Subscription to California Tech, is refundable upon withdrawal at any time.

1Paid 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.

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

3Required 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 $20.00 and $10.00, respectively to cover balance of school year.

4Optional.

5Although the Institute charges full tuition for over 32 units, the Veterans Administration allows the following subsistence percentages: 25% for 10 through 20 units per term; 50% for 21 through 29; 75% for 30 through 41; and 100% for 42 and over. See footnote page 114.

6Graduate Students see paragraph 6, page 98.

7Pro 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 74-75).

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

General Deposit. Each student is required to make a general deposit of $25, to cover possible loss and/or damage of Institute property. Upon his graduation or withdrawal from the Institute, any remaining balance of the deposit will be refunded.

Student Houses. Students in the Houses must supply their own blankets but bed linen and towels are furnished and laundered by the Institute.

Application for rooms in the Student Houses may be made by addressing the Master of Student Houses.

Special Fees. Students taking the Spring Field Trip in Geology (Ge 122) and the Summer Field Geology course (Ge 123) are charged for travel at an estimated rate of one cent per automobile mile plus reasonable subsistence expense.

The fee for auditing courses (see page 68) is $15.00 per term, per lecture hour.

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

Tuition increase and deferred payments. Commencing in September, 1959 tuitions will be increased to $1275 for the three terms of the academic year. The health fee of $30 will then no longer be charged as a separate fee but will be incorporated in the tuition. Because of rising costs the increase in tuition is unavoidable, but the Institute is developing deferred tuition payment plans under which it is hoped that the student and his family may arrange to pay the tuition charge in monthly payments over a period as long as ten years. The increase in tuition will, of course, be taken into consideration in setting the amounts carried by the various scholarships which will be awarded for the 1959-60 academic year and thereafter.

SCHOLARSHIPS, STUDENT AID, AND PRIZES*

Freshman Honors and Scholarship Grants

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

Honors at Entrance

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

Freshman Scholarship Grants

The recipients of scholarship grants are selected by the Admissions Committee from the candidates who have stood sufficiently high on the entrance examinations, and have otherwise satisfied the entrance requirements of the Institute, and have submitted a **Parent's Confidential Statement.**

Scholarship grants are awarded to the extent of available funds where financial need is demonstrated. Awards are made on the basis of all the information available in regard to the applicants—the results of their examinations, their high school records and recommendations, the statements submitted as to their student activities and outside interests, and the result of personal interviews where these are possible. A list of scholarship grants will be found on pages 82 to 87. Where the amount of a grant is not specified there is a certain total sum available each year to be distributed among several scholarship holders in any proportion. Grants from these funds are usually for full tuition, or less if the need of the recipient is less.

The California Institute uses a uniform scholarship grant application which has been adopted by many colleges in the United States. All applications for scholarship grants where financial need exists must be made on this form. The form, called a **Parent's Confidential Statement,** may be obtained by writing to the Admissions Office at the California Institute or by calling at the office. The form is put out by the College Scholarship Service of the College Entrance Examination Board and is to be returned directly to the appropriate office of the College Board (see page 136) and not to the California Institute. Space is provided on the form for the applicant to indicate that he wishes a copy sent to the California Institute and to such other colleges as he may desire. A fee of two dollars is 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.

Parent's Confidential Statement forms must be sent to the appropriate College Board office not later than March 1 of the year in which admission is desired.

*For further information on Graduate Scholarships and Fellowships, see page 114.

Honorary Scholarships

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

Regulations and Renewals

Recipients of honorary scholarships and of scholarship grants are expected to maintain a satisfactory standing in their academic work during the year for which the scholarship is granted. If the recipient fails to maintain such an academic standing, or if, in the opinion of the Committee on Undergraduate Scholarships and Honors, the recipient in any other way fails to justify the confidence placed in him, the Committee may cancel the scholarship for the balance of the academic year. Recipients of scholarships which run for more than one year are in general expected to maintain a rank in the upper half of the class. The amount of the award carried by these scholarships may be increased or decreased at the beginning of any year if the financial need has changed. Freshmen who receive scholarship awards for the freshman year only will be considered for scholarship aid in subsequent years on the basis of need according to the regulations in the following paragraph.

Upper Class Scholarships

Sophomores, juniors, and seniors are considered for scholarships if need is demonstrated and if throughout the preceding year they have carried at least the normal number of units required in their respective options, and if they have completed the preceding academic year with a grade-point average of at least 2.0. Awards are made in order of rank to the extent of the funds available. Most awards are for full or part tuition. When individual scholarships carry amounts in excess of full tuition this fact is noted in the list of scholarships below. A student who ends the academic year with a grade-point average of 2.0 or higher and who wishes to apply for a scholarship grant for the next year should obtain a scholarship form from the Admissions Office in June. This form is to be filled out by the student and his parents (or guardian) and returned to the Admissions Office two weeks before the beginning of the fall term. No one will be considered for a scholarship grant unless a scholarship form completely filled out and signed by parents (or guardian) is submitted by the proper date. If a scholarship applicant feels that his parents should no longer be responsible for his support he may attach an explanatory note to the form, but the form must be filled out.

It is expected that students to whom awards are made will maintain a high standard of scholarship and conduct. Failure to do so at any time during the school year may result in the termination of the award.

Scholarship Funds

Funds for Freshman and Upperclass Scholarships are provided in large part from the special scholarship funds named below. It is not necessary, however, to apply for any particular scholarship by name. Applicants for admission who have a **Parent's Confidential Statement** on file will be considered for the best award to which their relative need and standing on the entrance examinations entitle them. For Honorary Scholarships see above.

Alumni Scholarships: The Alumni Association of the California Institute provides scholarships covering full tuition to be awarded to entering freshmen. The recipients of these scholarships can expect to receive this amount for four years provided their conduct and grades continue to be satisfactory.

The Automotive Council Scholarship: The Automotive Council of Los Angeles, Inc. is providing a tuition scholarship for the 1958-59 academic year for a junior or senior in mechanical engineering.

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

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

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

Meridan Hunt Bennett Scholarships and Fellowships: Mrs. Russell M. Bennett of Minneapolis, in January, 1946, made a gift of approximately $50,000 to the Institute to constitute the Meridan Hunt Bennett Fund, as a memorial to her son, Meridan Hunt Bennett, a former student at the 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 1958-59 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 established the Class of 1927 Scholarship Endowment Fund. The income from this fund is to be used for an undergraduate scholarship.

Lewis Crank Scholarship: Loma Vista Investment, Inc., of Culver City, California, has established a $1000 scholarship to be awarded to a sophomore in one of the science options. The holder of this scholarship may expect it to be renewed for each of his last two years subject to the regulations on page 81.

Crown Zellerbach Foundation Scholarships: The Crown Zellerbach Foundation provides two scholarships of $900 each for juniors or seniors majoring in a science option.

Cyprus Mines Corporation Scholarships: The Cyprus Mines Corporation of Los Angeles has given $3000 to be used for undergraduate scholarships.

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

Douglas Aircraft Company Scholarship: The Douglas Aircraft Company has made provision for a $1350 scholarship for the 1958-59 academic year to be awarded to a junior or senior in aeronautical engineering, mechanical engineering, electrical engineering, or physics in that order of preference.

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.

Electric Club Scholarship: The Electric Club of Los Angeles awards a $500 scholarship every other year to a senior in electrical engineering.

Garrett Corporation Scholarships: The Garrett Corporation of Los Angeles has given $3000 for scholarships to be awarded to juniors or seniors majoring in mechanical engineering or applied chemistry, and to fifth-year students in mechanical engineering and chemical engineering. These were formerly known as AiResearch Manufacturing Company Scholarships.

General Motors Corporation Scholarship: The General Motors Corporation has established a scholarship at the California Institute to be awarded to an entering freshman. The award may range from a prize scholarship of $200 for a student not in need of financial assistance to an amount as high as $2000 a year depending on need. Holders of this scholarship may expect it to be renewed in each of the three upper-class years provided the holder's grades and conduct remain satisfactory.

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

Goodyear Scholarship: The Goodyear Foundation, Inc., has established a scholarship of $750 to be awarded to a junior or senior in engineering who may be interested in a career in business or industry.

Graham Brothers Foundation Scholarship: The Graham Brothers Foundation of Long Beach has made possible the award of a full tuition scholarship for the 1958-59 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.

International Nickel Company Scholarship: The International Nickel Company has provided a two-year scholarship in the amount of $1250 each year for a student transferring to the California Institute under the 3-2 Plan see page 66). The holder of this award must be a major in geology or in one of the engineering options.

International Telephone and Telegraph Corporation Scholarship: The International Telephone and Telegraph Corporation has given a $1000 scholarship for a junior majoring in electrical engineering, mathematics, or physics. This award is renewable in the senior year.

J. B. Keating Scholarships: Mr. John B. Keating has made possible the award of two scholarships for undergraduate juniors or seniors.

Kelman Scholarship: Mr. J. N. Kelman of Los Angeles and the I. T. E. Foundation of Philadelphia have made possible the award of a scholarship of $1200 for an entering freshman. The recipient of this scholarship can expect to receive this amount each year for four years provided his conduct and grades continue to be satisfactory.

Kennecott Copper Corporation Scholarship: The Kennecott Copper Corporation has given a $1000 scholarship for a junior or senior student majoring in applied chemistry.

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.

Peter Kiewit Sons Scholarship: The Peter Kiewit Sons' Company of Arcadia, California, has established a $500 scholarship for a senior in civil engineering.

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

Lockheed National Engineering Scholarship: The Lockheed Aircraft Corporation of Burbank, California, has established a scholarship covering tuition and certain other expenses totaling $1450 a year. This scholarship is to be awarded to an entering freshman who indicates that he intends to pursue a course in engineering. The recipient of this scholarship may expect to continue to receive this award during each of the three upper-class years, provided that his grades and conduct remain satisfactory.

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

Mayr Foundation Scholarships: The George H. Mayr Foundation of Beverly Hills granted funds for twenty-five undergraduate scholarships for the academic year 1958-59. Not open to freshmen.

David Lindley Murray Educational Fund: Mrs. Katherine Murray of Los Angeles, by her will, established the David Lindley Murray Educational Fund, the income to be expended in assisting worthy and deserving students to obtain education, particularly in engineering courses.

Neely Enterprises Scholarship: Neely Enterprises has given a $1000 scholarship for a sophomore student majoring in physics or electrical engineering whose home is in Arizona, California, Nevada, or New Mexico.

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

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

Edgar H. Pflager Scholarship Fund: Mr. Edgar H. Pflager has given a sum of money the income from which is to be used for undergraduate scholarships.

Procter and Gamble Scholarship: The Procter and Gamble Fund has provided for a four-year undergraduate scholarship in the amount of $1025 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 1958-59 in the amount of $800. Freshmen are not eligible for this award.

Rayonier Foundation Scholarship: The Rayonier Foundation will provide two scholarships of $500 each in 1958-59 for undergraduates majoring in applied chemistry or mechanical engineering.

Regional Prize Scholarships: A Regional Prize Scholarship is awarded to one entering freshman student each year in each of seven regions in the United States. The scholarship carries a stipend of $1200 for the freshman year. Regional Scholarships are an academic honor and are awarded, without regard to financial need, on the basis of high scholastic grades, high scores on the College Board Examinations required for admission, the recommendations of teachers and principals or headmasters, and on the result of a personal interview with a member of the Admissions Committee. To be eligible to compete for these scholarships an applicant must be nominated by the principal or headmaster of his school and must be attending school in one of the following regions: Region I: California;

Region II: Idaho, Montana, Oregon, Washington, Wyoming; Region III: Arizona, Colorado, Nevada, New Mexico, Texas, Utah; Region IV: Illinois, Iowa, Minnesota, Missouri, Nebraska, Wisconsin; Region V: Indiana, Michigan, Ohio; Region VI: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont; Region VII: Delaware, Maryland, New Jersey, New York, Pennsylvania. Nomination forms will be sent on request to principals or headmasters of schools in these regions.

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

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

Socony Vacuum Oil Company-General Petroleum Corporation has established a scholarship of $1300 for a junior or senior student in engineering. The Corporation is likewise giving a scholarship for a junior or senior or graduate student in geology.

Standard Oil Company of California Scholarships: The Standard Oil Company of California has provided a scholarship for an undergraduate majoring in applied chemistry and another scholarship for an undergraduate majoring in mechanical engineering.

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

J. T. Thorpe, Inc. Scholarship: The J. T. Thorpe Company has provided two full-tuition scholarships for 1958-59 to be awarded preferably to juniors in mechanical engineering.

Union Carbide Scholarships: The Union Carbide Corporation has established at the California Institute three scholarships covering full tuition and certain other expenses amounting to a total of $1000 a year. Recipients of these scholarships may expect the award to continue through the three upper-class years provided the recipient's grades and conduct continue to be satisfactory.

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

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

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

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

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 Dudley Loan Fund
The Dudley Foundation Loan Fund
The Claire Dunlap Loan Fund
The Roy W. Gray Fund
The Raphael Herman Loan Fund
The Vaino A. Hoover Student Aid Fund
The Howard R. Hughes Student Loan Fund
The Thomas Jackson Memoral Fund
The Ruth Wydman Jarmie Loan Fund
The John McMorris Memorial Loan Fund
The Noble Loan and Scholarship Fund
The 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 Placements is always available for consultation and guidance on placement problems.

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

PRIZES

THE FREDERIC W. HINRICHS, JR., MEMORIAL AWARD

The Board of Trustees of the California Institute of Technology established the Frederic W. Hinrichs, Jr., Memorial Award in memory of the man who served for more than twenty years as Dean and Professor at the Institute. In remembrance of his honor, courage, and kindness, the award bearing his name is made annually to the senior who, in the judgment of the undergraduate Deans, throughout his undergraduate years at the Institute has made the greatest contribution to the welfare of the student body and whose qualities of character, leadership, and responsibility have been outstanding. At the discretion of the Deans, more than one award or none may be made in any year. The award, presented at Commencement without prior notification, consists of $100 in cash, a certificate, and a suitable memento.

THE CONGER PEACE PRIZE

The Conger Peace Prize was established in 1912 by the Reverend Everett L. Conger, D.D., for the promotion of interest in the movement toward universal peace, and for the furtherance of public speaking. The annual income from $1,000 provides for a first and second prize to be awarded at a public contest and announced at Commencement. The contest is under the direction of representatives of the Division of the Humanities.

THE MARY A. EARL MCKINNEY PRIZE IN ENGLISH

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

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

THE DON SHEPARD AWARD

Relatives and friends of Don Shepard, class of 1950, have provided an award in his memory. The award is presented to a student, the basic costs of whose education have already been met but who would find it difficult, without additional help, to engage in extracurricular activities and in the cultural opportunities afforded by the community. The recipient, an upperclassman, is selected on the basis of his capacity to take advantage of and to profit from these opportunities rather than on the basis of his scholastic standing.

THE AMERICAN CHEMICAL SOCIETY PRIZE

A prize of $250 is awarded each year in connection with the annual high school contest of The American Chemical Society, Southern California Section. The prize goes to the highest ranking man in the contest who applies, is admitted, and registers at the California Institute in the fall following his senior high school year, provided that the candidate does not rank below the top five in the contest.

THE SCAAPT PRIZE

A prize of $250 is awarded each year in connection with the annual high school contest of the Southern California Section of the American Association of Physics Teachers. The prize goes to the highest ranking man in the contest who applies, is admitted, and registers at the California Institute in the fall following his senior high school year, provided that the candidate does not rank below the top five in the contest.

THE DAVID JOSEPH MACPHERSON PRIZE IN ENGINEERING

The David Joseph Macpherson Prize in Engineering was established in 1957 by Margaret V. Macpherson in memory of her father, a graduate of Cornell University in Civil Engineering, class of 1878.

A prize of $100 is awarded annually for the winning essay submitted by a senior in any of the three undergraduate options in the Division of Engineering. The object of the contest is to stimulate interest and excellence in English composition. The subjects of the essays are set by a Faculty Committee of three, appointed annually by the Chairman of the Division, each member representing one of the three options. The subjects may include those set by national engineering societies for their annual student-paper contests. The three judges of the contest, appointed by the Faculty Committee of three, are engineers who hold no official appointmnt at the California Institute.

Section III

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 114) need not make separate application for admission to graduate standing. For requirements in regard to physical examination, see pages 62 and 74.

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 93, 94, 99 for special requirements for residence.

Graduate students will be required to carry at least 36 units during each of their first three terms of attendance at the Institute.

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

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

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

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

III. TUITION FEES

The tuition charge for all students registering for graduate work is $900 for the 1958-59 academic year, payable in three installments at the beginning of each term, and will be increased to $1275 beginning 1959-60. Graduate students who cannot devote full time to their studies are allowed to register only under special circumstances. Except by specific action of the Committee on Graduate Study, graduate students will be required to register for at least 36 units during each of their first three terms of attendance at the Institute. A graduate student who is registered for 36 or more units is classed as a full-time graduate student. Students desiring permission to register for fewer than 33 units should petition therefor on a blank obtained from the Registrar. If such reduced registration is permitted, the tuition is at the rate of $225 a term for 32 to 25 units, and at the rate of $9 a unit for fewer than 25 units, with a minimum of $90 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. Beginning 1959-60, proportionately higher charges will be made.

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 98.)

There is a fee of $30 per academic year to assist in defraying expenses for medical care and emergency hospitalization, and a summer health fee of $1 for graduate students who register for summer work. Beginning 1959-60, the health fee will be covered by the tuition. (See pages 78 and 79.) 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 114 of this catalog. In addition, to students of high scholastic attainments there may be awarded *graduate scholarships* covering the whole or a part of the tuition fee. For such students *loans* also may be arranged, for which application should be made to the Student-Aid Committee.

B. Regulations Concerning Work for the Degree of Master of Science

I. GENERAL REQUIREMENTS

To receive the degree of Master of Science the student must complete in a satisfactory way the work indicated in the schedule of fifth-year courses (see pages 137-148) as well as in the schedule of the four-year course in science or in engineering, except that, in the case of students transferring from other institutions, equivalents will be accepted in subjects in which the student shows by examination or otherwise that he is proficient, and except in so far as substitutions may be approved by special vote of the committee in charge.

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

All programs of study, and applications for admission to candidacy for the degree of Master of Science shall be in charge of the Committee on the

Course in Science (in case the advanced work is to be astronomy, biology, chemistry, chemical engineering, geology, geophysics, mathematics, or physics), or of the Committee on the Course in Engineering (in case the work is to be in civil, mechanical, or electrical engineering, in engineering science, or in aeronautics); and recommendations to the Faculty for the award of the degree shall be made by the appropriate one of these committees, all such actions being taken in general after consideration of recommendations by the department concerned.

A student before entering upon work for the degree of Master of Science should, after consultation with the department concerned, submit a plan of study, and make application to the committee in charge for acceptance as a candidate for that degree. Application forms for admission to candidacy for these degrees may be obtained from the Registrar, and must be submitted not later than the sixth week of the academic year in which the degree is to be granted.

II. REGISTRATION

1. The regulations governing registration and student responsibilities as given for undergraduate students on pages 69-71 of the catalog apply also to students working toward the master's degree.

2. Before registering, the graduate student should consult with members of the department in which he is taking his work to determine the studies which he can pursue to the best advantage.

3. A student will not receive credit for a course unless he is properly registered, and at the first meeting of each class should furnish the instructor with a regular assignment card for the course, obtained on registration.

4. Students registering for more than 50 units but fewer than 63 units in any term must have the approval of their department. Registration for more than 62 units must in addition have the approval of the Registration Committee.

5. In the case of a student registered for the degree of Master of Science and holding a position as a graduate assistant, the actual number of hours per week required by his teaching or research services shall be deducted from the total number of units for which he might otherwise register. This number of units shall be determined by his department.

III. SCHOLASTIC REQUIREMENTS

1. A minimum of 140 units of graduate residence at this Institute is required for the master's degree, but specific departmental requirements often exceed this number. All or any part of this residence may be acquired prior to the completion of the work for the bachelor's degree provided a total of fifteen terms of acceptable college work equivalent to 45 units per term is completed. Courses used to fulfill requirements for the bachelor's degree may not be counted as graduate residence. A student will not, in general, be admitted to graduate standing until he has completed work equivalent to that required for the bachelor's degree.

2. Scholastic requirements for undergraduate students (see page 70) also apply to students working toward the master's degree. In meeting the

graduation requirements on page 72, the following rule will apply for master's degree candidates: only those courses shown on the candidacy blank and approved by the department representative shall be counted in figuring the grade-point average. Students who become ineligible to register, having failed to meet the scholastic requirements stated on pages 71-72 of the catalog, may submit to the Dean of Graduate Studies a petition for reinstatement. This petition should have the endorsement of the department in which the student is registered. The Dean of Graduate Studies will pass on this petition if he concurs with the departmental recommendation; otherwise the petition will be referred to the Committee on Graduate Study for final action. Changes on the candidacy blank which are not initialed by the proper authority are not to be recognized. No course which appears on the candidacy blank and for which the candidate is registered may be removed after the last date for dropping courses as listed in the catalog.

3. Candidates for the degree of Master of Science who have completed the senior year at the Institute are subject to the same regulations as are seniors, as listed on pages 69-72.

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 69-72.

5. A written placement examination is required of incoming graduate students in the Division of Geological Sciences. For details see page 108. Candidates for the master's degree in the Division of Geological Sciences should familiarize themselves with, and are expected to meet, certain special requirements concerning basic sciences and field geology. Detailed information on these requirements may be obtained from the Division Secretary.

6. Candidates for the master's degree in the Division of Chemistry and Chemical Engineering are required to take placement examinations. See pages 138-139.

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 111, section 2a.)

IV. THESIS

In the case of a required thesis two final copies must be filed with the Division concerned ten days before the degree is to be conferred. 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 99. Regulations governing registration will be found on page 97.

2. *Residence.* At least six terms of graduate residence (as defined on pages 90-91) subsequent to a baccalaureate degree equivalent to that given by the California Institute are required for an engineer's degree. Of these, at least the last three terms must be at the California Institute. It must be understood that these are minimum requirements, and students must often count on spending a somewhat longer time in graduate work.

To qualify for an engineer's degree a student must complete the work prescribed by his supervising committee with a grade-point average of at least 1.90, considering the grade of P as being equivalent to C and excluding grades for research. Work upon research and the preparation of a thesis must constitute no fewer than 55 units. More than 55 units may be required by certain departments and the student should determine the particular requirements of his department when establishing his program.

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

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

The student will be admitted to candidacy for the degree when his supervising committee certifies: (a) That all the special requirements for the desired degree have been met, with the exception that certain courses of not more than two terms in length may be taken after admission to candidacy; (b) That the thesis research has been satisfactorily started and probably can be finished at the expected time.

Such admission to candidacy must be obtained by mid-term of the term in which the degree is to be granted.

4. *Thesis.* At least two weeks before the degree is to be conferred, each student is required to submit to the Dean of Graduate Studies a ribbon copy, a reproduced copy, and the vellum of a satisfactory individual thesis describ-

ing his research, including a one-page digest or summary of the main results obtained. In form, the thesis must satisfy the requirements for theses for the degree of Doctor of Philosophy. (See page 101.)

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 103, 139.

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 105, except that a grade of D in Ph 131 is acceptable.

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. For details see page 108. 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 55 units of this work shall be for research and thesis, the exact number of units to be left to the discretion of the supervising committee appointed by the Dean of Graduate Studies. The courses shall be closely related to mechanical engineering, and the specific courses to be taken and passed with a grade of "C" or better by each candidate shall be determined by the supervising committee, but must include one of the following:

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

A list of possible courses from which a program of study may be organized will be found on page 147.

D. Regulations Concerning Work for the Degree of Doctor of Philosophy

I. GENERAL REGULATIONS

The degree of Doctor of Philosophy is conferred by the Institute primarily in recognition of breadth of scientific attainment and of power to investigate scientific problems independently and efficiently, rather than for the completion of definite courses of study through a stated period of residence. The work for the degree must consist of scientific research and the preparation of a thesis describing it, and of systematic studies of an advanced character primarily in science or engineering. In addition, the candidate must have acquired the power of expressing himself clearly and forcefully both orally and in written language, and he must have a good reading knowledge of at least two foreign languages chosen among French, German, and Russian. With the permission of the department concerned and the Dean of Graduate Studies, another modern language may be substituted for one of these languages.

Subject to the general supervision of the Committee on Graduate Study, the student's work for the degree of Doctor of Philosophy is specifically directed by the department in which he has chosen his major subject. Each student should consult his department concerning special divisional and departmental requirements. See Section VI.

With the approval of the Committee on Graduate Study, any student studying for the doctor's degree whose work is not satisfactory may be refused registration at the beginning of any term by the department in which the student is doing his major work.

II. REQUIREMENTS FOR ADMISSION TO WORK FOR DOCTOR'S DEGREE

With the approval of the Committee on Graduate Study, students are admitted to graduate standing by the department in which they choose their major work toward the doctor's degree. In some cases, applicants for the doctor's degree may be required to register for the master's or engineer's degree first. These degrees, however, are not general prerequisites for the doctor's degree. Students who have received the master's degree and wish to pursue further studies leading toward either the engineer's or the doctor's degree must file a new application to continue graduate work toward the desired degree. Students who have received an engineer's degree will not in general be admitted for the doctor's degree.

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

III. REGISTRATION

1. Students are required to register and file a program card in the Registrar's office at the beginning of each term of residence, whether they are attending regular courses of study, carrying on research or independent reading only, writing a thesis or other dissertation, or utilizing any other academic service.

2. Before registering, the student should consult with members of the department in which he is taking his major work to determine the studies which he can pursue to the best advantage.

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

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

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

6. Registration, with at least minimum tuition (see page 78), 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 93, 95 with reference to total work load of graduate students.)

IV. GRADES IN GRADUATE COURSES

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

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

3. The following system of grades is used to indicate class standing in graduate courses: "A" excellent, "B" good, "C" satisfactory, "D" poor, "E" conditioned, "F" failed, "Inc" incomplete. In addition to these grades, which are to be interpreted as having the same significance as for undergraduate courses (see page 69), 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 Fields*: 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.

A student, at his option, may undertake a program of study as a minor subject in a discipline other than that of his major subject. The disciplines offered are listed in Section VI under special requirements adopted by the various divisions of the Institute. This minor program must include at least 45 units of advanced work in that discipline, and must be comprehensive enough to give the student a fundamental knowledge of it. The program must be approved by both major and minor divisions on a form obtainable from the Graduate Office. A student who has satisfied the requirements of one or more minor subjects will be given recognition for this work by explicit mention of his minor subjects on his Ph.D. diploma.

If the student does not elect to undertake a minor program, he must include in the work presented for the doctorate at least 45 units of advanced work in one or more disciplines in the humanities or science or engineering different from that of his major subject. The choice and scope of this work must be approved by the division in charge of the major subject, on a form obtainable from the Graduate Office.

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

2. *Residence*: At least three academic years of residence subsequent to a baccalaureate degree equivalent to that given by the Institute are required for the doctor's degree. Of this at least one year must be in residence at the Institute. It should be understood that these are minimum requirements, and students must usually count on spending a somewhat longer time in residence. However, no student will be allowed to continue work toward the doctor's degree for more than 15 terms of graduate residence, 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 91 regarding summer registration for research.)

A graduate student who, by special arrangement made in advance, is permitted to conduct a portion of his research in the field, in government laboratories, or elsewhere off the campus, must file in advance a registration card for this work in the office of the Registrar, in order that it may count in fulfillment of residence requirements. This work must be carried out under the direct supervision of a member of the Institute staff. The number of units to be credited for such work shall be determined by the Dean of Graduate Studies in consultation with the Chairman of the Division in which the student is carrying his major work; and a recommendation as to the proportion of the full tuition to be paid for such work shall be made by the Dean to the Vice-President in charge of Business Affairs.

A student whose undergraduate work has been insufficient in amount or too narrowly specialized, or whose preparation in his special field is inadequate, must count upon spending increased time in work for the degree.

3. *Admission to Candidacy*: On recommendation of the Chairman of the Division concerned, the Committee on Graduate Study will admit a student to candidacy for the degree of Doctor of Philosophy after he has been admitted to work toward the doctor's degree and been in residence at least one term thereafter; has satisfied the several departments concerned by written or oral examination or otherwise that he has a comprehensive grasp of his major and minor (if any) subjects as well as of subjects fundamental to them; has fulfilled the language requirements; has shown ability in carrying on research, with a research subject approved by the Chairman of the Division concerned; and has initiated a program of study approved by his major and minor (if any) departments. For special departmental regulations concerning admissions to candidacy, see Section VI. Members of the Institute staff of rank higher than that of Assistant Professor are not admitted to candidacy for a higher degree.

A regular form, to be obtained from the Dean of Graduate Studies, is provided for making application for admission to candidacy. Such admission to candidacy must be obtained before the close of the first term of the year in which the degree is to be conferred, and must be followed by two terms of further residence (45 units per term; see pages 91-92) before the degree is conferred. *The student himself is responsible for seeing that admission is secured at the proper time.*

4. *Examinations.* (a) The language requirements are a prerequisite to admission to candidacy for the degree of Doctor of Philosophy. As soon as possible after beginning their graduate study, students are urged to consult with the department of languages to determine the best means of satisfying these requirements early. Graduate students are permitted to audit all courses in languages (page 68). The language requirements in either or both of the approved languages can be met in one of three ways:

i. To pass language examinations. Examinations are given three times a year. The dates are announced on the calendar on pages 4, 5.

ii. To pass with a grade of B- or better one of the following courses: L 1 ab in French, L 35 in German, or L 50 abc in Russian.

iii. With the approval of the department of languages, to complete a translation project. A knowledge of the fundamentals of the language is presupposed in such a case.

(b) During his course of study every doctoral candidate shall be examined broadly and orally on his major subject, the scope of his thesis and its significance in relation to his major subject, and on any minor subject which he may have elected to present. 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 101.

5. *Thesis*: Two weeks before the degree is to be conferred, the candidate is required to submit to the Dean of Graduate Studies a ribbon copy, a reproduced copy, and the vellum of a satisfactory thesis describing his research. For special departmental regulations concerning theses, see Section VI.

With the approval of the department concerned, a portion of the thesis may consist of one or more articles published jointly by the candidate and members of the Institute staff or others. In any case, however, a substantial portion of the thesis must be the candidate's own exposition of his work. For regulations regarding use of "classified" material, see page 96.

Regulations and directions for the preparation of theses may be obtained from the office of the Dean of Graduate Studies, and should be followed carefully by the candidate.

Before submitting his thesis to the Dean of Graduate Studies, the candidate must obtain approval of it by the Chairman of his Division and the members of his examining committee. This approval must be obtained in writing on a form which will be furnished at the office of the Dean. *The candidate himself is responsible for allowing sufficient time for the members of his committee to examine his thesis.*

VI. SPECIAL REQUIREMENTS FOR THE DOCTOR'S DEGREE

In agreement with the general requirements for the doctor's degree adopted by the Committee on Graduate Study, as set forth in Section V (page 98), 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 national fellowship to do graduate work in the Division of Biology

may be assigned to assist in teaching undergraduate courses if his advisory committee considers it to be of value for him to gain teaching experience. The amount of teaching may vary, but it will not be more than 15 hours per week for one term per year.

4. *Major Subjects of Specialization.* The fields within the Division of Biology in which a student may pursue major work leading to the doctor's degree are listed herewith. They are divided into three main disciplines for purposes of the regulations concerning minor subjects as stated on page 98.

A. Physiological Biology
- Plant Physiology
- Animal Physiology
- Psychobiology
- Embryology
- Biophysics

B. Genetical Biology
- Genetics
- Immunology
- Virology

C. Chemical Biology
- Biochemistry

5. *Minor Subjects.* A student majoring in one of these fields may elect to take a minor subject either (a) in another discipline of Biology or (b) in another division of the Institute. A student majoring in the Biology Division who does not elect to undertake a minor program is required to select 45 units of advanced course work in one or more disciplines in the humanities, sciences (other than biology), or engineering, subject to the approval of the Biology Division.

A student majoring in another division of the Institute may, with the approval of the Biology Division, elect as a minor subject any one of those listed above in section 4. When electing not to undertake a minor program he may with the approval of his major division take graduate courses in the Biology Division in partial fulfillment of the requirements of the doctor's degree.

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

a. A student taking his major subject in the Division of Biology who elects to take a minor subject in the same division is required to take four candidacy examinations. One must be in the field of the major and one in the field of the minor; the two others may be in general botany and general zoology, or in one of these and one of the subjects listed above in section 4, subject to approval of the Biology Division.

b. In case the minor subject is taken outside the Biology Division, the student will be required to fulfill the minor requirement of the outside division and, in addition, will be required to take three candidacy examinations. One must be in the field of the major; the two others may be in general botany and general zoology, or in one of these and one of the subjects listed above in section 4, subject to approval of the Biology Division.

c. A student taking his major subject in the Division of Biology who prefers not to take a minor subject is required to take three candidacy examinations. One must be in the field of the major; the two others may be in general botany and general zoology, or in one of these and one of the subjects listed above in section 4, subject to the approval of the Biology Division.

d. A student majoring in another division 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.

Although grades of C are considered to be passing in candidacy examinations, a grade of B or better is required in the student's major and minor subjects, except in general biology in which a C is accepted.

7. *Final Examination and Thesis.* A final oral examination covering principally the work of the thesis will be held at least two weeks before the degree is to be conferred. The original typed copy of the thesis, the vellum copy, and two reproduced copies must be submitted at least two weeks before the date of the final examination. One of the two reproduced copies is retained by the Division Library. The examining committee will consist of the instructors in charge of the major and minor work and such other individuals as may be recommended by the Chairman of the Division and approved by the Dean of Graduate Studies.

Division of Chemistry and Chemical Engineering

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

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

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

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

1B. *Chemical Engineering.* The requirements in chemical engineering are essentially the same as those in chemistry except that the placement examinations for students planning for the Ph.D. degree will be required in the fields of engineering thermodynamics of one-component systems (on the Wednesday before registration), elementary fluid flow (on Tuesday), the unit operations of chemical engineering (on Thursday), and either physical chemistry (on Monday) or industrial chemistry (on Friday). Those students who propose to register for Ch 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 case the applicant's training is less extensive than this, the Division of Chemistry and Chemical Engineering may prescribe additional work in these subjects prior to recommending him as a candidate.

3. The units of study offered for satisfaction of a minor requirement are to consist in general of graduate courses other than research; however, the Division of Chemistry and Chemical Engineering may, by special action, permit up to one-half of these units to consist of appropriate research. If the student does not elect to undertake a minor program the 45 units or more of advanced work which must be presented for a doctorate must represent an integrated program approved by the Division and for students in Chemistry shall consist of courses other than chemistry and for students in Chemical Engineering shall consist of courses other than chemical engineering.

4. The candidate must submit to the Chairman of the Division of Chemistry and Chemical Engineering four copies of his thesis, in final form (the original copy, a copy on vellum, and two copies reproduced from the vellum), at least two weeks before the date of his final examination. Three copies are returned to the candidate after his examination.

5. The final examination will consist in part of the candidate's oral presentation of a brief résumé of his research and its defense against attack, and in part of the defense of a set of propositions prepared by the candidate. The candidate may also expect questions related to his minor 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 or to subjects offered in lieu of a 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.

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

Division of Engineering

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

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

Ph 131 abc	Electricity and Magnetism
EE 132 abc	Circuit Analysis

and one of the following subjects:

Ma 108 abc	Introduction to Real and Complex Analysis
AM 125 abc	Engineering Mathematical Principles
AM 126 abc	Applied Engineering Mathematics
Ph 129 abc	Methods of Mathematical Physics

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

Students working toward the doctorate are required to take three oral examinations. The first of these, which is normally given during the fifth year, may be waived at the discretion of the faculty. The second must be taken prior to admission to candidacy and covers broadly his major field and his minor field. The third, which is taken after admission to candidacy, covers his doctorate thesis and its significance in and its relation to his major field. This final examination will be given not less than one month after the thesis has been presented in final form and subsequent to its approval.

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

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

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

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

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

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

The student, at his option, may undertake a program of study as a minor subject in a discipline other than that of his major subject of study and/or research. The discipline in which the minor program is taken must be outside the Division of Engineering. This program must include at least 45 units of advanced work in that discipline, and must be comprehensive enough to give the student a thorough fundamental knowledge of it. The program must be approved by both major and minor divisions on a form obtainable from the Graduate Office.

If the student does not elect to undertake a minor program, he must include in the work presented for candidacy at least 45 units of advanced work in one or more disciplines in the humanities or science or engineering different from that of his major subject of study and/or research. In general, it is preferable for the student to do at least a portion of this work outside the Division of Engineering. The choice and scope of this work must be approved by the student's advisor and the Faculty in Mechanical Engineering.

A student majoring in another branch of engineering or another division of the Institute may, with the approval of the Faculty in Mechanical Engineering, elect as a minor subject a group of courses that differ markedly from the major subject of study or research. The student shall acquire a thorough knowledge of that particular discipline. Such discipline may be fluid mechanics and thermodynamics, applied mechanics, jet propulsion, or physical metallurgy.

4. *Aeronautics.* In general, a graduate student is not admitted to work for the doctor's degree in aeronautics until he has completed at least 20 units of research in his chosen field. Thus, upon completion of his fifth year's work, he will be admitted to work towards the engineer's degree 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 and if he satisfactorily passes a qualifying oral examination, 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 end 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 one of the following subjects with a grade of C or better:

AM 125 abc	Engineering Mathematical Principles,
AM 126 abc	Applied Engineering Mathematics,
Ph 129	Methods of Mathematical Physics,
Ph 108 abc	Theoretical Mechanics

and two of the following subjects:

Ae 107 abc	Elasticity Applied to Aeronautics	
Ae 201 abc	Inviscid Fluid Mechanics	
Ae 204 abc	Mechanics of Real Gases	
JP 121 abc	Rocket	considered as one subject
JP 130 abc	Thermal Jets	

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

5. *Engineering Science.* The program of study leading to advanced degrees in engineering science must be approved by the Engineering Science Committee.

a. Placement examinations. On the Thursday and Friday preceding the beginning of instruction for his first term of graduate study, a student is required to take placement examinations in basic mathematics and physics.

b. Admission to candidacy. To be recommended for candidacy for the Ph.D. degree in engineering science the student must, in addition to the general Institute requirements, take at least 12 units of research and pass the candidacy examinations. Before the end of the second term of his second year of residence, the student must take an examination in applied mathematics and theoretical physics and in addition an examination in one or more specific topics in engineering science such as fluid mechanics, physical metallurgy, principles of jet propulsion, nuclear engineering, electromagnetic wave propagation, communication theory.

c. Thesis and final examination. A final examination will be given not less than one month after the thesis has been presented in final form. Immediately after the submission of his thesis, a topic of study outside his field of specialization will be assigned to the candidate by the Engineering Science Committee. During the next month 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. The final examination will cover the thesis and fields related to it and the assigned topic of study.

Division of Geological Sciences

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

1. *Placement Examinations*: Applications for admission to graduate study in the Division of Geological Sciences should be supported by a report of the student's score on both the aptitude test and the advanced test in geology of the Graduate Record Examination. This is not an absolute requirement but compliance is strongly urged. On Thursday and Friday of the 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 expected that he possess detailed informational knowledge, but it is expected that he demonstrate a degree of proficiency not less than that attained by abler undergraduate students at the California Institute. A student who has demonstrated proficiency in earlier residence at the Institute may be excused from these examinations.

The student's past record and his performance in the placement examinations will be used to determine whether he should register for certain undergraduate courses. Any deficiencies must be corrected at the earliest possible date. All students who do not demonstrate adequate proficiency in mathematics will be required to register for Ge 108 in their first year of graduate residence.

Each member of the Division faculty serves as an adviser to a small number of graduate students. Each graduate student will be notified, prior to his arrival, as to who his adviser is to be, and prior to registration day in the fall the student should seek the counsel of his adviser in planning his program for the first term.

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

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

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

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

3. *Field Requirement*: Many problems in the earth sciences require for their solution an understanding of field techniques and field relations. 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 Subject*: The work for the doctorate in the Division of the Geological Sciences shall consist of advanced studies and of research in some discipline in the geological sciences which will be termed the "major subject" of the candidate. The Division will accept as major subjects any of the disciplines listed herewith, provided that the number of students working under the staff members in that discipline does not exceed the limit of efficient supervision.

Geology	Geochemistry
Geobiology	Geophysics

5. *Minor Requirement*: The purpose of the minor requirement is to give diversification of training and a broadening of outlook. It should involve basic approaches, techniques, and knowledge distinct from those of the major subject. The minor requirement can be satisfied by taking 45 units of advanced study outside the Division or in one of the four subjects, other than the major, specified in section 4 (above), subject to approval of the Division and of the Dean of Graduate Studies.

For regulation concerning minor subjects see page 98.

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 oral defense of a set of propositions prepared by the candidate. The propositions should be from 3 to 5 in number and about half of them should relate to the branch of earth sciences of major interest to the candidate. The remaining propositions should cover aspects

of the sciences in fields other than that of the major interest. As prepared by the candidate himself, each proposition should represent his grasp of the basic features and his critical evaluation of a significant scientific point or question. The entire group of propositions should display scholarship, originality, and breadth of interest. A clear statement of the basic problem and of the candidate's specific approach to, or evaluation of, it should be incorporated in a succinct paragraph for each proposition. The candidate will be judged upon his selection and formulation of the propositions and upon his defense of them. In addition the examining committee will ask questions designed to evaluate his basic background in the earth sciences and allied fields as related to the propositions and to determine his capabilities in applying fundamental scientific principles to specific problems.

A copy of a list of propositions which has been drawn from past qualifying examinations is on file in the Division office, for student reference. This list is offered as a guide to satisfactory form and treatment rather than as a yardstick for choice of subject matter and originality.

Three copies of the propositions should be filed in the office of the Division of the Geological Sciences, not later than midterm of the fifth term of graduate residence, for approval by the Division Examining Committee (see page 97). An examining committee will then be appointed and a date will be set for the examination which is mutually agreeable to those concerned. The list of propositions, as approved by the supervising committee, must be filed by the candidate in the Division office at least two weeks in advance of the date set for the examination.

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

A student admitted to work for the Ph.D. degree who fails to satisfy the Division's requirements for candidacy by the end of his fifth term of residence will not be allowed to register in a subsequent academic year except by special permission of the Division of the Geological Sciences. Successful completion of the qualifying examination is a necessary step in admission to candidacy. The remaining steps are outlined on page 100, 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 member of the staff supervising the major research on the choice of subject and on the scope of the paper. This paper must either be accepted by an agency of publication or be in such form that the examining committee believes that it will be published. A first draft of the thesis must be submitted by February 1 of the year in which it is proposed to take the degree.

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. Major and Minor Fields

The disciplines offered by the Division in which major or minor work may be undertaken, as specified on page 98, are Astronomy, Mathematics, and Physics.

2. Physics

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

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

b. *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, if the student has elected to present a minor subject, 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, through either 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 the second year of graduate study at the Institute will not be allowed to register in a subsequent academic year without special permission of the Physics Department Graduate Committee. When a student is required to take courses prerequisite to those listed in section 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 requirement for 45 units in a discipline other than physics, 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	Electron Theory	27
Ph 227 ab	Thermodynamics, Statistical Mechanics, and Kinetic Theory	18
	GROUP III	
Ph 203 ab	Nuclear Physics	18
Ph 204 ab	Low Temperature Physics	18
Ph 207 ab	X- and Gamma-Rays	18
Ph 217	Spectroscopy	9
Ph 218 ab	Electronic Circuits	18
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 scheduling by the Division of more than one final oral examination per day.

3. MATHEMATICS

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

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

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

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

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

f. Candidates who have selected a minor subject must pass a special examination in their minor subject. It is the responsibility of the candidate to make arrangements for this examination. It should be held as soon as possible after admission to candidacy and completion of the course-work in his minor subject.

4. ASTRONOMY

The Placement Examination, p. 111, Section 2a covering the material of Ph 107, Ph 108, Ph 112, and an additional examination in astronomy, covering the material in Ay 2, will be required of first-year students. Their goal is to ascertain whether the background of atomic and nuclear physics, mathematical physics, and astronomy is sufficiently strong to permit advanced study in these subjects.

To be recommended for candidacy for the doctor's degree in astronomy the applicant must complete satisfactorily 18 units of research, Ay 142, pass with a grade of C or better, or by special examination Ay 131abc, Ay 132ab, Ay 211, and a satisfactory program, approved by the Department, in fields which will depend on the student's specialty.

The student's program during the first two years of graduate study should include a minimum of 63 units of advanced subjects in physics; for those students specializing in radio astronomy or in electronics advanced courses in electrical engineering and applied mechanics can be substituted. This program of study must be planned, and approved by the Department, during the first year, and special permission will be required for further registration if the candidacy course requirement is not satisfactorily completed by the end of the second year of graduate study. For admission to candidacy an oral examination will be given covering the entire field of study.

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

Opportunities for Graduate and Scientific Work at the Institute

ATHENAEUM

Graduate students are privileged to join the Athenaeum (Faculty Club), which affords the possibility of contact not only with fellow graduate students but also with others using the Athenaeum, including the Associates of the Institute, distinguished visitors, and members of the professional staffs of the Mount Wilson Observatory, the Huntington Library, and the California Institute. Students may have meals at the Athenaeum, and lodging when space is available.

GRADUATE FELLOWSHIPS, SCHOLARSHIPS, AND ASSISTANTSHIPS

The Institute offers in each of its divisions a number of fellowships, scholarships, and graduate assistantships. In general, scholarships carry tuition grants; assistantships, cash stipends; and fellowships often provide both tuition and cash grants. Graduate assistants are eligible to be considered for scholarship grants.

Forms for making application for fellowships, scholarships, or assistantships may be obtained on request from the Dean of Graduate Studies. In using these forms it is not necessary to make separate application for admission to graduate standing. When possible, these applications should reach the Institute by February 15. Appointments to fellowships, scholarships, and assistantships are for one year only; and a new application must be filed each year by all who desire appointments for the following year, whether or not they are already holders of such appointments.

GRADUATE ASSISTANTSHIPS

Graduate Assistants devote during the school year not more than fifteen hours a week to teaching, laboratory assistance, or research of a character that affords them useful experience. This time includes that required in preparation and in marking note-books and papers, as well as that spent in classroom and laboratory. The usual assistantship assignment calls for fifteen hours per week at the most and ordinarily permits the holder to carry a full graduate residence schedule as well.

Graduate Scholarships and Fellowships*

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

Cole Fellowhips: The income from the Cole Trust, established by the

*Fellows receiving grants equivalent to tuition and $1000 or more per academic year are permitted to accept employment or other appointment from the Institute during the academic year only with special approval of the Dean of Graduate Studies.

will of the late Mary V. Cole in memory of her husband, Francis J. Cole, is used to provide three fellowships annually, one in each of the following fields: electrical engineering, mechanical engineering, and physics. The recipients are designated as Cole Fellows.

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

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

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

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

Meridan Hunt Bennett Scholarships: The scholarships for graduate students are granted from the Meridan Hunt Bennett Fund as stated on page 82.

Bridge Fellowship: The late Dr. Norman Bridge provided a fund, the income of which is used to support a research fellowship in physics. The recipient is designated as the Bridge Fellow.

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

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

Edith Newell Brown Scholarships: The income from the Edith Newell Brown Fund is used to maintain scholarships for graduate students. The recipients are designated as Edith Newell Brown Scholars.

Theodore S. Brown Scholarships: The income from the Theodore S. Brown Fund is used to maintain scholarships for graduate students. The recipients are designated as Theodore S. Brown Scholars.

Clarence J. Hicks Memorial Fellowship in Industrial Relations: This fellowship is supported by a fund made available by Industrial Relations Counselors, Inc., and other contributors. The fellowship is granted to a graduate student who undertakes some studies in industrial relations, as approved by the Director of the Industrial Relations Section.

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

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

Royal W. Sorensen Fellowship: The income from a fund created in honor of Royal W. Sorensen is used to provide a fellowship or a scholarship for a student in electrical engineering.

Von Kármán Scholarship Fund: Given by Dr. William Bollay for scholarships for sons or daughters of Aerophysics Development Corporation employees. The recipients are designated as von Kármán Scholars.

Ray G. Coates Scholarship: Provided by the income from a bequest made by the late Mrs. Alice Raymond Scudder Coates, to maintain a scholarship for a student of physics. The graduate student recipient is designated as Ray G. Coates Scholar.

SPECIAL FELLOWSHIP AND RESEARCH FUNDS

The following corporations, foundations, and individuals contribute funds for the support of Graduate Fellowships which are administered by the Institute: Allied Chemical and Dye Corporation, Bell Telephone Laboratories, Bendix Aviation Corporation, Boeing Airplane Company, California Research Corporation, Consolidated Electrodynamics Corporation, Convair, Corning Glass Works Foundation, Crane Company, Curtiss-Wright Corporation, Douglas Aircraft Company, Dow Chemical Company, E. I. du Pont de Nemours and Company, Eastman Kodak Company, Firestone Tire and Rubber Company, Fluor Foundation, Garrett Corporation, General Electric Educational and Charitable Fund, General Motors Corporation, General Petroleum Corporation, D. Foster Hewett, Hughes Aircraft Company, International Business Machines Corporation, International Nickel Company, Inc., Kaiser Aluminum & Chemical Corporation, Kennecott Copper Corporation, Paul E. Lloyd, Lockheed Leadership Fund, Arthur McCallum Fund, Monsanto Chemical Company, Ohio Oil Company, Paper Mate Mfg. Co., Pan American Petroleum Foundation, Phillips Petroleum Company, Radio Corporation of America, Ramo-Wooldridge Corporation, Rand Corporation, Raytheon Manufacturing Company, Richfield Oil Corporation, Sidney Schafer, Schlumberger Foundation, Shell Companies Foundation, Standard Oil Company of California, Stauffer Chemical Company, Stauffer Foundation, Sunray Mid-Continent Oil Company, Union Carbide Corporation, United States Rubber Company, United States Steel Foundation, Westinghouse Educational Foundation.

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

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

Daniel and Florence Guggenheim Fellowships in Jet Propulsion: These are fellowships established with the Guggenheim Jet Propulsion Center by the Daniel and Florence Guggenheim Foundation for graduate study in jet propulsion.

AEC Special Fellowships in Nuclear Science and Engineering: These fellowships are made available and are administered by the Atomic Energy Commission to support study in the general field of nuclear energy technology. The California Institute is a participating school at which AEC Fellows may pursue graduate study.

II. POST-DOCTORAL FELLOWSHIPS

A number of government agencies, foundations, societies, and companies support fellowships for the encouragement of further research by men who hold the doctor's degree. These grants usually permit choice of the institution at which the work will be done, and include, among others, those administered by the National Research Council, Rockefeller Foundation, John Simon Guggenheim Memorial Foundation, Commonwealth Fund, American Chemical Society, Bell Telephone Laboratories, E. I. du Pont de Nemours and Company, Merck and Company, Inc., American Cancer Society, the Atomic Energy Commission, the U. S. Public Health Service, the National Science Foundation, the National Foundation for Infantile Paralysis, and other government agencies, as well as various foreign governments. Applications for such fellowships should in general be directed to the agency concerned.

Institute Research Fellowships: The Institute each year appoints as Research Fellows a number of men holding the degree of Doctor of Philosophy who desire to pursue further research work. Applications for these appointments, as well as for the other special fellowships listed below, should be made on forms provided by the Institute. These forms, which should be filed with the Dean of the Faculty, may be obtained either from his office or from the Chairman of the Division in which the applicant wishes to work.

Gosney Fellowships: In 1929, Mr. E. S. Gosney established and endowed the Human Betterment Foundation. Following the death of Mr. Gosney in 1942, the Trustees of this Foundation transmitted the fund to the California Institute for the study of biological bases of human characteristics. The Trustees of the Institute have, for the present, set the income aside for the establishment of Gosney Fellowships. These are post-doctoral research fellowships, the conditions being similar to those of Guggenheim Fellowships. The stipend varies with the experience of the Fellow.

Harry Bateman Research Fellowship: In honor of the late Professor Harry Bateman, the Institute offers a research fellowship in pure mathematics to a candidate holding the doctorate. The recipient will devote the major part of his time to research, but will be expected to teach one course in mathematics. The appointment is normally made for one year, but may be renewed for a second year.

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

Noyes Fellowships: Dr. Noyes further left his entire estate, after providing for certain specific bequests and annuities, to the Institute to constitute a fund to be known as the "Noyes Chemical Research Fund." The purpose of this fund, as stated in his will, is to provide for the payment of salaries or grants to competent persons to enable them to carry on scientific investigations in the field of chemistry at the Institute. Such persons shall have the status of members of the staff of the Institute, and shall devote their time and attention mainly to the execution at the Institute of experimental and theoretical researches upon the problems of pure science (as distinct from those of applied science) in the field of chemistry. Dr. Noyes further provided that "no portion of the income of said fund shall be used for the payment of tuition fees, nor for scholarships or fellowship grants to persons still registered as students, or in general for the education of persons as to existing knowledge; but on the contrary the whole thereof shall be used for promoting, in the manner aforesaid in the field aforesaid, the search for new or more exact knowledge by persons who have completed their period of formal study and are devoting at least one-half of their working time to scientific investigations."

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

Richard Chace Tolman Fellowship: A fellowship in theoretical physics established in honor of Dr. Tolman, late Professor of Physical Chemistry and Mathematical Physics.

III. INSTITUTE GUESTS

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

Section IV

SCHEDULES OF THE COURSES

The school year is divided into three terms. The number of units assigned in any term to any subject represents the number of hours spent in class, laboratory, and preparation. In the following schedules, figures in parentheses denote hours in class (first figure), hours in laboratory (second figure), and hours of outside preparation (third figure).[1]

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

KEY TO ABBREVIATIONS

Aeronautics	Ae
Air Science	AS
Applied Chemistry	ACh
Applied Mechanics and Applied Mathematics	AM
Astronomy	Ay
Biology	Bi
Chemistry	Ch
Civil Engineering	CE
Graphics	Gr
Economics	Ec
Electrical Engineering	EE
Engineering Science	ES
English	En
Geology	Ge
History and Government	H
Hydraulics	Hy
Jet Propulsion	JP
Languages	L
Mathematics	Ma
Mechanical Engineering	ME
Philosophy	Pl
Physical Education	PE
Physical Metallurgy	PM
Physics	Ph

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

Note to Veteran Students: Inasmuch as subsistence allowances for Veterans are based on total "standard semester hours of credit *for a semester*, or their equivalent," it must be borne in mind that 1½ Institute terms are equivalent to one semester. Therefore, for purposes of determining your subsistence entitlement each term, multiply total Institute units by 2/9 (to reduce to semester hours per term) and then by 1½ (to evaluate your course in terms of semester hours per semester). This is more simply accomplished by multiplying total units for the term by ⅓.

[2]See page 74 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.[1]

		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	General Chemistry (3-6-3)	12	12	12
En 1 abc	English: Reading, Writing, and Speaking (3-0-3)	6	6	6
H 1 abc	History of European Civilization (2-0-3)	5	5	5
Gr 1	Basic and Applied Graphics (0-3-0)	3	.	.
PE 1 abc[2]	Physical Education (0-3-0)	3	3	3
		53	50	50

[1]Honor electives (3 units) to be given second and third terms. See page 73.

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

SENIOR HUMANITIES ELECTIVES

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

ASTRONOMY OPTION

(For First Year see page 120)

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 71.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Electrostatics, Electrodynamics, and Optics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
Ay 1	Introduction to Astronomy (3-1-5)	.	.	9
	Electives	6-10	6-10	6-10
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		48-52	48-52	48-52

ELECTIVES

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

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 111 abc	Properties of Matter (3-0-6)	9	9	9
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Electives (see below) to make[2]	9-15	9-15	9-15
		47-53	47-53	47-53

FOURTH YEAR

		1st	2nd	3rd
	Humanities Electives (3-0-6)	9	9	9
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
Ph 112 abc	Atomic and Nuclear Physics (4-0-8)	12	12	12
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Electives (see below) to make[3]	11-18	9-11	9-11
		46-53	50-52	50-52

ELECTIVES

With Approval of Adviser

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

[1]AFROTC students will substitute AS 2 abc for PE 2 abc.

[2]AFROTC students will substitute AS 3 abc for PE 3 abc and take 6-10 units electives per term.

[3]AFROTC students will substitute AS 4 abc for PE 4 abc and take electives to make 6-10 units each term.

[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 120)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A full statement of this regulation will be found on page 71.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
Bi 2	Genetics (3-3-3)	.	.	9
PE 2 abc[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

		1st	2nd	3rd
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Bi 107 abc	Biochemistry 3-0-7; 3-3-4; 3-5-1)	10	10	10
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
L 32 abc	Elementary German (4-0-6)	10	10	10
Bi 3	Plant Biology (4-6-2)	12	.	.
Bi 5	Advanced Plant Biology (3-6-3)	.	.	12
Bi 20	Mammalian Anatomy and Histology (2-6-4)	.	12	.
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
		52	52	52

FOURTH YEAR

		1st	2nd	3rd
Bi 116 ab	Animal Physiology (3-3-4)	10	10	.
Bi 117	Psychobiology (3-3-3)	.	.	9
Bi 106	Embryology (2-6-4)	12	.	.
Bi 115	Plant Physiology (3-6-3)	.	12	.
Bi 110	Microbiology (3-4-5)	.	.	12
	Humanities Electives[4] (3-0-6)	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	.
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Biology Electives[5]	9-12	6-9	15-18

[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 students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

[4]For list of Humanities electives, see page 120.

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

FIRST TERM

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

SECOND TERM

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

THIRD TERM

Bi 127	Chemical Genetics Laboratory (0-6-0)	6 units
Bi 128	Advanced Microtechnique (1-4-1)	6 units
Bi 129 c	Special Problems	units by arrangement
Bi 22	Biophysics (2-0-4)	6 units
Ge 30	Introduction to Geochemistry (3-0-7)	10 units

CHEMISTRY AND APPLIED CHEMISTRY OPTIONS

(For First Year see page 120)
(See pages 124 and 125 for Applied Chemistry Options)

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.

CHEMISTRY OPTION

The following fourth-year schedule applies to students whose first year was completed in 1955-56 or earlier.

FOURTH YEAR

		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
Ch 16	Instrumental Analysis (0-6-2)	8	.	.
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
	Elective subjects[2]	28-32	28-32	28-32
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3

APPROVED ELECTIVE COURSES IN THE CHEMISTRY OPTION

Others may be taken with the permission of the adviser. The choice of electives must include courses with a total of 18 hours of laboratory work or a total of 36 hours of research (CH 80).

		Units per Term 1st	2nd	3rd
Ch 13 abc	Inorganic Chemistry (2-0-4)	6	6	6
Ch 117	Electroanalytical Chemistry (2-0-2)	.	.	4
Ch 118	Electroanalytical Chemistry Laboratory (0-6-0)	.	.	6
Ch 125 abc	Advanced Physical Chemistry (3-0-6)	9	9	9
Ch 127 ab	Radioactivity and Isotopes (2-0-4)	.	6	6
Ch 129	Surface and Colloid Chemistry (3-0-5)	.	.	8
Ch 130	Photochemistry (2-0-4)	.	6	.
Ch 144 abc	Advanced Organic Chemistry (3-0-6)	9	9	9
Ch 148 abc	Characterization of Organic Compounds (2-0-2)	4	4	4
Ch 149 abc	Laboratory in Characterization of Organic Compounds (0-6-0)	6	6	6
Ch 61 ab	Principles of Industrial Chemistry (3-0-5)	8	8	.
Ch 63 ab	Chemical Engineering Thermodynamics (3-0-6)	.	9	9
Ch 63 c	Chemical Engineering Thermodynamics (3-0-6)	9	.	.
Ch 64	Introduction to Fluid Flow (3-0-7)	.	.	10
Ch 80	Chemical Research (units to be arranged)			
Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
Ph 111 abc	Properties of Matter (3-0-6)	9	9	9
Ph 112 abc	Introduction to Atomic and Nuclear Physics (4-0-8)	12	12	12
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8)	12	12	12
AM 15 abc	Engineering Mathematics (3-0-6)	9	9	9
AM 102 abc	Applied Nuclear Physics (2-0-4)	6	6	6
Bi 107 abc	Biochemistry (3-0-7; 3-3-4; 3-5-2)	10	10	10
Bi 110	General Microbiology (3-4-5)	.	.	12
Bi 127	Chemical Genetics Laboratory (0-6-0)	.	.	6
Ge 3	Materials of the Earth's Crust (3-0-6)	.	9	.
Ge 130	Introduction to Geochemistry (3-0-3)	.	.	6
Ge 151 b	Laboratory Techniques in the Earth Sciences (0-5-0)	.	.	.
L 35	Scientific German (4-0-6)	10	.	.

[1]For list of Humanities electives see page 120.
[2]Approved elective courses listed on page 123.
[3]AFROTC students will substitute 8 units of Air Science (AS 4 abc, 4-1-3) for Physical Education (PE 4 abc, 0-3-0). AFROTC students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

REVISED CHEMISTRY OPTION

(For First Year see page 120)

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.

The following schedule is for students who completed the first-year work during 1956-57 or later.

Second Year

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, and Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Electricity, Optics, and Modern Physics (3-3-6)	12	12	12
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
H 2 abc	History and Government of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
Bi 2	Genetics (3-3-3)	.	.	9
	or		or	
Ay	Introduction to Astronomy (3-1-5)	.	.	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	52	52

Third Year

		1st	2nd	3rd
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
L 32 abc	Elementary German[2] (4-0-6)	10	10	10
Ch 14	Quantitative Analysis (2-6-2)	10	.	.
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
	Electives[3]	10-14	6-10	6-10
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
PE 3 abc[4]	Physical Education (0-3-0)	3	3	3
		50-54	50-54	50-54

Fourth Year

		1st	2nd	3rd
	Humanities electives (3-0-6)[5]	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
	Electives[3]	36-40	36-40	36-40
PE 4 abc[6]	Physical Education (0-3-0)	3	3	3
		50-54	50-54	50-54

[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]May be taken in either third or fourth year.

[3]Approved elective courses listed on page 123.

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

[5]For list of Humanities electives see page 120.

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

APPLIED CHEMISTRY OPTION

(For 1958-59 only)

(For First Year see page 120)

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
H 2 abc	History and Government of the United States (2-0-4)	6	6	6
Ma 2 abc	Sophomore Mathematics (4-0-8)	12	12	12
Ph 2 abc	Electrostatics, Electrodynamics, Optics (3-3-6)	12	12	12
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
Ch 60	Introduction to Chemical Engineering Problems (3-0-6)	.	.	9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3)	9 or	9	.
	Elective	9 or	9	.
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	52	52

Third Year

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
Ch 14	Quantitative Analysis (2-6-2)	10	.	.
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
Ch 63 ab	Chemical Engineering Thermodynamics (3-0-6)	.	9	9
EE 1 a	Basic Electrical Engineering (3-0-6)	9	.	.
AM 15 abc	Engineering Mathematics (3-0-6)	9	9	9
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
		48	52	52

Fourth Year

		1st	2nd	3rd
	Humanities electives[3] (3-0-6)	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	6	.
Ch 16	Instrumental Analysis (0-6-2)	8	.	.
Ch 26 ab	Physical Chemistry Laboratory (0-6-2; 0-3-1)	.	8	4
Ch 61 ab	Industrial Chemistry (3-0-5; 3-0-3)	8	6	.
Ch 63 c	Chemical Engineering Thermodynamics (3-0-6)	9	.	.
Ch 64	Introduction to Fluid Flow (3-0-7)	.	.	10
Ch 129	Surface and Colloid Chemistry (3-0-5)	.	.	8
AM 5 ab	Applied Mechanics—Dynamics (3-0-6)	9	9	.
AM 4 a	Applied Mechanics—Strength of Materials (3-0-6)	.	.	9
EE 1 bc	Basic Electrical Engineering (3-0-6)		9	9
EE 2 a	Basic Electrical Engineering Laboratory (0-3-0)	.	3	.
PE 4 abc[4]	Physical Education (0-3-0)	3	3	3
		54	55	54

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

[3]For list of Humanities electives, see page 120.

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

APPLIED CHEMISTRY OPTION

(For First Year see page 120)

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.

The following schedule is for students who completed the first-year work during 1956-57 or later.

Second Year

		Units per Term 1st	2nd	3rd
H 2 abc	History and Government of the United States (2-0-4)	6	6	6
Ma 2 abc	Sophomore Mathematics (4-0-8)	12	12	12
Ph 2 abc	Electrostatics, Electrodynamics, Optics (3-3-6)	12	12	12
Ch 41 abc	Basic Organic Chemistry (2-0-2)	4	4	4
Ch 46 abc	Basic Organic Chemistry Laboratory (1-5-0)	6	6	6
Ch 60	Introduction to Chemical Engineering Problems (3-0-6)	.	.	9
	Science Elective (Ge 1, 4-2-3; Bi 1, 3-3-3)	9 or	9	.
	Elective	9 or	9	.
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		52	52	52

Third Year

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	.	6	6
Ch 14	Quantitative Analysis (2-6-2)	10	.	.
Ch 21 abc	Physical Chemistry (3-0-6)	9	9	9
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	.	8	8
Ch 63 ab	Chemical Engineering Thermodynamics (3-0-6)	.	9	9
EE 1 a	Basic Electrical Engineering (3-0-6)	9	.	.
AM 15 abc	Engineering Mathematics (3-0-6)	9	9	9
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
		48	52	52

Fourth Year

		1st	2nd	3rd
	Humanities electives[3] (3-0-6)	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ch 61 ab	Industrial Chemistry (3-0-5; 3-0-3)	8	6	.
Ch 63 c	Chemical Engineering Thermodynamics (3-0-6)	9	.	.
Ch 64	Introduction to Fluid Flow (3-0-7)	.	.	10
AM 5 ab	Applied Mechanics—Dynamics (3-0-6)	9	9	.
AM 4 a	Applied Mechanics—Strength of Materials (3-0-6)	.	.	9
EE 1 bc	Basic Electrical Engineering (3-0-6)	.	9	9
EE 2 a	Basic Electrical Engineering Laboratory (0-3-0)	.	3	.
	Elective[4]	9-12	9-12	9-12
PE 4 abc[5]	Physical Education (0-3-0)	3	3	3
		49-52	50-53	51-54

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

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

[3]For list of Humanities electives, see page 120.

[4]Approved elective courses listed on page 123.

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

CIVIL ENGINEERING OPTION

(For First Year see page 120)

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 71.

Second Year

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ec 2 ab	General Economics and Economic Problems (3-0-6)	9	9	.
Ec 18	Industrial Organization (3-0-4)	.	.	7
	or		or	
Ec 25	Engineering Law (3-0-4)	.	.	7
ME 1	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

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

Fourth Year

		1st	2nd	3rd
	Humanities elective (3-0-6)	9	9	9
H 5 abc	Public Affairs (1-0-1)	2	2	2
AM 3	Testing Materials Laboratory (0-3-3)	.	6	.
AM 5 ab	Dynamics (3-0-6)	9	9	.
CE 10 abc	Theory of Structures (2-3-4; 3-3-6; 3-0-6)	9	12	9
CE 12	Reinforced Concrete (3-3-6)	.	.	12
CE 14 abc	Engineering Conference (1-0-1; 0-2-0)	2	2	2
CE 17	Civil Engineering (3-0-6)	.	.	9
CE 20	Introduction to Sanitary Engineering (3-0-4)	.	6	.
CE 115 a	Soil Mechanics (2-3-4)	9	.	.
CE 155	Hydrology (3-0-6)	9	.	.
Hy 11	Fluid Mechanics Laboratory (0-6-0)	.	.	6
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
		52	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 students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

[4]For list of Humanities electives, see page 120.

ELECTRICAL ENGINEERING OPTION

(For First Year see page 120)

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 71.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ec 2 ab	General Economics and Economic Problems (3-0-6)	9	9	.
Ec 18	Industrial Organization (3-0-4)	.	.	7
	or		or	
Ec 25	Engineering Law (3-0-4)	.	.	7
ME 1	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

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
AM 5 ab[2]	Dynamics (3-0-6)	9	9	.
EE 1 abc	Basic Electrical Engineering (3-0-6)	9	9	9
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0)	.	3	3
AM 15 abc[2]	Engineering Mathematics (3-0-6)	9	9	9
AM 116[2]	Complex Variables and Applications (3-0-6)	.	.	9
or				
AM 115 ab[2]	Engineering Mathematics (3-0-6)	.	9	9
AM 116[2]	Complex Variables and Applications (3-0-6)	9	.	.
	Elective (To be approved by Electrical Engineering Faculty)	.	.	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5)	10	10	10
PE 3 abc[3]	Physical Education (0-3-0)	3	3	3
		48	51	51

FOURTH YEAR
(Senior Year for 1958-59 only)

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

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

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

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

SUGGESTED ELECTIVES[5]

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

[5]Selection must be approved by the Electrical Engineering Faculty. Other courses may be allowed with approval.

GEOLOGICAL SCIENCES OPTION

(For First Year see page 120)

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	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
Ch 14*	Quantitative Analysis (2-6-2)	10	.	.
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	.	.
B 1	Elementary Biology (3-3-3)	.	9	.
Ge 2	Geophysics (3-0-6)	.	.	9
Ge 3	Minerology (3-3-3)	.	9	.
Ge 5	Geobiology (3-0-6)	.	.	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
*Offered 1958-59. See Adviser.		52	51	51

THIRD YEAR[4]

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (3-0-3)	6	.	6
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[3]	Physical Education (0-3-0)	3	3	3
	Geology and Geochemistry Options[6]			
Ge 4 a	Petrology, Igneous (3-3-2)	8	.	.
Ge 4 b	Petrology, Sedimentary (3-4-3)	.	10	.
Ge 4 c[7]	Petrology, Metamorphic (2-3-2)	.	.	7
Ge 9[7]	Structural Geology (1-3-2)	6	.	.
Ch 24 ab	Physical Chemistry for Geologists (4-0-6)	10	10	.
Ge 30	Introduction to Geochemistry (3-0-7)	.	.	10
	Electives[7]	.	6-9	.
		51	48-51	50
	Geophysics Option			
Ph 107 abc	Electricity and Magnetism (3-0-6)[7]	9	9	9
	Electives	6-12	11-17	5- 6
		[7]42-48	[7]42-48	[7]42-48

[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]Summer Field Geology, Ge 123, 30 units, required after third year in Geology and Geochemistry Options.

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

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

GEOLOGICAL SCIENCES OPTION

FOURTH YEAR[1]

		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
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	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; 0-5-6)	14	10	11
	Electives to be selected from any advanced courses in the Division of Geological Sciences or courses in other Science or Engineering Divisions. The elective courses must be approved by the student's adviser	9-12	12-15	11-14
		48-51	47-50	47-50
	Geophysics Option			
Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
	Geology electives	7-10	7-10	7-10
	General electives	.	.	.
		41-44	41-44	41-44

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

[2]For list of Humanities electives, see page 120.

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

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

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

MATHEMATICS OPTION

(For First Year see page 120)

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 71.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12	12	12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ma 5 ab	Introduction to Abstract Algebra (3-0-6)	9	9	.
Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
Ay 1	Introduction to Astronomy (3-1-5)	.	.	9
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
	Ma 31, 32, 33, or electives	.	.	9-10
		51	51	51-52

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 4 ab	Economic Principles and Problems (or a selected course in the Humanities[5]) (can be taken in senior year) . . . Minimum	6	6	.
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8)	12	12	12
PE 3 abc[2]	Physical Education (0-3-0)	3	3	3
	Selected courses in Mathematics . . . Minimum	9	9	9
	Electives [4] . . . Minimum	9	9	9
	The total number of units must fall within the range	47-52	47-52	47-52

FOURTH YEAR

		1st	2nd	3rd
H 5 abc	Public Affairs (1-0-1)	2	2	2
Ec 4 ab	Economic Principles and Problems (or a selected course in the Humanities[5]) (if not taken in junior year) . . . Minimum	6	6	.
PE 4 abc[3]	Physical Education (0-3-0)	3	3	3
	Selected courses in Mathematics . . . Minimum	9	9	9
	Selected courses in the Humanities[5]	9	9	9
	Electives[4] . . . Minimum	8	8	8
	The total number of units must fall within the range	41-51	41-51	41-51

Normally a junior will select 9 units each term and a senior 18 units each term in Mathematics. Students intending to proceed to graduate work in Mathematics are encouraged to choose at least one full-year graduate course in Mathematics. They are strongly advised to take one or preferably two full-year courses in languages.

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

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

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

4 An elective is any course in any subject other than Mathematics.

5 For list of Electives in the Humanities, see page 120. AFROTC students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

MECHANICAL ENGINEERING OPTION

(For First Year see page 120)

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 71.

SECOND YEAR

		Units per Term 1st		2nd		3rd
Ma 2 abc	Calculus, Vectors, & Differential Equations (4-0-8)	12		12		12
Ph 2 abc	Optics, Electrostatics, and Electrodynamics (3-3-6)	12		12		12
H 2 abc	History of the United States (2-0-4)	6		6		6
Ec 2 ab	General Economics and Economic Principles (3-0-6)	9		9		.
Ec 18	Industrial Organization (3-0-4)	.		.		7
	or			or		
Ec 25	Engineering Law (3-0-4)	.		.		7
ME 1	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

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

FOURTH YEAR

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

[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 students must take H 23 (Modern War) as their Humanities elective in the second term. For this they will receive 8 units of Air Science credit and will also satisfy the Humanities elective requirement for this term.

[4]For list of Humanities electives, see page 120.

FOURTH YEAR

Aeronautics

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

Mechanical Engineering

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

Physical Metallurgy

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

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

PHYSICS OPTION

(For First Year see page 120)

Attention is called to the fact that any student whose grade-point average for any three consecutive terms is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A more complete statement of this regulation will be found on page 71.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ph 2 abc	Electricity, Optics, and Modern Physics (3-3-6)	12	12	12
Ma 2 abc	Calculus, Vectors, and Differential Equations (4-0-8)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1	Physical Geology (4-2-3)	9	.	.
Bi 1	Elementary Biology (3-3-3)	.	9	.
Ay 1	Introduction to Astronomy (3-1-5)	.	.	9
	Electives	6-10	6-10	6-10
PE 2 abc[1]	Physical Education (0-3-0)	3	3	3
		48-52	48-52	48-52

SUGGESTED ELECTIVES

The student may elect any course that is offered in any term, provided only that he has the necessary prerequisites for that course. The following subjects are suggested as being especially suitable for a well-rounded course of study.

		1st	2nd	3rd
Bi 2	Genetics ((3-3-3)	.	.	9
Ec 4 a	Economic Principles and Problems (3-0-3)	6 or	6	.
4 b	(3-0-3)	.	6 or	6
Ge 2	Geophysics (3-0-6)	.	.	9
L 32 abc	Elementary German (4-0-6)	10	10	10
Ma 5 ab	Introduction to Abstract Algebra (3-0-6)	9	9	.
Ma 31	Constructive Theory of Functions (3-0-6)	.	.	9
ME 1	Empirical Design (0-9-0)	9 or	9 or	9
ME 3	Materials and Processes (3-3-3)	9 or	9 or	9

THIRD YEAR

		1st	2nd	3rd
Ph 107 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 111 abc	Structure of Matter (3-0-6)	9	9	9
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
	Electives[2]	18-22	18-22	18-22
PE 3 abc[3]	Physical Education (0-3-0)	3	3	3
		47-51	47-51	47-51

SUGGESTED ELECTIVES

		1st	2nd	3rd
Ay 2 abc	General Astronomy (3-3-3)	9	9	9
Bi 2	Genetics (3-3-3)	.	.	9
EE 1 abc	Basic Electrical Engineering (3-0-6)	9	9	9
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0) ...	.	3	3
Ge 2	Geophysics (3-0-6)	.	.	9
Ge 165	General Geophysics (3-0-3)	.	.	6
L 32 abc	Elementary German (4-0-6)	10	10	10
L 50 abc	Elementary Russian (4-0-6)	10	10	10
Ma 108 abc	Introduction to Real and Complex Analysis (4-0-8) .	12	12	12
ME 15 abc	Thermodynamics and Fluid Mechanics (3-2-5)	10	10	10
Ph 115 abc	Geometrical and Physical Optics (2-0-4)	.	6	6
Ph 108 abc[4]	Theoretical Mechanics (3-0-6)	9	9	9
	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 EE 1 abc is prerequisite to most advanced electrical engineering courses, and that Ma 108 abc is prerequisite to most advanced mathematics courses.

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

[4]A student may register for Ph 108 abc as a third-year elective only if he has attained an average grade of B+ or better in both Ph 2 abc and Ma 2 abc.

Fourth Year

Ph 108 abc	Theoretical Mechanics (3-0-6)	9	9	9
Ph 112 abc	Atomic and Nuclear Physics (4-0-8)	12	12	12
	Laboratory Course ... Minimum	6	.	.
Ec 4 abc	Economic Principles and Problems (3-0-3)	.	6	6
H 5 abc	Public Affairs (1-0-1)	2	2	2
	Humanities elective[1]	9	9	9
	Electives	9-11	9-11	9-11
PE 4 abc[2]	Physical Education (0-3-0)	3	3	3
		50-52	50-52	50-52

Laboratory Courses

Ph 77	Experimental Physics Laboratory	6-9	or 6-9	.
EE 7 abc	Experimental Techniques in Electrical Engineering (0-3-2)	5	5	5
Ph 172	Experimental Research in Physics (units as arranged with instructor)	.	.	.

Suggested Electives[3]

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

[1]For list of Humanities electives, see page 120.

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

[3]Students who elect EE 160 abc should *not* elect EE 162 abc, EE 103 abc, or EE 104 abc.

SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

AERONAUTICS

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities electives	9 or 10	9 or 10	9 or 10
Ae 103 abc	Aerodynamics of Aircraft (3-0-6)	9	9	9
Ae 107 abc	Elasticity Applied to Aeronautics (3-0-6)[1]	9	9	9
	Mathematics[2]	9-12	9-12	9-12
	Electives[1]	13-9	13-9	13-9
Ae 150 abc	Aeronautics Seminar (1-0-0)	1	1	1
		50	50	50

[1]Students who have not previously had courses equivalent to those listed under the Fourth Year Aeoonautics Option must take these courses during the Fifth Year instead of Ae 107 abc and the Elective units.

The elective units may be selected from Aeronautics courses (pages 149-152); Jet Propulsion courses (pages 200-201); or advanced work in other fields, with the approval of the departmental adviser.

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

GRADUATE HUMANITIES ELECTIVES

H 100 abc	Seminar in History and Government
En 100 abc	Seminar in Literature
Pl 100 abc	Seminar in Philosophy
Pl 101 abc	History of Thought
Ec 100 abc	Business Economics
Ec 110	Industrial Relations
Ec 111	Business Cycles and Fiscal Policy
Ec 112	Modern Schools of Economic Thought
Ec 126 abc	Economics Analysis and Policy (Seminar)
H 124	Foreign Area Problems
Ec 124	Economics of Underdeveloped Areas

AERONAUTICS

Sixth Year

(Leading to the degree of Aeronautical Engineer)

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

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

[1]Seminar elective should be chosen from one of the following: Ae 208 abc, Ae 209 abc, or JP 280 abc.

[2]Elective subjects are to be chosen from Aeronautics courses (pages 149-152) or advanced courses in other fields, as approved by the departmental adviser.

AERONAUTICS (JET PROPULSION OPTION)

Sixth Year

JP 208	Research in Jet Propulsion	20	20	20
Ae 201 abc	Inviscid Fluid Mechanics (3-0-6)	9	9	9
or				
Ae 204 abc	Mechanics of Real Gases (3-0-6)	9	9	9
	Seminar elective (see Note 1 above)	1-3	1-3	1-3
	Elective (not less than)[3]	15-13	15-13	15-13
		45	45	45

[3]The electives are to be chosen from the Jet Propulsion subjects on pages 200-201 with the approval of the Goddard Professor of Jet Propulsion.

ASTRONOMY

Fifth Year

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

Ay 131 abc, or Ay 132 ab, Astrophysics (3-0-6)

	Units per Term 1st	2nd	3rd
Humanities elective (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
Ay 131 abc, or Ay 132 ab, Astrophysics (3-0-6) and Ay 211	9	9	9
Electives to total	48 to 50	48 to 50	48 to 50

Elective subjects program, to be approved by the department, from advanced subjects in astronomy and physics. Placement examination will be required. (See page 188, section 2(a). Ay 108, Ay 112, Ma 108, Ph 108, Ph 107, may be required of those students whose previous training in some of these subjects proves to be insufficient.

[1]For list of Humanities electives, see page 137.

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 re-receipt of his petition to be allowed to continue.

The needs of Chemistry majors vary so widely in specialized fields of this subject that no specific curricula can be outlined. Before registering for the first time, a candidate for the master's degree should consult a member of the Committee on Graduate Study of the Division.

The Humanities requirement for a master's degree will be found on page 137. 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 Graduate Study of the Division.

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

CHEMICAL ENGINEERING

Fifth Year

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

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

Elective subjects are to be approved by a member of the Division and are to be chosen from advanced subjects in Chemistry, Chemical Engineering, Physics, Mathematics, Applied Mechanics, and Mechanical Engineering.

Students admitted for work toward the M.S. in Chemical Engineering will be required to take the placement examination in engineering thermodynamics and in elementary fluid flow. (See pages 103 and 104.) 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 page 137.

CIVIL ENGINEERING

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities elective (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
Am 115 ab	Engineering Mathematics (3-0-6)	.	9	9
CE 120 a	Statically Indeterminate Structures (3-3-6)	12	.	.
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	.	.
	Electives as below (minimum)[2]	15	27	27
	Total (Minimum)	46	46	50

Electives

		1st	2nd	3rd
AM 105	Advanced Strength of Materials (2-0-4)	.	6	.
AM 106	Problems in Buckling (2-0-4)	.	.	6
AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
CE 112	Reinforced Concrete (3-0-6)	.	9	.
CE 120 bc	Statically Indeterminate Structures[3]	.	.	.
CE 121 abc	Structural Design (0-9-0)	9	9	9
CE 122	Earthquake Effects upon Structures[3]	.	.	.
CE 126	Masonry Structures (2-3-4)	.	.	9
CE 115 ab	Soil Mechanics (2-3-4; 3-0-6)	9	9	.
CE 106	Soil Mechanics Laboratory (0-3-3)	.	6	.
CE 150	Foundations (3-0-6)	.	.	9
CE 155	Hydrology (3-0-6)	9	.	.
CE 125	Water Supply, Utilization, & Drainage (3-0-6)	.	9	.
CE 132	Water Power Engineering (2-3-4)	.	.	9
CE 160	Advanced Hydrology[3]	.	.	.
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 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	.
Hy 134	Flow in Porous Media (3-0-6)	.	.	9
Hy 104	Advanced Hydraulics Laboratory[3]	.	.	.
AM 116	Complex Variables and Applications (3-0-6)	9	.	.
Ma 112	Elementary Statistics (3-0-6)	9 or	9	.

[1]For list of Humanities electives, see page 137.
[2]Electives must be approved by Civil Engineering faculty.
[3]Six or more units as arranged.

ELECTRICAL ENGINEERING

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
EE 132 abc	Circuit Analysis (3-0-6)[2]	9	9	9
EE 220 abc	Research Seminar in Electrical Engineering	2	2	2
	Two or more of the following electives:			
EE 140 abc	Electric Communication (3-0-6)	9	9	9
EE 150 abc	Electromagnetic Fields (3-0-6)	9	9	9
EE 164 abc	Microwave Electronics and Circuits (3-0-6)	9	9	9
EE 170 abc	Feedback Control Systems (3-0-6; 3-3-6)	9	12	12
EE 180	Digital Computer Design (3-3-3)	9	.	.
EE 181 ab	Principles of Analog Computation (3-3-6)	.	12	12
EE 190 abc	Transistor Electronics (3-0-6; 3-0-6; 1-2-6)	9	9	9
Ph 112 abc	Introduction to Atomic & Nuclear Physics (4-0-8)	12	12	12
	Other electives as approved by Electrical Engineering Faculty			

Sixth Year

(Leading to the degree of Electrical Engineer)

AM 126 abc	Applied Engineering Mathematics (3-0-9)[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 page 137.
[2]Required unless comparable work done elsewhere.
[3]This course is also required for the doctor's degree in electrical engineering.

ENGINEERING SCIENCE

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

Most engineering science majors work for the doctor's degree and follow programs arranged by the student in consultation with members of the Division. A master's degree can be awarded after two years of study under special circumstances. Requirements for the master's degree include the following fifth-year program:

		Units per Term 1st	2nd	3rd
	Humanities electives	9 or 10	9 or 10	9 or 10
AM 125 abc	Engineering Mathematical Principles	9	9	9
or				
MA 108 abc	Introduction to Real and Complex Analysis	12	12	12
or				
Ma 118 abc	Functions of Complex Variable	9	9	9
Ph 112 abc	Introduction to Atomic and Nuclear Physics	12	12	12
	Electives	18	18	18
		48 or 49 or 51 or 52	48 or 49 or 51 or 52	48 or 49 or 51 or 52

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	11
Ge 123	Summer Field Geology (30 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

		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 123	Summer Field Geology (30 units, in summer)[2]	.	.	.
Ge 150	The Nature and Evolution of the Earth (any 12 units)	6	6	.
Ge 175	Introduction to Applied Geophysics	.	.	6
Ge 176	Elementary Seismology	.	6	.
Ge 282 abc	Geophysics—Geochemistry (Seminar)	1	1	1
	Elective units to be chosen from advanced courses in the Geological Sciences, physics, mathematics, or electrical engineering to total 140 units.			

Option leading to degree of Master of Science in Geochemistry

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

A. GEOLOGY

Fifth and Sixth Years

(Leading to the degree of Geological Engineer)

		1st	2nd	3rd
Ge 100	Geology Club	1	1	1
Ge 102	Oral Presentation	1 or	1 or	1
Ge 103	Paleontology	9	.	.
Ge 105	Optical Mineralogy	12	.	.
Ge 106 ab	Petrography	.	9	9
Ge 107	Stratigraphy	.	.	10
Ge 109	Structural Geology	4	.	.
Ge 111 ab	Invertebrate Paleontology	.	10	10
Ge 121 abc	Advanced Field Geology	14	10	11
Ge 122	Spring Field Trip	.	.	1
Ge 123	Summer Field Geology (30 units, in summer)	.	.	.
Ge 126	Geomorphology	10	.	.
Ge 130	Introduction to Geochemistry	.	.	6
Ge 150 ab	The Nature and Evolution of the Earth	6	6	.
Ge 150 cd	The Nature and Evolution of the Earth	6	6	.
Ge 150 ef	The Nature and Evolution of the Earth	6	6	.
Ge 151 abc	Laboratory Techniques in the Earth Sciences (5 unit minimum, additional units by arrangement)	5	5	5
Ge 165	General Geophysics	.	.	6

[1]For list of Humanities electives, see page 137.

[2]Students with limited experience in geological field work may be required to take all or a portion of Ge 120 abc as a prerequisite to Ge 121 abc or Ge 123. By approval of the Committee on Field Geology the field geology requirements may be satisfied by evidence of equivalent training obtained elsewhere.

[3]If Ph 106 is not offered a course covering the equivalent material must be taken.

Ge 200	Mineragraphy	15	.	.
Ge 202	Ore Deposits	.	15	.
Ge 209	Sedimentary Petrology	.	10	.
Ge 211 abc	Advanced Petrology	15	15	15
Ge 212	Nonmetalliferous Deposits	.	.	10
Ge 213	Mineralogy (Seminar)	5	.	.
Ge 215	Ore Deposits (Seminar)	.	.	5
Ge 228	Geomorphology of Arid Regions	.	10	.
Ge 229	Glacial Geology	.	10	.
Ge 230	Geomorphology (Seminar)	.	5	.
Ge 237	Tectonics	.	.	8
Ge 244 abc	Paleozoology (Seminar)	5	5	5
Ge 245	Vertebrate Paleontology (Seminar)	5	5	5
Ge 250	Invertebrate Paleontology and Plaeoecology (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.

B. GEOPHYSICS

Fifth and Sixth Years

(Leading to the degree of Geophysical Engineer)

		Units per Term 1st	2nd	3rd
Ge 150 ab	The Nature and Evolution of the Earth	6	6	.
Ge 150 cd	The Nature and Evolution of the Earth	6	6	.
Ge 150 ef	The Nature and Evolution of the Earth	6	6	.
Ge 151	Laboratory Techniques in the Earth Sciences *(5 units minimum, additional units by arrangement)*	5	5	5
Ge 165	General Geophysics	.	.	6
Ge 167	Propagation of Elastic Waves	.	3	.
Ge 171	Applied Geophysics I	10	.	.
Ge 173 ab	Applied Geophysics II	.	5	5
Ge 174	Well Logging	.	5	.
Ge 175	Introduction to Applied Geophysics	.	.	6
Ge 176	Elementary Seismology	.	.	6
Ge 264 ab	Elastic Waves	8	8	.
Ge 268 ab	Selected Topics in Theoretical Geophysics		6	6
Ge 274 ab	Applied Geophysics III	.	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	6	6	6
Ma 112	Elementary Statistics	9 or	9	.
Ph 107 abc	Electricity and Magnetism	9	9	9
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 16	Electrical Measurements	.	6	.

MATHEMATICS

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

MECHANICAL ENGINEERING OPTION

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 below)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
	Electives as below (minimum total for year 81)	27	27	27
		47 or 48	47 or 48	47 or 48

Electives

AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 101 abc	Advanced Design (1-6-2)	9	9	9
ME 115 abc	Thermodynamics and Heat Transfer (3-0-6)	9	9	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9

MECHANICAL ENGINEERING (JET PROPULSION OPTION)

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (See Note 4 below)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
JP 121 abc	Rocket (3-0-6)	9	9	9
JP 130 abc	Thermal Jets (2-0-4)	6	6	6
JP 200 abc	Chemistry Problems in Jet Propulsion (3-0-6)	9	9	9
	Electives as below (minimum total for year 81)	6	6	6
		50 or 51	50 or 51	50 or 51

Electives

AM 110 abc	Elasticity (2-0-4)	6	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
ME 101 abc	Advanced Design (1-6-2)	9	9	9
ME 115 abc	Thermodynamics and Heat Transfer (3-0-6)	9	9	9
Hy 101 abc	Advanced Fluid Mechanics (3-0-6)	9	9	9

MECHANICAL ENGINEERING
(PHYSICAL METALLURGY OPTION)

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (See Note 4 below)	9	9	9
AM 110 a	Elasticity (2-0-4)	6	.	.
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
PM 103	Physical Metallurgy Laboratory (0-9-0)	9	.	.
PM 112 ab	Advanced Physical Metallurgy (3-0-6)	.	9	9
PM 117	X-Ray Metallography II (0-6-3)	.	9	.
PM 121	Theory of Alloys (3-0-6)	9	.	.
PM 125	Industrial Physical Metallurgy (0-6-3)	.	.	9
	Electives (minimum 24 units for the year)	6	9	9
		50 or 51	47 or 48	47 or 48

Electives

AM 110 bc	Theory of Plates and Shells, Mechanics of Materials (2-0-4)	.	6	6
AM 150 abc	Mechanical Vibrations (2-0-4)	6	6	6
Ch 226 abc	Introduction to Quantum Mechanics, with Chemical Applications (3-0-6)	9	9	9
ME 101 abc	Advanced Design (1-6-2)	9	9	9
ME 115 abc	Thermodynamics and Heat Transfer (3-0-6)	9	9	9
Ph 205 abc	Principles of Quantum Mechanics (3-0-6)	9	9	9

MECHANICAL ENGINEERING (NUCLEAR ENERGY OPTION)

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities electives (3-0-6; 4-0-6)[1]	9 or 10	9 or 10	9 or 10
	Laboratory elective (see Note 4 below)	9	9	9
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
AM 101 abc	Introduction to Nuclear Reactor Analysis (3-0-6)	9	9	9
AM 102 abc	Applied Nuclear Physics (2-0-4)	6	6	6
	Electives as below (minimum)	12	12	12
		47 or 48	47 or 48	47 or 48

Electives

		Units per Term 1st	2nd	3rd
Ch 127 ab	Radioactivity and Isotopes (2-0-4)	.	6	6
ME 115 abc	Thermodynamics and Heat Transfer (3-0-6)	9	9	9
Hy 101 abc	Fluid Mechanics (3-0-6)	9	9	9
AM 110 abc	Elasticity (2-0-4)	6	6	6
PM 101	Physical Metallurgy (3-3-3)	9	.	.
PM 115	Crystal Structure of Metals and Alloys (3-0-6)	.	9	.
PM 116	X-Ray Metallography I (0-6-0)	.	.	6

Note: Students holding AEC Fellowships may substitute electives for certain of the above required courses by special approval of the faculty in Mechanical Engineering.
Notes applying to all options in Mechanical Engineering:

Note 1: Students who have not had a course in Engineering Mathematics, Advanced Calculus, or the equivalent in their undergraduate work are required to include AM 115 ab and AM 116 among the elective units.

Note 2: Students who plan advanced study past the fifth year, and who have had AM 115 ab and AM 116 or an equivalent course in their undergraduate work may substitute one of the following courses for one of the professional courses listed above, subject to the approval of the faculty in Mechanical Engineering:

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

Note 3: Substitutions for the scheduled electives may be made upon specific approval of the faculty in Mechanical Engineering. The following are examples of substitutions that have been made in some instances and may be used as a guide by those desiring to make substitutions:

AM 105 Advanced Strength of Materials, 6 units second term
AM 106 Problems in Buckling, 6 units third term
Ae 101 abc Introductory Mechanics and Thermodynamics of Fluids, 9 units each term
EE 160 abc Electronics and Circuits, 6 units each term
EE 170 abc Feedback Control Systems, 9 units each term
JP 121 abc Rocket, 9 units each term
JP 130 abc Thermal Jets, 6 units each term
PM 105 Mechanical Behavior of Metals, 6 units first term

Note 4: Laboratory electives

First Term: AM 103, AM 155, PM 104
Second Term: AM 111, Ma 112, ME 127
Third Term: ME 126, PM 102, JP 170 c

[1]For list of Humanities electives, see page 137.

MECHANICAL ENGINEERING

Sixth Year
(Leading to the degree of Mechanical Engineer)

Specific requirements for the degree of Mechanical Engineer are given on page 96. The following list will suggest possible subjects from which a program of study may be organized:

ME 200	Advanced Work in Mechanical Engineering
ME 217 abc	Turbomachines
ME 300	Thesis—Research
Hy 200	Advanced Work in Hydraulic Engineering
Hy 201 abc	Hydraulic Machinery
Hy 203	Cavitation Phenomena
Hy 210 ab	Hydrodynamics of Sediment Transportation
Hy 300	Thesis
Ae 201 abc	Hydrodynamics of Compressible Fluids
Ae 204 abc	Theoretical Aerodynamics of Real and Perfect Fluids
Ae 205 abc	Statistical Problems in Gas Dynamics
Ae 107 abc	Elasticity Applied to Aeronautics
AM 201 abc	Advanced Reactor Theory
Ch 163 ab	Chemical Engineering Thermodynamics
Ch 226 abc	Introduction to Quantum Mechanics
Ch 227 abc	The Structure of Crystals
Ch 229	Diffraction Methods of Determining the Structure of Molecules
Ch 262 ab	Thermodynamics of Multi-Component Systems
Ph 112 abc	Introduction to Atomic and Nuclear Physics
Ph 205 abc	Principles of Quantum Mechanics
Ph 227 ab	Thermodynamics, Statistical Mechanics, and Kinetic Theory
PM 103	Physical Metallurgy Laboratory
PM 112 ab	Advanced Physical Metallurgy
PM 117	X-Ray Metallography II
PM 121	Theory of Alloys
PM 205	Theory of Mechanical Behavior of Metals
PM 250 abc	Advanced Topics in Physical Metallurgy
JP 220 abc	Theory of Stability and Control

MECHANICAL ENGINEERING, JET PROPULSION OPTION

Sixth Year

(Leading to the degree of Mechanical Engineer)

		Units per Term 1st	2nd	3rd
JP 280 abc	Jet Propulsion Research (Thesis)	18	18	18
	Electives (not less than)	30	30	30
		—	—	—
		48	48	48

The list of subjects which could be chosen as electives for the sixth-year work is given above.

PHYSICS

Fifth Year

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

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)[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 107 abc	Electricity and Magnetism (3-0-6)[1]	9	9	9
Ph 108 abc	Theoretical Mechanics (3-0-6)[1]	9	9	9
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 (2-0-4)	.	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	Introduction to Real & Complex Analysis (4-0-8)[3]	12	12	12
Ma 118 abc	Functions of Complex Variable (3-0-6)	9	9	9

[1]Prerequisite for most other fifth-year courses.

[2]For list of Humanities electives, see page 137.

[3]Prerequisite for Ma 118.

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

Section V

SUBJECTS OF INSTRUCTION

AERONAUTICS

ADVANCED SUBJECTS

Ae 101 abc. Thermodynamics and Dynamics of Continua. *9 units (3-0-6); each term. Prerequisites: AM 115, AM 116* (may be taken concurrently with approval of instructor). Thermodynamics of solids, liquids, and gas mixtures. Equilibrium relations, dissociation and ionization. Black body radiation. General irreversible processes. Elements of kinetic theory and statistical mechanics. Stress-strain relations. Discussion of typical problems in subsonic flow and supersonic flow such as simple air foil theory, steady one-dimensional flows, nozzle flow, shock waves, laminar and turbulent skin friction and heat transfer. Texts: *Thermodynamics,* Fermi; *Elements of Gasdynamics,* Liepmann and Roshko. Instructors: Liepmann and Roshko.

Ae 102 abc. Aircraft Structural Analysis. *9 units (3-0-6); each term. Prerequisites: Applied Mechanics and Strength of Materials.* A study of the fundamental equations of applied elasticity and their application to aircraft structural analysis. Basic stress-strain relationship, exact and approximate methods of beam and truss analysis, and other two- and three-dimensional problems are treated. Buckling phenomena of columns and plates and shells are discussed and an introduction is given to analog methods of static and dynamic structural analysis. Texts: *Elasticity in Engineering,* Sechler; *Airplane Structural Analysis and Design,* Sechler and Dunn. Instructor: Sechler.

Ae 103 abc. Aerodynamics of Aircraft. *9 units (3-0-6); each term. Prerequisite: AM 15, Hydraulics.* Airfoil lift, drag and moment characteristics. Boundary layers. Effects of compressibility. Calculation of spanwise lift distribution on finite wings. Performance of complete airplane. Static and dynamic stability and control. Determination of response characteristics. Texts: *Aerodynamics of the Airplane,* Millikan; *Airplane Performance, Stability, and Control,* Perkins and Hage. Instructor: Royce.

Ae 105. Wind Tunnel Operation and Techniques. *6 units (1-3-2); one term.* A one-term course covering pressure and velocity measuring instruments, balances, model suspensions, wind tunnel calibration and correction factors, data reduction and presentation, extrapolation of model results to full scale. Experiments on various aerodynamic phenomena are carried out by the students in a special wind tunnel constructed for instruction purposes. Text: *Wind Tunnel Testing,* Pope. Instructor: W. Bowen.

Ae 106 ab. Experimental Methods in Aeronautics. *6 units (2-2-2); second and third terms. Prerequisites: Ae 101 a, Ae 102 a, Applied Mechanics.* One term is devoted to a study of experimental techniques in the field of aircraft structures and applied elasticity; methods of reducing and correlating experimentally obtained data; and a study of sources of error in experimentation. The second term is devoted to experimental techniques in the field of fluid mechanics and aerodynamics. Statistical methods; analogs; hot-wire measurements; and boundary layers are among the problems discussed from an experimental standpoint. Texts: *Similitude in Engineering,* Murphy, and numerous reference works on experimental methods. Instructors: Sechler, D. Coles.

Ae 107 abc. Elasticity Applied to Aeronautics. *9 units (3-0-6); each term. Prerequisites: Ae 102 abc, AM 115 ab, AM 116.* Stress, strain and displacement relations in anisotropic elastic media. Classical problems of thermal stress, bending, torsion, and plane strain. Formulation of the non-linear large deflection problem of combined stretching and bending of thin plates; examination of the classical limit cases. Shell theory. Considerable emphasis on the development of approximate analysis methods for the above problems based on minimum potential and complementary energy theorems. Brief treatment of elastic stability and wave propagation in elastic media. Instructor: Williams.

Ae 109. Instrumentation Design. *4 units (2-0-2); one term.* The problem of design and use of instrumentation and the fundamental principles involved in making precision measurements. Instructor: Klein.

Ae 110 abc. Systems Concepts in Aeronautics. *6 units (2-0-4); each term.* An integrated study of various related subjects in the field with emphasis upon synthesizing the interactions which affect aeronautical vehicles. The interplay between performance requirements, strength-weight analysis, power plant characteristics, air loads analysis, dynamic stability and control of a flexible aircraft, and economic factors is evaluated in conjunction with familiarizing the student with some of the more elementary features of the mathematical tools at his disposal, such as operations analysis, digital computation and the variational calculus. Instructor: Williams.

Ae 150 abc. Aeronautical Seminar. *1 unit (1-0-0); each term.* Speakers from campus and outside research and manufacturing organizations who will discuss current problems and advances in aeronautics.

Ae 200 abc. Research in Aeronautics. *Units to be arranged.* Theoretical and experimental investigations in the following fields: aerodynamics, compressibility, fluid and solid mechanics, supersonic and hypersonic flow, aeroelasticity, structures, thermoelasticity, fatigue, photoelasticity. Instructors: Staff.

Ae 201 abc. Inviscid Fluid Mechanics. *9 units (3-0-6); each term. Prerequisites: Ae 101, Ae 103.* A course covering the general theory of compressible and incompressible fluid mechanics of a non-viscous fluid. Among the topics studied are: General equations of motion, general energy and vorticity theorems, incompressible flow and potential theory, lifting surfaces and lifting lines, shock waves and expansion waves characteristics, linearized theory for subsonic and supersonic flow applied to drag and lift, minimum theorems of linearized theory, transonic and hypersonic approximations. Text: Class notes and reference material. Instructors: J. Cole, Millikan, and Stewart.

Ae 202 abc. *6 units (2-0-4); each term as described below. To be offered in alternate years beginning in 1956-1957. Prerequisite: for all courses, Ae 107 abc.*

Ae 202 a. Thermal Stress Problems. General survey of thermal problems in the design of high speed aircraft. Heat generation in the boundary layer. Temperature distribution in structures. Stress-strain relationship. Thermodynamics of strained elastic solids. Fundamental differential equations of equilibrium, compatibility, and motion. Variational principles. Energy theorems. Thermal stresses in beams, trusses, plates and shells. Buckling due to thermal stresses. Stiffness of structures. Effect on the aeroelastic properties of aircraft. Instructor: Valluri.

Ae 202 b. Mechanics of Inelastic Materials. Ultimate strength of aircraft structures. Mechanical properties of structural materials at high temperature. Modes of failure of structures. Theory of anelasticity. Theory of perfectly plastic solids. Thermodynamics of irreversible process and the basic laws of viscoelastic materials. Rate process and the theory of dislocations. Creep analysis. Elastic analogies for linear viscoelastic materials and nonlinear secondary creep. Repeated loads. Fatigue. Limit design. Instructor: Valluri.

Ae 202 c. Nonlinear Problems in Structures and Aeroelasticity. Large deflection of beams, columns, and plates. Edge layer theories. Post-buckling behavior of circular and rectangular plates. Slightly curved plates. Nonlinear vibrations of plates and shells. Buckling of arches and shells. Critical examination of the criteria of buckling. Nonlinear static aeroelastic problems. Flutter of buckled plates. Flutter of airfoils with nonlinear stiffness and damping characteristics. Stall flutter. Instructor: Staff.

Ae 203 abc. Advanced Problems in Aerodynamics. *6 units (2-0-4); each term. Prerequisites: Ae 101, AM 125, Ae 103.* Introduction to theory of servo-mechanisms and application to stability and control. Helicopter aerodynamics, propeller theory, boundary layer theory, and internal aerodynamics. Aerodynamics of high speed flight including the effects of compressibility on stability and control. Fundamentals of aeronautical electronics. Instructor: Staff.

Ae 204 abc. Mechanics of Real Gases. *9 units (3-0-6); each term. Prerequisites: Ae 101, Am 125, Ae 103.* Motion of real gases as determined by state and transport properties. Navier-Stokes equations and boundary conditions. Some exact solutions for incompressible flow. Stokes and Oseen approximations for low Reynolds numbers. Prandtl boundary-layer approximation for high Reynolds numbers. Boundary layer equations for chemically reacting mixtures of perfect gases. Integral methods; discussion of laminar skin-friction, heat transfer, and mass transfer. Turbulent shear flow. Dimensional arguments and similarity laws. Integral methods; semi-empirical formulas for turbulent skin friction and heat and mass transfer. Separation and other unsolved problems of laminar and turbulent flow, including discussions of experimental observations of these phenomena. Instructors: Lees and Coles, D.

Ae 205 abc. Statistical Problems in Gas Dynamics. *9 units (3-0-6); each term. Offered in alternate years beginning in 1955-56. Prerequisites: Ae 101, Ae 201, AM 125, or Ma 114.* Fundamental concepts: concept of probability, randoms 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, magnetohydrodynamics. 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 in 1956-57. Prerequisites: Ae 101, Ae 201, Ae 204, or* consent of instructor. Selected topics in fluid mechanics: for example, advanced problems in linearized theory of inviscid fluids; non-linear theory of transonic, supersonic and hypersonic flow; theory of viscous incompressible flow and of viscous heat-conducting compressible flow; related topics from physics and mathematics. Instructors: Lagerstrom, Kaplun.

Ae 207 abc. Aeroelasticity. *9 units (3-0-6); each term. To be offered in alternate years beginning in 1957-58. Prerequisites: Ae 103 abc, Ae 107 abc.* Aeroelastic oscillations of cylinders, transmission lines, and suspension bridges. Steady-state problems: divergence, loss of control, and lift-distribution. Flutter. Dynamic stresses: landing and gust loads. Buffeting. Stall flutter. General formulation of aeroelastic problems. Linearized theory of oscillating airfoils. Comparison of the unsteady airfoil theory with experimental results. Texts: *An Introduction to the Theory of Aeroelasticity*, Fung; *Aeroelasticity*, Bisplinghoff, Ashley and Halfman. Instructor: Fung.

Ae 208 abc. Seminar in Fluid Mechanics. *1 unit (1-0-0); each term.* A seminar course in modern fluid dynamics. Instructor: Liepmann.

Ae 209 abc. Seminar in Solid Mechanics. *1 unit (1-0-0); each term.* A seminar course for students whose interests lie in the general field of advanced elasticity. Recent (theoretical and experimental) developments and original research in the field as reviewed for possible application to the current problems in the aircraft and related industries. Instructor: Sechler.

JET PROPULSION

(For Jet Propulsion see page 200)

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, Operations, and Careers in the U. S. Air Force. 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.* 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 and Staff.

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

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

AM 5 ab. Applied Mechanics—Dynamics. *9 units (3-0-6); first and second terms.* Principles of dynamics; dynamics of a particle; dynamics of rigid bodies; Lagrange's equations; applications to engineering problems involving dynamic characteristics of machine parts, mechanical and structural vibrations, impact, momentum transport, etc. Text: *Applied Mechanics-Dynamics,* Housner and Hudson. Instructors: Hudson and Assistants.

AM 15 abc. Engineering Mathematics. *9 units (3-0-6); first, second, third terms. Prerequisites: Ma 1 abc, Ma 2 abc.* A course in the mathematical treatment of problems in engineering and physics. Emphasis is placed on the setting up of problems

[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.

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: Penner, Wayland and Assistants.

ADVANCED SUBJECTS

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

AM 101 abc. Introduction to Nuclear Reactor Analysis. *9 units (3-0-6); each term. Prerequisite: AM 15 abc or Ph 107 abc.* Neutron chain reactions and the criticality condition; the slowing down of neutrons in an infinite medium; one-speed diffusion of neutrons in multiplying and non-multiplying systems; combined slowing down and diffusion; bare and reflected homogeneous reactors; effects of heterogeneity; time-dependent behavior of reactors; control rod theory; elements of transport theory. Instructor: Lurie.

AM 102 abc. Applied Nuclear Physics. *6 units (2-0-4); each term. Prerequisites: Ph 2 abc; AM 15 abc or equivalent.* An introductory course covering those aspects of nuclear physics which are encountered in nuclear engineering. Topics covered will include radioactivity, the interactions of charged particles and gamma rays with matter, nuclear reactions, neutron physics and nuclear fission. Part of the third term will be devoted to such specialized topics as radiation shielding including bulk and thermal shields. Text: Kaplan, *Nuclear Physics*. Instructor: Plesset.

AM 103. Nuclear Engineering Laboratory. *9 units (1-6-2); first term. Prerequisite: AM 102 abc (may be taken concurrently).* A one-term laboratory course designed to familiarize students with the basic nuclear detecting and measuring devices which are used in reactor technology. Consideration will be given to some of the basic measurement problems involved in counting techniques. The instruments are first used to determine the properties of particles and radiations, and their interaction with matter. A subcritical assembly then allows the student to gain familiarity with some of the methods used for determining macroscopic reactor properties. Instructor: Lurie.

AM 105. Advanced Strength of Materials. *6 units (2-0-4); second term. Prerequisite: AM 4 ab.* Analysis of problems of stress and strain that are described by ordinary differential equations, such as beams on elastic foundation, curved bars, combined bending and axial loading of beams, combined bending and torsion of beams. Energy methods of solution. Instructor: Housner.

AM 106. Problems in Buckling. *6 units (2-0-4); third term. Prerequisite: AM 4 ab.* Analysis of problems dealing with the elastic instability of columns, beams, arches and rings, and the inelastic buckling of columns. Instructor: Housner.

AM 110 a. Introduction to the Theory of Elasticity. *6 units (2-0-4); first term. Prerequisite: AM 4 ab.* Fundamental concepts of elasticity theory. Equations of stress equilibrium and strain compatibility. Solution of two-dimensional problems. Photoelastic method of stress measurements. Analysis of stress and strain in three dimensions. Solution of torsion problems. Wave propagation in elastic solids. Instructors: Housner, Miklowitz.

AM 110 b. Theory of Plates and Shells. *6 units (2-0-4); second term. Prerequisite: AM 4 ab.* Simplifications introduced in elasticity theory. Laterally loaded plates with various boundary conditions. Elastic stability of plates. Membrane theory of shells. General theory of shells. Instructors: Housner, Miklowitz.

AM 110 c. Mechanics of Materials. *6 units (2-0-4); third term. Prerequisites: AM 4 ab, AM 110 a.* Use of tensors in elasticity theory. Non-linear stress-strain relations. Theory of plasticity. Theories of failures of stressed materials. Instructors: Housner, Miklowitz.

AM 111. Experimental Stress Analysis. *9 units (1-6-2); second term.* Static and dynamic stress and strain measurements, including the use of piezoelectric materials; wire resistance strain gages; mechanical, optical, inductance, and capacitance displacement gages; photoelastic materials; brittle lacquer coatings; x-rays, and associated instrumentation and recording systems. Instructor: Staff.

AM 115 ab. Engineering Mathematics. *9 units (3-0-6); second and third terms. Prerequisites: Ma 1 abc, Ma 2 abc or equivalent.* A course in the mathematical treatment of problems in engineering or physics, primarily for fifth year students who have not had a course in advanced engineering mathematics as undergraduates. The mathematical content is similar to that of AM 15 abc, but less emphasis is placed on ordinary differential equations. Instructors: Miklowitz, Wayland and Assistants.

AM 116. Complex Variables and Applications. *9 units (3-0-6); first term. Prerequisites: Ma 1 abc, Ma 2 abc or equivalent.* A basic introduction to analytic functions of a complex variable. Emphasis is placed on application of conformal mapping to boundary value problems and on techniques of contour integration. Text: Churchill, *Introduction to Complex Variables and Applications.* Instructors: Miklowitz, Wayland and Assistants.

AM 125 abc. Engineering Mathematical Principles. *9 units (3-0-6); each term. Prerequisites: AM 15, AM 115 ab and AM 116, Ma 108, or equivalent.* Topics from ordinary and partial differential equations with applications to vibrations, elasticity, theory of sound, fluid mechanics, and diffusion. Instructor. De Prima.

AM 126 abc. Applied Engineering Mathematics. *12 units (3-0-9); each term. Prerequisites: AM 15, AM 115 ab and AM 116, Ma 108, or equivalent.* A problem and lecture course in engineering mathematics. Preparation of approximately six reports per term on problems taken from all branches of engineering. First term lectures cover topics in ordinary differential equations including: Lagrange's equations, normal modes of vibration, and nonlinear systems. Second and third term lectures cover topics in partial differential equations including: characteristics, vibration theory, Rayleigh-Ritz method, conformal mapping, Laplace transform, difference equations, relaxation methods. Instructor: Lindvall.

AM 130 abc. Classical Field Theory I. *9 units (3-0-6); first, second, and third terms. Prerequisites: AM 15 abc, or equivalent.* Analytical mechanics of systems of particles, kinetic theory, statistical mechanics and mechanics of continuous media. Instructors: Plesset and Wu.

AM 140. Advanced Mechanics of Solids I. *6 units (2-0-4); first term. Prerequisites: AM 110 ac, AM 115 ab.* Further study in plasticity. Composite plastic and viscous solids. Flow in polymers. Plastic-elastic flow in bars, cylinders, and disks. Creep and relaxation in metals and polymers. Plane strain and theory of slip surfaces. Two-dimensional problems. Experiments in yielding and fracture. Instructor: Miklowitz.

AM 141. Advanced Mechanics of Solids II. *6 units (2-0-4); second term. Prerequisites: AM 5 ab, AM 110a, AM 115ab, AM 116.* Study of wave propagation. Waves in elastic media. Dispersion of waves in bounded solids. Approximate elasticity theories and solutions governing waves in rods, beams, plates and shells. Related experiments. Waves in plastic and visco-elastic media. Damage due to wave action. Instructor: Miklowitz.

AM 150 abc. Mechanical Vibrations. *6 units (2-0-4); first, second, and third terms. Prerequisites: AM 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; general normal mode theory. The third term is an introduction to non-linear vibration theory. Instructors: Caughey, Hudson, Lurie.

AM 155. Dynamic Measurements Laboratory. *9 units (162); first term.* Theory and technique of making measurements encountered in engineering practice and research, with special reference to dynamic measurements. Experiments in vibrations and stability using the latest electro-mechanical and electronic instruments are performed. Instructor: Caughey.

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: Caughey.

AM 174 abc. Advanced Dynamics I. *6 units (3-0-3). Prerequisites: AM 125 abc and AM 150 abc or equivalents.* The first two terms will cover topics in advanced linear vibration theory with special emphasis on approximate methods of analysis of complex systems and topics in non-linear vibration theory with special emphasis on systems with strong non-linearities. The third term will be devoted to noise and stochastic processes applied to vibration problems. This course will be given every other year to alternate with AM 176. Given 1958-59. Instructors: Caughey, Hudson and Staff.

AM 176 abc. Advanced Dynamics II. *6 units (3-0-3). Prerequisites: AM 125 abc and AM 150 abc or equivalents.* The first term will be devoted to topics in engineering applications of acoustics. The second and third terms will cover topics in stability of dynamic mechanical systems and in control of mechanical-electrical systems. This course will be given every other year to alternate with AM 174. Instructors: Caughey, Hudson and Staff.

AM 180. Matrix Algebra. *9 units (3-0-6); first term.* Theory of matrices from the standpoint of mathematical physics and as used in the formulation of problems on high speed analog and digital computers. Canonical forms are developed for self-adjoint and for general matrices. Text: *Principles of Numerical Analysis,* Householder. Instructor: Franklin.

AM 200. Special Problems in Advanced Mechanics. Dynamics of solid and deformable bodies, fluids, and gases; mathematical and applied elasticity. By arrangement with members of the staff, properly qualified graduate students are directed in independent studies. Hours and units by arrangement.

AM 201 abc. Advanced Reactor Theory. *9 units (3-0-6); first, second, and third terms. Prerequisites: AM 102 abc, or equivalent.* Neutron scattering and absorption cross-sections; the fission process. The neutron transport equation. Stationary and time-dependent problems. The monoenergetic case; the Milne problem; the diffusion approximation. Energy dependent problems; slowing-down problems. Not given in 1958-59. Instructor: Plesset.

AM 204 abc. Hydrodynamics of Free Surface Flows. *9 units (3-0-6); each term. Prerequisites: Hy 101 abc, AM 125 ab and AM 116, or equivalent.* Theory of surface waves in a liquid; initial value problems and boundary value problems. Wave pattern due to moving disturbances. Wave resistance of a floating or submerged body. Theory of thin ships. Lifting surfaces in flows having a free surface: planing surfaces, hydrofoils. Theory of tidal waves. The mathematical method of characteristics will be applied to the problems of the flow in open channels, river waves and flood waves. Free boundary theory; theories of physical cavity flows. Dynamics and stability of vapor bubbles in a liquid. Water entry problems. Given in alternate years. Offered in 1959-60. Instructor: Wu.

AM 205 abc. Theory of Solids. *9 units (3-0-6); first, second, and third terms.* Theory of specific heats. Free electron theory of metals and semi-conductors. Thomas-Fermi and Hartree-Fock approximations. Theory of cohesion, conductivity, and optical properties. Instructor: Plesset.

AM 225. Advanced Topics in Applied Mathematics. *Prerequisites: AM 125 or equivalent.* Advanced mathematical techniques used in Engineering and Physics. Special emphasis on a systematic theory of partial differential equations. This will include theory of characteristics, Green's functions, tensor analysis, perturbation methods, similarity, Wiener-Hopf method. Selected advanced topics, such as Calculus of Variation, Integral Equations, will be included. The connections between physical and mathematical problems will be emphasized. Instructors: Cole, Lagerstrom.

AM 230 abc. Classical Field Theory II. *9 units (3-0-6); first, second, and third terms. Prerequisites: AM 130 abc, or equivalent.* Analytical mechanics of fields, electromagnetic field theory, particle transport theory, radiation transport theory, magnetohydrodynamics. Not given in 1958-59. Instructors: Plesset and Wu.

AM 250 abc. Research in Applied Mechanics. Research in the field of Applied Mechanics. By arrangement with members of the staff, properly qualified graduate students are directed in research. Hours and units by arrangement.

Astronomy

UNDERGRADUATE SUBJECTS

Ay 1. Introduction to Astronomy. *9 units (3-1-5); third term.* This course is intended to give the student sufficient familiarity with general astronomy to enable him to read with profit all but the more technical books and articles dealing with this subject. Instructors: Deutsch, Matthews.

Ay 2 abc. General Astronomy. *9 units (3-3-3); first, second, and third terms. Prerequisites: Ay 1, Ph 2 abc, Ma 2 abc.* The planets, the sun and solar-terrestrial relations. Physical properties of the stars and the spectral sequence. Binary and variable stars. Dynamics of the galaxy, extragalactic nebulae. Instructor: Oke.

ADVANCED SUBJECTS

Ay 108 ab. Astronomical Instruments and Radiation Measurement. *9 units (3-1-5), (3-2-4); first and second terms.* The use of the photographic plate as a scientific instrument; quantitative techniques in laboratory photography. Astronomical optics. Theory of reflectors, schmidts and spectrographs. Photoelectric detectors, amplifiers. Photometric systems and their applications. Open to qualified undergraduates. Instructors: Arp, Bowen, Miller.

Ay 112 abc. General Astronomy. *6 units; first, second, and third terms.* This subject is the same as Ay 2, but with reduced credit for graduate students. Instructor: Oke.

Ay 131 abc. Astrophysics I. *9 units (3-0-6); first, second, third terms. Prerequisites: Ay 2 abc, Ph 112 abc.* The masses, luminosities and radii of the stars. The sun. Atomic spectroscopy. Stellar spectra. The theory of radiative equilibrium in stellar atmospheres. The continuous absorption by atoms and the production of the continuous spectrum of the stars; the line absorption coefficient and the formation of spectral lines. The solar atmosphere. Analysis of stellar spectra. Abundances of the elements. Instructor: Greenstein.

Ay 132 ab. Astrophysics II. *9 units (3-0-6); first and second terms. Prerequistes: Ay 2 abc, Ph 112 abc, or their equivalents.* Introduction to the study of stellar interiors; polytropes; opacity and energy generation. Stellar models. Red giants and white dwarfs. Stellar evolution. Pulsating stars. Given in alternate years. Not given in 1958-59.

Ay 133. Radio Astronomy. *6 units (2-0-4); second term.* Radio measurements of the flux and brightness of celestial noise sources. Outline of receiver principles; antennae and interferometers. Solar noise, normal and disturbed; theory of thermal emission. Galactic noise. Discrete sources and their identification; theory of non-thermal emission. The 21-cm hydrogen line and galactic structure. Open to qualified undergraduates. Given in alternate years. Not given in 1958-59.

Ay 140 abc. Seminar in Astrophysics. *4-12 units; first, second, third terms.* Discussions on the large scale distribution of matter in the Universe, statistics of the distribution of nebulae and clusters of nebulae. Hydrodynamic and statistical mechanical analysis of the morphology of nebulae. Theory and discussion of observational data obtained from observations on stars of special interest, such as supernovae, novae, white dwarfs, variable stars, and emission line stars. Theory and practice of new types of telescopes and other observational devices. Practical work of reduction of data obtained with the Schmidt telescopes on Palomar Mountain. Only students, assistants, faculty members, and visiting research personnel are admitted to the seminar who have the time, inclination and ability to engage in active, constructive work on problems which will be formulated in this seminar. Meetings throughout the year according to agreement. Instructor: Zwicky.

Ay 141 abc. Research Conference in Astronomy. *2 units; first, second and third terms.* Meets weekly to discuss work in progress in connection with the staff of the Mount Wilson and Palomar Observatories.

Ay 142. Research in Astronomy, Radio Astronomy, and Astrophysics. *Units in accordance with the work accomplished.* The student should consult a member of the department and have a definite program of research outlined before registering. Eighteen units required for candidacy.

Ay 204. Stellar Spectroscopy. *9 units (2-2-5); third term.* Techniques and theory of the study of stellar atmospheres. The location of various types of stars in the Hertzsprung-Russell diagram. Normal and peculiar stellar sequences. The composition of the stars. Evidence on stellar evolution. Not given in 1958-59.

Ay 211. Stellar Dynamics and Galactic Structure. *9 units (3-0-6); third term.* Dynamical principles. Time of relaxation of stellar systems. Structure of the galaxy and external systems. Dynamics of star clusters. Not given in 1958-59.

Ay 215. Seminar in Theoretical Astrophysics. *6 units (2-0-4); third term. Prerequisites: Ay 131 and/or Ay 132.* Recent developments in astrophysics for advanced students. The current theoretical literature will be discussed with special reference to possible observational applications. Subject matter will vary from year to year. Not given in 1958-59.

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

Ay 201. The Sun and the Planetary System.

Ay 202. The Solar Atmosphere.

Ay 203. Stellar Electromagnetism.

Ay 205. Spectra of Emission-line Stars.

Ay 207. Stellar Luminosities and Colors.

Ay 208. Photometry.

Ay 209. Planetary and Diffuse Emission Nebulae.

Ay 210. Interstellar Matter.

Ay 212. Extragalactic Nebulae.

Ay 213. The Observational Approach to Cosmology.

Ay 214. Theoretical Cosmology.

Ay 216. Advanced Stellar Interiors.

Biology

UNDERGRADUATE SUBJECTS

Bi 1. Elementary Biology. *9 units (3-3-3); second term.* A study of the organisms as a structural and functional entity, and of the relation of biological problems to human affairs. Instructors: Bonner, Staff.

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

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

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

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

Bi 18. Review in Botany. *3 units (1-0-2). No graduate credit. This course is given when convenient for professors and students.* A short review of general botany and plant physiology. Required of graduate students who take a minor in plant physiology but have had no previous courses in botany. Not offered in 1958-59. Instructor: Went.

Bi 20. Mammalian Anatomy and Histology. *12 units (2-6-4); second term. Prerequisite: Bi 4.* Macroscopic and microscopic structure of a mammal, including elementary instruction in preparation of tissue for microscopic inspection. Instructors: Van Harreveld, Keighley.

Bi 22. Special Problems. *Units to be arranged; first, second, and third terms.* Special problems in one of the fields represented in the undergraduate biology curriculum; to be arranged with instructors before registration. Instructors: The Biology teaching staff.

ADVANCED SUBJECTS

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

Bi 106. Embryology. *12 units (2-6-4); first term. Prerequisite: Bi 4.* The subject deals mainly with vertebrate embryology and includes some invertebrate, experimental and cytological material. Instructor: Tyler.

Bi 107 abc. Biochemistry. *10 units (3-0-7; 3-3-4; 3-5-2); first, second, and third terms. Prerequisite: Ch 41.* A lecture course on the chemical constitution of living matter and the chemical changes in animals, with laboratory work illustrating principles and methods in current use. In the third quarter emphasis is placed upon the application of physical methods to biochemical problems. Instructors: Borsook, Mitchell, Sinsheimer.

Bi 109. Advanced Genetics Laboratory. *Units to be arranged; first term.* An advanced laboratory course in the genetics of Drosophila. Instructor: Lewis.

Bi 110. General Microbiology. *12 units (3-4-5); third term. Prerequisites: Bi 2, Bi 107 a.* A course dealing with the various aspects of microorganisms, including: cytology, antigenic properties of bacteria; nutritional requirements, with particular emphasis on autotrophic bacteria; the influence of environment; growth; spontaneous death and artificial killing; microbial variation; sexuality in microorganisms; taxonomical problems. Instructor: Dulbecco.

Bi 114. Immunology. *9 units (2-4-3); first term. Prerequisites: Bi 2, Ch 41 abc.* A course on the principles and methods of immunology and their application to various biological problems. Instructor: Owen.

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

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

Bi 117. Psychobiology I. *9 units (3-3-3); third term. Prerequisite: Bi 1.* An introduction to the biology of behavior with correlated laboratory study of the vertebrate nervous system. Instructor: Sperry.

Bi 120. Mammalian Anatomy and Histology. *9 units; second term. Prerequisite: Bi 4.* This subject is the same as Bi 20 but with reduced credit for graduate students. Graduate students majoring in Biology receive no credit for this subject. Instructors: Keighley, Van Harreveld.

Bi 125. Topics in Plant Biology. *12 units (3-3-6); first term.* Special topics in plant physiology, plant biochemistry, and plant ecology. Instructors: Bonner, Staff.

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

Bi 128. Advanced Microtechnique. *6 units (1-4-1); third term.* Theory and practice of preparing biological material for microscopic examination; histochemical methods; phase contrast microscopy; methods in electron microscopy. Instructor: Tyler.

Bi 129 ac Biophysics. *6 units (2-0-4); first and third terms.* The subject matter to be covered will be repeated approximately in a three-year cycle. During the fall term the subject matter will be organized according to various biological functions, such as replication, contractility, sensory processes, endogenous rhythms, etc. Each function will be discussed in its various biophysical aspects. During the spring term the subject matter will be organized according to methods of research, roughly as follows:

1959 Applications of spectroscopy; action spectra; biological effects of ultraviolet radiation.

1950 Methods for the analysis of cell structure; tissue ultra-structure.

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

This course together with Ch 132 constitutes an integrated program covering the physical and physico-chemical approaches to biology. Instructors: Delbrück, Sinsheimer.

B. Subjects primarily for graduate students.

Bi 201. General Biology Seminar. *1 unit; all terms.* Meets weekly for reports on current research of general biological interest by members of the Institute Staff and viisting scientists. In charge: Horowitz, Lewis, Van Harreveld.

Bi 202. Biochemistry Seminar. *1 unit; all terms.* A seminar on selected topics and on recent advances in the field. In charge: Mitchell.

Bi 204. Genetics Seminar. *1 unit; all terms.* Reports and discussion on special topics. In charge: Anderson, Lewis.

Bi 205. Experimental Embryology Seminar. *1 unit; all terms.* Reports on special topics in the field; meets twice monthly. In charge: Tyler.

Bi 206. Immunology Seminar. *1 unit; all terms.* Reports and discussions; meets twice monthly. In charge: Owen, Tyler.

Bi 207. Biophysics Seminar. *1 unit; all terms.* A seminar on the application of physical concepts to selected biological problems. Reports and discussions. Open also to graduate students in physics who contemplate minoring in Biology. Instructor: Delbrück.

Bi 214 abc. Chemistry of Bio-Organic Substances. *3 units (1-0-2); first, second, and third terms. Prerequisite: Ch 41 ab.* A series of lectures on selected topics of organic chemistry that have special interest from a biological viewpoint. Instructor: Haagen-Smit.

Bi 217. Quantitative Organic Microanalysis. *Units to be arranged; second term.* Laboratory practice in the methods of quantitative organic microanalysis required for structure determination of organic compounds. Students must obtain permission from the instructor before registering for this subject as the enrollment is necessarily limited. Instructor: Haagen-Smit.

Bi 218. Virology. *9 units (2-3-4); second term. Prerequisites: Bi 1, Bi 2, and permission of instructor.* The multiplication of viruses, the origin of their chemical constituents, and the determination and transmission of their genetic properties. Instructor: Dulbecco.

Bi 220 abc. Experimental Embryology. *6 units (2-0-4); first, second and third terms.* Lectures and discussion of the problems of embryonic development, including such topics as growth of the ovary, breeding habits of animals, fertilization, cleavage, organ formation, metamorphosis, regeneration, tissue culture, embryonic metabolism, etc. The subject may be taken for two consecutive years since the subject matter will be duplicated only in alternate years. Instructor: Tyler.

Bi 221. Experimental Embryology Laboratory. *Units to be arranged; all terms.* The work will include certain classical experiments and instruction in the methods of studying embryonic metabolism, transplantation, vital staining, cytochemistry, etc. Instructor: Tyler.

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

Bi 230. Psychobiology II. *9 units (3-3-3); third term. Prerequisite: Bi 1.* An advanced course on the neural organization of behavior including laboratory study of the mammalian central nervous system. Instructor: Sperry.

Bi 240 abc. Plant Physiology. *6 units (2-0-4); first, second, and third terms.* Reading and discussion of the problems of plant physiology. Instructor: Bonner.

Bi 241 abc. Advanced Biochemistry. *6 units (2-0-4); first, second, and third terms.* Detailed discussions of biochemical topics on an advanced level. Instructor: Bonner.

Bi 242 abc. Physical Factors and Plant Growth. *6 units (2-0-4); first, second, and third terms. Prerequisite: Bi 5.* 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. Not offered in 1958-59. 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: Van Harreveld, Wiersma.

Bi 270. Special Topics in Biology. *Units to be arranged. First, second, and third terms.* Students may register with permission of the responsible faculty member.

Bi 280-290. Biological Research. *Units to be arranged. First, second, and third terms.* Students may register for research in the following fields after consultation with those in charge: Animal physiology (280), biochemistry (281), bio-organic chemistry (282), embryology (283), genetics (284), immunology (285), marine zoology (286), plant physiology (287), biophysics (288), psychobiology (289), virology (290).

Chemistry and Chemical Engineering

UNDERGRADUATE SUBJECTS

Ch 1 abc. General Chemistry. *12 units (3-6-3); first, second, third terms.* Lectures, recitations, and laboratory exercises dealing with the general principles of chemistry. In the first and second terms the properties of substances and the fundamental laws and theories of chemistry are treated. The laboratory instruction includes gravimetric and volumetric chemical measurements as well as qualitative analysis for common elements. Texts: *General Chemistry*, Pauling; *Introductory Quantitative Chemistry*, Olson, Koch, Pimental. Instructors: Waser, other staff members, and assistants.

Ch 13 abc. Inorganic Chemistry. *6 units (2-0-4); first, second, third terms. Prerequisites: Ch 1 abc, Ch 21 ab.* The chemical and physical properties of the elements are discussed with reference to the periodic system and from the viewpoints of atomic structure and radiation effects. Such topics as coordination compounds, the liquid ammonia system, the compounds of nitrogen, the halides, and selected groups of metals are taken up in some detail. The class work is supplemented by problems which require a study of current literature. Instructor: Yost.

Ch 14. Quantitative Analysis. *10 units (2-6-2); first term.* Laboratory instruction in advanced gravimetric and volumetric chemical measurements, supplemented by lectures in which the principles involved in the laboratory work are emphasized. Text: *Introductory Qualitative Analysis*, Swift. Instructors: Anson, Swift.

Ch 16. Instrumental Analysis. *8 units (0-6-2); first term. Prerequisite: Ch 1 abc.* Laboratory practice designed to familiarize the student with special analytical apparatus and methods, used both for process and control and for research. Instructor: Sturdivant.

Ch 21 abc. Physical Chemistry. *9 units (3-0-6); first, second, third terms. Prerequisites: Ch 1 abc; Ph 2 abc; Ma 2 abc.* Conferences and recitations dealing with the general principles of chemistry from an exact, quantitative standpoint, and including studies on the pressure-volume relations of gases; on thermodynamics, on vapor-pressure, boiling point, freezing point, and osmotic pressure of solutions; on the molecular and ionic theories; on electrical transference and conduction; on chemical and phase equilibria; on thermochemistry, and the elements of thermodynamic chemistry and electrochemistry. A large number of problems are assigned to be solved by the student. Text: Mimeographed notes. Instructors: Badger, Dintzis.

Ch 24 ab. Physical Chemistry for Geologists. *10 units (4-0-6); first, second terms. Prerequisites: Ch 1 abc; Ma 2 ab; Ph 2 abc.* A discussion of selected topics in physical chemistry, adapted to the needs of Science Course students in the Geology Option. Instructor: Hughes.

Ch 26 ab. Physical Chemistry Laboratory. *8 units (0-6-2); second term; and 8 units (0-6-2) or 4 units (0-3-1), third term. Prerequisites: Ch 1 abc; Ch 21 a.* Text: Mimeographed notes. Instructors: Badger, Dintzis.

Ch 41 abc. Basic Organic Chemistry. *4 units (2-0-2); first, second, third terms. Prerequisite: Ch 1 abc.* Lectures and recitations relating to the classification of carbon compounds, development of fundamental theories, and preparation and characteristic properties of the principal classes of carbon compounds. Text: *Organic Chemistry*, Lucas. Instructors: Buchman, Roberts.

Ch 46 abc. Basic Organic Chemistry Laboratory. *6 units (1-5-0); first, second, third terms. Prerequisite: Ch 1 abc.* Laboratory exercises to accompany Ch 41 abc. The preparation and purification of carbon compounds and the study of their characteristic properties. Qualified students may pursue research work. Text: *Principles and Practice in Organic Chemistry,* Lucas and Pressman. Instructors: Richards and Assistants.

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

Ch 61 ab. Industrial Chemistry. *8 units (3-0-5); first term; 6 units (3-0-3); second term. Prerequisite: Ch 21 abc.* A study of the most important industrial chemical processes, from the point of view not only of the chemical reactions, but of the conditions and equipment necessary to carry on these reactions. Instructor: Manning.

Ch 63 abc. Chemical Engineering Thermodynamics. *9 units (3-0-6); second, third, first terms. Prerequisite: Ch 21 a.* Class exercises and problems in engineering thermodynamics studied from the point of view of the chemical engineer. Text: *Thermodynamics of One-Component Systems,* Lacey and Sage. Instructor: Lacey.

Ch 64. Introduction to Fluid Flow. *10 units (3-0-7); third term.* A study of the steady flow of fluids in situations commonly encountered by chemical engineers. Estimation of pressure and frictional losses for flow of fluids in pipes and other conduits, and measurement of pressure and flow rates. Incompressible and compressible fluids, and both laminar and turbulent flow are considered. Text: *Unit Operations of Chemical Engineering,* McCabe and Smith. Instructor: Longwell.

Ch 80. Chemical Research. *Offered to B.S. candidates in Chemistry and Applied Chemistry.*

Ch 90. Oral Presentation. *2 units (1-0-1); third term.* Training in the technique of oral presentation of chemical topics. Practice in the effective organization and delivery of reports before groups. Instructors: Corey, Thomas.

ADVANCED SUBJECTS

Ch 113 abc. Inorganic Chemistry. *4 units (2-0-2); first, second, third terms.* Selected groups of inorganic compounds will be considered from modern physicochemical viewpoints; thus with reference to their physical properties, their thermodynamic constants (their heat-contents, free-energies, and entropies), their rates of conversion into one another (including effects of catalysis and energy radiations), and their molecular structure and valence relations. Instructor: Yost.

Ch 117. Electroanalytical Chemistry. *4 units (2-0-2); third term. Prerequisite: Ch 21 abc.* The theory and practice of selected electroanalytical techniques will be presented. Topics to be covered include potentiometric titrations, conductometric titrations, polarography, amperometry, coulometric analysis, chronopotentiometry, and other electrochemical methods. Text: *Electroanalytical Chemistry,* Lingane. Instructor: Anson.

Ch 118. Electroanalytical Chemistry Laboratory. *6 units (0-6-0); third term. Prerequisite: Ch 21 abc.* Laboratory experiments involving the use of electroanalytical instruments. Instructor: Anson.

Ch 124 ab. Physical Chemistry for Geologists. *6 units (4-0-2); first, second terms.* This course is the same as Ch 24. Instructor: Hughes.

Ch 125 abc. Advanced Physical Chemistry. *9 units (3-0-6); first, second, third terms. Prerequisite: Ch 21 abc or the equivalent.* Among the topics included in this course are a review of thermodynamic principles, the elements of statistical mechanics, the relation between statistical mechanics and thermodynamics and the calculation of thermodynamic quantities from information obtained by spectroscopic and diffraction methods of determining the structure of molecules, the elementary principles of quantum theory, the electronic structure of atoms and molecules, paramagnetic resonance and nuclear magnetic resonance, experimental methods of determining the structure of molecules and crystals, and the relation of the properties of substances to their molecular structure. Instructor: McConnell.

Ch 127 ab. Radioactivity and Isotopes. *6 units (2-0-4); second, third terms. Prerequisite: AM 102 a or equivalent.* The fundamental particles and isotopes. Nuclear structure. Natural and artificial radioactivity. Instrumentation in nuclear studies. Techniques of radiochemistry. The applications of stable and radioactive isotopes to chemical, biological, and geological studies. Text: *Nuclear and Radiochemistry,* Friedlander and Kennedy. Instructors: Brown, McKinney.

Ch 129. Surface and Colloid Chemistry. *8 units (3-0-5); third term. Prerequisite: Ch 21 abc or equivalent.* Class room 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); second 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 b. Biophysical Chemistry. *6 units (2-0-4); second term.* This course considers the physical chemistry of macromolecules of biological interest. Together with Bi 129 ac it constitutes an integrated program covering the physical and physicochemical approaches to biology. The subject matter to be covered will be repeated approximately in a three-year cycle. A discussion of the principles and methods employed in the determination of size, shape, charge, and thermodynamic properties of biological macromolecules. The methods considered are acid-base titrations, electrophoresis, sedimentation, diffusion, viscosity, osmotic pressure, and light scattering. The use of instruments will be demonstrated. This will be covered in two successive years beginning in 1958-59. During the third year the physical chemistry of membrane phenomena will be discussed. Instructors: Vinograd, Davidson.

Ch 144 abc. Advanced Organic Chemistry. *9 units (3-0-6); first, second, third terms.* A survey of synthetic and theoretical organic chemistry at an advanced level with emphasis on stereochemistry. Applications of fundamental principles to the chemistry of naturally occurring substances. Instructor: Hammond.

Ch 148 abc. Characteristics of Organic Compounds. *4 units (2-0-2); first, second, third terms. Prerequisites: Ch 41 abc, Ch 46 abc.* Lectures and recitations emphasizing the analytical methods of organic chemistry. Consideration of the general problem of the characterization of organic compounds by qualitative and quantitative procedures. Instructor: Niemann.

Ch 149 abc. Laboratory in Characterization of Organic Compounds. *6 units (0-6-0); first, second, third terms. Prerequisites: Ch 41 abc, Ch 46 abc, and consent of instructor.* Laboratory exercises to accompany Ch 148. The isolation, purification, and identification of organic compounds with special reference to the manipulation of milligram and decigram quantities. Qualified students may pursue research work. Instructors: Niemann and Assistant.

Ch 163 abc. Chemical Engineering Thermodynamics. *6 units; first term (Ch 163 c), second, third terms (Ch 163 ab). Prerequisite: Ch 21 abc or Me 15 abc.* This subject is the same as Ch 63 abc for third- and fourth-year students, but with reduced credit for graduate students. No graduate credit is given for this subject to students in chemistry or chemical engineering.

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

Ch 167 abc. Chemical Engineering Laboratory. *15 units (0-15-0); first, second, third terms. Prerequisites: Ch 21 abc, Ch 61 ab, Ch 63 abc.* A laboratory course providing fundamental training in the methods and techniques of engineering measurements and in research encountered by the chemical engineer. Instructors: Sage, Reamer.

Ch 168 ab. Mechanics of Fluid Flow. *6 units (2-0-4); second, third terms. Prerequisite: Ch 64 or equivalent.* Study of the flow of compressible and incompressible fluids in conduits with emphasis on estimation of velocity and pressure distribution. The Navier-Stokes equation, turbulence, boundary-layer theory, flow in porous media, and non-Newtonian fluids are also treated. Instructor: Longwell.

Ch 169. Advanced Industrial Chemistry. *6 units (2-0-4); first term. Prerequisites: Ch 61 ab, Ch 63 abc.* 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. Chemical Research. *Offered to M.S. and Ch.E. candidates in Chemistry and Chemical Engineering.*

Ch 190. Oral Presentation. *2 units (1-0-1); first term.* Training in the technique of oral presentation of chemical topics; graduate teaching assistants in chemistry are required to take this course, unless excused for demonstrated proficiency. Instructors: Thomas, Waser.

Ch 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. Not offered in 1958-59. 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 1958-59. 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. Instructor: Mazo.

Ch 226 abc. Introduction to Quantum Mechanics, with Chemical Applications. *9 units (3-0-6); first, second, third terms.* A review of the Lagrangian and Hamiltonian mechanics and of the old quantum theory is first given, followed by the discussion of the development and significance of the new quantum mechanics and the thorough treatment of the Schrödinger wave 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 1957-58. Text: *Introduction to Quantum Mechanics, with Applications to Chemistry,* Pauling and Wilson.

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 1957-58. 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.

Ch 229 ab. X-Ray Diffraction Methods. *6 units (2-0-4); second, third terms. Prerequisite: Ch 227 abc or equivalent.* An advanced discussion of the techniques of structure analysis by x-ray diffraction. Offered in 1958-59. Instructors: Hughes, Sturdivant.

Ch 233 ab. The Metallic State. *6 units (2-0-4); first, second terms.* The physical, electrical, and magnetic as well as the structural, chemical, 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 poly-atomic 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 1958-59. 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. Not offered in 1958-59. Instructor: Davidson.

Ch 242 abc. Chemistry of Natural Products. *4 units (2-0-2); first, second, third terms. Prerequisite: Ch 41 abc.* The chemistry of antibiotics, alkaloids, pigments, steroids, terpenes, etc. is used as a vehicle for a discussion of the general principles of structural elucidation, total synthesis, and biogenesis of natural products. The course is given as a continuing cycle such that each of the major areas is presented once every three years. Instructor: Richards.

Ch 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 1958-59. 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 1959-60. Instructor: Roberts.

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. Instructor: Niemann.

Ch 254 abc. The Chemistry of Amino Acids and Proteins. *3 units (1-0-2); first, second, third terms. Prerequisites: Ch 41 abc, Ch 46 abc.* A consideration of the physical and chemical properties of the amino acids, peptides, and proteins. Given every third year. Offered in 1958-59. Instructor: Niemann.

Ch 255 abc. Chemistry of Bio-organic Substances. *3 units (1-0-2); first, second, third terms.* Lectures on selected subjects of organic chemistry such as alkaloids, essential oils, and other major groups of natural products. Instructor: Haagen-Smit.

Ch 258. Immunochemistry. *8 units (2-3-3); second term. Prerequisite: Ch 129 and Bi 114, or consent of Instructor.* Lectures cover the following material: (1) the fundamental physical and biochemical factors of importance in immunochemistry; (2) the nature of antigens; (3) the nature of antibodies; (4) the physical and biological manifestations of antigen-antibody reactions; (5) the basis of immunological specificity; and (6) practical aspects of immunology. The laboratory consists of a variety of experiments designed essentially to familiarize the student with the preparation of antigens and antibodies and the nature of antigen-antibody interactions. Particular emphasis is given to quantitative aspects of the precipitin reaction and its significance. Texts: *Principles of Immunology*, Cushing and Campbell; *Experimental Immunochemistry*, Kabat and Mayer; *Fundamentals of Immunology*, Boyd. Instructor: Campbell.

Ch 262 abc. Thermodynamics of Multi-Component Systems. *8 units (2-0-6); first, second, third terms. Prerequisites: Ch 166 abc, AM 15 ab, Ch 63 abc 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 1959-60. Instructor: Sage.

Ch 266 abc. Applied Chemical Kinetics of Homogeneous and Heterogeneous Reactions. *8 units (2-0-6); first, second, third terms. Prerequisite: Ch 166 abc.* Kinetics of various reactions. Primary emphasis will be placed upon predicting the course of chemical reaction under the conditions encountered in processing operations. The third term will be concerned with the application of high-speed digital computation to reaction-rate problems. Given in alternate years. Offered in 1958-59. Instructor: Corcoran.

Ch 280. Chemical Research. *Offered to Ph.D. candidates in Chemistry and Chemical Engineering.* The main lines of research now in progress are: In physical and inorganic chemistry—

Free energies, equilibria, and electrode potentials of reactions.
Distribution of chemical compounds between immiscible phases.
Studies of inorganic analytical methods.
Kinetics of chemical reactions including photochemical reactions.
Determination of the structure of crystals and gas molecules by the diffraction of X-rays and electrons.
Application of quantum mechanics to chemical problems.
Study of molecular structure and of chemical problems by spectroscopic methods.
Nature of the metallic bond and the structure of metals and intermetallic compounds.
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.
Isolation of alkaloids and determination of their structure.
Synthesis of substances related to cyclobutadiene.
Chemistry of amino acids and peptides.
Chemistry of small-ring carbon compounds.
Application of isotopic tracer and nuclear magnetic resonance techniques to problems in organic chemistry.
Relation of structure to reactivity of organic compounds.
Organic chemistry of metal chelates.
Solution photochemistry.
Reactions of free radicals in solutions.

In immunochemistry and other fields of application of chemistry to biological and medical problems—

Study of the mechanism of antigen-antibody reactions and the structure of antibodies.
Functional significance of antibodies.
Chemical and physical properties of blood.
Investigation of plasma substitutes.
Isolation and characterization of cellular antigens.
Studies on the enzymatic cleavage and formation of amide bonds.
Chemical analysis of proteins and determination of the order of amino-acid residues in polypeptide chains.
Crystal structure of amino acids, peptides, and proteins.
Investigation of fluorescent compounds in plants and animals, including microorganisms.
Study of plant hormones and related substances of physiological importance.
Investigation of mammalian and bacterial polysaccharides including the blood-group specific substances.
Nature of sickle cell anemia and other hemolytic diseases.
Chemistry in relation to mental disease.

In applied chemistry and chemical engineering—

Influence of turbulence upon heat transfer in fluids.
Influence of turbulence on the transfer of material through fluids.
Phase and thermodynamic behavior of hydrocarbons and other fluids.
Studies of non-equilibrium behavior of fluid systems at elevated pressure.
Reaction kinetics in flow and non-flow systems.
Application of mathematics to complex chemical engineering problems.

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 Conference. *2 units (1-0-1); first, second, third terms.* Oral presentations of industrial chemistry and chemical engineering problems of current interest. Not offered in 1958-59.

Civil Engineering

UNDERGRADUATE SUBJECTS

CE 1. Surveying. *12 units (2-6-4); third term.* A study of the elementary operations employed in making surveys for engineering work, including the use, care, and adjustment of instruments, linear measurements, angle measurements, note keeping, stadia and plane table surveys, calculation and balancing of traverses, topographic mapping and field methods. Triangulation, base line measurements, determination of latitude and a true meridian by sun and circumpolar star observations, stream gauging. Route location of highways. Instructor: Long.

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

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

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

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

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

ADVANCED SUBJECTS

CE 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. Instructors: Converse, Long.

CE 112. Reinforced Concrete. *9 units (3-0-6).* This subject is the same as CE 12 but with reduced credit for graduate students who have had no previous course work in this subject.

CE 115 a. Soil Mechanics. *9 units (2-3-4); first term. Prerequisites: AM 1, AM 4 ab.* 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. Instructors: Converse, Long.

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. Instructors: Converse, Long.

CE 120 a. Statically Indeterminate Structures. *12 units (3-3-6); first term. Prerequisites: CE 10 abc, CE 12.* A study of the analysis of rigid frames and indeterminate trusses with particular emphasis on the use of moment distribution in the solution of indeterminate frames. Instructors: Martel, McCormick.

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

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

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

CE 125. Water Supply, Utilization, and Drainage. *9 units (3-0-6); second term. Prerequisites: Hy 2 ab, CE 20, CE 155.* 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); third term. Prerequisite: CE 12.* Theory of design and methods of construction of masonry structures; foundations, dams, retaining walls, and arches. Instructors: Martel, McCormick.

CE 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); third term. Prerequisite: CE 155.* The application of hydraulics and hydrology to the development of hydroelectic power. Estimates of water power available from streamflow records. Impulse and reaction turbines, penstocks, draft tubes, governors and surge tanks. Water hammer and cavitation problems. Design of power plant at a particular site. Instructor: Ingersoll.

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 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.* An introductory study of the occurrence and movement of water on the earth's surface, including such topics as precipitation, evaporation, transpiration, infiltration, ground water, runoff, and flood flows; applications to various phases of hydraulic engineering such as water supply, irrigation, water power, and flood control; the use of statistical methods in analyzing hydrologic data. Instructor: Brooks.

CE 156. Industrial Wastes. *9 units (3-0-6); third term. Prerequisite: CE 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 160. Advanced Hydrology. *6 or more units as arranged; any term. Prerequisite: CE 155.* Advanced studies of various phases of hydrology. The course content will vary depending on needs and interests of students enrolling in the course. Instructor: Brooks.

CE 300. Civil Engineering Research.

Computers and Machine Methods of Computation

The following courses in computers and their application to applied mathematics and engineering analysis are offered under the various options indicated.

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

EE 180. Digital Computer Design. *9 units (3-3-3); first term.* This course is concerned with the basic principles of logical design and instrumentation of digital computers. Modern switching theory including Boolean algebra and other forms of symbolic logic; pulse circuitry; magnetic drum, electrostatic, magnetic core and ferroelectric principles as applied to switching and data storage. The basic design philosophies of stored and externally programmed matrices will be given. The design and operating characteristics of a magnetic drum, serial-stored program binary computer will be treated in detail. Text: Course notes. Instructor: McCann.

EE 181 ab. Principles of Analog Computation. *12 units (3-3-6); second, third terms. Prerequisite: AM 180.* General survey of the basic principles of electric analog computing techniques. Development and application of electronic differential analyzer and direct analogy principles. Synthesis of passive analogies—lumped parameter systems. Synthesis of passive analogies—distributed systems. Synthesis of active circuit analogies. Applications to solid mechanics, aeroelasticity, heat transfer, fluid mechanics, servomechanisms. Text: Course notes. Instructor: McCann.

EE 280 abc. Advanced Course in Machine Computing Methods for Engineering Analysis. *9 units (2-3-4); first, second, third terms.* The application of analog and digital methods to problems in engineering analysis. Specific system and design analysis problems in such fields as electricity and magnetism, solid mechanics, fluid mechanics, aeroelasticity and thermal conductivity will be solved by machine computing techniques. Course open only to advanced graduate students and by permission of instructor. Instructors: Franklin, McCann, Wilts.

AM 180. Matrix Algebra. *9 units (3-0-6); first term.* Theory of matrices from the standpoint of mathematical physics and as used in the formulation of problems on high speed analog and digital computers. Canonical forms are developed for self-adjoint and for general matrices. Text: *Theory of Matrices,* Perlis. Instructor: Franklin.

Ma 105 ab. Introduction to Numerical Analysis. *11 units (3-2-6); second, third terms. Prerequisites: Ma 108 or AM 15, and Ma 5 or AM 180, or equivalent, and familiarity with coding procedures by the middle of the first quarter of the course.* Topics will include: interpolation and quadrature; numerical solution of algebraic and transcendental equations; matrix inversion and determination of eigenvalues; numerical solution of ordinary differential equations; numerical solution of elliptic, parabolic, and hyperbolic partial differential equations. Instructor: Franklin.

Ma 107. Advanced Topics in Numerical Analysis. *9 units (3-0-6); first, second, third terms. Prerequisites: Ma 105 or equivalent.* Discussion at an advanced level of areas of current interest in numerical analysis, and in related mathematics, such as matrix inversion and decomposition, ordinary differential equations, partial differential equations and integral equations, discrete problems, linear programming and game theory, approximation theory, applications of functional analysis, theory of machines, estimates of eigenvalues of matrices. Each quarter will be treated as a separate unit. Where appropriate, accompanying laboratory periods will be arranged as a separate reading course. Instructor: Todd (in charge) and other members of staff.

Economics

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

Ec 2 ab. General Economics and Economic Problems. *9 units (3-0-6).* A course in economic life and institutions, the principles underlying them, and the major problem they present. Subjects studied include production, exchange, distribution, money and banking, the economic activities and policies of government, and international trade. Instructor: Brockie.

Ec 4 ab. Economic Principles and Problems. *6 units (3-0-3); first term, and either second or third term.* A course in economic life, institutions, and problems, stressing the national income approach. Subjects studied parallel those of Ec 2 ab, with such difference in emphasis as is necessary to make this shorter course complete in itself. Instructor: Sweezy.

Ec 13. Reading in Economics. *Units to be determined for the individual by the department.*

Ec 18. Industrial Organization. *7 units (3-0-4); third term.* After outlining the historical background of industry with the economic changes involved, this subject surveys the major problems facing management, especially in factory operations. The principal topics included are organization, plant layout, costs and budgets, methods, time and motion study, production control, labor relations, and wage scales. Instructors: Gray, Wermel.

Ec 25. Engineering Law. *7 units (3-0-4); third term.* The law of business, with particular emphasis on the legal rights and obligations pertaining most directly to the engineering profession. Contracts and specifications, agency, property, mechanics' liens, workmen's compensation, and the principles of legal liability are studied. Instructor: Hayden.

Ec 48. Introduction to Industrial Relations.* *9 units (3-0-6). Senior Elective.* This course stresses the personnel and industrial relations functions and responsibilities of supervisors and executives. The history, organization, and activities of unions and the provisions of current labor legislation are included. The relationships of a supervisor or executive with his employees, his associates, and his superiors are analyzed, and the services which he may receive from the personnel department are examined. The course also discusses the use of basic tools of supervision. Instructors: Gordon, Gray.

ADVANCED SUBJECTS

Ec 100 abc. Business Economics. *10 units (4-0-6); first, second, third terms. Open to graduate students.* This course endeavors to bridge the gap between engineering and business, especially industry. It is intended for two groups of technically trained students: 1) those who wish sooner or later, to take advantage of opportunities in industry beyond their strict technical fields, and 2) those who will be engaged in teaching and in scientific research, but who wish to get an understanding of industry in both its technical and philosophical aspects. The broad

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

assumptions in the course are that technical training is an excellent approach to positions of general responsibility in business and industry, and that technically trained men going into industry can make significant contributions to the improved functioning of the economy. The principal divisions of the subject matter of the courses are: 1) business organization, 2) industrial promotion and finance, 3) factory management, 4) industrial sales, and 5) business economic topics, especially the business cycle. This treatment provides a description of the industrial economy about us and of the latest management techniques. The points of most frequent difficulty are given special study. The case method of instruction is used extensively in the course. Instructor: Gilbert.

Ec 106 abc. Business Economics (Seminar). *Units by arrangement; first, second, third terms. Open to graduate students.* This seminar is intended to assist the occasional graduate student who wishes to do special work in some part of the field of business economics or industrial relations. Special permission to register for this course must be secured from the instructors. Instructors: Gilbert, Gray, Wermel.

Ec 110. Industrial Relations. *9 units (3-0-6); first term. Not open to students who have taken Ec 48, Introduction to Industrial Relations.* An introductory course dealing with basic problems of employer-employee relationships and covering the internal organization of an enterprise, the organization and functions of unions, and the techniques of personnel administration with emphasis on the problems of setting wage rates. Instructor: Gray.

Ec 111. Business Cycles and Governmental Policy. *9 units (3-0-6); second term.* A study of the nature, causes, and possible control of economic fluctuations with special emphasis on the interrelationship of business cycles and such fiscal matters as national debt control, national budgetary control, and the maintenance of high levels of employment, production, and purchasing power. The course also integrates the international problems of war, reconstruction, trade, and investment with the analysis of business cycles and internal fiscal policies in order to provide a unified theory of national and international equilibrium. May be taken as a senior elective. Instructor: Brockie.

Ec 112. Modern Schools of Economic Thought. *9 units (3-0-6); third term.* A study of economic doctrine in transition, with particular emphasis on the American contribution. Against a background of Marshall and Keynes, a critical examination will be made of the institutional, collective, quantitative, social, experimental, and administrative schools of economics.

Ec 124. Economic Problems of Underdeveloped Areas.* *9 units (3-0-6); third term. Senior elective.* An examination of economic conditions in low income countries. Modern techniques of promoting development are studied, including international assistance programs and national economic planning. Instructor: Sweezy.

Ec 126 abc. Economics Analysis and Policy* (Seminar). *9 units (3-0-6); first, second, third term. Senior elective.* Open to students who have taken Ec 2 ab or Ec 4 ab and to other qualified students with the consent of the instructor. Instructor: Sweezy.

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

ELECTRICAL ENGINEERING

ADVANCED SUBJECTS

EE 1 abc. Basic Electrical Engineering. *9 units (3-0-6); first, second, third terms. Prerequisites: Ma 2 abc; Ph 2 abc.* An introductory course in circuit analysis, energy conversion, electromechanical devices, vacuum and solid state devices and circuits. Instructors: MacMillan, Martel, McCann, Middlebrook.

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

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

EE 15 abc. Electromagnetism. *9 units (3-0-6); first, second terms; 6 units (2-0-4); third term. Prerequisites: Ph 2 abc; Ma 2 abc; AM 15.* A course in theoretical electricity and magnetism, primarily for electrical engineering students. Topics covered include electrostatics, magnetostatics, Maxwell's equations, wave-guides, cavity resonators, and antennas. EE 15 c will include topics on propagation in the ionosphere, propagation over the earth's surface, and modern microwave tubes. Text: Course notes. Instructor: Langmuir.

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

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

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

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

ADVANCED SUBJECTS

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

EE 103 abc. Electric Circuit Theory. *9 units (3-0-6) first and second terms; 6 units (2-0-4) third term. Prerequisites: EE 1 abc; EE 2 ab; AM 116.* A course of study relating to general methods of steady state and transient analysis of linear electric circuits. Application of transform methods. Elementary principles of circuit synthesis, maximally flat and Chebyshev approximations. Filter theory, low-pass, band-pass. Feedback amplifiers and oscillators. Classical transmission-line theory. Instructors: Mason, Wilts.

EE 104. Electronic Systems. *9 units (3-0-6); first term. Prerequisites: EE 1 abc; EE 2 ab; AM 116.* A course of study in large-signal and nonlinear electronics and communication systems. Class-C amplifiers, modulators, mixers, detectors, limiters, and discriminators. AM and FM systems. Frequency spectra. Text: Course notes; *Frequency Analysis Modulation and Noise,* Goldman. Instructor: Macmillan.

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

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

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

EE 124. Specifications and Design of Electrical Machinery. *Units to be arranged. Prerequisites: EE 7, and preceding subjects.* Preparation of specifications and design calculations for alternating and direct current machinery. Text: *Electrical Machine Design,* Gray.

EE 132 abc. Network Synthesis. *9 units (3-0-6); first, second, third terms. Prerequisite: EE 103 ab.* Mathematical properties and limitations of network functions, Brune, Darlington, and other synthesis techniques. The approximation problem in time and frequency domains.

EE 140 abc. Communication Theory. *9 units (3-0-6); first, second, third terms. Prerequisites: EE 103 abc; EE 104.* Modern basis of the theory of communication of information. Review of probability and statistical methods. Noise, its description, properties and effects; random time series; autocorrelation and cross-correlation functions; spectral density; physical origins and mathematical models of noise; effects of linear and non-linear circuits. Information theory; entropy of a source and channel capacity; equivocation and redundancy; coding theorems; error detecting and correcting codes; continuous information; modulation methods—AM, FM, PM, PCM. Optimum linear circuits (Wiener filters) for smoothing or prediction of statistical signals in noise. Text: Course notes. Instructor: H. Martel.

EE 150 abc. Electromagnetic Fields. *9 units (3-0-6); first, second, third terms. Prerequisites: EE 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. *6 units (2-0-4); first, second, and third terms. Prerequisite: EE 1 abc.* Physical electronics and introduction to theory of solid state. Fundamental theory of electron tubes and applications to communication and control circuits. Instructor: Langmuir.

EE 162 abc. Physical Electronics. *6 units (2-0-4); first, second, third terms. Prerequisites: EE 1 abc.* A course in the physical principles of electron devices and an introduction to atomic and molecular physics. Motion of charged particles in electric and magnetic fields and applications. Electronic phenomena in metals; conduction, emission, contact potential. Electrical conduction in gases; breakdown, plasmas, gas tubes. Electronic phenomena in semiconductors; transistors. Instructor: Gould.

EE 164 abc. Microwave Electronics and Circuits. *9 units (3-0-6); first, second, third terms. Prerequisites: EE 15 ab and EE 160 abc or EE 162 abc.* Principles of the interaction of electron beams and microwave electromagnetic fields. Generation and focusing of high current electron beams with electric and magnetic fields, electron optics. The Llewellyn Peterson equations and transit time effects in diodes and triodes. Velocity modulation, space charge wave propagation, and traveling wave interaction with electron beams with application to microwave amplifiers and oscillators. The electromagnetic theory of slow wave circuits. Noise in electron beams and microwave amplifiers. Instructor: Field.

EE 165 a. Ultra High Frequency Laboratory. *6 units (0-3-3); third term. Prerequisites: EE 15; EE 150 and EE 164 or may be taken concurrently.* Covering experiments on microwave generation, bridges, precise impedance measurement, nodal shift methods, and the properties of microwave circuit elements such as matched T's, directional couplers and antennas. Instructor: Gould.

EE 170 abc. Feedback Control Systems. *9 units (3-0-6); first term; 12 units (3-3-6); second and third terms. Prerequisites: EE 102, EE 103.* A study of automatic feedback control systems. Basic theory and methods of analysis and synthesis; root locus methods, the Nyquist criterion, and analog computer techniques. Multiple loop systems. Non-linear systems with emphasis on phase plane and describing function techniques. Sampled-data systems. The laboratory experiments are designed to acquaint the student with characteristics of practical components, but emphasis is placed on a correlation of observed response with predictions based on the various theoretical methods. Instructor: Wilts.

EE 180. Digital Computer Design. *9 units (3-3-3); first term.* This course is concerned with the basic principles of logical design and instrumentation of digital computers. Modern switching theory including Boolean algebra and other forms of symbolic logic; pulse circuitry; magnetic drum, electrostatic, magnetic core and ferroelectric principles as applied to switching and data storage. The basic design philosophies of stored and externally programmed matrices will be given. The design and operating characteristics of a magnetic drum, serial-stored program binary computer will be treated in detail. Text: Course notes. Instructor: McCann.

EE 181 ab. Principles of Analog Computation. *12 units (3-3-6); second, third terms. Prerequisite: AM 180.* General survey of the basic principles of electric analog computing techniques. Development and application of electronic differential analyzer and direct analogy principles. Synthesis of passive analogies–lumped parameter systems. Synthesis of passive analogies–distributed systems. Synthesis of active circuit analogies. Applications to solid mechanics, aeroelasticity, heat transfer, fluid mechanics, servomechanisms. Text: Course notes. Instructor: McCann.

EE 190 abc. Transistor Electronics.

EE 190 a. *9 units (3-0-6); first term.* Crystal structure; simplified solution of the wave equation. Insulators, conductors, and semiconductors. Motion of electrons and holes in crystals. Fermi-Dirac distribution function, mobile carrier densities and Fermi level. Drift and diffusion current flow; the continuity equation. Detailed treatment of boundary values.

EE 190 b. *9 units (3-0-6); second term.* The p-n junction rectifier characteristic. The p-n-p transistor under d-c and a-c applied signals; d-c operating characteristics and simple low-frequency equivalent circuit. Capacitance and feedback effects; Laplace transform solution of the continuity equation; wide-range approximations and equivalent circuits.

EE 190 c. *9 units (3-0-6); second term.* Transistor bias methods and use in D. C. low-frequency and high-frequency amplifiers; power amplifiers; oscillators, switching circuits; regulators. Associated analysis, synthesis, and problems. Text: *An Introduction to Junction Transistor Theory, Middlebrook.* Instructor: Mead.

EE 200. Advanced Work in Electrical Engineering. Special problems relating to electrical engineering will be arranged to meet the needs of students wishing to do advanced work. The Institute is equipped to an unusual degree for the following lines of work: electronic devices and their application, physical electronics, microwave tubes, transistor applications, electromechanical devices, control systems, communications and information theory, electromagnetic wave propagation and antennas, analog and digital computers, engineering analysis requiring large scale computing techniques.

EE 220. Research Seminar in Electrical Engineering. *2 units.* Meets once a week for discussion of work appearing in the literature and in industry. All advanced students in electrical engineering and members of the electrical engineering staff are expected to take part. In charge: Electrical Engineering Faculty.

EE 240 abc. Advanced Communication Theory. *9 units (3-0-6). Prerequisite: EE 140 abc.* A continuation of EE 140 with a more detailed treatment of stochastic processes, random time series, information theory and optimum linear filters. Emphasis will be on recent developments in the field. Course content will vary. Typical subjects are: time varying systems and signals, finite time delay coding, two-way channels, matched filters, finite time and finite order filters. Instructor: H. Martel.

EE 250 abc. Advanced Electromagnetic Field Theory. *9 units (3-0-6); first, second, third terms.* This course covers the application of Maxwell's equations to problems involving antennas, waveguides, cavity resonators, and diffraction. It includes the solution of problems by the classical methods of retarded potentials and orthogonal expansions and lectures in the modern techniques of Schwinger that employ the calculus of variations and integral equations. Text: *Static and Dynamic Electricity,* Smythe; *Randwertprobleme der Mikrowellenphysik,* Borgnis and Papas. Instructors: Smythe, Papas.

EE 260 abc. Topics in Physical Electronics. *4 units (1-0-3); first, second, third terms. Prerequisite: EE 164 abc.* Recent developments in the field of microwave interaction with electron beams and atoms in gases and solids. Content will vary from year to year. Typical topics are: nonlinear theory of traveling wave interaction, MASER oscillators and amplifiers, noise in electron beams, plasma oscillations in electrical discharges. Instructor: Gould.

EE 280 abc. Advanced Course in Machine Computing Methods for Engineering Analysis. *9 units (2-3-4); first, second, third terms.* The application of analog and digital methods to problems in engineering analysis. Specific system and design analysis problems in such fields as electricity and magnetism, solid mechanics, fluid mechanics, aeroelasticity and thermal conductivity will be solved by both analog and digital methods with the comparison of various machine computing techniques. Course open only to advanced graduate students and by permission of instructor. Instructors: Franklin, McCann, Wilts.

EE 281. Seminar in Electronic Computers. *4 units (1-0-3); first, second, third terms.* Special topics on new developments in digital and analog computers and their applications to engineering analysis. Instructors: McCann, Wilts.

EE 290. Topics in Solid State Devices and Circuits. *Prerequisite: EE 190 ab.* Advanced seminar in solid state devices and circuits. A term paper will be required. Instructors: Middlebrook, Mead.

ENGINEERING GRAPHICS

Gr 1. Basic Graphics. *3 units (0-3-0); first term.* The study of geometrical forms and their representation by means of freehand orthographic and perspective drawings. Instruction includes the techniques of freehand pencil rendering, lettering forms, analysis of the elements of three-dimensional shapes and their proportional relationships, introduction to the principles of orthographic and perspective projection, principal views, visualization, shading techniques, sections and conventions. Problems are given involving the drawing of basic geometrical forms, machine parts and scientific apparatus as well as elementary space solutions of straight lines and planes. Emphasis is placed on a constructive approach, careful observation and accuracy. Instructors: Welch, Wilcox.

Gr 5. Descriptive Geometry. *6 units (0-6-0); third term. Prerequisite: Gr 1.* The course is primarily for geology students and is designed to supplement the study of shape description as given in Gr 1 and to present a graphical means of solving the more difficult three-dimensional problems. The student reviews geometrical relationships of straight lines and planes, then advances to curved lines, single and double curved surfaces, warped surfaces and intersections. Methods of combining the analytical solution of the simpler problems with the graphical solution are discussed and applied. Emphasis is placed throughout the course on practical problems in mining and earth structures and on the development of an ability to visualize in three dimensions. Instructors: Tyson, Wilcox.

Gr 7. Advanced Graphics. *Maximum of 6 units. Elective; any term. Prerequisites: Gr 1; Me 1.* Further study in the application of graphics to the solution of engineering problems and in the basic elements of design for production. Emphasis is placed on one of the following subjects to be selected as the need requires: analysis of the more complex machine mechanisms; basic elements of product design; 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 209.*

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, poems. Instructors: Bowerman, Clark, Eagleson, Langston, Mayhew, Miller, D. Smith, Stanton.

En 6 ab. Literary Masterpieces. *8 units (3-0-5); second, third terms. Prerequisite: En 1 a and permission of the instructor.* A two-term version of En 7 abc for specially selected freshmen. Instructors: H. Smith, Clark.

En 7 abc. Introduction to Literature. *8 units (3-0-5); first, second, third terms. Prerequisite: En 1 abc.* This course is designed to give the student a discriminating acquaintance with a selected group of principal literary works. The reading for the first term is concentrated on Shakespeare; for the second and third terms, on representative English authors. Instructors: Bowerman, Clark, Eagleson, Eaton, Jones, Langston, Mayhew, Miller, Piper, D. Smith, Stanton.

En 8. Contemporary English and European Literature.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A survey of English and Continental literature from 1859 to the present time. Emphasis is placed on the influence of science, particularly biological and psychological theory, on content and techniques. Instructor: Eagleson.

En 9. American Literature.* *9 units (3-0-6). Senior Elective. Prerequisite: En 7.* A study of major literary figures in the United States from Whitman and Mark Twain to those of the present time. The larger part of the course is concerned with contemporary writers. An emphasis is placed on national characteristics and trends as reflected in novel and short story, biography, poetry, and drama. Instructor: 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. Instructor: Stanton.

En 11. Literature of the Bible.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A study of the Old and New Testaments, and the Apocrypha, exclusively from the point of view of literary interest. The history of the English Bible is reviewed, and attention is brought to new translations. Opportunity is offered for reading modern fiction, poetry, and drama dealing with Biblical subjects. Instructor: H. Smith.

*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).* A study of the principles of argumentation; systematic practice in debating; preparation for intercollegiate debates. Instructor: Thomas.

En 13. Reading in English and History. *Units to be determined for the individual by the department.* Collateral reading in literature and related subjects, done in connection with regular courses in English or history, or independently of any course, but under the direction of members of the department.

En 14. Special Composition. *2 units (1-0-1).* This subject may be prescribed for any student whose work in composition, general or technical is unsatisfactory.

En 15 abc. Journalism. *3 units (1-0-2); first, second, third terms.* A study of the elementary principles of newspaper writing and editing, with special attention to student publications at the Institute. Instructor: Hutchings.

En 16. Spelling. *No credit.* This subject may be prescribed for any student whose spelling is unsatisfactory.

En 17. Technical Report Writing.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* Practice in writing reports and articles in engineering, science, or business administration. The course ncludes some study of current techncal and scientific periodicals. The major project is the preparation of a full-length report. Instructor: Piper.

En 18. Modern Poetry.* *9 units (3-0-6). Senior elective. Prerequisite: En 7.* A study of three or four major poets of the twentieth century, such as Yeats, T. S. Eliot and W. H. Auden. Modern attitudes toward the world and the problem of Belief. Some consideration of recent theories of poetry as knowledge. 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 n consultation with a member of the staff. Critical essays on reading will be required.

ADVANCED SUBJECTS

En 100 abc. Seminar in Literature. *9 units (2-0-7); first, second, third terms.* A survey of recent critical methods, from I. A. Richards to the present time, and the application of these methods to the work of such major writers as Joyce, Yeats, Eliot and Mann. The influence of modern psychology and anthropology on creative writing and criticism. Instructor: H. Smith.

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

French

(See under Languages)

Geological Sciences

UNDERGRADUATE SUBJECTS

Ge 1. Physical Geology. *9 units (4-2-3); first term. Prerequisites: Ch 1 abc, Ph 1 abc.* An introduction to the basic principles of the earth sciences. Geology, geochemistry and geophysics in relation to materials and processes acting upon and within the earth's crust. Consideration is given to: rocks and minerals, structure and deformation of the earth's crust, earthquakes, volcanism, and the work of wind, running water, ground water, the oceans and glaciers upon the earth's surface with the aim of stimulating the student's interest in the geological aspects of the environment in which he will spend his life. Text: *Principles of Geology,* Gilluly, Waters, and Woodford. Instructors: Allen, Sharp, and Teaching Fellows.

Ge 2. Geophysics. *9 units (3-0-6); third term. Prerequisites: Ge 1, Ma 2 ab, Ph 2 ab.* A selection of topics in the field of geophysics using, as fully as possible, the prerequisite background. Included are consideration of the earth's gravity and magnetic fields, geodesy, seismology, and the deformation of solids, tides, thermal properties, radioactivity, age determinations, the continents, the oceans, and the atmosphere. Observations followed by their analysis in terms of physical principles. Instructor: Dix.

Ge 3. Mineralogy. *9 units (3-3-3); second term. Prerequisites: Ge 1, Ch 1, Ph 1.* A study of the fundamental structure of minerals, rocks, and other earth materials and their behavior under the varying physical conditions of the earth's crust. Topics discussed include crystallography, stability relations of minerals, solid-state transformations, and mechanisms of material transfer with strong emphasis on the basic atomistic relations. This course is intended to provide fundamental information needed for subsequent studies in mineralogy, petrology, and structural geology. Instructor: Wasserburg.

Ge 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. Texts: *Sedimentary Rocks,* Pettijohn; *Principles of Geochemistry,* Mason. Instructor: Mankin.

Ge 4 c. Metamorphic Petrology. *7 units (2-3-2); third term. Prerequisites: Ge 3, Ch 24 ab.* A study of the origin, occurrence, and classification of the principal metamorphic rocks, with training in the megascopic identification, description, and interpretation of these rocks. Emphasis is placed upon problems of genesis, which are viewed mainly in the light of chemical equilibria and features of geologic occurrence. Text: *Igneous and Metamorphic Petrology,* Turner and Verhoogen. Instructor: 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. Structural Geology. *6 units (1-3-2); first term. Prerequisites: Ge 1, Ge 2, Ge 3.* A problem course in the interpretation and description of geologic structures. Includes use of descriptive geometry and stereographic projection in solution of geologic problems; mechanical properties of rocks; geologic scale models. Text: *Structural Geology,* Billings. Instructor: Allen.

Ge 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 (20 a); Mankin (20 b); Allen (20 c).

Ge 30. Introduction to Geochemistry. *10 units (3-0-7); third term. Prerequisites: Ch 14, Ch 24 ab, Ma 2 abc, Ph 2 abc, Ge 1.* A lecture and problem course to include topics in stable and radioactive isotopic geochemistry. Instructors: Brown, Epstein, Patterson.

ADVANCED SUBJECTS

Courses given in alternate years are so indicated. Courses in which the enrollment is less than five may, at the discretion of the instructor, not be offered.

Ge 100. Geology Club. *1 unit (1-0-0); all terms.* Presentation of papers on research in geological science by the students and staff of the Division of the Geological Sciences and by guest speakers. Generally required of all senior and graduate students in the Division; optional for sophomores and juniors. Instructor: Press.

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 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: Ray.

Ge 106 ab. Petrography. *9 units (2-6-1) second term; 9 units (2-4-3) third term. Prerequisites: Ge 105, Ch 24 ab.* A systematic study of rocks; identification of their constituents by means of the polarizing microscope; interpretation of textures; problems of genesis; qualitative and quantitative classifications. Text: *The Petrology of the Igneous Rocks,* Hatch, Wells, and Wells. Instructor: Campbell.

Ge 107. Stratigraphy. *10 units (3-2-5); third term. 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 108. Mathematical Techniques for Geologists. *6 units (3-0-3); first term.* A review of some of the mathematical methods used in formulating and solving geologic problems. The purpose of this course is to give new graduate students a reasonable proficiency with those mathematical techniques which will be used in advanced courses in the earth sciences. Instructor: Wasserburg.

Ge 109. Structural Geology. *4 units; first term.* This subject is the same as Ge 9 but with reduced credit for graduate students. Instructor: Allen.

Ge 111 ab. Invertebrate Paleontology. *10 units (2-6-2); second, third terms. Prerequisite: Ge 1.* Morphology and geologic history of the common groups of the lower invertebrates, with emphasis on their evolution and adaptive modifications. Second term: consideration of the higher invertebrates groups; preparation of fossils and problems of invertebrate paleontology.

Ge 120 abc. This is the same subject as Ge 20 abc, but with credit for graduate students.

Ge 121 abc. Advanced Field Geology. *14 units (4-8-2), first term; 10 units (0-8-2), second term; 11 units (0-5-6), third term. Prerequisites: Ge 3, Ge 20 abc.* Interpretation of geologic features in the field, with emphasis on problems of the type encountered in professional geologic work. Advanced techniques of investigation are discussed. The student investigates limited but complex field problems in igneous, sedimentary, and metamorphic 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); Campbell (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. *30 units. Prerequisites: Ge 4 abc, Ge 20 abc.* Intensive field study of a 10-15 square mile area from a centrally located, temporary camp. Emphasis is placed on stratigraphic and structural interpretation, and on detailed mapping techniques, including the use of aerial photographs. Each student prepares a geologic map, stratigraphic and structural sections, and a complete geologic report. The work is performed under close supervision of regular staff members. The area chosen generally lies in a part of the Rocky Mountains, or the Basin and Range Province. The course is designed to complement the field training in southern California afforded by the regular school year courses, Ge 20 and Ge 121. The course begins the Monday following commencement (about June 12) and lasts for six weeks. It is required at the end of the junior year of candidates for the bachelor's degree in the geology and geochemistry options; of candidates for the Master of Science degree; and, at the discretion of the staff, of candidates for other advanced degrees in the Division of Geological Sciences. Registration is limited to students regularly enrolled in the California Institute of Technology or to those entering the following term. Text: *Suggestions to Authors,* Wood and Lane. Instructors: Ray (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 130. Introduction to Geochemistry. *6 units (3-0-3); third term.* This subject is the same as Ge 30 but with reduced credit for graduate students.

Ge 150 abcdef. The Nature and Evolution of the Earth. *6 units (3-0-3). Ge 150 cd offered in 1958-59; Ge 150 ef offered in 1959-60, first and second terms.* Discussions at an advanced level of problems of current interest in the earth sciences. The course is designed to give graduate students in the geological sciences and scientists from other fields a broad sampling of data and thought concerning current problems. The lectures are given by members of the staff of the Division of the Geological Sciences. Staff members from other divisions and visiting lecturers from the outside also participate in the instruction. Students may enroll for any or all terms of this course without regard to sequence. Instructors: Brown (in charge), and other members of the staff.

Ge 150 d Geodynamics. Instructor: Scheidegger.

Ge. 151. Laboratory Techniques in the Earth Sciences. *5 units (0-5-0); second term.* Introductory training in the use of tools and techniques used in earth sciences research. Experiments of geological interest are done using the emission spectrograph, spectrophotometer, x-ray spectrometer, alpha and beta counters, mass spectrometers, wet chemical techniques and other available tools and techniques. The course carries a minimum of 5 units but additional units may be elected. In charge: Epstein.

Ge 165. General Geophysics. *6 units (3-0-3); third term.* A survey course for geology students in the physics of the earth. Among topics included are seismology, gravity terrestrial magnetism, geothermal measurements, oceanography and submarine geology. Instructor: Press.

Ge 167. Propagation of Elastic Waves. *3 units (1-0-2); second term.* 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 171. Applied Geophysics, I. *10 units (4-0-6); first term.* Theory of potential including the background necessary for interpretation and planning of gravity, magnetic and electrical prospecting. Gravity and related methods applied to geologic problems and prospecting. Not offered in 1958-59.

Ge 173 ab. Applied Geophysics, II. *5 units (2-0-3); second and third terms.* Methods of seismology applied to geological problems and prospecting. Theory and practice. Offered in 1958-59. Text: *Seismic Prospecting for Oil,* Dix. Instructor: Dix.

Ge 174. Well Logging. *5 units (3-0-2); second term, 1958-59.* Physical principles of various methods of well logging and their applicants. 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. Text: *Elementary Seismology,* Richter. 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); third term, 1958-59. 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.

Ge 211 abc. Topics in Advanced Petrology. *15 units each term (4-4-7).* Integrated lecture, laboratory and seminar treatments of topics in igneous and metamorphic petrology and the mechanics of rock deformation at an advanced level. Laboratory and field studies will be pursued in close association with the classwork. Consideration of petrologic problems in terms of basic principles and modern investigative approaches will be emphasized.

211 a. Problems in igneous petrology: the origin, nature, distribution, and behavior of magmas and analogous chemical systems. Critical comparison of theoretical predictions and natural systems. *Prerequisites: Ge 106 ab, Ch 124 ab.* Instructors: Jahns, Wasserburg.

211 b. Topics in metamorphic petrology, including the facies principle and the thermodynamic equilibrium of metamorphic mineral assemblages. These problems are attacked using the tools of thermodynamics, chemical kinetics and isotope geology, and are evaluated in terms of field evidence. *Prerequisites: Ge 211 a.* Instructors: Engel, Epstein, and Silver.

211 c. Mechanics of rock deformation: Tensors; analysis of stress and strain; deformation of single crystals and polycrystals; plasticity; fracture patterns; recrystallization; petrofabrics. *Prerequisites: Ge 211 b, or Ph 106 abc.* Instructors: Ray and Allen.

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,* Gillson (editor) 3rd edition. Instructor: Campbell.

Ge 213. Mineralogy-Petrology (Seminar). *5 units; first term. Prerequisite: Ge 211 ab.* Discussion of special problems and current literature related to the general provinces of mineralogy and petrology. Topics in such broad fields as crystal structure, mechanics of crystallization, geochemistry, techniques of mineral identification, and the origin of rocks and mineral deposits are selected for critical attention during the term, largely on the basis of trends of interests among members of the group. Instructors: Engel, Jahns, Ray, Silver, Wasserburg.

Ge 215. Ore Deposits (Seminar). *5 units; first 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, 1959-1960. 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. Prerequisite: Ge 126.* Origin of glaciers, existing glaciers, glaciology and glacial mechanics, erosional and depositional features of mountain and continental glaciers, chronology of the Pleistocene. Text: *Glacial and Pleistocene Geology,* Flint. Offered in 1958-59. Instructor: Sharp.

Ge 230. Geomorphology (Seminar). *5 units; second term.* Discussion of research and current literature in geomorphology. In charge: Sharp.

Ge 237. Tectonics. *8 units (3-0-5); third term. Prerequisites: Ge 9 or equivalent.* Advanced structural and tectonic geology. Structure of some of the great mountain ranges; theories of origin of mountains, mechanics of crustal deformation; isostasy, continental drift. Not offered in 1957-58. Instructor: 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. Instructor: Lowenstam.

Ge 245. Vertebrate Paleontology (Seminar). *5 units; second term.* 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. Instructor: Lowenstam.

Geophysics

Ge 261. Advanced Seismology: Theoretical. *6 units (3-0-3); first term. Prerequisite: Ph 108 abc.* Discusses essential material not covered in Ge 264 (Elastic Waves), including equations of electromagnetic seismographs and paths of seismic rays within the earth. Instructor: Richter.

Ge 264 ab. Elastic Waves. *8 units (4-0-4); first and second terms. Prerequisites: Ph 106 abc.* Experimental and theoretical aspects of elastic wave propagation in a layered half space, in plates, cylinders, and spheres, with application to seismic waves and underwater acoustics. Not offered in 1958-59. Instructor: Press.

Ge 268 ab. Selected Topics in Theoretical Geophysics. *6 units (3-0-3); second and third terms. 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. Not offered in 1958-59. Instructor: Dix.

Ge 274 ab. Applied Geophysics, III. *5 units (2-0-3), second term; 6 units (2-1-3); third term. Prerequisite: Ph 106 abc or equivalent.* Magnetic and electric methods applied to geological problems and to prospecting, mainly to mining. Theory and practice. Not offered in 1958-59. Instructor: Potapenko.

Ge 282 abc. Geophysics-Geochemistry (Seminar). *1 unit; first, second, third terms. Prerequisite: At least two subjects in geophysics or geochemistry.* Discussion of papers in geochemistry, general and applied geophysics. In charge: Epstein, Press.

Ge 295. Master's Thesis Research. *Units to be assigned. Listed as to field according to the letter system under Ge 299.*

Ge 297. Advanced Study. Students may register for 8 units or less of advanced study in fields listed under Ge 299. Occasional conferences; final examination.

Ge 299. Research. Original investigation, designed to give training in methods of research, to serve as theses for higher degrees, and to yield contribution to scientific knowledge. These may be carried on in the following fields.

(E) engineering geology,
(F) petroleum geology,
(G) ground water geology,
(H) metalliferous geology,
(I) nonmetalliferous geology,
(J) geochemistry,
(M) mineralogy,
(N) areal geology,
(O) stratigraphic geology,
(P) structural geology,
(Q) geomorphology,
(R) petrology,
(S) vertebrate paleontology,
(T) invertebrate paleontology,
(U) seismology,
(W) general geophysics,
(X) applied geophysics,
(Y) geophysical instruments,
(Z) glacial geology.

German

(See under Languages)

History and Government

UNDERGRADUATE SUBJECTS

H 1 abc. History of European Civilization. *5 units (2-0-3); first, second, third terms.* An introduction to the history of Europe from 1648 to the present. The course will include discussions of political, social, and economic problems, and of the more important theoretical concepts of the period. Instructors: Ellersieck, Elliot, Fay.

H 2 abc. History and Government of the United States. *6 units (2-0-4); first, second, third terms.* The United States since the Revolution. Particular attention will be given to the great questions of domestic and foreign policy which the United States has faced in recent times. The course will include a study of the Constitution and form of government of the United States and the State of California, and will trace the evolution of national and local political institutions and ideas. Instructors: J. Davies, Findley, Paul, Piper.

H 4. The British Commonwealth of Nations.* *9 units (3-0-6). Senior elective.* A study of imperial relationships. Instructor: Elliot.

H 5 abc. Public Affairs. *2 units (1-0-1); first, second, third terms.* In this course a selection of important contemporary problems connected with American political and constitutional development, economic policies, and foreign affairs will be considered. Instructors: Elliot, Sweezy; occasional lectures by other members of the department.

H 7. Modern and Contemporary Germany.* *9 units (3-0-6). Senior elective.* A study of what is sometimes called "The German Problem." Attention will be focused on the rise of Prussia, on Prussian leadership in the unification and direction of Germany, and on the place of Germany in the economy of Europe. Particular stress will be placed upon the German experience since the first World War.

H 8. Modern and Contemporary Russia.* *9 units (3-0-6). Senior elective.* An attempt to discover and interpret the major recurring characteristics of Russian history and society, with attention particularly to developments in the Soviet period. Instructor: Ellersieck.

H 15. Europe Since 1914.* *9 units (3-0-6). Senior elective.* Since 1914 the world has felt the impact of two great wars and powerful revolutionary ideas. This course will analyze these upheavals of the twentieth century and their effect on domestic and international organization. Instructor: Fay.

H 16. American Foreign Relations.* *9 units (3-0-6). Senior elective.* How American foreign policy has been formed and administered in recent times: the respective roles of the State Department, Congress, and the President, of public opinion and pressure groups, of national needs and local politics. Instructor: Paul.

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

H 17. The Far West and the Great Plains.* *9 units (3-0-6) Senior elective.* A study of the development of the great regions that compose the western half of the United States. Especial attention will be paid to the influence of the natural environment on the men who settled the West, from pioneer days to the present time, and the exploitation of natural resources, through such industries as mining, ranching, oil, and farming. Instructor: Paul.

H 19. Modern America.* *9 units (3-0-6). Senior elective.* An experimental course in which the main theme will be the conflict between government regulation and private enterprise in Twentieth-Century America. Classes will be conducted as discussions under the joint leadership of an historian and an economist. Instructors: Paul, Sweezy.

H 20. Modern and Contemporary France.* *9 units (3-0-6). Senior elective.* A study of modern France in the light of her revolutionary tradition. A consideration of the French Revolution followed by an examination of selected episodes between 1815 and 1944 (the June Days, the Paris Commune, the Dreyfus affair, the Stavisky riots, the Vichy regime) which reflect continuing revolutionary strain. Instructor: Fay.

H 22. Modern Britain.* *9 units (3-0-6). Senior elective.* A study of Britain's recent past with particular emphasis upon the development of the working class movement. Instructor: Elliot.

H 23. Modern War.* *9 units (3-0-6). Senior elective.* The course will trace the major developments within the military establishment, such as the growth of the general staff and mass armies. It will discuss the major strategic concepts of the nineteenth and twentieth centuries and the problems of modern war, with some consideration of the political, economic, and social aspects of waging war. Instructor: Ellersieck.

H 24. The Dynamics of Political Behavior.* *9 units (3-0-6). Senior elective.* An examination of general behavior patterns and tendencies of individuals as related to their political behavior and to appropriate types of political institutions. Relevant psychological and sociological theory and research will be discussed in an effort to find the kinds of government suitable to people living in modern technological and industrial society. Instructor: J. Davies.

H 25. Political Parties and Pressure Groups.* *9 units (3-0-6). Senior elective.* A study of those institutions through which individuals and groups seek to control governmental policy and administration. Particular attention will be focused on parties as formulators of individuals' political wants, fears, and expectations and as transmitters of these programs to government. Instructor: J. Davies.

H 26. The Political Novel.* *9 units (3-0-6). Senior elective.* A political and literary appraisal of modern novels that attempt to explain and to judge relationships between the individual and the state in both free and totalitarian societies. The class will meet under the joint supervision of a professor of English and a political scientist. Instructors: J. Davies, Stanton.

H 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*

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

excess units are involved. Reading in history and related subjects, done either in connection with the regular courses or independently of any course, but under the direction of members of the department. A brief written report will usually be required.

H 41. Summer Reading. *Units to be determined for the individual by the department. Maximum, 8 units. Elective.* Reading in history and related subjects during summer vacation. Topics and books to be selected in consultation with members of the department. A brief written report will usually be required.

ADVANCED SUBJECTS

H 100 abc. Seminar in History and Government. *9 units (2-0-7).* Studies in English and American civilization. The reading will be chiefly in biographies of great men and women, famous novels, and suggestive essays in historical and political interpretation. Instructor: Paul.

H 124. Seminar in Foreign Area Problems.* *9 units (3-0-6); second term. Senior elective.* The object of this course is to give students an opportunity to study in some detail problems current in certain selected foreign areas. Three or four areas will be considered each time the course is given, and the selection will normally vary from year to year. Instruction will be given mainly by area specialists of the American Universities Field Staff. Instructors: Elliot and members of AUFS.

H 140. Reading and Research in History and Government. *Units to be determined for the individual by the department.*

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

Hydraulics

UNDERGRADUATE SUBJECTS

Hy 2 ab. Introductory Fluid Mechanics. *10 units (3-2-5); first and second terms.* 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; elements of aerodynamics; hydraulic turbines; centrifugal pumps. Instructor: Ingersoll.

Hy 11. Fluid Mechanics Laboratory. *6 units (0-6-0); second term. Prerequisites: ME 15 ab or Hy 2 ab.* A laboratory course designed to give the student experience in making engineering measurements, observing and analyzing basic flow phenomena, and preparing engineering reports. Instructor: Vanoni.

ADVANCED SUBJECTS

Hy 100. Hydraulics Problems. *Units to be based upon work done, any term.* Special problems or courses arranged to meet the needs of fifth-year students or qualified undergraduate students.

Hy 101 abc. Fluid Mechanics. *9 units (3-0-6); first, second, third terms. Prerequisites: Hy 1 or Hy 2 ab and Hy 11 or equivalent.* Continuity, momentum, and energy equations for viscous, compressible fluids; circulation and the production of vorticity; potential flow and applications to flow around bodies; gravity waves; laminar flow; laminar boundary layers; turbulence and turbulent shear flow; transport of sediment; introduction to fluid mechanics of turbomachines. Instructor: Rannie.

Hy 103 a. Advanced Hydraulics. *9 units (3-0-6); first term. Prerequisite: Hy 2 ab.* Ideal fluid flow, turbulence and diffusion, boundary layer, dimensional analysis, theory and use of hydraulic models, resistance of flow, steady flow in open channels, hydraulic jump, backwater curves and flood routing. Instructor: Vanoni.

Hy 103 b. Hydraulic Structures. *9 units (3-0-6); second term. Prerequisite: Hy 103 a.* High velocity flow in open channels, sediment transportation, theory and design of hydraulic structures, surface waves and coastal engineering. Instructor: Vanoni.

Hy 104. Advanced Hydraulics Laboratory. *6 or more units as arranged; any term. Prerequisite: Consent of instructor.* A laboratory course primarily for fifth-year students dealing with flow in open channels, sedimentation, waves, hydraulic structures, hydraulic machinery, or other phases of hydraulics of special interest. Students may perform one comprehensive experiment or several shorter ones, depending on their needs and interests. Instructor: Staff.

Hy 112 ab. Introductory Fluid Mechanics. *8 units (3-2-3); first and second terms.* This subject is the same as Hy 2 ab, but with reduced credit for graduate students in all fields except Ae, ChE, CE and ME. No graduate credit is given for this subject to students in these fields except by special approval of the department concerned. Instructor: Ingersoll.

Hy 134. Flow in Porous Media. *9 units (3-0-6); third term. Prerequisites: AM 15 abc or AM 115 ab or equivalent. AM 116 is also recommended. (AM 15 c or AM 115 b may be taken concurrently).* A study of the hydrodynamics of flow through porous media, with applications primarily in the field of ground water flow, including seepage through earth dams and levees, uplift pressures on dams and foundations, flow toward wells, ground water recharge, drainage, and dewatering for excavations. Emphasis is placed on flow-net analysis and mathematical methods. This course was previously listed as CE 134. Instructor: Brooks.

Hy 200. Advanced Work in Hydrodynamics or Hydraulic Engineering. *Units to be based upon work done; any term.* Special courses on problems to meet the needs of students beyond the fifth year.

Hy 201 abc. Hydraulic Machinery. *6 units (2-0-4); first, second, third terms.* A study of such rotating machinery as turbines, pumps, and blowers, and their design to meet specific operating conditions. This course will be given in seminar form led by members of the Hydrodynamics and Mechanical Engineering staffs.

Hy 203. Cavitation Phenomena. *6 units (2-0-4).* Study of the experimental and analytical aspects of cavitation and allied phenomena. Problems will be considered in the field of hydraulic machinery and also for bodies moving in a stationary fluid.

Hy 210 ab. Hydrodynamics of Sediment Transportation. *6 units (2-0-4).* A study of the mechanics of the entrainment, transportation, and deposition of solid particles by flowing fluids. This will include problems of water and wind erosion, and density currents. Instructor: Vanoni.

Hy 300. Thesis.

Jet Propulsion

ADVANCED SUBJECTS

JP 121 abc. Rocket. *9 units (3-0-6); each term. Prerequisites: AM 15, ME 15.* Study of flow through rocket nozzle; over- and under-expanded nozzles. Combustion chamber and grain proportions for solid propellant rocket motors; properties and burning characteristics of solid propellants. Combustion and combustion instability in solid propellant rockets. Combustion chamber, propellant supply, and injection system for mono- and bipropellant rocket motors. Turbopump powerplants for liquid rocket propellant supply. Low and high frequency instability in liquid rocket motors. Problems of heat transfer and cooling in rocket motor injectors, combustion chambers, and nozzles. Exterior ballistics and performance analysis of rocket-propelled vehicles. Instructor: Rannie.

JP 130 abc. Thermal Jets. *6 units (2-0-4); each term. Prerequisites: AM 15, ME 15.* Analysis of ramjet performance; detailed study of subsonic and supersonic ramjet diffuser performance and stability, combustion and flame stabilization in ramjet combustors, off-design performance, transient operation, and starting. Operating principles of pulsejet, ducted rocket, and thrust augmentors. Performance cycle analysis of turbojet, turbopropeller, and ducted fan or by-pass engines. Operating principles, design, and performance of compressor, turbine, and combustion chamber and afterburner components. Component matching, engine-diffuser matching, and calculation of complete engine performance; problems of starting and off-design operation. Study of turbine cooling, liquid injection, regenerative systems, and other modifications to basic cycles. Performance analysis of thermal jet propelled aircraft and vehicles. Instructor: Zukoski.

JP 170. Jet Propulsion Laboratory. *9 units (0-9-0); second term.* Laboratory experiments in jet propulsion. Instructor: Zukoski.

JP 200 abc. Chemistry Problems in Jet Propulsion. *9 units (3-0-6); each term.* Descriptive discussions on atomic and molecular structure. 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: John, 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. Not offered in 1958-59. Instructor: Penner.

JP 202 abc. Gas Emissivities. *6 units (2-0-4); each term.* Blackbody radiation laws, Einstein coefficients, integrated intensities and f-numbers. Spectral line widths and shapes; the curves of growth. Infrared gas emissivities and absorptivities for combustion products. Equilibrium radiation from heated air. Radiant heat transfer to hypersonic vehicles during reentry of the atmosphere. Flame temperatures. Influence of radiation on the burning of liquid and solid propellants. Emission of radiation behind shock fronts. Not given every year. Instructor: Penner.

JP 210. High Temperature Design Problems. *6 units (2-0-4); third term. Prerequisite: 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. Not given every year.

JP 220 abc. Theory of Stability and Control. *6 units (2-0-4); each term. Prerequisite: AM 125 or AM 126.* Stability and control of systems with constant coefficients, principles of feed-back servomechanisms, automatic control of propulsion systems. Stability and control of system with time lag, Satche diagram. Stability of systems with time varying coeffiicients. Ballstic disturbance theory, applications to the problem of control and guidance of ballistic vehicles. Control design by specified criteria. Reliability and control of error. Not given every year.

JP 270. Special Topics in Jet Propulsion. *6 units (2-0-4).* The topics covered will vary from year to year. Critical and systematic review of current literature in various fields connected with jet propulsion. Instructors: Staff Members.

JP 280 abc. Research in Jet Propulsion. *Units to be arranged.* Theoretical and experimental investigations in jet propulsion power plants and their applications. Instructors: Staff Members.

JP 290 abc. Advanced Seminar in Jet Propulsion. *2 units (1-0-1); each term.* Seminar on current research problems in jet propulsion. Instructors: Staff Members.

LANGUAGES

The subjects in languages are arranged primarily to meet the needs of science students who find it necessary to read books, treatises, and articles in French, German, and Russian. In the study of these languages correct pronunciation and the elements of grammar are taught, but the emphasis is laid upon the ability to translate from them into English.

UNDERGRADUATE SUBJECTS

L 1 ab. Elementary French. *10 units (4-0-6); second, third terms.* A subject in grammar, pronunciation, and reading that will provide the student with a vocabulary and with a knowledge of grammatical structure sufficient to enable him to read at sight French scientific prose of average difficulty. Accuracy and facility will be insisted upon in the final tests of proficiency in this subject. Students who have had French in the secondary school should not register for this subject without consulting the department of languages. Instructor: Stern.

L 5. French Literature.* *9 units (3-0-6); second term. Senior elective. Prerequisite: L 1 ab, or the equivalent.* The reading of selected classical and modern literature, accompanied by lectures on the development of French literature. Elective and offered when there is sufficient demand. Instructors: Bowerman, Stern.

L 32 abc. Elementary German. *10 units (4-0-6); first, second, third terms.* This subject is presented in the same manner as the Elementary French. Students who have had German in the secondary school or junior college should not register for this subject without consulting the department of languages. Instructors: Bowerman, Stern, Wayne.

L 35. Scientific German. *10 units (4-0-6); first term. Prerequisite: L 32 abc, or equivalent.* This is a continuation of L 32 abc, with special emphasis on the translation of scientific material in the student's field. Instructor: Bowerman.

L 39 abc. Reading in French or German. *Units to be determined for the individual by the department.* Reading in scientific or literary French or German under the direction of the department.

L 40. German Literature.* *9 units (3-0-6); third term. Senior elective. Prerequisite: L 35, or L 32 abc with above average grades.* The reading of selected classical and modern literature, accompanied by lectures on the development of German literature. Instructor: Stern.

L 50 abc. Elementary Russian. *10 units (4-0-6); first, second, third terms.* A subject in pronunciation, grammar, and reading that is intended to enable a beginner to read technical prose in his field of study. Students are expected to become familiar with a basic scientific vocabulary. Articles from current Russian scientific periodicals are used in the second and third terms. Instructor: Kosloff.

L 51 abc. Intermediate Russian. *10 units (4-0-6); first, second, third terms. Prerequisite: L 50 abc or the equivalent.* A continued study of the Russian language with increased emphasis on conversation. The reading of selected classical and modern literature. Discussions in Russian. Continuation of reading and translation of scientific material. Instructor: Kosloff.

ADVANCED SUBJECTS

L 105. Same as L 5. For graduate students.

L 140. Same as L 40. For graduate students.

*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 geometry. Professors in charge: Apostol, 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,* (To be announced). Professor in charge: Erdélyi.

Ma 5 ab. Introduction to Abstract Algebra. *9 units (3-0-6); first and second terms.* This course is intended for mathematicians and those physicists, chemists, and engineers who are interested in the methods and techniques of abstract algebra. The course provides an introduction to the theory of groups, vector spaces, matrix algebra, linear transformations of vector spaces and quadratic forms over the real and complex fields. Characteristic roots, characteristic vectors, similarity and congruence of matrices, orthogonal and unitary transformations are discussed. Text: *A Survey of Modern Algebra,* Birkhoff and MacLane. Instructors: Dean, Dilworth, J. Todd.

Ma 18. Introduction to Mathematical Logic. *10 units (3-0-7); third term. Prerequisites: Ma 5 ab or equivalent.* This course gives an introduction to the more important formal algebraic systems which have been proposed for the development of foundations of mathematics. Not offered in 1958-59.

Ma 31. Introduction to the Constructive Theory of Functions. *9 units (3-0-6); third term. Prerequisites: Ma 1 abc.* Polynomial approximation. The Weierstrass theorem and the Bernstein polynomials. Extremal properties of the Chebyshev polynomials. Markoff's theorems. Classical orthogonal polynomials. Applications to interpolation and approximate integration. Instructor: J. Todd.

Ma 32. Introduction to the Theory of Algebraic Fields. *9 units (3-0-6); third term. Prerequisites: Ma 5 ab.* Polynomial rings. Factorization. Symmetric functions. Construction of field extensions. Cyclotomic fields. Finite fields. Text: *A Survey of Modern Algebra,* Birkhoff and MacLane. Instructor: Dean.

Ma 33. Algebra of Sets and the Real Number System. *9 units (3-0-6); third term. Prerequisites: Ma 5 ab.* Classes of sets are studied as algebraic systems. The results are applied to give a rigorous development of the real number system from an algebraic point of view. Instructor: Dilworth.

Ma 59 ab. Tensor Analysis and Applications. *9 units (3-0-6); second, third terms. Prerequisite: Ma 108 a, Ma 5 or equivalent.* Topics: The algebraic theory of tensors. Manifolds. Tensor fields on a manifold. Applications to the geometry of affine and Riemannian manifolds, differential forms on manifolds, analytic dynamics, mechanics of continuous media. Not offered in 1958-59.

*Graduate students who wish to take any of the courses Ma 59, 61, 62, 63, 68, 91 should register for them under the numbers Ma 159, 161, . . ., 191. These courses carry a credit of 9 units. Graduate students enrolled in Mathematics will be permitted to register for these courses only with the consent of the instructor.

Ma 61.* Algebra. *9 units (3-0-6); first term. Prerequisites: Ma 5 ab.* This course will present a modern algebraical discussion of quadratic fields, factorization, and ideal theory. Given in 1958-59 and alternate years.

Ma 62.* Differential Geometry. *9 units (3-0-6); second term.* Selected topics in metrical differential geometry. Given in 1958-59 and alternate years. Text: *Differential Geometry*, Struik. Instructor: Gary.

Ma 63.* Theory of Sets. *9 units (3-0-6); third term.* The basic concepts of the theory of sets. Cardinal and ordinal numbers. Introduction to point set topology. Discussion of real numbers. Given in 1959-60 and alternate years.

Ma 64.* Projective and Algebraic Geometry. *9 units (3-0-6); first term.* Homogeneous coordinates, projective group. Duality principle. Singular points of curves. Birational transformations. Given in 1959-60 and alternate years.

Ma 68.* Operational Calculus. *9 units (3-0-6); third term.* Introduction to operational calculus based on the Laplace integral. Applications to ordinary and partial differential equations. Given in 1959-60 and alternate years.

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 1958-59).
(d) Game Theory. (Given in 1955-56).
(e) Theory of Probability. (Given in 1956-57).

Ma 92 abc. Senior Thesis. *9 units (0-0-9); three terms. Prerequisite: Approval of adviser.* Open only to seniors who are qualified to pursue independent reading and research. The work must begin in the first term and will be supervised by a member of the staff. Students will consult periodically with their supervisor, and will submit a thesis at the end of the year.

Ma 98. Reading. *3 units or more by arrangement.* Occasionally a reading course under the supervision of an instructor will be offered. Topics, hours, and units by arrangement. Only qualified students will be admitted after consultation with the instructor in charge of the course.

ADVANCED SUBJECTS

[A] The following courses are open to undergraduate and graduate students:

Ma 105 ab. Introduction to Numerical Analysis. *11 units (3-2-6); second and third terms. Prerequisites: Ma 108 or AM 15 or equivalent, Ma 5 or AM 180 or equivalent, and familiarity with coding procedures by the middle of the first quarter of the course.* The topics considered include: Interpolation and quadrature. Numerical solution of algebraic and transcendental equations. Matrix inversion and determination of eigenvalues. Numerical solution of ordinary differential equations. Numerical solution of elliptic, parabolic, and hyperbolic partial differential equations. Instructor: J. Franklin.

*Graduate students who wish to take any of the courses Ma 59, 61, 62, 63, 64, 68, 91 should register for them under the numbers Ma 159, 161, . . ., 191. These courses carry a credit of 9 units. Graduate students enrolled in Mathematics will be permitted to register for these courses only with the consent of the instructor.

Ma 107 abc. Advanced Topics in Numerical Analysis. *9 units (3-0-6); 3 terms. Prerequisites: Ma 105, or equivalent.* Discussion at an advanced level, of areas of current interest in numerical analysis, and in related mathematics, such as: Matrix Inversion and Decomposition, Ordinary Differential Equations, Partial Differential Equations, Integral Equations, Discrete Problems, Linear Programming and Game Theory, Approximation Theory, Applications of Functional Analysis, Theory of Machines, Estimates of Eigenvalues of Matrices. Each quarter will be treated as a separate unit. Where appropriate, accompanying laboratory periods will be arranged as a separate reading course. Instructor: Todd (in charge) and other members of staff.

Ma 108 abc. Introduction to Real and Complex Analysis. *12 units (4-0-8); three terms. Prerequisites: Ma 1, Ma2.* This course is an introduction to advanced methods in analysis. Each year the course will include a discussion of functions of a complex variable; line, surface, volume integrals and their inter-relations; applications of the differential calculus of functions of several variables; functions defined by infinite series and integrals. In addition the course will contain topics selected from: Fourier series and integrals; special functions, such as the gamma and beta functions, Bessel functions, error function; Stieltjes integrals. The aim of this course is to provide a thorough understanding of basic principles, a facility in the use of techniques and a familiarity with applications. This course, or its equivalent, is a prerequisite to graduate mathematics courses in analysis. Instructors: Gary, Luxemburg, Ward.

Ma 112. Elementary Statistics. *9 units (3-0-6); first and second terms. Prerequisites: Ma 1, Ma 2.* This course is intended for anyone interested in the application of statistics to science and engineering. The topics treated will include the preparation and systematization of experimental data, the fundamental statistical concepts; population, sample, mean and dispersion, curve fitting and least squares, significance tests and problems of statistical estimation. Instructor: Knowles.

Ma 115 abc. Introduction to Probability and Statistics. *9 units (3-0-6); three terms. Prerequisite: Ma 2.* This course is designed to lead up to a mathematical treatment of important probabilistic and statistical models. The basic ideas of probability and of statistical inference are introduced. Limit and ergodic theorems, methods of estimation and of testing hypotheses are treated in some detail. The formulation and development of statistical problems is based on decision theory, and the probability models on the theory of Markov processes. Not offered in 1958-59.

[B] The following courses are intended primarily for graduate students. They count fully towards a major or a minor for the degree of Doctor of Philosophy:

Ma 117 abc. Set Theory and Theories of Integration. *9 units (3-0-6); three terms. Prerequisite: Ma 108 abc.* Beginning with the theory of sets the course consists of a detailed study of the integration and differentiation of functions of one real variable. It includes a modern treatment of Lebesgue and of Lebesgue-Stieltjes integrals, the theory of functions of bounded variation, applications to measure theory. Not offered in 1958-59.

Ma 118 abc. Functions of Complex Variable. *9 units (3-0-6); three terms. Prerequisite: Ma 108 abc or equivalent.* The basic results in the theory of analytic functions such as Cauchy's theorems, residues, singularities, analytic continuation are reviewed. The main part of the course is devoted to more advanced topics selected from: entire functions, mapping theorems, algebraic functions, special functions, functions of several complex variables. The subjects are presented from a modern point of view introducing topological and group theoretical considerations. Instructor: Ward.

Ma 120 abc. Abstract Algebra. *9 units (3-0-6); three terms. Prerequisites: Ma 5, Ma 61.* Abstract treatment of groups, rings and fields including topics chosen from: structure theory of groups and rings, Galois theory, and valuation theory of fields. Text: *Modern Algebra*, Volume 1, Van der Waerden. Not offered in 1958-59.

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. Instructor: Fuller.

Ma 160 abc. Theory of Numbers. *9 units (3-0-6); three terms. Prerequisites: Ma 108 and Ma 118 ab for the last two terms.* The first term, Ma 160 a, is an introduction to the elementary theory of numbers including divisibility, numerical functions, elementary theory of primes, quadratic residues. The second and third terms, Ma 160 bc, include topics selected from: Dirichlet series, distribution of primes, additive number theory. Not offered in 1958-59.

Ma 170 abc. Theory of Probability. *9 units (3-0-6); three terms. Prerequisites: Ma 65 and Ma 108 abc.* An introduction to the classical theory of probability leading to the limit theorems and the theory of infinitely divisible distributions. The theory of Markoff processes. Not offered in 1958-59.

Ma 180 abc. Mathematical Methods in Physics. *9 units (3-0-6); three terms. Prerequisite: Ma 108 abc.* Topics selected from matrices and bilinear forms, spectral analysis in Hilbert space, Fourier series and integrals, expansions in orthogonal function systems, integral equations, introduction to the calculus of variations, partial differential equations, characteristic value problems, perturbation methods. Not offered in 1958-59.

Ma 182 abc. Ordinary Differential Equations. *9 units (3-0-6); three terms. Prerequisites: Elements of real and complex variable theory.* Basic existence and uniqueness theorems. Linear systems. Theory of singularities (real and complex variables). Boundary value problems. Geometrical theory. Topics selected from: asymptotic theory; stability; perturbation theory; ergodic theorems; differential equations in abstract spaces. Emphasis will be put on general concepts and methods rather than on the study of particular equations. Text: *Ordinary differential equations*, Coddington and Levinson. Instructor: Erdélyi.

Ma 185 abc. Mathematical Theory of Hydrodynamics. *9 units (3-0-6); three terms.* Mathematical description of fluid. Vorticity; compressibility; continuity. Forces: gravitational, pressure, stress, stress tensor. Equations of motion, Bernoulli's law, vorticity and energy theorems. Viscous fluids, boundary-layer theory, free-boundary problem. Compressible flows, topological properties of subsonic flows, existence and uniqueness theorems, supersonic flows, shock waves, mixed flows. The course will present pure mathematical aspects of the theory and emphasize the direction of modern mathematical research in this field. Not offered in 1958-59.

Ma 190 abc. Elementary Seminar. *9 units; three terms.* This seminar is restricted to first year graduate students and is combined with independent reading. The topics will vary from year to year. In charge: Dean.

[C] The following courses and seminars will be offered according to demand. They are intended for graduate students sufficiently advanced to take an active interest in contemporary fields of research. The courses and seminars to be offered and the topics to be covered will be announced at the beginning of each term:

Ma 210 abc. Advanced Topics in Analysis. *9 units; three terms.* Topics selected from: the theories of functions of one and of several complex variables, quasi-analytic functions, asymptotic expansions; transform theories with applications; orthogonal expansions and almost periodic functions; topological methods in analysis; calculus of variations; analytic number theory. Not given in 1958-59.

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 1957-58.

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. Instructor: Zassenhaus.

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 applcations to analysis. Not given in 1957-58.

Ma 235 abc. Seminar in Geometry. *6 units; three terms.*

Ma 262 abc. Seminar in Number Theory. *6 units; three terms.*

Ma 275 abc. Seminar in Probability and Statistics. *9 units; three terms.*

Ma 280 abc. Advanced Topics in Applied Mathematics. *9 units; three terms.* Topics selected from: non-linear mechanics, mathematical problems in fluid mechanics, mathematical theory of diffraction and scattering; probability methods in analysis with applications; singular integral equations with applications; abstract space methods in applied mathematics. Not given in 1958-59.

Ma 285 abc. Seminar in Applied Mathematics. *6 units; three terms.*

Ma 290. Reading. Occasionally advanced work is given by a reading course under the direction of an instructor. Hours and units by arrangement.

Ma 291. Research. By arrangement with members of the staff, properly qualified graduate students are directed in research. Hours and units by arrangement.

Ma 292. Research Conference in Mathematics. *2 units.* Reports on current literature or their own work will be presented at regular intervals by members of the staff, graduate students or visitors.

APPLIED MATHEMATICS COURSES OFFERED BY OTHER DEPARTMENTS

AM 15 Engineering Mathematics. *See Applied Mechanics section, for description.*

AM 115 Engineering Mathematics. *See Applied Mechanics section, for description.*

AM 116 Complex variables and applications. *See Applied Mechanics section, for description.*

AM 125 Engineering Mathematical Principles. *See Applied Mechanics section, for description.*

AM 175 Non-linear Vibrations. *See Applied Mechanics section, for description.*

AM 180 Matrix Algebra. *See Applied Mechanics section, for description.*

Ph 107 Electricity and Magnetism. *See Physics section, for description.*

Ph 108 Theoretical Mechanics. *See Physics section, for description.*

Ph 129 Methods of Mathematical Physics. *See Physics section, for description.*

EE 280 Advanced Course in Mechanical Computing Methods. *See Electrical Engineering section, for description.*

Mechanical Engineering

UNDERGRADUATE SUBJECTS

ME 1. 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 machines; cam design, gearing, 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 ab, Ch 1 abc.* A study of the materials of engineering and of the processes by which these materials are made and fabricated. The fields of usefulness and the limitations of alloys and other engineering materials are studied, and also the fields of usefulness and limitations of the various methods of fabrication and of processing machines. The student is not only made acquainted with the technique of processes but with their relative importance industrially and with the competition for survival which these materials and processes continually undergo. Text: *Engineering Materials and Processes,* Clapp and Clark. Instructors: Buffington, Clark.

ME 5 abc. Design. *9 units (2-6-1); first, second, and third terms. Prerequisites: ME 1, ME 3, ME 15 abc, AM 4 ab, AM 5 ab (may be taken concurrently), AM 15 abc.* The purpose of this course is to develop creative ability and engineering judgment through work in design and engineering analysis. Existing devices are analyzed to determine their characteristics and the possibilities for improving their performance or economy and to evaluate them in comparison with competitive devices. Practice in the creation or synthesis of new devices is given by problems in the design of machines to perform specified functions. The fundamental principles of scientific and engineering knowledge and appropriate mathematical techniques are employed to accomplish the analysis and designs. Text: *Design and Production,* Kent. Instructor: Morelli.

ME 15 abc. Thermodynamics and Fluid Mechanics. *10 units (3-2-5); first, second, third terms. Prerequisites: Ph 2 abc, Ma 2 abc.* A study of the first and second laws of thermodynamics with applications to flow and non-flow processes. Properties of various fluids and the use of standard tables are discussed. Basic cycles employing gases and vapors are studied. Some concepts of kinetic theory. Introduction to fluid mechanics, the continuity equation, Euler equations of motion, momentum theorem, etc. Topics in one dimensional compressible flow; velocity of sound, the normal shock wave, flow through a De Laval nozzle. Elements of potential flow, principles of similarity, and a brief study of boundary layers. Flow in open channels, surface waves and some elements of pump and turbine design are also included. A quantitative discussion of heat transfer. Instructor: Acosta.

ME 16 abc. Thermodynamics. *9 units (3-0-6); first, second, and third terms. Prerequisite: ME 15 abc.* Application of thermodynamics to engines and power plants, the study of one dimensional compressible flow, elements of design of turbo machinery. Study of the inter-relations of thermodynamic properties of the elements of combustion and of the thermodynamic equilibrium of mixtures of perfect gases. Discussion of the basic equations of heat transfer by conduction, convection, and radiation and the application of the theory of heat transfer to applied problems. A survey of the thermodynamic characteristics of power producing machinery, including nuclear installations. Text: Notes. Instructors: Sabersky, Marble.

ME 25. Mechanical Laboratory. *9 units (0-6-3); third term. Prerequisite: ME 15 abc.* Principles of engineering measurements. Instructor: Zukoski.

ME 50 ab. Engineering Conferences. *2 units (1-0-1); second, third terms.* A course in public speaking for engineers, on engineering topics. Instructors: Clark, Thomas.

ADVANCED SUBJECTS

ME 100. Advanced Work in Mechanical Engineering. The staff in mechanical engineering will arrange special courses or problems to meet the needs of fifth-year students or qualified undergraduate students.

ME 101 abc. Advanced Design. *9 units (1-6-2); first, second, and third terms. Prerequisite: ME 5 abc or equivalent.* Creative design and analysis of machines and engineering systems is developed at an advanced level. Laboratory problems are given in terms of the need for accomplishing specified end results in the presence of broadly defined environments. Investigations are made of environmental conditions to develop quantitative specifications for the required designs. Searches are made for the possible alternate designs and these are compared and evaluated. Preferred designs are developed in sufficient detail to determine operational characteristics, material specifications, general manufacturing requirements and costs. Instructor: Morelli.

ME 104 abc. Design. *7 units (2-6-1); first, second, and third terms. Prerequisites: Same as for ME 5 abc.* This subject is the same as ME 5 abc, but with reduced credit for graduate students in all fields except Ae, CE, and ME. No graduate credit is given for this subject to students in Ae, CE, and ME, except by special approval of the faculty in Mechanical Engineering.

ME 115 abc. Thermodynamics and Heat Transfer. *9 units (3-0-6); first, second, and third terms. Prerequisites: ME 15 abc, ME 16 abc.* Macroscopic thermodynamics and the elements of microscopic thermodynamics with applications to engineering processes; the transport of energy by conduction, convection, and radiation; the thermodynamics of flow systems. Instructor: Sabersky.

ME 124 abc. Thermodynamics. *7 units (3-0-4); first, second, and third terms. Prerequisite: ME 15 abc.* This subject is the same as ME 16 abc, but with reduced credit for graduate students in all fields except Ae, ChE, and ME. No graduate credit is given for this subject to students in Ae, ChE, and ME, except by special approval of the faculty in Mechanical Engineering. Instructor: Sabersky.

ME 126. Fluid Mechanics and Heat Transfer Laboratory. *9 units (0-6-3); third term.* Introduction to some of the basic measurements and phenomena in fluid mechanics and heat transfer. The student will become acquainted with the use of hot wire equipment, thermocouples, thermistors, velocity probes, as well as with electrical and hydraulic analogues. The experiments in which these instruments will be used will include, for example, the flow over a flat plate, heat transfer and flow through a supersonic nozzle, the use of a water table, and electric analog techniques for solving two-dimensional potential problems. Instructors: Acosta, Sabersky, Wu.

ME 127. High Frequency Measurements in Fluids and Solids. *9 units (1-6-2); second term.* The course will treat the theory and application of modern instrumentation to dynamic problems in fluid mechanics and elasticity which will be selected to provide familiarity with a wide range of electronic devices, transducers, and high speed photographic and photoelectric techniques. Instructor: Ellis.

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 in mechanical engineering will arrange special courses on problems to meet the needs of students beyond the fifth year.

ME 217 abc. Turbomachines. *6 units (2-0-4); first, second, and third terms. Prerequisites: Hy 101 abc or Ae 101 abc or equivalent.* The fluid mechanics of turbomachines; potential flow through two-dimensional cascades of airfoils; the theory of three-dimensional rotational flow in axial turbomachines; stall propagation in compressors; tip clearance flow and losses; boundary layer and other secondary flows in turbomachines; applications of the above to the design of turbomachines. Not offered in 1958-59. Instructor: Rannie.

ME 300. Thesis Research.

Many advanced courses in the field of Mechanical Engineering may be found listed in other engineering options such as:

Applied Mechanics, page 157.

Hydraulics, page 198.

Jet Propulsion, page 200.

Physical Metallurgy, page 214.

Paleontology

(See under Geological Sciences)

Philosophy and Psychology

UNDERGRADUATE SUBJECTS

Pl 1. Introduction to Philosophy.* *9 units (3-0-6). Senior elective.* A study of the major problems of philosophy in terms of the most influential contemporary world views, including naturalism, idealism, theism, pragmatism, and positivism. Instructors: Mead, Bures.

Pl 2. Logic.* *9 units (3-0-6). Senior elective.* A study of modern and traditional logic. An analysis of knowledge into basic symbolic forms. Detailed consideration of such logical concepts as: proposition, truth, variable, definition, implication, inference, class, syllogism, logical law, deductive system. Emphasis on the fundamental role of logical methods in the rational approach to knowledge. Instructor: Bures.

Pl 3. Contemporary European Philosophy.* *9 units (3-0-6). Senior elective.* A critical analysis of the main trends in contemporary European philosophy, especially in France, Germany, Italy, and Spain. The course will include neo-Kantianism, neo-Hegelianism, Bergsonism, Logical-Positivism, Phenomenology, neo-Thomism, and Existentialism, in their influence on the whole of modern culture. Instructor: Stern.

Pl 4. Ethics.* *9 units (3-0-6). Senior elective.* A study of ethical values in relation to human nature and culture. Among the major topics considered are: the moral systems of some representative cultures; the development of personality and values in these cultures; the possibility of a rational basis for ethics; competing views of human nature; ethical conflicts in American culture. Instructor: Bures.

Pl 6. General Psychology.* *9 units (3-0-6). Senior elective.* 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. *7 units (3-0-4); third term.* An introduction to the principles of human relations with major emphasis on the development of groups. Psychological and emotional factors influencing group behavior, group leadership and group co-operation will be explored. Instructors: Ferguson, Weir.

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.

Physical Metallurgy

UNDERGRADUATE SUBJECTS

PM 1. Physical Metallurgy. *12 units (3-3-6); first term. Prerequisite: ME 3.* A study of the properties of ferrous and non-ferrous metals and alloys with respect to their application in engineering; the principles of heat treatment for a proper understanding by engineers for application of alloys for design. The microstructures of ferrous and non-ferrous metals and alloys are studied in the laboratory. Text: *Physical Metallurgy for Engineers*, Clark and Varney. Instructors: Buffington, Clark.

PM 2. Metallography Laboratory. *3 units (0-3-0); third term. Prerequisite: PM 1.* Technique of metallographic laboratory practice including microscopy, preparation of specimens, etching reagents and their use, photomicrography. Text: *Principles of Metallographic Laboratory Practice*, Kehl. Instructors: Buffington, Clark.

ADVANCED SUBJECTS

PM 101. Physical Metallurgy. *9 units (3-3-3); first term. Prerequisite: ME 3.* This subject is the same as PM 1 but with reduced credit for graduate students who have not had PM 1 or the equivalent.

PM 102. Pyrometry. *9 units (1-6-2); third term.* Study of the principles of thermometry and the theory underlying instruments that are used to measure temperatures. Experiments will be conducted with a variety of such instruments to illustrate their applications and limitations. Instructor: Staff.

PM 103. Physical Metallurgy Laboratory. *9 units (0-9-0); first term. Prerequisites: PM 2, PM 110.* Experimental studies of heat treatment, grain size, hardenability, and recrystallization. Text: *Principles of Metallographic Laboratory Practice*, Kehl. Instructor: Clark.

PM 104. Photography. *9 units (1-6-2); first term.* Study and synthesis of optical systems in the use of photographic methods in research. Experiments will be conducted with various systems to illustrate the effectiveness of photographic methods as research tools. Instructor: Staff.

PM 105. Mechanical Behavior of Metals. *6 units (2-0-4); first term. Prerequisites: AM 4 ab, PM 1.* A study of the various types of behavior of metals under applied load which are of significance for engineering applications. Properties under simple tension and compression loading, hysteresis and damping capacity, the influence of temperature, behavior under rapidly applied and impact loads, fatigue, mechanical wear, behavior under combined stress, and selection of working stresses. Text: *Strength and Resistance of Metals*, Lessells. Instructor: Vreeland.

PM 110. Thermodynamics of Physical Metallurgy. *9 units (3-0-6); third term. Prerequisites: PM 1, ME 15 abc.* General thermodynamic relationships; thermodynamics of equilibrium diagrams; nucleation and growth including basic principles, transformations in steel, precipitation hardening, recrystallization and grain growth; heat transfer. Instructor: Buffington.

PM 112 ab. Advanced Physical Metallurgy. *9 units (3-0-6); second and third terms. Prerequisites: PM 110, PM 115, PM 120.* Ternary phase diagrams; order-disorder transformations; solid state diffusion; semiconductors and semiconductor devices; theory of gas-metal reactions; advanced consideration of magnetic properties; effects of radiation on materials. Instructor: Buffington.

PM 115. Crystal Structure of Metals and Alloys. *9 units (3-0-6); second term. Prerequisite: PM 1.* Atomic structure of metals and alloys, physics of X-rays, elementary crystal structure, symmetry operations, symmetry classes, space groups. Typical structures of metals and of intermetallic compounds. Instructor: Duwez.

PM 116. X-Ray Metallography I. *6 units (0-6-0); third term. Prerequisite: PM 115.* Experimental methods of X-ray diffraction for the study of the structure and texture of metals and alloys. The Laue and Debye-Scherrer methods. Use of the X-ray spectrometer. Interpretation of diffraction patterns and measurement of lattice parameters. Text: *X-ray Metallography*, Taylor. Instructor: Duwez.

PM 117. X-Ray Metallography II. *9 units (0-6-3); second term. Prerequisite: PM 116.* Methods of X-ray diffraction analysis involving single crystals. Quantitative interpretation of diffraction patterns of metals and alloys. Study of phase diagrams, plastic deformation and grain orientation. Recrystallization texture, precipitation and age hardening. Stress measurement by X-ray diffraction methods. Text: *X-ray Metallography*, Taylor. Instructor: Duwez.

PM 120. Physics of Metals. *9 units (3-0-6); second term. Prerequisite: AM 15 abc or equivalent.* Introduction to wave mechanics. Free electron theory and band theory of solids. Electrical, magnetic, and thermal properties of solids. Instructor: Buffington.

PM 121. Theory of Alloys. *9 units (3-0-6); first term. Prerequisites: PM 115, PM 120.* Atomic structure of alloys. General principles of alloying. Physical properties of solid solutions in relation to their atomic structure. Electron compounds. Relations between crystal structure and physical properties of alloys. Text: *Atomic Theory for Students of Metallurgy*, Hume-Rothery. Instructor: Duwez.

PM 125. Industrial Physical Metallurgy. *9 units (0-6-3); third term. Prerequisites: PM 103, PM 117.* Application of the principles of physical metallurgy and the techniques of metallographic laboratory practice to the solution of problems concerning the causes of failure of commercial parts. Typical cases are used as problems to be solved by the student and presented and discussed before the class and staff in the form of reports. Instructor: Clark.

PM 135. Radioisotopes Laboratory. *9 units (0-9-0); third term. Prerequisite: AM 103.* Experiments illustrating the use of radioisotopes in the field of physical metallurgy. Typical examples are studies of solid state diffusion and the determination of chemical inhomogeneities in metals and alloys. Instructor: Buffington.

PM 205. Theory of the Mechanical Behavior of Metals. *9 units (3-0-6); third term. Prerequisites: AM 110 a, PM 115.* A study of the nature and physical theory of the deformation of metals under the influence of applied stress. Elasticity of single crystals, plastic flow in crystals by slip and twinning, the concept of dislocations, stress fields of dislocations, dislocation interactions, generation of dislocations, dislocations in crystal lattices, arrays of dislocations, application of dislocaton theory. Text: *Dislocations and Plastic Flow in Crystals, Cottrell.* Instructor: Wood.

PM 250 abc. Advanced Topics in Physical Metallurgy. *6 units (2-0-4); first, second, and third terms.* The content of this course will vary from year to year. Topics of current interest will be chosen according to the interests of students and staff. Visiting professors may present portions of this course from time to time. Instructor: Staff.

PM 300. Thesis Research.

Physics

UNDERGRADUATE SUBJECTS

Ph 1 abc. Mechanics, Molecular Physics, Heat and Sound. *12 units (3-3-6); first, second, third terms. Prerequisites: High school physics, algebra and trigonometry.* The first year of a general college course in physics extending through two years. The course work consists of class recitations in which the basic material of physics is presented largely by means of analytical solutions to problems. Bi-weekly demonstration lectures by staff members from various divisions illustrate some of the more interesting application of physics. The weekly laboratory allows some choice of problem on the part of the student. In addition to many standard experiments, some material is provided for original experiments. Text: *Introduction to Mechanics and Heat,* Frank. Instructors: Sutton, Strong, Watson, and Graduate Assistants.

Ph 2 abc. Electricity, Optics, and Modern Physics. *12 units (3-3-6); first, second, and third terms. Prerequisites: Ph 1 abc, Ma 1 abc, or their equivalent.* A continuation of Ph 1 abc to form a well-rounded two-year course in general physics. The first two terms deal with electricity and physical optics, and the third term with modern physics. Texts: *Introduction to Electricity and Optics,* Frank; *Atomic Physics,* Semat. Instructors: Peterson, Gomez, King, Neher, and Graduate Assistants.

Ph 77. Experimental Physics Laboratory. *6-9 units (subject to arrangement with instructor). Either first or second term.* A one-term laboratory course open to senior physics majors. The purpose of the course is to familiarize the student with laboratory equipment and procedures that are used in the research laboratory. The experiments are designed to illustrate fundamental physical phenomena, such as Compton scattering, nuclear and paramagnetic resonance, the photoelectric effect, the interaction of charged particles with matter, etc. Instructors: Whaling, Kavanagh.

ADVANCED SUBJECTS

Ph 107 abc. Electricity and Magnetism. *9 units (3-0-6); first, second, third terms. Prerequisites: Ph 2 abc; Ma 2 abc.* A course in classical electricity and magnetism, with an introduction to the solution of boundary value problems in electricity. Topics include electrostatics, magnetostatics, and current flow; electromagnetic induction; electromagnetic radiation, including plane waves, spherical waves, and dipole radiation; electromagnetic field energy and momentum; special relativity. The emphasis is upon the more general aspects of the subject, and upon physical principles. Graduate students majoring in physics or astronomy will be given only 6 units credit for this course. Text: *Electromagnetism,* Slater and Frank. Instructors: Barnes, Cowan, Teem, Tollestrup.

Ph 108 abc. Theoretical Mechanics. *9 units (3-0-6); first, second and third terms. Prerequisites: Ph 1 abc, Ph 2 abc, and preferably Ph 107 abc.* An intermediate course in the application of mathematical methods to problems in mechanics. Topics include particle mechanics, Lagrange and Hamilton equations, damped vibrations, coupled vibratory systems, rigid body dynamics. Graduate students majoring in physics or astronomy will receive only 6 units credit for this course. Text: *Classical Mechanics,* Goldstein. Instructors: Anderson, Mathews.

Ph 110 ab. Kinetic Theory of Matter. *9 units (3-0-6); second and third terms. Prerequisites: Ph 1 abc; Ma 2 abc.* A lecture course in kinetic theory and its basic applications (and limitations) to the "stable" and "steady" state phenomena in gases. Specific discussion of transfer, surface and low pressure phenomena, Brownian movement and kinetics of airborne particulate matter (aerosols) and condensation phenomena in such systems. Text: *Kinetic Theory of Gases*, Kennard, Loeb and selected chapters from literature. Instructor: Goetz.

Ph 111 abc. Structure of Matter. *9 units (3-0-6); first, second, third terms. Prerequisites: Ph 1 abc; Ph 2 abc.* A course dealing with those properties of matter which can be treated from a relatively simple, largely classical, point of view. The connection between the properties of matter and the properties of the atoms of which it is composed is stressed. Topics include electron theory of dielectrics and magnetic materials; electrical conduction in gases; kinetic theory of gases; transport phenomena; degenerate gases; free electron theory of metals; quantum theory of specific heats; mechanical properties of gases, liquids and solids. Quantum concepts are introduced but no formal development of quantum mechanics is included. Graduate students majoring in physics or astronomy will receive only 6 units credit for this course. Instructor: T. Lauritsen.

Ph 112 abc. Atomic and Nuclear Physics. *12 units (4-0-8); first, second, third terms. Prerequisites: Ph 107 abc and Ph 111 abc, or equivalent.* A problem and lecture course in the experimental and theoretical foundations of modern atomic and nuclear physics. Topics include an introduction to quantum mechanics with illustrative applications to the harmonic oscillator, the free particle, the one-electron atom, and selection rules. Also treated, but on a less analytical basis, are the exclusion principle and atomic shell structure; optical spectroscopy; molecular binding and molecular spectra; quantum statistics; the band theory of solids; X-rays; radioactivity and nuclear structure; nuclear reactions; elementary particles; high energy physics. Graduate students majoring in physics and astronomy will receive only 8 units credit for this course. Text: *Principles of Modern Physics,* Leighton. Instructor: Leighton.

Ph 115 ab. Geometrical and Physical Optics. *6 units (2-0-4); second and third terms. Prerequisite: Ph 2 abc.* An intermediate lecture and problem course dealing with the fundamental principles and applications of geometrical optics, interference, diffraction and other topics of physical optics. Instructor: King.

Ph 129 abc. Methods of Mathematical Physics. *9 units (3-0-6); first, second, third terms. Prerequisites: Ph 107 abc and Ph 108 abc or the equivalents (may be taken concurrently), and some knowledge of complex variables.* Aimed at developing familiarity with the mathematical tools useful in physics, the course discusses practical methods of summing series, integrating, and solving differential equations, including numerical methods. The special functions (Bessel, Elliptic, Gamma, etc.) arising in physics are described, as well as Fourier series and transforms, partial differential equations, orthogonal functions, eigenvalues, calculus of variations, integral equations, matrices and tensors, and non-commutative algebra. The emphasis is toward applications, with special attention to approximate methods of solution. Instructor: Walker.

Ph 131 abc. Electricity and Magnetism. *9 units (3-0-6); first, second, and third terms. Prerequisite: An average grade of C in Ph 107 abc.* A problem course in electricity, magnetism and electromagnetic waves for students who are doing or plan to do graduate work. The first two terms cover potential theory as applied to electrostatics, magnetostatics and current flow in extended mediums; eddy currents; and the laws of electromagnetic induction as applied to linear circuits. The third term covers electromagnetic waves and the motion of charged particles in electromagnetic fields. Text: *Static and Dynamic Electricity,* Smythe. Instructor: Smythe.

Ph 172. Experimental Research in Physics. *Units in accordance with the work accomplished. Approval of the department must be obtained before registering.*

Ph 173. Theoretical Research in Physics. *Units in accordance with the work accomplished. Approval of the department must be obtained before registering.*

Ph 201 ab. Analytical Mechanics. *9 units (3-0-6); first and second terms. Prerequisites: Ph 108 abc or AM 15 abc; Ph 129 ab is desirable.* A problem and lecture course dealing with the various formulations of the laws of motion of systems of particles and rigid bodies, and with both exact and approximate solutions of the resulting equations. Topics considered include Lagrange's and Hamilton's equations, canonical transformations, the dynamics of axially symmetric rigid bodies, and vibrations about equilibrium and steady motion. Instructor: Davis.

Ph 202. Topics in Classical Physics. *9 units (3-0-6); third term.* The content of this course will vary from year to year. Typical topics: Non-linear vibrations, dynamics of particles in accelerators, elasticity, hydrodynamics, potential theory, mechanical wave motions. Instructor: Davis.

Ph 203 abc. Nuclear Physics. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 112 abc or equivalent.* A problem and lecture course in nuclear physics. Subjects include fundamental properties and structure of nuclei, including the liquid drop, shell, and collective models, nuclear forces, modes of nuclear decay, nuclear reactions, interaction of particles and radiation with matter, and particle acceleration and detection. The third term is usually devoted to such specialized topics as nuclear processes in stars including energy generation and element synthesis. Text: *The Atomic Nucleus,* Evans. Instructor: Fowler.

Ph 204 abc. Low Temperature Physics. *9 units (3-0-6); first, second, third terms. Prerequisite: Ph 112 abc. Recommended: Ph 205 abc, Ph 227 abc.* First and second terms: Introductory exposition of the subject of cryogenics. General coverage of topics includes (1) liquid helium II, (2) superconductivity, and (3) adiabatic demagnetization and nuclear alignment. Emphasis to be based on correlating behavior of matter at low temperatures with existing theoretical interpretations. Third term. Advanced topics on specific aspects of low temperature physics to be covered by special reading assignments. Given in alternate years. Offered in 1958-59. Instructor: Pellam.

Ph 205 abc. Principles of Quantum Mechanics. *9 units (3-0-6); first, second and third terms. Prerequisites: Ph 112 abc or equivalent; Ph 129 abc is desirable.* Subjects include Schroedinger equation (hydrogen atom, etc.); particle scattering; operators and transformation theory; angular momentum; atomic structure; perturbation theory and other approximation methods useful in atomic, molecular, and nuclear problems; introduction to the quantum theory of radiation. Instructor: Christy.

Ph 207 abc. X- and Gamma-rays. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 112 abc, or equivalent.* Covers the generation of X-rays and gamma-rays and the various interactions of these with matter both in practical applications to research physics and in theory. The first term is devoted to a descriptive general survey of the subject. The second term deals with nuclear gamma-ray and X-ray emission spectra, the mean lives of excited states, elementary theory of multipole radiation, theories of the generation and intensities of characteristic X-ray line spectra and also of the continuous X-ray spectrum covering briefly under the latter topic the theories of Sommerfield and of Heitler and their experimental verifications. The third term covers in considerable detail the scattering of these radiations by matter, both coherent and incoherent processes being considered, and presents the resulting physical conclusions regarding the structure of atoms, molecules, liquids, solids and the Compton effect with its manifold implications. Other interactions between radiation and matter are also treated. Solution of a moderate number of illustrative problems required in all three terms. Instructor: DuMond.

Ph 209 abc. Electron Theory. *9 units (3-0-6); first, second, and third terms. Prerequisites: Ph 107 abc; and Ph 131 ab is desirable.* Electromagnetic fields in vacuum and in matter; classical electron theory, retarded potentials; radiation, dispersion, and absorption; theories of the electric and magnetic properties of materials; selected topics in optics; special relativity. Given in alternate years. Offered in 1958-59. Instructor: Sands.

Ph 212 ab. Mechanics of Continuous Media. *9 units (3-0-6); second and third terms. Prerequisite: Ph 201 ab.* Hydrodynamics of nonviscous fluids; Euler and Lagrange equations; general integrals and special problems. Hydrodynamics of viscous fluids; application of the Navier-Stokes equations to special problems. Theory of supersonic flow and shock waves. Fundamental equations of the theory of elasticity. Not given in 1957-58. Instructor: Plesset.

Ph 217. Spectroscopy. *9 units (3-0-6); third term. Prerequisite: Ph 112 ab or the equivalent.* Atomic line spectra. Experimental techniques of excitation and observation of the spectra of atoms and ions. A discussion of observed spectra, including complex spectra, in terms of atomic structure theory. Given in alternate years. Offered in 1958-59. Instructor: King.

Ph 218 ab. Electronic Circuits and their Application to Physical Research. *9 units (3-0-6); first and second terms.* Permission of the instructor is required in order to register for this course. A course on electronic circuits with primary emphasis on basic factors entering into the design and use of electronic instruments for physical research. Topics considered will include the theory of response of linear networks to transient signals, linear and nonlinear properties of electron tubes and practical circuit components, basic passive and active circuit combinations, cascade systems, amplifiers, feedback in linear and nonlinear systems, statistical signals, noise, and practical construction. Particular examples will be taken from commonly used research instruments. Given in alternate years. Not offered in 1958-59. Instructor: Sands.

Ph 219 abc. Advanced Electromagnetic Field Theory. *9 units (3-0-6); first, second, and third terms.* This course covers the applications of Maxwell's equations to problems involving antennas, waveguides, cavity resonators, and diffraction. It includes the solution of problems by the classical methods of retarded potentials and orthonogal expansions and lectures in the modern techniques of Schwinger that employ the calculus of variations and integral equations. (Identical with EE 250 abc.) Texts: *Static and Dynamic Electricity*, Smythe; *Randwertprobleme der Microwellenphysik*, Borgnis and Papas. Instructors: Smith 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. Given in alternate years. Not offered in 1958-59. Instructor: Pellam.

Ph 231 ab. High Energy Physics. *9 units (3-0-6); second and third terms.* A course covering the properties of high-energy particles and radiation, and their interactions. Topics covered include nucleon-nucleon collisions, interactions of pi mesons and nucleons, photoproduction of pi mesons, mesic atoms, "curious" particles and hyperfragments. Given in alternate years. Offered in 1958-59.

Ph 234 abc. Topics in Theoretical Physics. *9 units (3-0-6); first, second, and third terms. Prerequisite: Ph 205 or equivalent.* The content of this course will vary from year to year. Topics presented will include: General methods in quantum mechanics such as operator calculus, group theory and its application; theory of meson and electromagnetic fields; atomic and molecular structure; theory of solids; theoretical nuclear physics. Instructor: Gell-Mann.

Ph 235 abc. Relativity and Cosmology. *9 units (3-0-6); first, second and third terms.* A systematic exposition of Einstein's special and general theories of relativity; the conflict between Newtonian relativity and the Maxwellian theory of the electromagnetic fields; its resolution in the special theory of relativity. The geometrization of the gravitational field accomplished by the general theory of relativity. The search for a unified theory of the electromagnetic and gravitational fields. Applications of the relativity theories to cosmology and cosmogony. Topics in the more advanced mathematical disciplines (tensor analysis, Riemannian geometry) will be developed as required as appropriate tools for the formulation of physical law. The first term, Ph 235a may be taken separately by students who are interested only in the principles and applications of the special theory of relativity. Given in alternate years. Offered in 1958-59. 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: Christy.

Ph 300. Research in Physics. *Units in accordance with work accomplished. Approval of the Department must be obtained before registering.* Ph 300 is elected in place of Ph 172 when the student has progressed to the point where his research leads directly toward the thesis of the degree of Doctor of Philosophy.

PSYCHOLOGY

(See under Philosophy)

RUSSIAN

(See under Languages)

Section VI

DEGREES CONFERRED JUNE 13, 1958

Doctor of Philosophy

Dang Dinh Ang (Aeronautics and Mathematics). *B.S., University of Kansas, 1955; M.S., California Institute of Technology, 1956.* Thesis: Radiation Problems in Elastodynamics.

Calvin LaRue Barker (Mechanical Engineering and Physics). *B.S., University of Texas, 1953; M.S., California Institute of Technology, 1954.* Thesis: Experiments Concerning the Occurrence and Mechanism of High-Frequency Combustion Instability.

Richard William Bell (Aeronautics and Mathematics). *B.A., Oberlin College, 1939.* Thesis: The Elastic Instability of Thin Cantilever Struts on Elastic Supports with Axial and Transverse Loads at the Free Ends.

Michael A. Bloch (Physics and Mathematics). *Dipl. Ing., Ecole Polytechnique (Paris), 1952.* Thesis: Photoproduction of Pion Pairs in Hydrogen.

David Frederic Bowersox (Chemistry and Mathematics). *B.A., Grinnell College, 1953.* Thesis: I. The Iodine-Iodine Monocyanide Half Cell Potential. II. Coulometric Studies. III. The Mechanism of the Precipitation of Metal Sulfides by Thiocetamide.

Harold Stanley Braham (Electrical Engineering and Physics). *B.S., Columbia University, 1950; M.S., 1951.* Thesis: An Investigation of the Use of Feedback Control to Raise the Flutter Speed of an Aeroelastic System.

Vernon Douglas Burrows (Plant Physiology and Biochemistry). *B.S.A., University of Manitoba, 1951; M.Sc., 1953.* Thesis: Studies on Translocation.

Warren Van Ness Bush (Chemistry and Chemical Engineering). *B.S.E., Princeton University, 1953.* Thesis: A study of the Boron Trifluoride Complexes of Some Carotenoid Hydrocarbons and the Products of their Hydrolytic and Alcoholytic Cleavage.

Donald Blair Chesnut (Chemistry and Physics). *B.S., Duke University, 1954.* Thesis: I. An X-Ray Diffraction Study of the Crystal Structure of Cyclopropane Carbohydrazide. II. A Theory of Isotropic Hyperfine Interactions in π-Electron Radicals.

John M. Clark, Jr. (Biochemistry and Chemistry). *B.S., Cornell University, 1954.* Thesis: Studies of Amino Acid Activation and Protein Synthesis.

Albert Charles Claus (Chemistry and Mathematics). *B.S., Northwestern University, 1952.* Thesis: The Intermetallic Compounds in the Silver-Strontium System and their Crystal Structures.

Terry Cole (Chemistry and Physics). *B.S., University of Minnesota, 1954.* Thesis: Studies of Free Radicals at 4.2°K by Electron Paramagnetic Resonance.

Anthony Demetriades (Aeronautics and Physics). *B.A., Colgate University, 1951; M.S., University of Minnesota, 1953.* Thesis: An Experimental Investigation of the Stability of the Hypersonic Laminar Boundary Layer.

William Bailey DeMore (Chemistry and Physics). *A.B., Emory University, 1952; M.A., 1953.* Thesis: Chemical Processes in Rigid Media at Low Temperatures.

David Severin Dennison (Biophysics and Biochemistry). *B.A., Swarthmore College, 1954.* Thesis: Studies on Phototropic Equilibrium and Phototropic-Geotropic Equilibrium in Phycomyces.

Paul Leighton Donoho (Physics and Mathematics). *B.A., The Rice Institute, 1952.* Thesis: The Photoproduction of Positive K Mesons in Hydrogen.

John Walter Drake (Virology and Embryology). *B.S., Yale University, 1954.* Thesis: Intracellular Interactions of Polioviruses: Interference and Multiplicity Reactivation.

Allen Eugene Fuhs (Mechanical Engineering and Physics). *B.S., University of New Mexico, 1951; M.S., California Institute of Technology, 1955.* Thesis: I. Experimental and Theoretical Studies on Heterogeneous Diffusion Flames. II. Spectroscopic Studies of Flames.

Derck Alexander Gordon (Chemistry and Mathematics). *B.A., University of Buffalo, 1953.* Thesis: I. Measurement of Diamagnetic Anisotrophy in Single Crystals. II. The Crystal Structure of Monomethylurea.

Ellsworth Herman Grell (Genetics and Biochemistry). *B.S., Iowa State College, 1954.* Thesis: The Genetics and Biochemistry of "red cells" in Drosophila melanogaster.

John Thomas Harding (Physics and Mathematics). *S.B., Massachusetts Institute of Technology, 1953.* Thesis: Electron Paramagnetic Resonance of Nitrogen Afterglow Condensed at 4.2°K.

Harry James Heimer (Aeronautics and Mathematics). *S.B., Massachusetts Institute of Technology, 1941; Ae.E., California Institute of Technology, 1944.* Thesis: Balanced Flap Type Supersonic Control Surfaces.

William Joseph Hooker (Engineering Science and Physics). *B.S., Webb Institute of Naval Architecture, 1953; M.S., Cornell University, 1955.* Thesis: Shock-Induced C_2H_2 Pyrolysis and CO Emissivity.

Robert Eugene Huffman (Chemistry and Physics). *B.S., Agricultural and Mechanical College of Texas, 1953.* Thesis: I. Kinetics of Thermal Decomposition of Nitrogen Dioxide behind Shock Waves. II. Kinetics of the Ferrous Ion-Oxygen Reaction in Sulfuric Acid Solution.

Robert Katz (Mechanical Engineering and Physics). *B.S., University of Colorado, 1948; M.S., California Institute of Technology, 1954.* Thesis: Performance of Axial Compressors with Asymmetric Inlet Flows.

James King, Jr. (Chemistry and Physics). *B.S., Morehouse College, 1953; M.S., California Institute of Technology, 1955.* Thesis: I. Magnetic Resonance Studies in Paramagnetic Solutions. II. The Ferrous Iron-Oxygen Reaction in Acidic Phosphate-Pyrophosphate Solutions.

Luiz Fernando Gouvêa Labouriau (Plant Physiology). *A.B., University of Michigan, 1953; M.S., 1954.* Thesis: Studies on the Initiation of Sporangia in Ferns.

Arthur Edward Lewis (Geology and Economics). *B.S., St. Lawrence University, 1950; M.S., California Institute of Technology, 1955.* Thesis: Geology and Mineralization Connected with the Intrusion of a Quartz Monzonite Porphyry, Iron Mountain, Iron Springs District, Utah.

Frank Bryant Mallory (Chemistry and Physics). *B.S., Yale University, 1954.* Thesis: I. Photochemical Reactions of Phenylcyclobutadienoquinone. II. Thermal Reactions of Phenylcyclobutadienoquinone in Methanol. III. The Photochemical Synthesis of Phenanthrenes.

Ronald Theodore McLaughlin (Civil Engineering and Chemical Engineering). *B.S., Queen's University, 1951; M.S., California Institute of Technology, 1952.* Thesis: On the Mechanics of Sedimentation in Artificial Basins.

Howard Martin McMahon (Aeronautics and Mathematics). *B.M.E., Santa Clara University, 1950; M.S., California Institute of Technology, 1951.* Thesis: Experimental Study of the Effect of Mass Injection at the Stagnation Point of a Blunt Body.

Roderic Bruce Park (Biology and Geochemistry). *B.A., Harvard College, 1953.* Thesis: I. The Biosynthesis of Open Chain Terpenes in Plants. II. Fractionation of the Stable Carbon Isotopes in Plants.

Arthur William Rose (Geology and Geochemistry). *B.S., Antioch College, 1953; M.S., California Institute of Technology, 1955.* Thesis: Trace Elements in Sulfide Minerals from the Central Mining District, New Mexico, and the Bingham Mining District, Utah.

Thomas Lee Russell (Mechanical Engineering and Physics). *B.S., California Institute of Technology, 1952; M.S., 1953.* Thesis: The Effect of Grain Size on the Yielding Behavior of Very Low Carbon Steel.

Allan Robert Sanford (Geophysics and Geology). *B.A., Pomona College, 1949; M.S., California Institute of Technology, 1954.* Thesis: I. An Analytical and Experimental Study of Some Simple Geologic Structures. II. Gravity Survey of a Part of the Raymond and San Gabriel Basins, Southern California.

Franco Scardiglia (Chemistry and Geology). *B.S., University of Illinois, 1954.* Thesis: I. Reactions of Non-activated Aryl Halides with Strong Basic and Nucleophilic Agents. II. Evidence for Cyclohexyne as an Intermediate in the Coupling Reactions of Phenyllithium with 1-chlorocyclohexene. III. Reactions of Non-activated Aryl Halides with Strong Bases at High Temperatures. IV. The Synthesis of Some Four-membered Ring Compounds.

James Walter Sedin (Electrical Engineering and Physics). *B.S., University of Minnesota, 1951.* Thesis: A Large-Signal Analysis of Beam-Type Cross-Field Traveling-Wave Tubes.

Wallace Walter Short (Chemical Engineering and Electrical Engineering). *B.S., Missouri School of Mines, 1951; M.S., California Institute of Technology, 1953.* Thesis: I. Heat Transfer Coefficients and Correction for Thermocouples in the Boundary Layer of a Sphere. II. Local Convective Heat Transfer from a Sphere. III. Thermal Transfer in Turbulent Gas Streams. Effect of Turbulence on Local Transport from Spheres.

Richard Isamu Tanaka (Electrical Engineering and Physics). *B.S., University of California, 1950; M.S., 1951.* Thesis: The Logical Design of a Serial General-Purpose Computer with Micro-Program Capabilities.

Thomas Tallot Taylor (Physics and Mathematics). *B.S., Purdue University, 1942; M.S., California Institute of Technology, 1953.* Thesis: Electromagnetic Scattering by a Short Right Circular Conducting Cylinder.

James Alex Lloyd Thomson (Engineering Science and Physics). *B.A.Sc., University of British Columbia, 1951; M.A.Sc., 1953.* Thesis: Emissivities and Absorptivities of Gases.

Herman Carl Thorman (Aeronautics and Mathematics. *B.S., Purdue University, 1946; M.S., California Institute of Technology, 1952.* Thesis: Boundary Layer Measurements on an Axisymmetric Body with Spin and Yaw.

William Grant Tifft (Astronomy and Physics). *A.B., Harvard College, 1954.* Thesis: Multicolor Photoelectric Photometry of Bright Extragalactic Systems.

Alvin William Trivelpiece (Electrical Engineering and Physics). *B.S., California State Polytechnic College, 1953; M.S., California Institute of Technology, 1955.* Thesis: Slow Wave Propagation in Plasma Waveguides.

Donald Lawson Turcotte (Aeronautics and Physics). *B.S., California Institute of Technology, 1954.* Thesis: Flame Stabilization in Turbulent Boundary Layers.

Wilton Emile Vannier, (Immunochemistry and Animal Physiology). *M.D., University of California, 1948.* Thesis: I. House Dust Allergens. II. Experiments on the Distensibility of the Excised Rabbit Bladder.

James Ira Vette (Physics and Mathematics). *B.A., The Rice Institute, 1952.* Thesis: Photoproduction of Neutral Pions in Hydrogen from 500 to 950 Mev.

George Wallerstein (Astronomy and Physics). *A.B., Brown University, 1951; M.S., California Institute of Technology, 1954.* Thesis: Spectra of Population II Cepheid Variable Stars.

Lloyd Richard Welch (Mathematics and Physics). *B.S., University of Illinois, 1951.* Thesis: The Rearrangement of Functions and Maximization of a Convolution Integral.

Norman Patrick Wilburn (Chemical Engineering and Electrical Engineering). *B.S., California Institute of Technology, 1953; M.S., 1954.* Thesis: Preliminary Studies in the Determination of the Volumetric Properties of Nitrogen Using a Ballistic Piston Apparatus.

Forman Arthur Williams (Engineering Science and Physics). *B.S.E., Princeton University, 1955.* Thesis: Theoretical Studies in Heterogeneous Combustion.

David James Wilson (Chemistry, Mathematics, and Physics). *B.S., Stanford University, 1952.* Thesis: I. Further Investigation of Energy Transfer Processes in the Unimolecular Decomposition of Nitryl Chloride. II. Decomposition of Nitrogen Pentoxide in the Presence of Nitric Oxide. (IV.) Effect of Noble Gases. III. Theoretical Pre-exponential Factors for Hydrogen Atom Abstraction Reactions. IV. Carbon Isotope Effect During Oxidation of Carbon Monoxide with Nitrogen Dioxide.

Robert Montague Worlock (Physics and Mathematics). *B.A., Carleton College, 1951.* Thesis: Photoproduction of Neutral Pions in Hydrogen from 600 to 800 Mev.

William Zimmerman, Jr. (Physics and Mathematics). *B.A., Amherst College, 1952.* Thesis: Experiments Concerning the Low-energy States of N^{16} and O^{19}.

Engineer's Degree

AERONAUTICAL ENGINEER

Andrew George Fabula. *B.S., Princeton University, 1949; M.S., California Institute of Technology, 1950.*

Danny Frederick Huebner. *B.Ae.E., University of Minnesota, 1955; M.S., California Institute of Technology, 1957.*

Malcolm LeRoy Matthews. *B.S., University of Washington, 1955.*

John Carver McCoy, Lt., U.S.N. *B.S., United States Naval Academy, 1949; B.S., United States Naval Postgraduate School, 1957.*

Kenneth F. Nicholson. *B.S., California Institute of Technology, 1953; M.S., 1954.*

Raymond Wilbur Prouty. *B.Sc. University of Washington, 1950; M.S., 1954.*

Dick Wright Thurston, Lt.(jg), U.S.N. *B.S., United States Naval Academy, 1950; B.S., United States Naval Postgraduate School, 1957.*

MECHANICAL ENGINEER

Sterge Theodore Demetriades. *A.B., Bowdoin College, 1950; M.S., Massachusetts Institute of Technology, 1951.*

Rolf Constantin Hastrup. *B.S., California Institute of Technology, 1953; M.S., 1954.*

Richard Keith Nelson. *B.S., University of Minnesota, 1952; M.S., 1953.*

Master of Science in Science

ASTRONOMY

Robert Henry Norton, Jr. *B.S., California Institute of Technology, 1957.*
Donald James Taylor. *B.S., California Institute of Technology, 1955.*
Robert LeRoy Wildey. *B.S., California Institute of Technology, 1957.*

CHEMISTRY

Bernhard August Kraus. *B.S., University of Southern California, 1955.*

CHEMICAL ENGINEERING

Robert Philo Chambers. *B.S., California Institute of Technology, 1957.*
Giles Roy Cokelet. *B.S., California Institute of Technology, 1957.*
Allan Morris Goldberg. *B.S., California Institute of Technology, 1957.*
Edwin Murray Perrin. *B.S., University of Alberta, 1957.*
Yui Loong Wang. *B.S., Taiwan College of Engineering, 1956.*
Lawrence Zanford Wieder. *B.S., University of Washington, 1957.*

GEOLOGY

Daniel Stephen Barker. *BS., Yale University, 1956.*
Gilles Betz. *Dipl. d'Ing., École Nationale Supérieure des Mines de Paris, 1956.*
Alain Boulanger, *Dipl. d'Ing., École Nationale Supérieure des Mines de Paris, 1956.*
Guy de Rimontiel de Lombares. *Dipl. d'Ing. École Nationale Supérieure des Mines de Paris, 1956.*
Claude David Fiddler. *A.B., Occidental College, 1954.*
René Edmond Maurice. *Dipl. d'Ing., École Nationale Supérieure des Mines de Paris, 1956.*
Walter Fay Reiss, Jr. *B.A., Whittier College, 1956.*
Dale Rodekohr Simpson. *B.S., The Pennsylvania State University, 1956.*
Arthur Ogilvy Spaulding. *B.S., California Institute of Technology, 1949.*

GEOPHYSICS

Thomas Julian Ahrens. *S.B., Massachusetts Institute of Technology, 1957.*
Stewart Wilson Smith. *S.B., Massachusetts Institute of Technology, 1954.*
Roger Dean Summer. *B.A., The Rice Institue, 1956.*

MATHEMATICS

Peter Linton Crawley. *B.S., California Institute of Technology, 1957.*
George Gerson. *B.S., Queens College, 1951.*
Morton Lowengrub. *B.A., New York University, 1956.*
Howard Calvin Rumsey, Jr. *B.S., California Institute of Technology, 1957.*

PHYSICS

Harvey Marshall Endler. *B.S., University of Illinois, 1956.*
Millard Alvin Habegger. *B.S., Purdue University, 1956.*
William Breckenridge Lindley. *B.S., California Institute of Technology, 1955.*
John David Rogers. *B.S., California Institute of Technology, 1956.*
Robert Emil Rothe. *B.A., Knox College, 1956.*
Mohammad Hussein Saffouri. *B.S., American University of Beirut, 1956.*

Master of Science in Engineering

AERONAUTICS

Sanford Abramowitz. *B.Ae.E., New York University, 1956.*

David Elsworth Anderson. *B.S.A.E., West Virginia University, 1954.*

Francis Edward Augustine. *B.Ae.E., The Catholic University of America, 1953.*

Charles Dwight Babcock, Jr. *B.S.A.E.,Purdue University, 1957.*

Richard George Batt. *B.S.E., Princeton University, 1955.*

Chester Robert Bauer. *B.Ae.E., New York University, 1942.*

Harold Dean Culver. *B.S., Oklahoma State University of Agriculture and Applied Science, 1955.*

Chester Harold Dale, Jr. *B.S., California Institute of Technology, 1957.*

Leonard Maurice Gaines. *B.S., Parks College of Aeronautical Technology, 1951.*

John Louis Gardner, Jr. *B.E.E., Louisiana State University, 1957.*

Herbert Ray Graham. *S.B., Massachusetts Institute of Technology, 1951.*

Darrel Leigh Hirsch. *B.S., University of Colorado, 1954.*

David Parks Hoult. *S.B., Massachusetts Institute of Technology, 1957.*

Richard M. Jali. *B.S., California Institute of Technology, 1955.*

Donald Harold Landauer. *B.S., University of Kansas, 1957.*

Jean Lemaître. *Dipl. d'Ing., École Nationale d'Ingénieurs Arts et Métiers, 1957.*

Robert Arthur Mowry. *B.A., Upland College, 1956.*

Jerry Clifford Peck. *B.S., California Institute of Technology, 1957.*

Charles Leslie Statham. *B.S., Louisiana State University, 1957*

Carl Jules Weyl. *B.S.Ae.E., Indiana Technical College, 1951.*

CIVIL ENGINEERING

Itiel Ike Haissman. *B.S., California Institute of Technology, 1957.*

Joseph Mortimer Kiernan, Jr., Capt., U.S.A. *B.S., United States Military Academy, 1948.*

George Donald Leal. *B.C.E., University of Santa Clara, 1955.*

George Everette Madsen. *B.S., California Institute of Technology, 1955.*

Robert Erich Reuven Pollak. *B.S., The University of Texas, 1957.*

Carl Alan Rambow. *B.S., California Institute of Technology, 1953.*

Rowland Richards, Jr. *B.S.E., Princeton University, 1957.*

Robert Hugh Taylor, Jr. *B.S., University of Colorado, 1957.*

ELECTRICAL ENGINEERING

Peter Kendall Abbey. *B.S., California Institute of Technology, 1957.*

Donn Anthony Allen. *B.S., California Institute of Technology, 1957.*

Majid Arbab. *B.A., Dartmouth College, 1957.*

Eugene Myron Barston. *B.S., California Institute of Technology, 1957.*

Charles Joseph Byrne, Jr. *B.E.E., Rensselaer Polytechnic Institute, 1957.*

Michel Jacques Canu. *Dipl. d'Ing., École Supérieure de l'Aéronautique, 1957.*

Michael Anthony Cowan. *B.S., Purdue University, 1957.*

Harold Ralph Dessau. *B.S., California Institute of Technology, 1957.*

Robert George Dietrich. *B.S., Washington University, 1957.*

Michel Abel Ebertin. *B.E.E., Polytechnic Institute of Brooklyn, 1957.*

Richard William Ehrhorn. *B.S., University of Minnesota, 1955.*

Duane Donald Erway. *B.S., California Institute of Technology, 1957.*

James Norval Giles. *B.S., California Institute of Technology, 1957.*

John Harvey Gliever. *B.S., California Institute of Technology, 1957.*

Lawrence Thompson Gurley. *B.E.E., The Cooper Union School of Engineering, 1957.*

Thomas Chandler Hays. *B.S., California Institute of Technology, 1957.*

Neil Hunter Herman. *B.S., California Institute of Technology, 1957.*

Roy Albert Jensen. *B.S., California Institute of Technology, 1957.*

Lawrence Irwin Kittiver. *B.E.E., The Cooper Union School of Engineering, 1955.*

William John Klenk, *B.E.E., University of Dayton, 1957.*

Allen Klinger. *B.E.E., The Cooper Union School of Engineering, 1957.*

Harold Gordon Knight. *B.A.Sc., University of Toronto, 1957.*

Jean Pierre Lacrouts. *Dipl. d'Ing., École Nationale Supérieure des Télécommunications, 1957.*

Daniel Rutchik Mack. *B.S., California Institute of Technology, 1957.*

Stephen Man-Fa Mak. *B.S., California Institute of Technology, 1957.*

Chester Leo Malone. *B.S., California Institute of Technology, 1957.*

Maury Ivan Marks. *B.S., Drexel Institute of Technology, 1957.*

Malcolm McCall. *B.S., Wayne University, 1957.*

William True McDonald. *B.S., California Institute of Technology, 1957.*

Murray Arlen Meldrum. *B.A.Sc., The University of British Columbia, 1956.*

John Hendrick Minkema, *B.S., University of Washington, 1947.*

Edwin Donald Nelson. *B.S., California Institute of Technology, 1957.*

Harry Patapoff. *B.S., California Institute of Technology, 1957.*

Donald Dean Peckham. *B.S., University of Washington, 1957.*

John Chester Porter, Jr. *B.S., California Institute of Technology, 1952.*

Jacques Marcel Rieunier. *Dipl. d'Ing., École Centrale des Arts et Manufactures, 1957.*

Ronald John Rockey. *B.S., California Institute of Technology, 1956.*

Fred Donald Russell. *B.S., California Institute of Technology, 1957.*

Robert Kenneth Schmidt. *B.S., Worcester Polytechnic Institute, 1957.*

Alex Shumka. *B.A.Sc., University of Toronto, 1957.*

Richard Louis Sicol. *B.S., Purdue University, 1956.*

Attila Imre Simanyi. *B.S., California Institute of Technology, 1957.*

Thomas Christian Sorensen. *B.S., California Institute of Technology, 1957.*

Richard Douglas Stark. *B.S., California Institute of Technology, 1957.*

Edwin Couthouy Stimpson, Jr. *B.S., University of Kansas, 1952.*

Robert Clem Titsworth. *B.S., New Mexico College of Agriculture and Mechanic Arts, 1957.*

Edvin Otto Tums. *B.S., Illinois Institute of Technology, 1957.*

Cavour Wei-Hou Yeh. *B.S., California Institute of Technology, 1957.*

ENGINEERING SCIENCE

Olaf Alexander Boedtker. *Dipl. Eng., Swiss Institute of Technology, 1944.*

Abraham Zukerman. *B.S., Parks College of Aeronautical Technology, 1954; M.S., University of Southern California, 1956.*

MECHANICAL ENGINEERING

Boris Auksmann. *B.A.Sc., The University of British Columbia, 1955.*

Frank Joseph Berto. *B.A.Sc., The University of British Columbia, 1952.*

John Kalman Dienes. *B.A., Pomona College, 1950.*

Antanas Vytautas Dundzila. *B.S., University of Illinois, 1955.*

Charles Gordon Fullerton. *B.S., California Institute of Technology, 1957.*

Andrew Guttman. *B.M.E., The College of The City of New York, 1957.*

Leighton D. Hanon, Jr. *B.S., California Institute of Technology, 1955.*

John Louis Hokanson. *B.S., Purdue University, 1957.*

Marcos Intaglietta. *B.S., University of California, 1957.*

Wilford Dean Iwan. *B.S., California Institute of Technology, 1957.*

Leon Morris Keer. *B.S., California Institute of Technology, 1956.*

Mitri Gabriel Khamis. *B.S., Rutgers University, 1957.*

Henri Marie Lacombe. *Dipl. d'Ing., École Supérieure de l'Aéronautique, 1957.*

Theodore Edmund Lang. *B.S., California Institute of Technology, 1957.*

Joe Edward Lingerfelt. *B.S., California Institute of Technology, 1957.*

Jean François Marin. *Dipl. d'Ing., École Supérieure des Mines de Paris, 1957.*

Morrow Harris Moore, Jr. *B.M.E., The George Washington University, 1957.*

Peter Marc Allen Moretti. *B.S., California Institute of Technology, 1957.*

Ulo Okapuu. *B.E., McGill University, 1957.*

Richard Walker Patch. *B.S., Purdue University, 1953.*

William Arthur Petri. *B.A., Alfred University, 1942; M.S., Syracuse University, 1944.*

Richard Allan Schapery. *B.S., Wayne State University, 1957.*

Richard Franklin Smisek. *B.S., California Institute of Technology, 1957.*

Derek Murray Squires. *The College of Aeronautics, Cranfield, 1957.*

Gunnar Erik Stenberg. *Dipl. Civil Eng., The Royal Institute of Technology, Stockholm, 1956.*

Richard Anthony Tanzilli. *B.M.E., Pratt Institute, 1957.*

Thomas Ova Thostesen. *B.S., Iowa State College, 1957.*

George Humphrey Tichenor, IV. *S.B., Massachusetts Institute of Technology, 1957.*

Milton George Wille. *B.E.S., Brigham Young University, 1957.*

James William Workman. *B.S., California Institute of Technology, 1957.*

Bachelor of Science in Science

David Anthony Ackley, Lakeside, California. *Physics.*
Gordon Stewart Barienbrock, Santa Monica, California. *Physics.*
Robert Leland Blakeley, Santa Ana, California, *Chemistry.*
Gordon Elliott Brown, Ellensburg, Washington. *Mathematics; Academic Honor.*
David G. Byles, Aberdeen, Washington. *Physics; Academic Honor.*
George M. Canova, Duarte, California. *Physics.*
Berken Chang, State College, New Mexico. *Physics; Academic Honor.*
Eugene Harold Cordes, Grand Island, Nebraska. *Chemistry; Honor Key.*
Robert S. Deverill, Hilo, Hawaii. *Chemistry; Academic Honor.*
Norman T. Ellett, River Forest, Illinois. *Physics.*
Alan S. Emanuel, Van Nuys, California. *Applied Chemistry; Academic Honor.*
James Henry Espenson, Pomona, California. *Chemistry.*
Barry Eric Feinberg, Plainfield, New Jersey. *Physics.*
Joseph Clinton Fineman, Shaftsbury, Vermont. *Physics; Academic Honor.*
Darrell Eugene Fleischman, Phoenix, Arizona. *Chemistry.*
Jerrold Fried, Phoenix, Arizona. *Physics; Academic Honor.*
Stuart Goff, Van Nuys, California. *Physics; Honor Key.*
David Eiben Groce, La Mesa, California. *Physics; Academic Honor.*
Nathaniel Grossman, Aurora, Illinois. *Mathematics.*
William Phillip Helman, Grand Junction, Colorado. *Chemistry.*
Stephen Ford Holtzman, Tempe, Arizona. *Physics.*
Daniel Henry Horowitz, Atlantic City, New Jersey. *Geology.*
Laurence Gordon Jones, Riverside, California. *Biology.*
Mauritz Jacob Kallerud, Casper, Wyoming. *Applied Chemistry.*
William Kern, Sacramento, California. *Physics.*
William Klement, Jr., Bensenville, Illinois. *Physics; Academic Honor.*
Michael Warren Konrad, Virginia Beach, Virginia. *Physics; Academic Honor, Honor Key.*
Edward Lee Krehbiel, Long Beach, California. *Biology.*
Gordon David Lange, Phoenix, Arizona. *Biology; Academic Honor.*
Loren R. Linstrom, Glendale, California. *Astronomy.*
Paul Carlson Minning, Williamsburg, Ohio. *Physics; Academic Honor.*
Louis B. Montoya, Los Angeles, California. *Physics.*
Harold D. Morris, Rosemead, California. *Physics.*
Wayne B. Nelson, Chicago, Illinois. *Physics.*
Charles Herbert Neuman, Fullerton, California. *Physics; Academic Honor.*
Hallan C. Noltimier, Whittier, California. *Geophysics.*
Ernest Roland Parkinson, Boulder City, Nevada. *Physics.*
Robert Reid Parmerter, Fontana, California. *Physics.*
Charles Ronald Penquite, Phoenix, Arizona. *Applied Chemistry.*
Dennis Gail Peters, Eagle Rock, California. *Chemistry; Academic Honor.*
Robert Joseph Phelan, Jr., Pasadena, California. *Physics.*
Gerald Michael Pjerrou, Fontana, California. *Physics.*
George McCoy Poor, McAlester, Oklahoma. *Geology.*
Donald Richard Reiterman, Altadena, California. *Applied Chemistry.*
Philip Lee Reynolds, Glendale, California. *Applied Chemistry.*

James Steven Rode, Glendale, California. *Applied Chemistry; Academic Honor.*

Michael Randolph Rusch, Glendale, California. *Chemistry; Academic Honor.*

Robert Earl Schenter, Inglewood, California. *Physics.*

Thomas Gerald Schumann, Tujunga, California. *Physics; Academic Honor.*

Lawrence Shepard Smith, Los Angeles, California. *Physics.*

Donald Stern, North Hollywood, California. *Physics; Academic Honor, Honor Key.*

Charles Joel Stone, Van Nuys, California. *Mathematics; Academic Honor.*

Howard Ewing Sturgis, Los Angeles, California. *Mathematics.*

Robert Leicester Tambling, Jr., Glen Ridge, New Jersey. *Physics.*

Vincent Deacon Taylor, Los Angeles, California. *Physics; Honor Key.*

Philip Duryea Thacher, Auberry, California. *Physics; Academic Honor.*

Martial Leon Thiebaux, Jr., Whittier, California. *Physics; Academic Honor.*

Jon René Valbert, Harvey, Illinois. *Applied Chemistry; Academic Honor.*

William Gerard Wagner, South Pasadena, California. *Physics; Academic Honor.*

Daniel Lewis Wulff, Santa Barbara, California. *Chemistry; Academic Honor.*

George Andrew Yankura, Bayonne, New Jersey. *Physics.*

Jack Henry Zeilenga, San Diego, California. *Physics; Academic Honor.*

ACADEMIC HONOR: *Graduated with scholastic honor in accordance with a vote of the Faculty.*
HONOR KEY: *Awarded by the Associated Students, CIT, for participation in student activities.*

BACHELOR OF SCIENCE IN ENGINEERING

Frank A. Albini, Madera, California. *Mechanical Engineering; Academic Honor.*

John Fredrich Asmus, Ontario, California. *Electrical Engineering; Academic Honor.*

Tracy Leon Atherton, Jr., Pasadena, California. *Electrical Engineering.*

Richard Lee Baron, Hollywood, California. *Electrical Engineering; Academic Honor.*

Gene Henry Beisman, Las Vegas, New Mexico. *Civil Engineering.*

Laurence Edward Berry, Berkeley, California. *Mechanical Engineering.*

Jay Bryan Clearwaters, Pasadena, California. *Electrical Engineering.*

Forrest Randall Cleveland, Sacramento, California. *Mechanical Engineering.*

Martin Leo Conneally, Sepulveda, California. *Mechanical Engineering.*

Glenn Leland Converse, Glen Rock, New Jersey. *Mechanical Engineering; Academic Honor, Honor Key.*

John Patrick Conway, Canoga Park, California. *Electrical Engineering.*

Richard K. Cooper, La Crescenta, California. *Electrical Engineering; Academic Honor.*

Richard Truman Cowley, Tigard, Oregon. *Mechanical Engineering; Academic Honor.*

John D. Eberhardt, San Diego, California. *Mechanical Engineering; Academic Honor.*

Craig T. Elliott, Oak Park, Illinois. *Mechanical Engineering; Honor Key.*

Stephen Arnold Emanuel, Tujunga, California. *Civil Engineering.*

Robert Clain Emmerling, Los Angeles, California. *Mechanical Engineering.*

George Frederick Engelke, Los Angeles, California. *Mechanical Engineering.*

Richard Walter Fiddler, Kirkland, Washington. *Mechanical Engineering; Academic Honor.*

Hugo Breed Fischer, Colorado Springs, Colorado. *Civil Engineering; Academic Honor.*

Harold Kay Forsen, San Diego, California. *Electrical Engineering; Academic Honor.*

Alan K. Forsythe, Bozeman, Montana. *Mechanical Engineering.*

Gordon Ellis Glattenberg, Los Angeles, California. *Mechanical Engineering.*

William Brewster Gray, Long Beach, California. *Mechanical Engineering.*

Thomas L. Gunckel, II, Pomona, California. *Mechanical Engineering; Academic Honor.*

Lance Gregory Hays, Burbank, California. *Mechanical Engineering.*

Richard F. Herlein, Portland, Oregon. *Electrical Engineering.*

Riley Hunter Holly, Los Angeles, California. *Electrical Engineering.*

Harvey Hiroaki Horiuchi, Junction City, Kansas. *Electrical Engineering.*

Anthony Livingstone Howell, Des Moines, Iowa. *Mechanical Engineering.*

Robert Slater Johnstone, Albuquerque, New Mexico. *Mechanical Engineering.*

Richard Miles Kirk, Sacramento, California. *Mechanical Engineering; Honor Key.*

Wolfgang Gustav Knauss, Altadena, California. *Mechanical Engineering; Academic Honor.*

David Brent Leeson, Los Angeles, California. *Electrical Engineering; Academic Honor, Honor Key.*

Keith Bryant Martin, Compton, California. *Electrical Engineering.*

Bruce Timoney McKeever, Pasadena, California. *Electrical Engineering; Academic Honor.*

Lawrence H. Nelson, Phoenix, Arizona. *Mechanical Engineering.*

Richard Coulston Neville, Tucson, Arizona. *Electrical Engineering; Academic Honor.*

Theodore Cameron Oakberg, Coeur d'Alene, Idaho. *Mechanical Engineering.*

George Norton Oetzel, Beloit, Wisconsin. *Electrical Engineering; Academic Honor.*

Andrew Louis Perga, Butte, Montana. *Electrical Engineering; Honor Key.*

Robert Gerald Polansky, South Pasadena, California. *Electrical Engineering.*

Clarke C. Rees, Inglewood, California. *Mechanical Engineering; Honor Key.*

Dalip Saund, Pasadena, California. *Mechanical Engineering.*

Walter Alan Schaal, La Crescenta, California. *Mechanical Engineering.*

Ralph George Schinnerer, Bellflower, California. *Electrical Engineering.*

Lee Otis Schmidt, Brea, California. *Electrical Engineering.*

Mitchell Harvey Seidman, Huntington Park, California. *Mechanical Engineering.*

Donald R. Sessler, Alhambra, California. *Electrical Engineering.*

Edward Bartley Shuster, Pasadena, California. *Mechanical Engineering.*

Joe Nelson Smith, Jr., San Clemente, California. *Electrical Engineering; Academic Honor.*

Peter Raymond Smith, Los Angeles, California. *Electrical Engineering.*

Robert Allen Smoak, Santa Ana, California. *Mechanical Engineering.*

Arthur Roy Stacy, La Canada, California. *Civil Engineering; Academic Honor.*

Lawrence Eugene Stanley, Wichita, Kansas. *Electrical Engineering.*

Donald Wesley Stocking, Tracy, California. *Mechanical Engineering.*

Jonathan Cilley Tibbitts, Jr., Central Valley, California. *Civil Engineering.*

Robert Edward Tokheim, Whittier, California. *Electrical Engineering; Academic Honor.*

Richard Lee Van Kirk, Glendale, Arizona. *Mechanical Engineering; Honor Key.*

David Edward Wallis, Jr., Glendale, California. *Electrical Engineering.*

Thomas Read Warriner, Saratoga, California. *Civil Engineering.*

James Norman Weaver, Pacific Grove, California. *Electrical Engineering; Academic Honor.*

Bruce Lambert Wilkinson, Coos Bay, Oregon. *Electrical Engineering.*

ACADEMIC HONOR: *Graduated with scholastic honor in accordance with a vote of the Faculty.*
HONOR KEY: *Awarded by the Associated Students, CIT, for participation in student activities.*

CANDIDATES FOR COMMISSIONS UNITED STATES AIR FORCE RESERVE OFFICERS' TRAINING CORPS

Gene Henry Beisman

Laurence Edward Berry*

Barry Eric Feinberg*

Hugo Breed Fischer

Robert Gerald Polansky

Walter Alan Schaal*

David Edward Wallis, Jr.

**Distinguished Air Force Reserve Officers' Training Corps Graduates*

HONORS AND AWARDS

Honor Standing

The undergraduate students listed below have been awarded honor standing for the current year, on the basis of excellence of their academic records for the year 1956-57:

CLASS OF 1961

Bauer, W. R.	Kasper, J. V.	Matthews, K.
Bowman, J. D.	Kendle, D. W.	Moler, C. B.
Brown, L. D.	Klein, S. A.	Norman, R. S.
Burke, B. G.	Loebbaka, D. S.	Poe, R. F.
Chernow, E. I.	Long, R. E.	Schwab, M.
Evans, E. T.	Ludwig, A. C.	Shampine, L. F.
Huld, B.	Luner, S. J.	

CLASS OF 1959

Baicher, V. V.	Handel, D.	Moores, E. M.
Brown, K. S., Jr.	Havey, J. H., Jr.	Morton, T. E.
Carroll, C. E.	Johnson, R.	Petersen, J. C.
Chandos, R. E.	Lange, R. V.	Pitzer, R. M.
Cheng, H.	Luenberger, D. G.	Roth, S.
Clark, B. G.	Maltz, C.	Schuster, J. J.
Doyle, R. J.	Massey, G. A.	Schwarz, S. E.
Groesbeck, F. W.	Milder, D. M.	Seltzer, E. C.

CLASS OF 1960

Anderson, D. W.	Efron, B.	Neville, M. K.
Bergstresser, T. K.	Hales, A. W.	Rony, P.
Black, N. A.	Jantscher, G. R.	Sinoff, W. A.
Cassel, D. G.	Koh, R. C.	Smith, P. W., Jr.
Cauley, J. M.	Munson, J. H.	Stephens, S. V.
Clark, L. E.	Nearing, J. C.	Toth, L. E.
		Weisberg, H. L.

Frederic W. Hinrichs, Jr., Memorial Award

Awarded annually to "the senior who, in the opinion of the undergraduate Deans, has throughout his years at the Institute made the greatest contribution to the welfare of the student body and whose qualities of leadership, character, and responsibility have been outstanding."

RICHARD L. VAN KIRK

Don Baxter, Inc. Prizes in Chemistry

Awarded to the two undergraduate students who during the year have carried out the best original researches in chemistry.

First prize: DENNIS G. PETERS

Second prize, divided between:

MICHAEL E. KIEFFER

DANIEL L. WULFF

Conger Peace Prize Oration

Established in 1912 by the late Everett D. Conger, D.D.

First prize: VINCENT D. TAYLOR

Second prize: KEITH S. BROWN, JR.

Institute of the Aeronautical Sciences Scholastic Award

Awarded to the student member of the I.A.S. attaining the best scholastic record in engineering or the physical sciences.

DAVID P. HOULT

David Joseph Macpherson Prize

Awarded annually for the winning essay in a contest open to Seniors in the Division of Engineering. The award is made in order to stimulate interest and excellence in written communication.

DAVID B. LEESON

Don Shepard Award

Awarded annually to one or more outstanding residents of the Student Houses in order to pursue cultural opportunities which they might otherwise not be able to enjoy.

D. MICHAEL MILDER

RICHARD C. MONTGOMERY

Sigma Xi Award

Awarded in recognition of research work of exceptional quality by a graduate student. The nomination for the award, rotated among the Divisions, is made in 1958 by the Division of Physics, Mathematics and Astronomy, to a student in the Mathematics department.

PETER CRAWLEY

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Chemistry and Chemical Engineering	Ernest H. Swift
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Superintendent of the Guggenheim Aeronautical Laboratory	Wm. H. Bowen

FACULTY OFFICERS AND COMMITTEES
1958-59

OFFICERS

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ACADEMIC FREEDOM AND TENURE—*Sharp*, Bacher, Bohnenblust, I. Campbell, Greenstein (alt.), Lindvall, Pauling.

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

CONVOCATIONS—*Eagleson*, D. S. Clark, J. Davies, Hertenstein, Capt. Lanman, Musselman, Newton, Paul.

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

COURSE IN ENGINEERING—*Wood*, Brockie, Gray, Housner, Hudson, H. Martel, Maxstadt, McKee, Plesset, Sechler.

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

EDUCATIONAL POLICIES—*Sabersky*, Anson, Brooks, Davies, Dilworth, Gell-Mann, Greenstein, Piper, J. D. Roberts, Sperry, Wasserburg, Wilts.

FOREIGN STUDENTS—*Gilbert*, C. D. Anderson, I. Campbell, Eaton, Elliot, Hershey, Horowitz, Ingersoll, Lagerstrom, T. Lauritsen, Vanoni, Waser.

FRESHMAN ADMISSION—*Jones*, Dilworth, Eaton, Gould, Huttenback, Jahns, Leighton, Mayhew, P. Miller, Niemann, Owen, Strong, Weir, Whaling, Wilts.

GRADUATE STUDY—*Bohnenblust*, C. D. Anderson, Bacher, Bonner, I. Campbell, Greenstein, Housner, Lindvall, Longwell, McCann, Niemann, Swift, Sechler, Sharp, H. D. Smith, Van Harreveld, Watson.

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

LIBRARY—*Stanton*, Apostol, Converse, DePrima, Deutsch, Elliot, Emerson, Engel, Gray, Ingersoll, King, Liepmann, Sage, Schroeder, Tyler, Wilts, Zwicky.

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

NOMINATIONS—*Watson*, Bohnenblust, Bonner, Eagleson, Eaton, Housner, Jones, Niemann, Sharp, Strong.

PATENTS—*Davidson*, C. D. Anderson (ex-officio), D. S. Clark, Corcoran, Langmuir, McCann, Niemann.

PHYSICAL EDUCATION—*Eaton*, Emery, Huttenback, Jahns, Jones, King, LaBrucherie, Maj. MacKenzie, H. Mitchell, Musselman, Nerrie, Preisler, Webb.

PUBLICATIONS AND PUBLIC RELATIONS—*Brown*, Bowen, D. S. Clark, Eaton, Hutchings, Jones, J. Miller, Newton, Watson.

REGISTRATION—*Langmuir*, Davis, Eaton, Hudson, Huttenback, Jones, Lewis, Maxstadt, McConnell, Noble, Strong.

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

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

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

STUDENTS' DAY—*Vreeland*, Davidson, Hertenstein, Lewis, Maxstadt, Newton, Sabersky, Sechler, Silver, Sutton.

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

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

STUDENT RELATIONS—*T. Lauritsen*, Apostol, J. K. Clark, Dean, Eaton, Huttenback, Langmuir, Mayhew, Peterson, Sabersky, Strong, Sutton, Sweezy, Waser, Wood.

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

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

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

STAFF OF INSTRUCTION AND RESEARCH SUMMARY

Division of Biology

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James F. Bonner, *Acting Chairman*

PROFESSOR EMERITUS

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Max Delbrück, Ph.D. .... *Biology*
Renato Dulbecco, M.D. .... *Biology*
Sterling Emerson, Ph.D. .... *Genetics*
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Edward B. Lewis, Ph.D. .... *Genetics*
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Robert L. Sinsheimer, Ph.D. .... *Biophysics*
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Anthonie Van Harreveld, Ph.D., M.D. .... *Physiology*
Frits W. Went, Ph.D.* .... *Plant Physiology*
Cornelis A. G. Wiersma, Ph.D. .... *Biology*

VISITING PROFESSOR

Willis E. Pequegnat, Ph.D. .... *Zoology*

RESEARCH ASSOCIATES

Gordon A. Alles, Ph.D. .... *Biology*
Henry O. Eversole, M.D. .... *Plant Physiology*
Albert E. Longley,[1] Ph.D. .... *Biology*
William S. Stewart, Ph.D. .... *Biology*
Esther Bogen, Ph.D., M.D. .... *Biology*
Jean J. Weigle, Ph.D. .... *Biophysics*

SENIOR RESEARCH FELLOWS

Jacob W. Dubnoff, Ph.D. .... *Biology*
Henry Hellmers,[2] Ph.D. .... *Biology*
Geoffrey L. Keighley, Ph.D. .... *Biology*
George G. Laties, Ph.D. .... *Biology*
Marguerite Vogt, M.D. .... *Biology*

[1]U. S. Department of Agriculture
[2]U. S. Forest Service
*On leave of absence in 1958-1959

GOSNEY FELLOW

Domenico Spinelli, M.D. . . . . *Biology*

RESEARCH FELLOWS

Harbans L. Arora, Ph.D.
Robert E. Black,[1] Ph.D.
Hugh J. F. Cairns,[2] M.D.*
Edward A. Carusi,[3] Ph.D.
Ikram I. Chaudhri,[4] D.Sc.
Pen Ching Cheo, Ph.D.
John H. Curme,[5] Ph.D.*
Emmanuel Epstein,[6] Ph.D.
Stephen O. Fejer,[7] Ing.Agr.
Marguerite Fling, Ph.D.
Alan E. Flood,[8] Ph.D.
Kenneth T. Glasziou,[9] Ph.D.
Franklin M. Harold,[10] Ph.D.
Harry R. Highkin, Ph.D.
Donald E. Hoard,[1] Ph.D.
Hendrik J. Ketellapper, Ph.D.
Dov Koller,[11] Ph.D.
Hildegard Lamfrom, Ph.D.
James A. Lockhart, Ph.D.
John B. Loefer,[12] Ph.D.
Peter Lowy, Doctorandum
Nettie MacGinitie, M.S.
William D. McBride,[13] D.D.S.
George A. McCallum,[14] Ph.D.*
Alexander Miller,[1] Ph.D.
Kenneth J. Mitchell,[7] Ph.D.
Mary B. Mitchell, M.S.
Wouter duT. Naudé,[15] M.Med.
Jean P. Nitsch,[16] Ph.D.*
Eiji Ohnishi,[11] B.S.
Roderic B. Park, Ph.D.
John R. Philip, B.C.E.
Louis J. Pierro,[1] Ph.D.*
Albert E. Purcell,[17] Ph.D.*
Lawrence Rappaport,[18] Ph.D.*
John Romberger, Ph.D.
Clifford S. Sato, Ph.D.
Johannes P. Schadé, M.D., Ph.D.
Walter A. Shropshire, Jr., Ph.D.
John D. Soule,[19] Ph.D.*
Lloyd P. Tevis, Jr., B.A.
Paul O. P. Ts'o, Ph.D.
Dietrich von Wettstein,[11] Ph.D.*

GRADUATE FELLOWS AND ASSISTANTS, 1957-1958

Peter Albersheim, B.S.
Dennis Barrett, A.B.
Harris Bernstein, B.S.
Vernon D. Burrows, M.Sc.
John M. Clark, Jr., B.S.
Cedric I. Davern, M.Sc.Agr.
David S. Dennison, B.A.
John W. Drake, B.S.
Benjamin S. Friesen, M.A.
Ellsworth H. Grell, B.S.
George D. Guthrie, A.B.
Charles R. Hamilton, B.S.
Boyd A. Hardesty, M.S.
Luiz F. G. Labouriau, M.S.
Jacob V. Maizel, Jr., M.S.
Roderic B. Park, B.A.
Ann Roller, M.S.
John R. Simmons, M.S.
Edward H. Simon, B.S.
Charles M. Steinberg, B.A.
William A. Strohl, B.A.
Noboru Sueoka, M.Agr.
Millard Susman, A.B.
Howard M. Temin, B.A.
Guy A. Thompson, Jr., B.S.
Colwyn B. Trevarthen, M.Sc.
Ivan Jeanne Mayfield Weiler, B.A.

[1]U. S. Public Health Service Fellow
[2]Australian National University
[3]Jane Coffin Childs Memorial Fund for Medical Research Fellow
[4]Southeast Asia Treaty Organization Fellow
[5]Campbell Soup Company
[6]John Simon Guggenheim Memorial Foundation Fellow
[7]Dept. of Scientific and Industrial Research, New Zealand
[8]W. K. Kellogg Foundation Fellow
[9]Colonial Sugar Refining Co., Ltd.
[10]National Science Foundation Fellow
[11]Rockefeller Foundation Fellow
[12]U. S. Department of the Navy, Office of Naval Research
[13]U. S. Public Health Service
[14]San Jose State College
[15]Eli Lilly Company Fellow
[16]Cornell University
[17]U. S. Department of Agriculture
[18]University of California
[19]University of Southern California
*In residence in 1957-1958

Division of Chemistry and Chemical Engineering

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J. H. Sturdivant, *Executive Officer*

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James E. Bell, Ph.D. .... *Chemistry*
Howard J. Lucas, D.Sc. .... *Organic Chemistry*

PROFESSORS

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

RESEARCH ASSOCIATES

Edwin R. Buchman, D.Phil. .... *Organic Chemistry*
Edward W. Hughes, Ph.D. .... *Physical Chemistry*
Joseph B. Koepfli, D.Phil. .... *Chemistry*
Allen Lein,[1] Ph.D. .... *Chemistry*
Seeley G. Mudd, M.D. .... *Medical Chemistry*
Walter A. Schroeder, Ph.D. .... *Chemistry*
Richard T. Smith, M.D. .... *Chemistry*
Jerome R. Vinograd, Ph.D. .... *Chemistry*
Oliver R. Wulf, Ph.D. .... *Physical Chemistry*

ASSOCIATE PROFESSORS

Paul A. Longwell, Ph.D. .... *Chemical Engineering*
Harden M. McConnell, Ph.D. .... *Physical Chemistry*

SENIOR RESEARCH FELLOWS

I. S. Edelman, M.D. .... *Chemistry*
Justine S. Garvey, Ph.D. .... *Chemistry*
Yuen Chu Leung, Ph.D. .... *Chemistry*
Richard E. Marsh, Ph.D. .... *Chemistry*
Chester M. McCloskey, Ph.D. .... *Chemistry*
H. Hollis Reamer, M.S. .... *Chemical Engineering*
Kenneth N. F. Shaw, Ph.D. .... *Chemistry*

[1] John Simon Guggenheim Memorial Foundation Fellow
*Part-time
**On leave of absence first term 1958-59

ASSISTANT PROFESSORS

Fred C. Anson, Ph.D. . . . . *Analytical Chemistry*
Howard M. Dintzis, Ph.D. . . . . *Chemistry*
Robert M. Mazo, Ph.D. . . . . *Physical Chemistry*
Matthew S. Meselson, Ph.D. . . . . *Physical Chemistry*
John H. Richards, Ph.D. . . . . *Organic Chemistry*
George Neal Richter, Ph.D. . . . . *Chemical Engineering*

INSTRUCTOR

Dwight M. Smith, Ph.D. . . . . *Chemistry*

RESEARCH FELLOWS

Herman Ainis,[1] Ph.D.
Harold W. Barrett,[1] Ph.D.
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William P. Bryan, Ph.D.
Desmond M. Burns, Ph.D.
Benjamin Carroll,[2] Ph.D.
Marjorie B. Caserio, Ph.D.
Terry Cole, Ph.D.
William G. Dauben,[2] Ph.D.
William B. DeMore, Ph.D.
Snegulka Detoni, Ph.D.
Ernest L. Eliel,[2] Ph.D.
Richard W. Fessenden,[2] Ph.D.
Gideon Fraenkel,[3] Ph.D.
Cafiero Franconi,[3] Ph.D.
Hans C. Freeman,[4] Ph.D.
Raymond Gerdil, D.Sc.
William H. Graham,[3] Ph.D.
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Chonon Heller,[3] Ph.D.
Karst Hoogsteen, D.Sc.
Kimishige Ishizaka, M.D.
Teruko Ishizaka, M.D.
Georg Johansson, Tekn.Lic.
Wesley M. Jones,* Ph.D.
Richard T. Keys, Ph.D.
Hideo Kon, D.Sc.
Aharon Loewenstein, Ph.D.
Genji Matsuda, M.D.
Walter M. Meier, Ph.D.
Albrecht W. Moschel, Ph.D.
Uma Sankar Nandi, D.Phil.
Gus J. Palenik,* B.S.
Harris E. Phipps,[2] Ph.D.
Ernst Renk, Ph.D.
Don Ridgeway,[1] Ph.D.
Christoph Rüchardt, Ph.D.
Sten Samson, Fil.Lic.
John P. Schaefer,[2] Ph.D.
Arthur G. Schnek, Ph.D.
Massimo Simonetta, Ph.D.
Richard H. Stanford, Jr., Ph.D.
I. M. Rosemary Summers, M.A.
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Wilton E. Vannier, M.D., Ph.D.
John R. Weber, Ph.D.
George Wilheim, Ph.D.
Norman Weliky, Ph.D.
Andrzej Witowski,[6] Ph.D.
Donald A. Wright, Ph.D.
Chin-Hua Wu, Ph.D.

[1]United States Public Health Service Fellow
[2]National Science Foundation Fellow
[3]Arthur Amos Noyes Fellow
[4]George Ellery Hale Fellow
[5]Rockefeller Foundation Fellow
**In residence during 1957-58*

Chemistry and Chemical Engineering

Graduate Fellows and Assistants, 1957-1958

Henry I. Abrash, A.B.
Norman E. Albert, B.S.
Harold R. Almond, Jr., B.S.
Louis N. Bathish, B.A.
William F. Beach, B.S.
Stuart B. Berger, B.A.
Frank B. Booth, M.S.
J. Philip Bromberg, S.B.
Ronald A. S. Brown, M.S.
Robert P. Chambers, B.S.
Giles R. Cokelet, B.S.
Terry Cole, B.S.
Henry H. Dearman, B.S.
William B. DeMore, M.A.
Rolf Engleman, Jr., B.S.
Grover L. Farrar, B.S.
Louis D. Ferretti, B.A.
Donald C. Garwood, B.A.
Concetto R. Giuliano, B.S.
Allan M. Goldberg, B.S.
Derck A. Gordon, B.A.
Thomas P. Gordon, M.S.
R. Clive Greenough, S.B.
David W. Hall, B.S.
John E. Hearst, B.E.
E. Alexander Hill, III, B.S.
William D. Hobey, B.S.
Konrad W. Hubele, B.S.
Robert E. Huffman, B.S.
Neilen W. Hultgren, B.S.
William D. Hutchinson, B.S.
Albert Hybl, B.A.
James B. Ifft, B.S.
Richard T. Jones, M.D.
John J. Kalvinskas, S.M.
Philip R. Kennicott, B.S.
Edgar F. Kiefer, B.S.
Donald M. King, B.S.
James King, Jr., M.S.
William Kozicki, M.A.Sc.
Abraham N. Kurtz, M.A.
Stanley L. Manatt, B.S.
William B. Mather, Jr., A.B.
Richard B. McGriff, B.S.
Richard A. McKay, M.S.
Hugh T. Millard, Jr., B.A.
Lawrence K. Montgomery, B.S.
Carleton B. Moore, B.S.
J. Eric Nordlander, B.A.
Manuel Panar, B.Sc.
Edward M. Perrin, B.Sc.
William W. Porterfield, B.S.
Odell F. Raper, B.S.
Robert G. Rinker, M.S.
Richard E. Robertson, B.A.
Roy R. Sakaida, M.S.
Bertrand A. Schoomer, Jr., B.S.
David I. Schuster, B.A.
Clay M. Sharts, B.S.
Wallace W. Short, M.S.
Marc S. Silver, A.B.
Darwin W. Smith, B.S.
Raymond L. Taylor, B.S.
Don D. Thompson, B.A.
Wilton Vannier, M.D.
Martin Vogel, B.S.
Hal R. Waite, B.S.
Yui-Loong Wang, B.S.
Lawrence Z. Wieder, B.S.
Norman P. Wilburn, M.S.
John P. Wolf, III, B.A.
Tetsuo Yamane, B.S.

Division of Civil, Electrical, and Mechanical Engineering and Aeronautics

Frederick C. Lindvall, *Chairman*

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

PROFESSORS EMERITI

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

PROFESSORS

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

RESEARCH ASSOCIATE

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

ASSOCIATE

Henry Dreyfuss .... *Industrial Design*

ASSOCIATE PROFESSORS

Francis S. Buffington, Sc.D. .... *Mechanical Engineering*
Thomas K. Caughey, Ph.D. .... *Applied Mechanics*
Charles E. Crede, M.S. .... *Mechanical Engineering*

**Leave of absence*

Albert T. Ellis, Ph.D. .... *Applied Mechanics*
Joel Franklin, Ph.D. .... *Applied Mechanics*
Yuan-Cheng Fung,* Ph.D. .... *Aeronautics*
Roy W. Gould, Ph.D. .... *Electrical Engineering*
Alfred C. Ingersoll, Ph.D. .... *Civil Engineering*
Harold Lurie, Ph.D. .... *Applied Mechanics*
Caleb W. McCormick, Jr., M.S. .... *Civil Engineering*
Hardy C. Martel, Ph.D. .... *Electrical Engineering*
Francis W. Maxstadt, Ph.D. .... *Electrical Engineering*
Robert D. Middlebrook, Ph.D. .... *Electrical Engineering*
Julius Miklowitz, Ph.D. .... *Applied Mechanics*
David E. Muller, Ph.D. .... *Electrical Engineering*
Charles H. Papas, Ph.D. .... *Electrical Engineering*
Rolf H. Sabersky, Ph.D. .... *Mechanical Engineering*
Howell N. Tyson, B.S. .... *Mechanical Engineering and Engineering Graphics*
Thad Vreeland, Jr., Ph.D. .... *Mechanical Engineering*
Max L. Williams, Jr., Ph.D. .... *Aeronautics*
David S. Wood,* Ph.D. .... *Mechanical Engineering*
Theodore Y. Wu, Ph.D. .... *Applied Mechanics*

VISITING ASSOCIATE PROFESSOR

Ian Proudman, Ph.D. .... *Aeronautics*

SENIOR RESEARCH FELLOWS

Saul Kaplun, Ph.D. .... *Aeronautics*
Eric Molo-Christensen, Ph.D. .... *Aeronautics*
Haruo Takeyama, Ph.D. .... *Engineering*
Sitaram Rao Valluri, Ph.D. .... *Aeronautics*

ASSISTANT PROFESSORS

Allan J. Acosta, Ph.D. .... *Mechanical Engineering*
Norman H. Brooks, Ph.D. .... *Civil Engineering*
Donald E. Coles, Ph.D. .... *Aeronautics*
Daniel G. Dow, Ph.D. .... *Electrical Engineering*
Robert Jahn, Ph.D. .... *Jet Propulsion*
James K. Knowles, Ph.D. .... *Applied Mechanics*
Francis J. Mullin, Ph.D. .... *Electrical Engineering*
Anatol Roshko, Ph.D. .... *Aeronautics*
Winston W. Royce, Ph.D. .... *Aeronautics*
William R. Samples, Ph.D. .... *Civil Engineering*
David F. Welch, I.D. .... *Engineering Graphics*
Nathaniel W. Wilcox, A.B. .... *Engineering Graphics*
Edward E. Zukoski, Ph.D. .... *Jet Propulsion*

VISITING ASSISTANT PROFESSOR

Ludwig E. Fraenkel, M.S. .... *Aeronautics*

RESEARCH FELLOWS

Dang Dinh Ang, Ph.D. .... *Aeronautics*
Ellis Cumberbatch, Ph.D. .... *Applied Mechanics*
Anthony Demetriades, Ph.D. .... *Aeronautics*
Joseph M. Denney, Ph.D. .... *Engineering*
Zohrab A. Kaprielian, Ph.D. .... *Electrical Engineering*
Toshi Kubota, Ph.D. .... *Aeronautics*
Ronald T. McLaughlin, Ph.D. .... *Engineering*

Angelo A. Molfino, Ph.D. . . . . *Electrical Engineering*
Robert Nathan, Ph.D. . . . . *Electrical Engineering*
Uri Oppenheim, Ph. D. . . . . *Jet Propulsion*
Georges G. Weill, Ph.D. . . . . *Electrical Engineering*
John L. Wilson, Ph.D. . . . . *Aeronautics*
David B. Wittry, Ph.D. . . . . *Engineering*
Shih-Cheng Zien, Dr. Ing. . . . . *Aeronautics*

INSTRUCTORS

Robert L. Harder, M.S. . . . . *Electrical Engineering*
Dennis V. Long, M.S. . . . . *Civil Engineering*
Peter V. Mason, M.S. . . . . *Electrical Engineering*
Carver A. Mead, M.S. . . . . *Electrical Engineering*
Willard V. T. Rusch, M.S. . . . . *Electrical Engineering*

LECTURER

Dino A. Morelli, Ph.D. . . . . *Applied Mechanics*

GRADUATE FELLOWS AND ASSISTANTS

1957-58

Daniel Kuo Yi Ai, M.S.
Donn Anthony Allen, B.S.
Dang Dinh Ang, M.S.
Richard Michael Aron, M.S.
Boris Auksmann, B.A.Sc.
Charles D. Babcock, Jr., B.S.
Calvin LaRue Barker, M.S.
Eugene M. Barston, B.S.
Richard G. Batt, B.S.E.
Frank J. Berto, B.A.Sc.
Gary D. Boyd, M.S.
Richard H. Briceland, M.S.
Gunnar E. Broman, M.S.
Carl J. Buczek, B.E.E.
Charles J. Bryne, Jr., B.E.E.
Gordon L. Cann, M.S.
Michel J. Canu, M.S.
I-dee Chang, M.S.
Robert L. Chapkiss, M.S.
Daniel J. Collins, M.S.
Michael A. Cowan, B.S.
Anthony Demetriades, M.S.
Harold R. Dessau, B.S.
Aldo Gene Di Loreto, M.S.
Michel A. Ebertin, B.S.E.E.
Everett T. Eiselen, M.S.
Duane D. Erway, B.S.
Viktor Evtuhov, M.S.
Donald C. Forster, M.S.
Charles G. Fullerton, B.S.
Albert E. Gaede, M.S.
John L. Gardner, B.E.
Nick George, Jr., M.S.
James N. Giles, B.S.
John H. Gliever, B.S.
Roger M. Golden, M.S.
Jacek P. Gorecki, Dipl. Ing.
Meredith C. Gourdine, B.S.
Herbert R. Graham, S.B.
Andrew Guttman, B.S.
Itiel I. Haissman, B.S.
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Neil H. Herman, B.S.
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Herbert E. Hunter, M.S.
Wilfred D. Iwan, B.S.
Roy A. Jensen, B.S.
Orval E. Jones, M.S.
Robert Katz, M.S.
John F. Kennedy, M.S.
Jirair Levon Kevorkian, M.A.E.
Mitri G. Khamis, B.S.
Kenneth R. King, M.S.
William J. Klenk, B.S.S.
Allen Klinger, B.E.E.
Harold G. Knight, B.Sc.
Henri M. Lacombe, M.S.
Jean P. Lacrouts, C.E.
Donald H. Landauer, B.S.
Theodore E. Lang, B.S.
Marshall Lapp, B.Eng.Ph.
Donald C. Larson, S.M.
Jean Lemaitre, Dip. Ing.
James R. Lloyd, M.S.
Kenneth Lock, M.Sc.
Malcolm H. Lock, H. Natl. Cert.
Yen-Mow Lynn, M.S.
Archibald D. MacGillivray, M.S.

Daniel B. Mack, B.S.
George E. Madsen, B.S.
Marcy R. Malcolm, Jr., B.S.
Jean F. Marin, Ing. Civ.
Maury I. Marks, B.S.E.E.
Peter V. Mason, M.S.
Malcolm McColl, B.S.
William T. McDonald, B.S.
Carver A. Mead, M.S.
Howard C. Merchant, S.M.
Roger E. Messick, M.S.
Harry Moerjono, B.S.
Norton L. Moise, M.S.
Louis L. Monroe, M.S.
Morrow H. Moore, Jr., B.M.E.
Roddam Narasimha, D.I.I.Sc.
Charl F. Naude, M.S.
Edwin D. Nelson, B.S.
Richard K. Nelson, M.S.
Gordon C. Oates, M.Sc.
Haruo Oguro, M.S.
Ulo Okapuu, B.Eng.
Daniel B. Olfe, B.S.E.
Harry Patapoff, B.S.
Richard W. Patch, B.S.
Jerry C. Peck, B.S.
Elliot N. Pinson, S.M.
Robert E. Pollak, B.S.
Carl A. Rambow, B.S.
Roy E. Reichenbach, M.S.
Eli Reshotko, M.M.E.
Jacques M. G. Rieunier, Ing.E.C.P.
Ronald J. Rockey, B.S.
Willard Van Tuyl Rusch, M.S.
David A. Russell, M.S.
Richard A. Schapery, B.S.
Robert K. Schmidt, B.S.
Attila I. Simanyi, B.S.
Richard F. Smisek, B.S.
Howard M. Smith, Jr., M.S.
Thomas C. Sorensen, B.S.
Derek M. Squires, Dip.
Ronald O. Stearman, M.S.
Erik G. Stenberg, Civ. Ing.
Edwin J. Stofel, M.S.
Henry J. Stumpf, M.S.
Bradford Sturtevant, M.S.
Salvatore P. Sutera, M.S.
Robert H. Taylor, B.S.
James A. L. Thomson, M.A.Sc.
Thomas O. Thostesen, B.S.
Robert C. Titsworth, B.S.
Richard R. Tracy, M.S.
Alvin W. Trivelpiece, M.S.
Edvin O. Tums, B.S.
Donald L. Turcotte, B.S.
Paul F. R. Weyers, M.S.
Milton G. Wille, B.E.S.
Ronald H. Willens, M.S.
Forman A. Williams, B.S.E.
James W. Workman, B.S.
Cavour Wei-Hou Yeh, B.S.
Abraham Zukerman, M.S.

Division of Geological Sciences

Robert P. Sharp, *Chairman*
Ian Campbell, *Executive Officer*
Frank Press, *Director of the Seismological Laboratory*

PROFESSORS

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

VISITING PROFESSORS

Andre Cailleux, Ph.D.	*Geology*
Egon Orowan, Ph.D.	*Geology*
Adrian E. Scheidegger, Ph.D.	*Geophysics*
Cecil E. Tilley, Ph.D.	*Geology*
Hatten S. Yoder, Jr., Ph.D.	*Geochemistry*

RESEARCH ASSOCIATE

Ziaoddin Esmailbeigi, Ph.D.	*Seismology*

ASSOCIATE PROFESSORS

Samuel Epstein, Ph.D.	*Geochemistry*
Gennady W. Potapenko,[1] Ph.D.	*Geophysics*

SENIOR RESEARCH FELLOWS

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

ASSISTANT PROFESSORS

Clarence R. Allen, Ph.D.	*Geology*
W. Barclay Kamb, Ph.D.	*Geology*
Charles J. Mankin, Ph.D.	*Geology*
Leon T. Silver, Ph.D.	*Geology*
Gerald J. Wasserburg, Ph.D.	*Geology*

[1]Member of the Division of Physics, Mathematics, and Astronomy

RESEARCH FELLOWS

Keiiti Aki, Ph.D. .... *Geophysics*
T. James Chow, Ph.D. .... *Geochemistry*
Egon T. Degens, Ph.D. .... *Geology*
V. Rama Murthy, Ph.D. .... *Geochemistry*
Roderic B. Park, Ph.D. .... *Geochemistry*
Sarah Deutsch Schnek, Ph.D. .... *Geochemistry*
H. Takeuchi, Ph.D. .... *Geophysics*

VISITING RESEARCH FELLOW

J. Donald Roll, S.J. .... *Seismology*

CURATOR OF MINERALOGY

William C. Oke .... *Mineralogy*

GRADUATE FELLOWS AND ASSISTANTS, 1957-1958

Shelton Alexander, B.S.
Daniel S. Barker, B.S.
Roy P. Basler, III, B.A.[1]
Carl S. Benson, M.S.
David A. Boots, M.S.
James E. Conel, M.S.
James R. Dodd, A.M.
Bruce R. Doe, M.S.
Claude D. Fiddler, A.B.
Edward A. Flinn, III, S.B.
Richard H. Frische, M.S.
M. Grant Gross, A.B.
David G. Harkrider, M.A.
T. Neil Irvine, M.S.
Marvin A. Lanphere, M.S.
R. Michael Lloyd, M.S.
Harvey J. Meyer, B.A.
Robert C. Newton, M.A.
Dean C. Presnall, B.S.
Bimalendu Raychaudhuri, M.S.
Henry P. Schwarcz, M.S.
Robert V. Shull, B.S.
Dale R. Simpson, B.S.
Stewart S. Smith, B.S.
Robert J. Stanton, M.S.
Hugh P. Taylor, M.S.
John Vinje, B.A.
Kenneth Watson, B.A.
Robert L. Wershaw, B.S.
Robert R. Zartman, B.S.

[1]Resigned at end of 1st term.

Division of The Humanities

Hallett D. Smith, *Chairman*

PROFESSORS EMERITI

John R. MacArthur, Ph.D.	*Languages*
George R. MacMinn, A.B.	*English*

PROFESSORS

Harvey Eagleson, Ph.D.	*English*
Horace N. Gilbert, M.B.A.	*Business Economics*
Robert D. Gray, B.S.	*Industrial Relations*
Hunter Mead, Ph.D.	*Philosophy and Psychology*
Rodman W. Paul, Ph.D.	*History*
Hallett D. Smith, Ph.D.	*English*
Roger Stanton, Ph.D.	*English*
Alan R. Sweezy, Ph.D.	*Economics*
Ray E. Untereiner,[1] Ph.D.	*Economics*

ASSOCIATE

Michael T. Wermel, Ph.D.	*Industrial Relations*

ASSOCIATE PROFESSORS

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

LECTURERS

Charles K. Ferguson, Ed.D.	*Psychology*
Milton Gordon, Ph.D.	*Industrial Relations*
Richard F. C. Hayden, LL.B.	*Business Law*
Edward Hutchings, Jr.	*Journalism*
Alexander Kosloff, Ph.D.	*Russian*
Peter Miller, Ph.D.	*English*

VISITING LECTURERS

Willard Hanna, Ph.D.	*International Affairs*
James G. Maddox, Ph.D.	*International Affairs*
Richard H. Nolte, M.A.	*International Affairs*
Phillips Talbot, Ph.D.	*International Affairs*

ASSISTANT PROFESSORS

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

INSTRUCTORS

James C. Findley, Ph.D.	*History*
David Smith, M.A.	*English*
Dwight Thomas, M.A.	*English and Speech*
Robert D. Wayne, M.A.	*German*

RESEARCH ASSISTANT

Doris Logan, B.A.	*Public Affairs*

[1]On leave of absence, 1958-59

Division of Physics, Mathematics, and Astronomy

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

PROFESSORS EMERITI

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

PROFESSORS

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

VISITING PROFESSORS

Fred Hoyle,[2] M.A. .... *Astronomy*
Hans J. Zassenhaus, M.A. .... *Mathematics*

RESEARCH ASSOCIATES

Robert A. Becker, Ph.D. .... *Physics*
Harry A. Kirkpatrick, Ph.D. .... *Physics*
Erwin Kreyszig, Ph.D. .... *Mathematics*
Olga T. Todd, Ph.D. .... *Mathematics*

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

ASSOCIATE PROFESSORS

T. M. Apostol, Ph.D. .... *Mathematics*
Charles A. Barnes, Ph.D. .... *Physics*
Eugene W. Cowan, Ph.D. .... *Physics*
Robert Finn,[1] Ph.D. .... *Mathematics*
Alexander Goetz, Ph.D. .... *Physics*
Robert B. Leighton, Ph.D. .... *Physics*
Guido Munch,[1] Ph.D. .... *Astronomy*
Matthew Sands, Ph.D. .... *Physics*
Alvin V. Tollestrup, Ph.D. .... *Physics*
Ward Whaling, Ph.D. .... *Physics*
Robert L. Walker, Ph.D. .... *Physics*

[1]On leave of absence
[2]Addison White Greenway Visiting Professor

VISITING ASSOCIATE PROFESSORS

Thomas E. Hull, Ph.D. .... *Mathematics*
K. C. Westfold, Ph.D. .... *Astronomy*

SENIOR RESEARCH FELLOWS

Juan J. Giambiagi, Ph.D. .... *Physics*
Ralph W. Kavanagh, Ph.D. .... *Physics*
Theodore B. Novey, Ph.D. .... *Physics*
James A. Roberts, Ph.D. .... *Radio Astronomy*
Gordon J. Stanley, Dipl.E.E. .... *Radio Astronomy*
Robert R. Stoll, Ph.D. .... *Mathematics*
John M. Teem, Ph.D. .... *Physics*

ASSISTANT PROFESSORS

Felix Boehm[1], Ph.D. .... *Physics*
Richard A. Dean, Ph.D. .... *Mathematics*
F. Brock Fuller, Ph.D. .... *Mathematics*
W. A. J. Luxemburg, Ph.D. .... *Mathematics*
J. B. Oke, Ph.D. .... *Astronomy*
Vincent Z. Peterson, Ph.D. .... *Physics*
Foster Strong, M.S. .... *Physics*
Calvin H. Wilcox,[1] Ph.D. .... *Mathematics*

INSTRUCTORS

Donald F. DuBois, B.A. .... *Mathematics*
John M. Gary, Ph.D. .... *Mathematics*
John T. Harding, Ph.D. .... *Mathematics*
Howard B. Jenkins, Ph.D. .... *Mathematics*
Jon Mathews, Ph.D. .... *Physics*

RESEARCH FELLOWS

Karl-Heinz Althoff, Ph.D. .... *Physics*
Graydon D. Bell, Ph.D. .... *Physics*
Sam Berman, M.S. .... *Physics*
E. Margaret Burbidge, Ph.D. .... *Physics*
Geoffrey R. Burbidge, Ph.D. .... *Physics*
Peter Fong, Ph.D. .... *Physics*
Charles Gallagher, Ph.D. .... *Physics*
Ricardo Gomez, Ph.D. .... *Physics*
Dale F. Hebbard, Ph.D. .... *Physics*
Thomas W. B. Kibble,[3] Ph.D. .... *Physics*
Geoffrey Manning, Ph.D. .... *Physics*
Thomas A. Matthews, Ph.D. .... *Radio Astronomy*
Horace R. Moore, Ph.D. .... *Physics*
Richard E. Norton,[2] Ph.D. .... *Theoretical Physics*
Bogdan Povh, Engr. .... *Physics*
Othmar Preining, Ph.D. .... *Physics*
Charles E. Roos, Ph.D. .... *Physics*
Philippe Rosselet, Dipl.Ing. .... *Physics*
Volker Soergel, Ph.D. .... *Physics*
Heber J. R. Stevenson, M.S. .... *Physics*
W. K. R. Watson, Ph.D. .... *Theoretical Physics*
Alan M. Wetherell,[3] Ph.D. .... *Physics*
Robert Worlock, Ph.D. .... *Physics*

[1]On leave of absence
[2]Richard Chace Tolman Fellow
[3]Commonwealth Fund Fellow

GRADUATE FELLOWS AND ASSISTANTS, 1957-58

Ethan D. Alyea, Jr., A.B.
John P. Andelin, Jr., B.S.
Hugh R. Anderson, B.A.
R. Keith Bardin, B.S.
Sam M. Berman, M.S.
Harry H. Bingham, Jr., A.B.
Ronald Blum, S.M.
Alan G. Bodine, B.S.
Thomas K. Boehme, M.S.
Walter K. Bonsack, B.S.
James H. Boyden, M.S.
Richard E. Bradbury, B.A.
Howard M. Brody, M.S.
Ronald E. Brown, B.S.
David B. Chang, B.S.
James T. Chang, B.S.
Marvin Chester, B.S.
Donald D. Clayton, B.S.
Richard L. Cohen, B.S.
Sidney R. Coleman, B.S.
Paul P. Craig, B.S.
Peter L. Crawley, B.S.
Melvin D. Daybell, B.S.
William E. Dibble, B.S.
Franklin P. Dixon, M.S.
Richard Dolen, B.E.Ph.
John J. Domingo, B.S.
Donald F. DuBois, B.A.
Ian M. Duck, M.Sc.
W. Farrell Edwards, M.S.
Frederick L. Ek, A.B.
David D. Elliott, M.S.
Christian A. Engelbrecht, B.Sc.
Marshall P. Ernestene, A.B.
James L. C. Ford, Jr., B.A.
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George Gerson, B.S.
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John R. Harding, Jr., S.B.
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Joseph R. Kilner, B.S.
Tatsuro Kodama, M.S.
Thomas R. Koehler, B.S.
Donald A. Kohler, M.S.
James D. Larson, S.B.
Andrew S. Lebor, B.S.
Paul H. Levine, M.S.
Morton Lowengrub, B.A.
Robert L. Luttermoser, M.S.
John O. Maloy, B.S.
J. Howard Marshall, III, B.S.
James A. McCray, M.S.
William G. Melbourne, M.S.
James E. Mercereau, M.S.
John J. Merrill, M.S.
Ralph F. Miles, Jr., B.S.
Alan T. Moffet, B.S.
Fernando B. Morinigo, B.S.
Arthur H. Muir, Jr., M.S.
Joe H. Mullins, M.S.
Henry R. Myers, M.S.
Gerry Neugebauer, B.A.
Peter D. Noerdlinger, A.B.
Thomas W. Noonan, B.S.
M. Emery Nordberg, Jr., B.S.
Robert H. Norton, B.S.
Harris A. Notarys, S.B.
Robert W. Noyes, B.A.
Jack C. Overley, S.B.
John D. Pearson, B.Sc.
Charles W. Peck, B.S.
Lewis S. Pilcher, S.B.
Philip M. Platzman, M.S.
Gerald L. Pollack, M.S.
R. Darden Powers, M.S.
David F. Rearick, M.S.
John R. Rice, M.S.
John D. Rogers, B.S.
Henry Ruderman, B.S.
Howard C. Rumsey, Jr., B.S.
Robert D. Ryan, B.S.
Mohammad H. Saffouri, B.Sc.
Lionel S. Senhouse, Jr., M.S.
Richard K. Sloan, M.S.
Theodore W. Speiser, B.S.
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Allan R. Sandage, Ph.D.
Olin C. Wilson, Ph.D.
Fritz Zwicky, Ph.D.

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Roger Cayrel, Ph.D.
Robert F. Howard, Ph.D.
George W. Preston, B.S.
Sumisaburo Saito, Ph.D.
Carlos M. Varsavsky, A.M.

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Byron Hill, B.S.

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Captain George Rokuhara, U.S.A.F., B.S.

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ASSISTANTS

Lee A. Andrews, B.A.
Shelby C. Calhoun, B.A.
John Lamb
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ATHLETIC COUNCIL

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

Industrial Relations Section

Robert D. Gray, B.S., *Director of Industrial Relations*
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Milton Gordon, Ph.D., *Associate Director, Management Development Center*
Michael T. Wermel, Ph.D., *Research Director, Benefits and Insurance Research Center; Research Associate in Economics and Insurance; Associate Director, Management Development Center*
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R. Stewart Harrison, M.D. . . . . *Consultant in Radiology*
Daniel C. Siegel, M.D. . . . . *Consulting Physician*
Alice A. Shea, R.N. . . . . *Nursing Supervisor*

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

Student Musical Activities

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

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

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

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

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

Arthur Erdelyi, D.Sc., *Professor of Mathematics*
Cand. Ing., Deutsche Technische Hochschule, Brno, Czechoslovakia, 1928; Dr. rer. nat. University of Prague, 1938; D.Sc., University of Edinburgh, 1940. California Institute, 1947-. (259 Church) 2121 Lambert Drive.

Ziaoddin Esmailbeigi, D.Sc., *Research Associate in Seismology*
Lic.Sc., Tehran Teachers College, 1932; D.Sc., Nancy University, France, 1937. Professor of Physics, Faculty of Science, Tehran University. California Institute, 1958-59.

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

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B.A., Harvard University, 1947; B.A., Oxford University, 1949; Ph.D., Harvard University, 1954; California Institute, 1955-. (11 Dabney) 818 North Holliston Avenue.

Stephen Oscar Fejer, Ph.D., *Research Fellow in Biology*
Ph.D., Budapest University, 1939; Ing.Agri., Federal Institute of Technology, Zurich, 1950. Plant Breeder, Grasslands Division, Department of Scientific and Industrial Research, New Zealand, 1950-. California Institute, 1958-59. (Earhart Lab.) 139 North Wilson Avenue.

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Richard Phillips Feynman,*** Ph.D., *Professor of Theoretical Physics*
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Peter Fong, Ph.D., *Research Fellow in Physics*
B.S., University of Chekiang, China, 1945; M.S., University of Chicago, 1950; Ph.D., 1953. Associate Professor, Syracuse University, 1957-. California Institute, 1957.

William Alfred Fowler, Ph.D., *Professor of Physics*
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Hans Charles Freeman, Ph.D., *George Ellery Hale Research Fellow in Chemistry*
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Mitchell E. Glickstein, Ph.D., *Research Fellow in Biology*
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*Leave of absence, 1958-59.

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Franklin M. Harold, Ph.D., *Research Fellow in Biology*
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Bertrand Fereday Harrison, Ph.D., *Research Fellow in Biology*
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Dale Furneaux Hebbard, Ph.D., *Research Fellow in Physics*
B.A., University of Melbourne, 1950; B.S., 1951; M.S., 1953; Ph.D., 1957. California Institute, 1957-. (04 Kellogg) 659 South Lake Avenue.

Ernest M. Heimlich, M.D., *Research Fellow in Chemistry*
B.A., University of California (Los Angeles), 1947; M.D., University of Lausanne, Switzerland, 1952. Instructor in Pediatrics, University of California Medical School (Los Angeles), 1956-. California Institute, 1957-58.

Chonon Heller, Ph.D., *Arthur Amos Noyes Research Fellow in Chemistry*
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Geoffrey Lorrimer Keighley, Ph.D., *Senior Research Fellow in Biology*
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Richard Taylor Keys, Ph.D., *Research Fellow in Chemistry*
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B.S., University of Wisconsin, 1951; M.S., California Institute, 1953; Ph.D., 1957. Research Fellow, 1957-. (015 Engineering Bldg.) 1211 Sinaloa Avenue.

David Shotwell Wood,** Ph.D., *Associate Professor of Mechanical Engineering*
B.S., California Institute, 1941; M.S., 1946; Ph.D., 1949. Lecturer, 1949-50; Assistant Professor, 1950-55; Associate Professor, 1955-. (309 Engineering Bldg.) 450 East Highland Avenue, Sierra Madre.

Robert Montague Worlock, Ph.D., *Research Fellow in Physics*
B.A., Carleton College, 1951; Ph.D., 1958. California Institute, 1958. Research Fellow, 1958-. (Synchrotron) 397 Chester Avenue.

Donald Allan Wright, Ph.D., *Research Fellow in Chemistry*
B.Sc., Auckland University College, 1955; M.Sc., 1956; Ph.D., University of Canterbury, 1958. California Institute, 1958-59.

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

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

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

Hatten Schuyler Yoder, Jr., Ph.D., *Visiting Professor of Geochemistry*
S.B., University of Chicago, 1941; Ph.D., Massachusetts Institute of Technology, 1948. Research Chemist, Carnegie Institution Geophysical Laboratory, Washington, D. C., 1942-. California Institute, 1958.

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

*Leave of absence, 1958-59.

**Leave of absence, fall term, 1958-59.

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

Hans J. Zassenhaus, M.A., *Visiting Professor of Mathematics*
M.A., Glasgow University, 1949. Professor of Mathematics, McGill University. California Institute, 1958-59.

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

Edward Edom Zukoski, Ph.D., *Assistant Professor of Jet Propulsion*
B.S., Harvard College, 1950; M.S., California Institute, 1951; Ph.D., 1954. Research Engineer, Jet Propulsion Laboratory, 1950-57; Lecturer, California Institute, 1956; Assistant Professor, 1957-. (227 Engineering Bldg.) 1946 Pasadena Glen Road.

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

GRADUATE FELLOWS, SCHOLARS AND ASSISTANTS, 1957-58

Henry Ivan Abrash, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Harvard College, 1956

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

Peter Albersheim, *Nutrition Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Biology*
B.S., Cornell University, 1956

Norman Edward Albert, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Polytechnic Institute of Brooklyn, 1954

Norman Webster Albright, *Laws Scholar, Physics*
B.S., California Institute, 1956

Shelton Setzer Alexander, *National Science Foundation Fellow, Geological Sciences*
B.S., University of North Carolina, 1956

Donn Anthony Allen, *Royal W. Sorensen Scholar, Electrical Engineering*
B.S., California Institute, 1957

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

Ethan Davidson Alyea, Jr., *Dow Chemical Company Fellow, Physics*
A.B., Princeton University, 1953

John Philip Andelin, Jr., *Howard Hughes Fellow, Physics*
B.S., California Institute, 1955

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

Dang Dinh Ang, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., University of Kansas, 1955; M.S., California Institute, 1956

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

Boris Auksmann, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.A.Sc., University of British Columbia, 1955.

Charles Dwight Babcock, Jr., *Graduate Teaching Assistant, Murray Scholar, Aeronautics*
B.S., Purdue University, 1957

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

Calvin LaRue Barker, *Institute Scholar, Mechanical Engineering*
B.S., University of Texas, 1953; M.S., California Institute, 1954

Daniel Stephen Barker, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
B.S., Yale University, 1956

Dennis Barrett, *Arthur McCallum Foundation Fellow, Graduate Teaching Assistant, Dobbins Scholar, Biology*
B.A., University of Pennsylvania, 1957

Eugene Myron Barston, *Firestone Tire and Rubber Company Fellow, Electrical Engineering*
B.S., California Institute, 1957

Louis Najib Bathish, *Graduate Research Assistant, Murray Scholar, Chemical Engineering*
B.A., Pomona College, 1957

Richard George Batt, *Convair Fellow, Aeronautics*
B.S.E., Princeton University, 1955

William Frederick Beach, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Rutgers University, 1957

Carl Sidney Benson, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
B.A., University of Minnesota, 1950; M.S., 1955

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

Sam Morris Berman, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Miami, 1954; M.S., 1955

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

Frank Joseph Berto, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.A.Sc., University of British Columbia, 1952

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

Michel A. Bloch, *Institute Scholar, Physics*
Ing., Ecole Polytechnique (Paris), 1952

Ronald Blum, *Graduate Teaching Assistant, Institute Scholar, Physics*
A.B., University of Chicago, 1954; S.B., 1955; S.M., 1956

Alan George Bodine, *National Science Foundation Fellow, Physics*
B.S., University of Illinois, 1957

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

Walter Karl Bonsack, *Van Maanen Fellow, Institute Scholar, Astronomy*
B.S., Case Institute of Technology, 1954

Frank Bliss Booth, *Dow Chemical Company Fellow, Chemistry*
B.S., University of California at Los Angeles, 1953; M.S., 1954

David Alan Boots, *National Science Foundation Fellow, Geological Sciences*
B.A., Montana State University, 1956; M.A., Indiana University, 1957

Gary Delane Boyd, *Schlumberger Foundation Fellow, Electrical Engineering*
B.S., California Institute, 1954; M.S., 1955

James Harrison Boyden, *Ramo-Wooldridge Fellow, Physics*
B.S., Carnegie Institute of Technology, 1954; M.S., 1955

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

Richard Harald Briceland, *Institute Scholar, Mechanical Engineering*
B.S., State University of Iowa, 1954; M.S., 1955

Howard M. Brody, *Graduate Research Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1954; M.S., California Institute, 1956

Gunnar Erik Broman, *Daniel and Florence Guggenheim Fellow, Institute Scholar, Mechanical Engineering*
C.E.(Ae.), Royal Institute of Technology (Stockholm), 1947; M.S., California Institute, 1955

J. Philip Bromberg, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
S.B., Massachusetts Institute of Technology, 1956

Ronald Anderson Steven Brown, *Peter E. Fluor Fellow, Chemical Engineering*
B.Sc., University of Alberta, 1956; M.S., California Institute, 1957

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

Carl James Buczek, *Graduate Research Assistant, Institute Scholar, Electrical Engineering*
B.E.E., Rensselaer Polytechnic Institute, 1956

William Davis Burnett, *Blacker Scholar, Physics*
B.S., Texas Western College, 1955

Vernon Douglas Burrows, *Lucy Mason Clark Fellow, Institute Scholar, Biology*
B.S.A., University of Manitoba, 1951; M.Sc., 1953

Charles Joseph Byrne, Jr., *National Science Foundation Fellow, Electrical Engineering*
B.E.E., Rensselaer Polytechnic Institute, 1957

Gordon Lawrence Cann, *Graduate Teaching Assistant, Aeronautics*
B.S., University of Toronto, 1949; M.S., California Institute, 1956

Michel Jacques Canu, *French Ministry of Foreign Affairs Fellow, Electrical Engineering*
M.S., Ecole Nationale Supérieure de l'Aeronautique (Paris), 1957

Robert Philo Chambers, *Dow Chemical Company Fellow, Chemical Engineering*
B.S., California Institute, 1957

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

I-dee Chang, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., National Central University (Nanking), 1944; M.S., Kansas State College, 1954

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

Robert Lynn Chapkiss, *Graduate Teaching Assistant, Aeronautics*
B.S., California Institute, 1956; M.S., 1957

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

John M. Clark, Jr., *Arthur McCallum Foundation Fellow, Biology*
B.S., Cornell University, 1954

Donald Delbert Clayton, *National Science Foundation Fellow, Physics*
B.S., Southern Methodist University, 1956

Richard Lewis Cohen, *National Science Foundation Fellow, Physics*
B.S., Haverford College, 1957

Giles Roy Cokelet, *General Petroleum Fellow, Chemical Engineering*
B.S., California Institute, 1957

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

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

James Ekstedt Conel, *Standard Oil of California Fellow, Geological Sciences*
B.A., Occidental College, 1955; M.S., California Institute, 1957

Michael Anthony Cowan, *Graduate Teaching Assistant, Murray Scholar, Electrical Engineering*
B.S., Purdue University, 1957

Paul Palmer Craig, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., Haverford College, 1954

Peter Linton Crawley, *National Science Foundation Fellow, Mathematics*
B.S., California Institute, 1957

Cedric Inglis Davern, *Commonwealth Scientific and Industrial Research Organization Fellow, Biology*
B.S.,Agr., University of Sydney, 1953; M.S.Agr., 1956

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

Henry Hursell Dearman, *National Science Foundation Fellow, Chemistry*
B.S., University of North Carolina, 1956

Anthony Demetriades, *Institute Scholar, Aeronautics*
B.A., Colgate University, 1951; M.S., University of Minnesota, 1953

David Severin Dennison, *Arthur McCallum Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Biology*
B.A., Swarthmore College, 1954

Harold Ralph Dessau, *Graduate Teaching Assistant, Dobbins Scholar, Electrical Engineering*
B.S., California Institute, 1957

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

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

Franklin Painter Dixon, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Texas, 1954; M.S., California Institute, 1957

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

Bruce Roger Doe, *Kennecott Copper Corporation Fellow, Geological Sciences*
B.S., University of Minnesota, 1954; B.Geol.E., 1954; M.S., Missouri School of Mines, 1956

Richard Dolen, *General Electric Company Fellow, Physics*
B.Eng.Phy., Cornell University, 1957

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

Paul Leighton Donoho, *Institute Scholar, Physics*
B.A., The Rice Institute, 1952

Donald Frank DuBois, *International Business Machines Fellow, Physics*
B.A., Cornell University, 1954

Ian Morley Duck, *Imperial Oil Graduate Research Fellow, Institute Scholar, Physics*
B.Sc., Queen's University, 1955; M.Sc., University of British Columbia, 1956

Michel Abel Ebertin, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*
B.S.E.E., Polytechnic Institute of Brooklyn, 1957

W. Farrell Edwards, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Utah, 1955; M.S., California Institute, 1957

Everett Truman Eiselen, *Shell Fellow, Mechanical Engineering*
B.S., California Institute, 1956; M.S., 1957

Frederick Lee Ek, *National Science Foundation Fellow, Physics*
A.B., Harvard College, 1957

David Duncan Elliott, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Stanford University, 1951; M.S., California Institute, 1953

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

Rolf Engleman, Jr., *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of Oklahoma, 1955

Marshall Paul Ernstene, *Graduate Research Assistant, Institute Scholar, Physics*
A.B., Harvard College, 1952

Duane Donald Erway, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*
B.S., California Institute, 1957

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

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

Louis Domenic Ferretti, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*
B.A., University of Pennsylvania, 1957

Claude David Fiddler, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
A.B., Occidental College, 1954

Edward Ambrose Flinn III, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
S.B., Massachusetts Institute of Technology, 1953

James Lawrence Collier Ford, Jr., *Graduate Teaching Assistant, Institute Scholar, Physics*
B.A., Montana State University, 1955

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

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

Benjamin S. Friesen, *Arthur McCallum Foundation Fellow, Institute Scholar, Biology*
B.A., Kansas University, 1952; M.A., 1954

Richard Henry Frische, *Graduate Research Assistant, Drake Scholar, Geological Sciences*
A.B., Miami University, 1954; M.S., New Mexico Institute of Mining and Technology, 1956

Charles Gordon Fullerton, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1957

Albert E. Gaede, *Institute Scholar, Aeronautics*
B.S., California Institute, 1957; M.S., 1957

John Louis Gardner, *Graduate Teaching Assistant, Aeronautics*
B.E., Louisiana State University, 1957

Donald Charles Garwood, *Upjohn Company Graduate Scholar, Chemistry*
B.A., Kalamazoo College, 1957

Nick George, Jr., *Howard Hughes Fellow, Electrical Engineering*
B.S., University of California, 1949; M.S., University of Maryland, 1956

George Gerson, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.S., Queens College, 1951

James Norval Giles, *Westinghouse Fellow, Electrical Engineering*
B.S., California Institute, 1957

Victor Gilinsky, *National Science Foundation Fellow, Physics*
B.E.Ph., Cornell University, 1956

Murlin Fern Gillis, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Washington, 1956

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

John Harvey Gliever, *Graduate Teaching Assistant, Bennett Scholar, Electrical Engineering*
B.S., California Institute, 1957

Allan Morris Goldberg, *Graduate Teaching Assistant, Institute Scholar, Chemical Engineering*
B.S., California Institute, 1957

Roger Morse Golden, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1954; M.S., 1955

Thomas Pascoe Gordon, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
A.B., Princeton University, 1954; M.S., California Institute, 1956

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

Meredith Charles Gourdine, *Ramo-Wooldridge Fellow, Engineering Science*
B.S., Cornell University, 1953

Herbert Ray Graham, *Institute Scholar, Aeronautics*
S.B., Massachusetts Institute of Technology, 1951

Ralph Clive Greenough, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
S.B., Massachusetts Institute of Technology, 1953

Howard Burt Greenstein, *Graduate Research Assistant, Institute Scholar, Physics*
Sc.B., Brown University, 1956

Ellsworth Herman Grell, *United States Public Health Service Fellow, Biology*
B.S., Iowa State College, 1954

Donald Eugene Groom, *National Science Foundation Fellow, Physics*
A.B., Princeton University, 1956

Meredith Grant Gross, Jr., *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
A.B., Princeton University, 1954

Daniel André Guinier, *Institute Scholar, Physics*
Lic. ès Sci. Phys., Sorbonne University, 1957

Lewis Brigham Gustafson, *Institute Scholar, Geological Sciences*
B.S.E., Princeton University, 1955

George Drake Guthrie, *Institute Scholar, Biology*
A.B., Wabash College, 1954

Andrew Guttman, *Daniel and Florence Guggenheim Fellow, Dobbins Scholar, Mechanical Engineering*
B.S., College of the City of New York, 1957

Millard Alvin Habegger, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., Purdue University, 1956

Gerhard Ernest Hahne, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1956

Itiel Ike Haissman, *Graduate Teaching Assistant, Institute Scholar, Civil Engineering*
B.S., California Institute, 1957

Charles Robert Hamilton, *National Science Foundation Fellow, Biology*
B.S., University of the South, 1957

Leighton D. Hanon, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1955

Robert Leland Harder, *Douglas Research Fellow, Aeronautics*
B.S., Carnegie Institute of Technology, 1954; M.S., 1955

Boyd Archer Hardesty, *Nutrition Foundation Fellow, Graduate Teaching Assistant, Blacker Scholar, Biology*
B.S., State College of Washington, 1953; M.S., 1956

John Thomas Harding, *Graduate Teaching Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1953

David Garrison Harkrider, *Phillips Petroleum Fellow, Geological Sciences*
B.S., The Rice Institute, 1953; M.A., 1957

Daniel Everett Harris, *Graduate Research Assistant, Laws Scholar, Astronomy*
B.A., Haverford College, 1956; M.S., California Institute, 1957

Rolf Constantin Hastrup, *Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1953; M.S., 1954

Thomas Chandler Hays, *Graduate Research Assistant, Drake Scholar, Electrical Engineering*
B.S., California Institute, 1957

John Helding Healy, *Institute Scholar, Geological Sciences*
S.B., Massachusetts Institute of Technology, 1951; M.S., California Institute, 1957

John Eugene Hearst, *National Science Foundation Fellow, Chemistry*
B.E., Yale University, 1957

Neil Hunter Herman, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1957

Robert Hickling, *International Nickel Company, Inc., Fellow, Engineering Science*
M.A., University of St. Andrews, 1954; M.Sc., University of London, 1957

E. Alexander Hill, III, *National Science Foundation Fellow, Chemistry*
B.S., Allegheny College, 1957

Henry Hoyt Hilton, III, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Yale University, 1952; M.S., 1952

Charles Ray Hobby, *Graduate Teaching Assistant, Drake Scholar, Mathematics*
B.S., University of California, 1951; M.S., University of Houston, 1957

William David Hobey, *National Science Foundation Fellow, Chemistry*
B.S., Tufts University, 1957

William Joseph Hooker, *Institute Scholar, Engineering Science*
B.S., Webb Institute of Naval Architecture, 1953; M.S., Cornell University, 1955

David Parks Hoult, *Douglas Aircraft Company Fellow, Aeronautics*
S.B., Massachusetts Institute of Technology, 1957

Din-Yu Hsieh, *International Nickel Company, Inc., Fellow, Engineering Science*
B.Sc., National Taiwan University, 1954; M.Sc., Brown University, 1957

Elisha Rhodes Huggins, *Graduate Teaching Assistant, Institute Scholar, Physics*
S.B., Massachusetts Institute of Technology, 1955

Neilen Wood Hultgren, *National Science Foundation Fellow, Chemistry*
B.S., University of California, 1955

Richard O'Neil Hundley, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1957

Herbert Erwin Hunter, *Graduate Teaching Assistant, Aeronautics*
B.S., University of Maryland, 1956; M.S., California Institute, 1957

William Day Hutchinson, *Paul E. Lloyd Fellow, Chemistry*
B.S., Morehouse College, 1955; M.S., California Institute, 1957

Albert Hybl, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.A., Coe College, 1954

Carl Kenneth Iddings, *National Science Foundation Fellow, Physics*
B.A., Harvard College, 1955

James Brown Ifft, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., Pennsylvania State University, 1957

T. Neil Irvine, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
B.Sc., University of Manitoba, 1953; M.Sc., 1954

Wilfred Dean Iwan, *Boeing Fellow, Mechanical Engineering*
B.S., California Institute, 1957

Earl Donald Jacobs, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., California Institute, 1953; M.S., 1954

Roy Albert Jensen, *Graduate Research Assistant, Murray Scholar, Electrical Engineering*
B.S., California Institute, 1957

Orval Elmer Jones, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., Colorado State University, 1956; M.S., California Institute, 1957

John Joseph Kalvinskas, *Stauffer Foundation Fellow, Chemical Engineering*
S.B., Massachusetts Institute of Technology, 1951; S.M., 1952

Robert Katz, *Institute Scholar, Mechanical Engineering*
B.S., University of Colorado, 1948; M.S., California Institute, 1954

John Fisher Kennedy, *Graduate Teaching Assistant, Institute Scholar, Civil Engineering*
B.S., University of Notre Dame, 1955; M.S., California Institute, 1956

Philip Ray Kennicott, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., University of Utah, 1953

Jirair Levon Kevorkian, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.A.E., Georgia Institute of Technology, 1955; M.A.E., 1956

Mitri Gabriel Khamis, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., Rutgers University, 1957

Edgar Francis Kiefer, *Graduate Teaching Assistant, Dobbins Scholar, Chemistry*
B.S., Stanford University, 1957

Joseph Roland Kilner, *Graduate Research Assistant, Drake Scholar, Physics*
B.S., Case Institute of Technology, 1957

Donald Menford King, *Graduate Teaching Assistant, Institute Scholar, Chemistry*
B.S., State College of Washington, 1957

James King, Jr., *Graduate Research Assistant, Chemistry*
B.S., Morehouse College, 1953; M.S., California Institute, 1955

Kenneth Robert King, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1953; M.S., 1954

William John Klenk, *General Electric Educational and Charitable Fund Fellow, Electrical Engineering*
B.S.S., University of Dayton, 1957

Allen Klinger, *Graduate Teaching Assistant, Drake Scholar, Electrical Engineering*
B.E.E., The Cooper Union, 1957

Harold Gordon Knight, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.Sc., University of Toronto, 1957

Tatsuro Kodama, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., Hiroshima University, 1954; M.S., 1956

Thomas Richard Koehler, *Standard Oil Company of California Fellow, Physics*
B.S., Seattle University, 1954

Donald Alvin Kohler, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Oregon, 1951; M.S., 1952

William Kozicki, *Shell Fellow, Chemical Engineering*
B.A.Sc., University of Toronto, 1953; M.A.Sc., 1957

Abraham Nathan Kurtz, *Institute Scholar, Chemistry*
B.A., Brooklyn College, 1937; M.A., 1943

Henri M. Lacombe, *French Ministry of Foreign Affairs Fellow, Graduate Teaching Assistant, Mechanical Engineering*
M.S., Ecole Supérieure de l'Aeronautique (Paris), 1957

Jean Pierre Lacrouts, *French Ministry of Foreign Affairs Fellow, Graduate Teaching Assistant, Electrical Engineering*
C.E., Ecole Nationale Supérieure des Télécommunications (Paris), 1957

Donald Harold Landauer, *Dobbins Scholar, Aeronautics*
B.S., University of Kansas, 1957

Theodore Edmund Lang, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1957

Marvin Alder Lanphere, *Graduate Teaching Assistant, Institute Scholar, Geological Sciences*
B.S., Montana School of Mines, 1955; M.S., California Institute, 1956

Marshall Lapp, *Institute Scholar, Engineering Science*
B.Eng.Ph., Cornell University, 1955

Donald Clayton Larson, *Kaiser Aluminum and Chemical Corporation Fellow, Mechanical Engineering*
B.S., University of Washington, 1956; S. M., Harvard University, 1957

James Daniel Larson, *National Science Foundation Fellow, Physics*
S.B., Massachusetts Institute of Technology, 1957

George Donald Leal, *Graduate Teaching Assistant, Civil Engineering*
B.C.E., University of Santa Clara, 1955

Andrew Scott Lebor, *Graduate Teaching Assistant, Institute Scholar, Physics*
B.S., University of Cincinnati, 1956

Jean Lemaître, *French Ministry of Foreign Affairs Fellow, Aeronautics*
Dip.Ing., Ecole Nationale d'Ingénieurs Arts et Métiers (Paris), 1957

Paul Hersh Levine, *Howard Hughes Fellow, Physics*
S.B., Massachusetts Institute of Technology, 1956; M.S., California Institute, 1957

James Reilly Lloyd, *Graduate Teaching Assistant, Institute Scholar, Mechanical Engineering*
B.S., California Institute, 1956; M.S., 1957

Ronald Michael Lloyd, *National Science Foundation Fellow, Geological Sciences*
B.S., University of Illinois, 1952; M.S., 1953

Kenneth Lock, *Graduate Research Assistant, Dobbins Scholar, Electrical Engineering*
B.Sc., Battersea Polytechnic Institute (London), 1955; M.Sc., Imperial College of London, 1957

Malcolm Harvey Lock, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
Higher Natl. Cert., Hatfield Technical College (Herts., England), 1954

Morton Lowengrub, *Graduate Teaching Assistant, Institute Scholar, Mathematics*
B.A., New York University, 1956

Robert Lee Luttermoser, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Michigan, 1948; M.S., 1950

Yen-Mow Lynn, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.S., National Taiwan University, 1956; M.S., California Institute, 1957

Archibald Dean MacGillivray, *Graduate Teaching Assistant, Institute Scholar, Aeronautics*
B.A.Sc., University of British Columbia, 1955; M.A.Sc., 1956; M.S., California Institute, 1957

Daniel Rutchik Mack, *Graduate Teaching Assistant, Institute Scholar, Electrical Engineering*
B.S., California Institute, 1957

George Everette Madsen, *Graduate Research Assistant, Institute Scholar, Civil Engineering*
B.S., California Institute, 1955

Jacob Valentine Maizel, Jr., *Nutrition Foundation Fellow, Graduate Teaching Assistant, Institute Scholar, Biology*
B.S., Pennsylvania State University, 1955; M.S., 1957

Marcy Ray Malcolm, Jr., *Graduate Research Assistant, Institute Scholar, Engineering Science*
B.S., California Institute, 1957

John Owen Maloy, *Graduate Research Assistant, Institute Scholar, Physics*
B.S., University of Arizona, 1954

Stanley Lawrence Manatt, *Monsanto Chemical Company Fellow, Chemistry*
B.S., California Institute, 1955

Jean François Marin, *Institute Scholar, Mechanical Engineering*
Ing. Civ., Ecole Nationale Supérieure des Mines (Paris), 1957

Maury Ivan Marks, *Graduate Teaching Assistant, Bennett Scholar, Electrical Engineering*
B.S.E.E., Drexel Institute of Technology, 1957

J. Howard Marshall, III, *National Science Foundation Fellow, Physics*
B.S., California Institute, 1957

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B.S., California Institute, 1951; M.S., 1952

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P. G. Winnett
Thomas Wolfe
Mrs. Archibald B. Young
Gerald C. Young

INDUSTRIAL ASSOCIATES

The Industrial Associates, established in 1949, consists of companies which have chosen to participate in an organized plan of cooperation with the Institute. An annual fee together with a strong research interest qualifies a company for membership; the income is unrestricted and is employed for the general support of the Institute. The purpose of the plan is to encourage better communication and intellectual interchange between the Institute staff and the Industrial Associates. This is achieved through exchange of visits by personnel of the companies and faculty members, by special conferences, and by distribution of research reports. The plan in no way affects the cordial relationships which exist generally between industrial personnel and the Faculty of the Institute.

Additional information is available at the Office for Industrial Associates, Throop Hall.

The members of the Industrial Associates as of September 1, 1958, are listed below.

Aerojet—General Corporation

Armour and Company

Avco Manufacturing Corporation

Beckman Instruments, Inc.

Bell Telephone Laboratories, Inc.

Bendix Aviation Corporation

Boeing Airplane Company

Burroughs Corporation

Byron Jackson Division, Borg-Warner Corporation

California Research Corporation

Campbell Soup Company

Carnation Company

Continental Oil Company

Convair—A Division of General Dynamics Corporation

Douglas Aircraft Company, Inc.

The Dow Chemical 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

Hughes Aircraft Company

International Business Machines Corporation

International Minerals and Chemical Corporation

Lockheed Aircraft Corporation

North American Aviation, Inc.

Pan American Petroleum Corporation

Phillips Petroleum Company

The Ramo-Wooldridge Corporation

Richfield Oil Corporation

Shell Oil Company

Standard Oil Company of California

The Texas Company

Union Carbide Corporation

Union Oil Company of California

United States Steel Corporation (Columbia-Geneva Steel Division and Consolidated Western Steel Division)

Westinghouse Electric Corporation

GENERAL INDEX