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VOLUME 56 NUMBER 4

A COLLEGE, GRADUATE SCHOOL, AND INSTITUTE OF RESEARCH IN SCIENCE, ENGINEERING, AND THE HUMANITIES

CATALOGUE NUMBER *for* 1947-1948

PASADENA • CALIFORNIA • NOVEMBER, 1947

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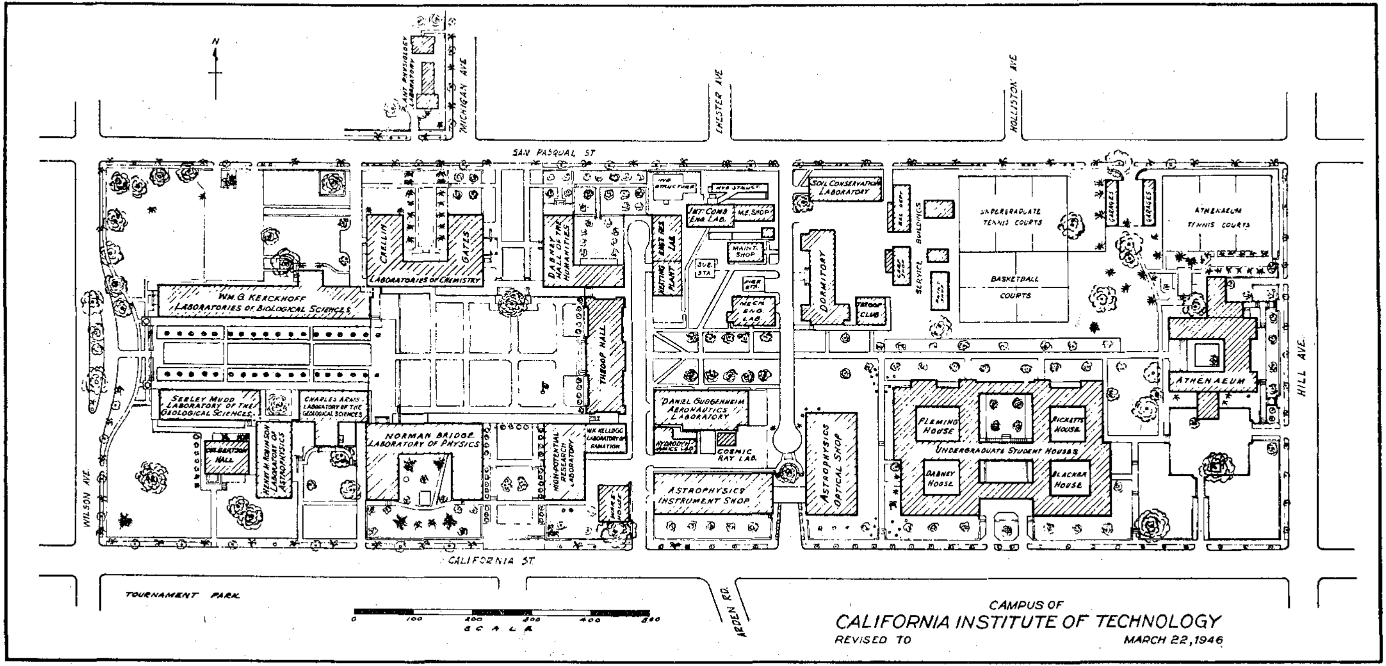

CAMPUS OF
CALIFORNIA INSTITUTE OF TECHNOLOGY
REVISED TO MARCH 22, 1946

CALENDAR

1947

JANUARY

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1948

JANUARY

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CALIFORNIA INSTITUTE OF TECHNOLOGY

CALENDAR 1947-48

1st TERM

1947	
September 23	Registration of entering freshmen—9:00 A.M. to 3:30 P.M.
September 25-26	Registration of students transferring from other colleges—8:30 A.M.
September 26	General registration—8:30 A.M. to 3:30 P.M.
September 29	Beginning of instruction—8:00 A.M.
October 18	Examinations for the removal of conditions and incompletes.
October 18	Last day for adding courses.
November 8	MID-TERM.
November 15	Last day for dropping courses.
November 21	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
November 24-December 13	Pre-Registration for 2nd term 1947-48.
November 27-30	Thanksgiving Recess.
December 15-20	Final Examinations—1st term 1947-48.
December 20	Last day for filing application for candidacy for the degree of Doctor of Philosophy in June, 1948.
December 20	End of 1st term 1947-48—12 M.
December 21-January 4	Christmas Vacation.
December 29	Meeting of Freshman Registration Committee.
December 30	Meeting of Upperclass Registration Committee.

2nd TERM

1948	
January 5	General registration—8:30 A.M. to 3:30 P.M.
January 6	Beginning of instruction—8:00 A.M.
January 24	Examinations for the removal of conditions and incompletes.
January 24	Last day for adding courses.
February 7	MID-TERM.
February 14	Last day for dropping courses.
February 20	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
February 23-March 13	Pre-Registration for 3rd term 1947-48.
March 6 & 13	Examinations for admission to the freshman class, September, 1948.
March 15-20	Final Examinations—2nd term 1947-48.
March 20	End of 2nd term 1947-48—12 M.
March 26	Meeting of Freshman Registration Committee.
March 27	Meeting of Upperclass Registration Committee.

3rd TERM

1948	
March 29	General registration—8:30 A.M. to 3:30 P.M.
March 30	Beginning of instruction—8:00 A.M.
April 17	Examinations for the removal of conditions and incompletes.
April 17	Last day for adding courses.
May 1	MID-TERM.
May 8	Last day for dropping courses.
May 14	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
May 17-June 5	Pre-Registration for 1st term of 1948-49.
May 29	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy.
May 31	Memorial Day Holiday.
June 1-June 5	Final examinations for senior and graduate students—3rd term 1947-48.
June 7-June 12	Final examinations for undergraduate students—3rd term 1947-48.
June 9	Meetings of Committees on Course in Science and Engineering —10:00 A.M.
June 9	Faculty meeting—2:00 P.M.
June 10	Class Day.
June 11	Commencement.
June 11-12	Examinations for admission to upper classes, September, 1948.
June 12	End of 3rd term 1947-48—12 M.
June 18	Meeting of Freshman Registration Committee.
June 19	Meeting of Upperclass Registration Committee.

1st TERM 1948-49

September 3-4	Comprehensive examinations in chemistry, mathematics, physics, English and history.*
September 21	Registration of entering freshmen—9:00 A.M.
September 21	Registration of undergraduate students transferring from other colleges—9:00 A.M.
September 22-24	New Student Camp for entering freshmen and undergraduate students transferring from other colleges.
September 24	General registration—8:30 A.M. to 3:30 P.M.
September 27	Beginning of instruction—8:00 A.M.

*These examinations are not for admission with advanced standing. The only examinations for transfer admission in 1948 will be on June 11 and 12.

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STAFF OF INSTRUCTION AND RESEARCH

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President

A.B., Cornell College (Iowa), 1922; Sc.D., 1940; A.M., University of Wisconsin, 1924; Ph.D., 1926; Sc.D., Brooklyn Polytechnic Institute, 1946; Wesleyan University, 1946. Instructor in Physics, University of Wisconsin, 1925-26; National Research Fellow, California Institute, 1926-28; Assistant Professor, Washington University (Missouri), 1928-33; Associate Professor, 1933-34. Professor and Chairman of Department of Physics, University of Rochester, 1934-46; Dean of Faculty of Arts and Sciences, 1938-46. Director, Radiation Laboratory, Massachusetts Institute of Technology, 1940-45. California Institute, 1946-

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A.B., Dartmouth College, 1898; Sc.D., 1913; A.M., University of Chicago, 1900; Sc.D., University of Munich, 1900-01; Sc.D., Columbia University and University of Southern California, 1926; LL.D., Pomona College, 1926; Sc.D., Princeton University, 1947. Assistant, Yerkes Observatory, 1901-1903; Instructor, 1903-04; Assistant Astronomer, Mt. Wilson Observatory, 1904-09; Astronomer and Assistant Director, 1909-23; Director, 1923-46. California Institute, 1947-

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National University of Mexico; M.S., California Institute, 1945; Ph.D., 1946. California Institute, 1947-

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315 South Hill Avenue

Edward Cecil Barrett, B.A.

Comptroller

Secretary of the Board of Trustees

Secretary of the Executive Committee

B.A., State University of Iowa, 1906. Assistant Secretary, Board of Regents, 1906-07; Registrar and Secretary to the President, State University of Iowa, 1907-11. California Institute, 1911-

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B.A., McMaster University, 1907; M.A., 1909; Ph.D., University of Illinois, 1912. Research Assistant, McMaster University, 1909-10; Fellow in Chemistry, University of Illinois, 1910-12; Research Associate in Physical Chemistry, 1912-13; Instructor in Analytical Chemistry, 1913-14; Research Associate in Physical Chemistry, Massachusetts Institute of Technology, 1922-23 (on leave from California Institute of Technology). California Institute, 1914-

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B.S., Pacific University, 1897; M.S., 1900; D.Sc., 1946. Professor of Chemistry, Pacific University, 1900-06. Chief Chemist, Oregon Experimental Station, 1906-10; Chemist, Rubber Regenerating Co., 1911-13; Mishawaka Rubber and Woolen Manufacturing Co., 1913-17; Director of Research Laboratories, U. S. Rubber Co., 1917-23; Assistant General Manager and Director of Laboratories, Mishawaka Rubber and Woolen Manufacturing Co., 1923-42. California Institute, 1947-

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Instructor in Economics

B.A., University of California at Los Angeles, 1942; M.A., 1944. Assistant in Economics, University of California at Los Angeles, 1943-46; Associate, 1946-47. California Institute, 1947-

959 Gayley Avenue, Los Angeles

DAVID H. BROWN, PH.D.

Research Fellow in Biology

B.S., California Institute, 1942; Ph.D., 1947. National Research Council Predoctoral Fellow, California Institute, 1946-47; Research Fellow, 1947-

2447 Morslay Road, Altadena

EDWIN R. BUCHMAN, DR. PHIL. NAT.

Research Associate in Organic Chemistry

Ch.E., Rensselaer Polytechnic Institute, 1922; S.M., Massachusetts Institute of Technology, 1925; Dr.Phil.Nat., University of Frankfurt, 1933; Columbia University, 1933-35; Johns Hopkins University, 1936-37. Research Fellow, California Institute, 1937-38; Research Associate, 1938-

2645 Lambert Drive

CHARLES R. BURNHAM, PH.D.

Gosney Fellow in Biology

A.B., University of Wisconsin, 1924; M.S., 1925; Ph.D., 1929. Assistant in Genetics, University of Wisconsin, 1924-29; National Research Council Fellow, Cornell and Harvard Universities, 1929-31; Teaching Fellow, California Institute, 1931-32; Research Fellow, University of Missouri and Cornell University, 1932-33; Sterling Fellow of Botany, Yale University, 1933-34; Assistant Professor of Genetics, University of West Virginia, 1934-36; Associate Professor, 1936-39; Professor of Plant Genetics, University of Minnesota, 1939- . California Institute, 1947-

831 Sunset Blvd., Arcadia

John Peter Buwalda, Ph.D.

Professor of Geology

B.S., University of California (Berkeley), 1912; Ph.D., 1915. Instructor, University of California (Berkeley), 1915-17; Assistant Professor of Geology, Yale University, 1917-21; Associate Professor of Geology, University of California (Berkeley), 1921-25; Professor of Geology, California Institute, 1925- . Chairman of the Division of Geological Sciences 1925-47.

2103 San Pasqual Street

Ralph Byrne, Jr., Ph.D.

Associate Professor of Applied Mechanics

B.S., California Institute, 1933; M.S., 1934; Ph.D., 1940. Assistant Professor, University of California at Los Angeles, 1940-46. California Institute, 1946-

335 South Greenwood Avenue

Dan Hampton Campbell, Ph.D.

Associate Professor of Immunochemistry

A.B., Wabash College, 1930; M.S., Washington University, 1932; Ph.D., University of Chicago, 1936. Research Fellow, University of Chicago, 1936-38; Instructor in Bacteriology, 1938-39; Assistant Professor of Immunochemistry, 1939-42; Assistant Professor of Immunochemistry, California Institute, 1942-45; Associate Professor, 1945-

1154 Mount Lowe Drive, Altadena

Ian Campbell, Ph.D.

Professor of Petrology

Associate Chairman of the Division of Geological Sciences

A.B., University of Oregon, 1922; A.M., 1924; Ph.D., Harvard University, 1931. Teaching Fellow, Northwestern University, 1923-24; Assistant Professor of Geology, Louisiana State University, 1925-28; Instructor in Mineralogy and Petrography, Harvard University, 1928-31; Assistant Professor of Petrology, California Institute, 1931-35; Associate Professor, 1935-46; Professor, 1946-

405 South Bonnie Avenue

John Scott Campbell, M.S.

Instructor in Engineering Drafting

B.S., University of Washington, 1934; M.S., 1936. Graduate Assistant, California Institute, 1946-47; Instructor, 1947-

John R. Cann, Ph.D.

Research Fellow in Chemistry

B.S., Moravian College, 1942; M.S., Lehigh University, 1943; M.A., Princeton University, 1945; Ph.D., 1946. Research Assistant, Manhattan Project, Princeton University, 1942-46; Research Associate in Chemistry, Cornell University, 1946-47. California Institute, 1947-

1747 East Villa St.

Gene B. Carpenter, Ph.D.

Research Fellow in Chemistry

B.A., University of Louisville, 1944; M.A., Harvard University, 1945; Ph.D., 1947. Teaching Fellow in Chemistry, Harvard University, 1944-47; National Research Council Postdoctoral Fellow, California Institute, 1947-

175 South Mentor Avenue

Jacob Chaitkin, LL.B.

Instructor in Russian

B.A., University of Pittsburgh, 1919; LL.B., 1921. California Institute, 1946-

340 South Michigan Avenue

S. K. Chakrabarty, D.Sc.

(Visiting) Research Fellow in Geology

B.Sc., Barasol College, 1929; M.Sc., Calcutta University, 1931; D.Sc., 1943. Director, Colaba and Alibag Observatories, Bombay. California Institute, 1947-

Way-Ming Chen, Ph.D.

Research Fellow in Mathematics

Ph.D., University of California, 1945. Instructor in Mathematics, Brown University, 1945-47. California Institute, 1947-

R. F. Christy, Ph.D.

Associate Professor of Theoretical Physics

B.S., University of British Columbia, 1935; Ph.D., University of California, 1941. Assistant Professor, University of Chicago, 1945-46. California Institute, 1946-

175 South Greenwood Avenue

W. Howard Clapp, E.M.

Professor of Mechanism and Machine Design, Emeritus

E.M., University of Minnesota, 1901. Instructor in Mathematics, Macalester College, 1897-98. Superintendent and Designing Engineer, Sherman Engineering Company, Salt Lake City, 1905-09; Superintendent, Nevada-Goldfield Reduction Company, Goldfield, Nevada, 1909-10. Instructor, California Institute, 1911-13; Assistant Professor, 1913-14; Associate Professor, 1914-18; Professor, 1918-

95 South Mentor Avenue

Donald Sherman Clark, Ph.D.

Associate Professor of Mechanical Engineering

Director of Placements

B.S., California Institute, 1929; M.S., 1930; Ph.D., 1934. Assistant and Teaching Fellow, California Institute, 1929-34; Instructor, 1934-37; Assistant Professor, 1937-45; Associate Professor, 1945-

665 Canterbury Road, San Marino

J. Kent Clark, A.B.

Instructor in English

A.B., Brigham Young University, 1939. Instructor, Stanford University, 1942-43 and 1946-47. California Institute, 1947-

4212 Camero Ave., Los Angeles

E. M. Cloran, B.S.

Lecturer in Machine Design

B.S., Harvard University, 1928. Engineering Practice, 1928- . California Institute, 1947-

2101 Woodlyn Road

Frederick James Converse, B.S.

Professor of Soil Mechanics

B.S., University of Rochester, 1914. Instructor in Applied Mechanics, University of Rochester, 1916-18; Instructor, California Institute, 1921-33; Assistant Professor, 1933-39; Associate Professor, 1939-47; Professor, 1947-

2167 Lambert Drive

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Research Associate in Structural Chemistry

B.Chem., University of Pittsburgh, 1919; Ph.D., Cornell University, 1924. Assistant in Inorganic Chemistry, Cornell University, 1919-22; Chemical Spectroscopy, 1922-23; Instructor in Analytical Chemistry, 1923-28; Assistant of the Rockefeller Institute for Medical Research, 1928-30; Associate, 1930-37; Senior Research Fellow, California Institute, 1937-47; Research Associate, 1947-

352 South Parkwood Avenue

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Instructor in Climatology and Meteorology

B.A., Simpson College, Iowa, 1939; M.S., California Institute, 1943. California Institute, 1947-

612 Lander Lane

E. E. Dale, Ph.D.

Research Fellow in Biology

A.B., University of Nebraska, 1913; M.S., Kansas State College, 1920; Ph.D., University of Michigan, 1928. Professor of Biology, Puerto Rico University, 1921-26; Instructor, Hunter College, 1926-28; Assistant Professor, Union College, 1929-. California Institute, 1947-

831 North Sunset Boulevard, Arcadia

Robert Long Daugherty, M.E.

Professor of Mechanical and Hydraulic Engineering

A.B., Stanford University, 1909; M.E., 1914. Instructor in Mechanical Engineering, Stanford University, 1909-10; Assistant Professor of Hydraulics, Cornell University, 1910-16; Professor of Hydraulic Engineering, Rensselaer Polytechnic Institute, 1916-19. California Institute, 1919-

373 South Euclid Avenue

NORMAN R. DAVIDSON, PH.D.

Instructor in Chemistry

B.S., University of Chicago, 1933; B.Sc., Oxford University, 1938; Ph.D., University of Chicago, 1941. Research Associate, University of Michigan, 1941-42; Instructor, Illinois Institute of Technology, 1942-43. California Institute, 1946-

259 Auburn Avenue, Sierra Madre

GODFREY DAVIES, M.A.

Associate in History

B.A., Honour School of Modern History, Oxford University, 1914. M.A., 1917. Secretary to Regius Professor of Modern History, Oxford University, 1914-16; Tutor and Lecturer in the School of Modern History, 1919-24; Assistant Professor of History, University of Chicago, 1925-30; Visiting Scholar of the Huntington Library, 1930-31; Member of Research Staff, 1931- . California Institute, 1930-

395 South Bonnie Avenue

LEVERETT DAVIS, JR., PH.D.

Assistant Professor of Physics

B.S., Oregon State College, 1936; M.S., California Institute, 1938; Ph.D., 1941. Graduate Assistant in Physics, California Institute, 1936-39; Teaching Fellow in Physics, 1939-40; Fellow of the Rockefeller Institute for Medical Research, 1940-41; Instructor in Physics, California Institute, 1941-46; Assistant Professor, 1946-

1041 East Mendocino Street, Altadena

CLARA LOUISE DEASY, PH.D.

Research Fellow in Bio-organic Chemistry

A.B., University of Cincinnati, 1937; M.S., 1939; Ph.D., 1940. Instructor in Chemistry, Nazareth College, 1940-. California Institute, 1947-

561 So. Wilson Ave.

MAX DELBRÜCK, PH.D.

Professor of Biology

Ph.D., University of Göttingen, 1931. Rockefeller Fellow, California Institute, 1937-39; Instructor, Vanderbilt University, 1939; Assistant Professor, 1945; Associate Professor, 1946. California Institute, 1947-

1321 Virginia Road, San Marino

CHARLES R. DEPRIMA, PH.D.

Assistant Professor of Applied Mechanics

B.A., New York University, 1940; Ph.D., 1943. Instructor, Washington Square College, New York University, 1942; Instructor, New York University, 1943-46. California Institute, 1946-

551 South Hill Avenue

ROBERT PALMER DILWORTH, PH.D.

Associate Professor of Mathematics

B.S., California Institute, 1936; Ph.D., 1939. Teaching Fellow, California Institute, 1936-39; Sterling Research Fellow, Yale University, 1939-40; Instructor, 1940-43; Assistant Professor, California Institute, 1943-45; Associate Professor, 1945-

827 West Huntington Drive, Monrovia

CHARLES HEWITT DIX, PH.D.

Associate Professor of Geophysics

B.S., California Institute, 1927; A.M., Rice Institute, 1928; Ph.D., 1931. Fellow, Rice Institute, 1928-29; Instructor, 1929-34; Research Geophysicist, Humble Oil and Refining Co., 1934-37; Geophysicist, Socony-Vacuum Oil Co., 1939-41; Chief Seismologist, United Geophysical Co., 1941- . California Institute, 1947-

628 Alameda St., Altadena

JERRY DONOHUE, III, PH.D.

Research Fellow in Biology

A.B., Dartmouth College, 1941; M.A., 1943; Ph.D., California Institute, 1947. Instructor in Chemistry, Dartmouth College, 1941-43; Assistant in Chemistry, California Institute, 1943-46; Research Fellow, 1946-

917 Morada Place, Altadena

ELLSWORTH C. DOUGHERTY, PH.D., M.D.

Research Fellow in Biology

A.B., University of California, 1940; Ph.D., 1944; M.D., 1946. Teaching Assistant in Zoology, University of California, 1941-43; Research Fellow in Zoology, 1944-47; Instructor in Zoology, 1947; Instructor in Zoology, Summer Session, 1946, Spring Semester, 1947, Summer Session, 1947; Research Fellow in Medical Physics, 1946-47. Fellow of the John Simon Guggenheim Memorial Foundation and Special Research Fellow of the National Cancer Institute, California Institute, 1948-

JAMES H. DRAKE, M.S.

Instructor in Electrical Engineering

B.S., California Institute, 1945; M.S., 1947. California Institute, 1947-

217 South Anita Avenue, Los Angeles

JOHN BEINERT HENRY DREYFUSS

Visiting Lecturer in Industrial Design

Industrial Designer; Lecturer in Industrial Design, New School for Social Research; Lectures at Yale University, New York University and University of California at Los Angeles. California Institute, 1947-

969 East San Pasqual St.

JACOB WILLIAM DUBNOFF, PH.D.

Senior Research Fellow in Biology

A.B., University of California (Los Angeles), 1931; M.A., 1933; Ph.D., California Institute, 1944. California Institute, 1936-

1871 Brigden Road

LEE A. DUBRIDGE, PH.D., SC.D.

(See page 14)

ANTONIO DUEROJO, S.J.

(Visiting) Research Fellow in Seismology

Director, Cartuja Observatory, Granada, Spain, 1939- . California Institute, 1947-

JESSE WILLIAM MONROE DUMOND, PH.D.

Professor of Physics

B.S., California Institute, 1916; M.S. (E.E.), Union College, 1918; Ph.D., California Institute, 1929. Teaching Fellow, California Institute, 1921-25; Research Fellow, 1925-31; Acting Associate Professor of Physics, Stanford University, 1931; Research Associate, California Institute, 1931-38; Associate Professor, 1938-46; Professor, 1946-

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Associate Professor of Aeronautics

Director of the Jet Propulsion Laboratory

B.S., California Institute, 1936; M.S. (M.E.), 1937; M.S. (A.E.), 1938; Ph.D., 1940. Research Assistant, California Institute, 1937-39; Research Fellow, 1939-40; Instructor, 1940-41; Assistant Professor, 1941-46; Associate Professor, 1946-; Director, Jet Propulsion Laboratory, 1947-

937 West Sierra Madre Avenue, Glendora

POL DUWEZ, D.SC.

Associate Professor of Mechanical Engineering

D.Sc., University of Brussels, 1933. Fellow of the Belgium American Educational Foundation, California Institute, 1933-35; Fellow of the National Foundation for Scientific Research, Belgium, 1935-37; Professor, School of Mines, Mons, Belgium, 1937-40; Research Engineer, California Institute, 1942-47; Associate Professor, 1947-

423 South Chester Ave.

HARVEY EAGLESON, PH.D.

Professor of English

B.A., Reed College, 1920; M.A., Stanford University, 1922; Ph.D., Princeton University, 1928. Instructor in English, University of Texas, 1922-26; Assistant Professor, California Institute, 1928-38; Associate Professor, 1938-47; Professor, 1947-

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PAUL CONANT EATON, A.M.

Associate Professor of English

Associate Dean for Upperclassmen

S.B., Massachusetts Institute of Technology, 1927; A.M., Harvard University, 1930. Instructor in English, Phillips Exeter Academy, 1927-29; Instructor and Assistant Professor of English, Massachusetts Institute of Technology, 1930-47; Visiting Lecturer in English, California Institute, 1946; Associate Professor, 1947-

551 South Hill Ave.

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Assistant Professor of Meteorology

B.S., California Institute, 1936; M.S., 1937. Instructor, California Institute, 1940-42; Assistant Professor, 1942-

285 West Laun Street, Altadena

STERLING EMERSON, PH.D.

Professor of Genetics

B.Sc., Cornell University, 1922; M.A., University of Michigan, 1924; Ph.D., 1928. Instructor in Botany, University of Michigan, 1924-28; Assistant Professor of Genetics, California Institute, 1928-37; Associate Professor, 1937-46; Professor, 1946-

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PAUL SOPHUS EPSTEIN, PH.D.

Professor of Theoretical Physics

B.Sc., Moscow University, 1906; M.Sc., 1909; Ph.D., University of Munich, 1914. Assistant in Physics, Moscow Institute of Agriculture, 1906-07; Assistant in Physics, Moscow University, 1907-09; Privatdozent, Moscow University, 1909-13; Privatdozent, University of Zurich, 1919-22; Exchange Professor, Aachen Institute of Technology, 1927 and 1929. California Institute, 1921-

1484 Oakdale Street

A. ERDÉLYI, D.SC.

Visiting Professor of Mathematics

Cand. Ing., Deutsche Technische Hochschule, Brno, Czechoslovakia, 1928; Dr. rer.nat., University of Prague, 1938; D.Sc., University of Edinburgh, 1940. Assistant in Mathematics, University of Edinburgh, 1941-42; Lecturer, 1942-. California Institute, 1947-

551 South Hill Ave.

HENRY OWEN EVERSOLE, M.D.

Research Associate in Plant Physiology

M.D., University of California, 1908. California Institute, 1947-

1856 Foothill Boulevard, La Canada

FRED J. EWING, PH.D.

Senior Research Fellow in Structural Chemistry

B.S., California Institute, 1927; Ph.D., 1935. Senior Research Fellow, California Institute, 1946-

2919 North Lake Avenue, Altadena

FREDERICK FELBERG, M.S.

Lecturer in Aeronautics

B.S., California Institute, 1942; M.S., 1945. Assistant in Aeronautics, 1942-45; Cooperative Wind Tunnel, 1945-; Lecturer in Aeronautics, 1947-

323 East Palm, Monrovia

MARGUERITE FLING, PH.D.

Research Fellow in Biology

A.B., Hunter College, 1941; Ph.D., Iowa State College, 1946. California Institute, 1946-

518 West Loma Alta Street, Altadena

WILLIAM ALFRED FOWLER, PH.D.

Professor of Physics

B.Eng. Physics, Ohio State University, 1933; Ph.D., California Institute, 1936. Research Fellow, California Institute, 1936-39; Assistant Professor, 1939-42; Associate Professor, 1942-46; Professor, 1946-

1108 Lura Street

ARTHUR W. GALSTON, PH.D.

Senior Research Fellow in Biology

B.S., Cornell University, 1940; M.S., University of Illinois, 1942; Ph.D., 1943. Instructor, Yale University, 1946-47. California Institute, 1947-

421 West Figueroa Drive, Altadena

JOSEPHINE B. GARST, PH.D.

Research Fellow in Biology

A.B., University of Michigan, 1926; M.S., 1938; Ph.D., University of Minnesota, 1945. California Institute, 1947-

85 North Orange Grove Avenue

PAUL A. GIGUÈRE, PH.D.

Research Fellow in Chemistry

B.A., Laval University, 1930; B.Sc., 1934; Ph.D., McGill University, 1937. Research Fellow, California Institute, 1939-41; Lecturer, Laval University, 1941-43; Assistant Professor, 1943-46; Professor, 1947- . Fellow of the John Simon Guggenheim Memorial Foundation, California Institute, 1947-

2121 Monte Vista Street

Horace Nathaniel Gilbert, M.B.A.

Professor of Business Economics

A.B., University of Washington, 1923; M.B.A., Harvard University, 1926. Instructor in Business Policy, Harvard University, 1926-28; Instructor in Business Economics, 1928-29; Visiting Lecturer on Industrial Mobilization, 1940-42; Assistant Professor of Business Economics, California Institute, 1929-30; Associate Professor, 1930-47; Professor, 1947-

385 South Bonnie Avenue

Alexander Goetz, Ph.D.

Associate Professor of Physics

Ph.D., University of Göttingen, 1921; Habilitation, 1923. Privatdozent and A.O. Professor, University of Göttingen, 1923-30; Rockefeller Fellow at California Institute, 1927-28; Guest Professor, University of Japan, Tsing-Hua University of China, 1929-30. Associate Professor of Physics, California Institute, 1930-

1317 Boston Street, Altadena

E. C. Goldsworthy, Ph.D.*

Master of the Student Houses

Assistant Professor of Mathematics

A.B., University of California, 1923; Ph.D., 1928. Instructor and Assistant Professor of Mathematics, University of California, 1923- . California Institute, 1946-

1245 Arden Road

Robert D. Gray, B.S.

Professor of Economics and Industrial Relations

Director of Industrial Relations Section

B.S., Wharton School of Finance and Commerce, University of Pennsylvania, 1930. Research Assistant, Industrial Research Department, University of Pennsylvania, 1927-36; Research Associate, 1936-39; Instructor in Geography and Industry, Wharton School of Finance and Commerce, 1934-37; Assistant Professor of Economics, University of Connecticut, 1937-40; Adviser, Division of Business and Commerce, 1939-40. Associate Professor, California Institute, 1940-42; Professor, 1942-

3059 Santa Rosa Ave., Altadena

Harry R. Greene, M.A.

Visiting Lecturer in Industrial Design

A.B., San Diego State College, 1939; M.A., California Graduate School of Design, 1941. Visiting Lecturer, California Institute, 1945-

262 South El Molino Avenue

Beno Gutenberg, Ph.D.

Professor of Geophysics

Director of the Seismological Laboratory

Ph.D., University of Göttingen, 1911. Research Assistant, Zentralbüro Internat. Seismolog. Vereinigung, Strassburg, 1913-14; Reichzentrale für Erdbebenforschung, Strassburg, 1914-19; Privatdozent für Geophysik, Frankfurt a/M, 1924-26; A.O. Professor, 1926-30. California Institute, 1930-

399 Ninita Parkway

Arie Jan Haagen-Smit, Ph.D.

Professor of Bio-organic Chemistry

A.B., University of Utrecht, 1922; A.M., 1926; Ph.D., 1929. Head Assistant, Department of Organic Chemistry, Utrecht, 1929-34; Lecturer in Organic Chemistry, Utrecht, 1934-36; Lecturer in Biological Chemistry, Harvard University, 1936-37. Associate Professor, California Institute, 1937-40; Professor, 1940-

416 South Berkeley Avenue

Bernard Hamermesh, Ph.D.

Research Fellow in Physics

B.S., City College of the College of the City of New York, 1940; M.S., New York University, 1942; Ph.D., 1944. Instructor, New York University, 1943-46. National Research Council Postdoctoral Fellow, California Institute, 1946-

1622 Brigden Road

Floyd Luther Hanes, D.O.

Physical Trainer, Track and Cross Country Coach

D.O., College of Osteopathic Physicians and Surgeons, Los Angeles, 1921. California Institute, 1923-

2141 Layton Street

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ANTHONIE VAN HARREVELD, PH.D., M.D.

Professor of Physiology

B.A., Amsterdam University, 1925; M.A., 1928, Ph.D., 1929; M.D., 1931. Assistant in Physiology, Amsterdam University, 1926-32; Chief Assistant in Physiology, Utrecht University, 1932-34; Research Assistant, California Institute, 1934-35; Instructor, 1935-40; Assistant Professor, 1940-42; Associate Professor, 1942-47; Professor, 1947-

764 South Oakland Avenue

DONNEL FOSTER HEWETT, PH.D.

Research Associate in Geology

Met.E., Lehigh University, 1902; Sc.D., 1942; Ph.D., Yale University, 1924. Instructor in Metallurgy and Mineralogy, Lehigh University, 1902-03; Junior Geologist, U. S. Geological Survey, 1911-13; Associate Geologist, 1913-18; Geologist, 1918-31; Principal Geologist, 1931-43; In Charge Section of Metalliferous Deposits, 1935-46; Staff Geologist, 1946- . California Institute, 1947-

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ALADAR HOLLANDER, M.E.

Associate Professor of Mechanical Engineering

M.E., Joseph Royal University, Budapest, 1904. Chief Engineer, Byron Jackson Co., 1923-39; Consulting Engineer, 1939- . Lecturer, California Institute, 1944-45; Associate Professor, 1945-

2385 Hill Drive, Los Angeles

RALSTON S. HOLMES, REAR ADMIRAL, U.S.N. (RET'D)

Associate in Naval History

U. S. Naval Academy, 1903; Rear Admiral, 1936- . California Institute, 1946-

Huntington Hotel

NORMAN H. HOROWITZ, PH.D.

Associate Professor of Biology

B.S., University of Pittsburgh, 1936; Ph.D., California Institute, 1939. Research Fellow, California Institute, 1940-42; Research Associate, Stanford University, 1942-46; Senior Research Fellow, California Institute, 1947; Associate Professor, 1947-

615 South El Molino Avenue

ELDRED WILSON HOUGH, PH.D.

Senior Research Fellow in Chemical Engineering

B.S., University of Illinois, 1939; M.S., California Institute, 1941; Ph.D., 1943. Research Assistant, California Institute, 1941-46; Senior Research Fellow, 1946-

365 South Wilson Avenue

MARY B. HOULAHAN, M.A.

Research Fellow in Biology

B.S., George Washington University, 1941; M.A., Stanford University, 1945. Research Assistant, Carnegie Institution, Department of Genetics, 1939-42; Research Assistant, Stanford University, 1943-46. California Institute, 1946-

1126 Cordova Street

GEORGE WILLIAM HOUSNER, PH.D.

Assistant Professor of Applied Mechanics

B.S., University of Michigan, 1933; M.S., California Institute, 1934; Ph.D., 1941. Teaching Fellow, California Institute, 1939-41; Assistant Professor, 1945-

4084 Chevy Chase Drive, Flintridge

DAVID R. HOWTON, PH.D.

Research Fellow in Chemistry

B.S., California Institute, 1942; Ph.D., 1946. California Institute, 1946-

36 East Tremont Street

DONALD ELLIS HUDSON, PH.D.

Assistant Professor of Mechanical Engineering

B.S., California Institute, 1938; M.S., 1939; Ph.D., 1942. Instructor, 1941-43; Assistant Professor, 1943-

640 North Chester Avenue

E. W. Hughes, Ph.D.
Research Associate in Chemistry

B. Chem., Cornell University, 1924; Ph.D., 1935. Resident doctor, Cornell University, 1935-38; Research Fellow, California Institute, 1938-43; Senior Research Fellow, 1945-46; Research Associate in Chemistry, 1946-

551 South Hill Ave.

William Huse, M.A.
Professor of English
Editor of Institute Publications

A.B., Stanford University, 1921; M.A., Princeton University, 1928. Instructor in English, Washington University, 1921-23; Instructor in English, Princeton University, 1923-24; Assistant Professor of English, University of Kansas, 1927-29. Assistant Professor, California Institute, 1929-38; Associate Professor, 1938-47; Professor, 1947-

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B.S., California Institute, 1929. California Institute, 1945-

426 Oaklawn Avenue, South Pasadena

Richard Henry Jahns, Ph.D.
Associate Professor of Geology

B.S., California Institute, 1935; M.S., Northwestern University, 1937; Ph.D., California Institute, 1943. Junior Geologist, U. S. Geological Survey, 1937-40; Assistant Geologist, 1940-42; Associate Geologist, 1942-44; Geologist, 1944- . Assistant Professor of Geology, California Institute, 1946-47; Associate Professor, 1947-

213 North Vega Avenue, Alhambra

Lloyd A. Jeffress, Ph.D.
Hixon Visiting Professor of Psycho-biology

A.B., University of California, 1922; Ph.D., 1926. Assistant Professor of Psychology, University of Texas, 1926-27; Associate Professor, 1927-37; Professor, 1937- . California Institute, 1947-

551 South Hill Ave.

Josef Jerome Johnson, Ph.D.
Research Associate in Astrophysics

B.S., California Institute, 1930; M.S., Ohio Wesleyan University, 1932; Ph.D., California Institute, 1935. California Institute, 1932-

1030 San Pasqual Street

Louis Winchester Jones, A.B.
Associate Professor of English
Director of Admissions
Registrar

A.B., Princeton University, 1922. Instructor, California Institute, 1925-37; Assistant Professor, 1937-43; Associate Professor, 1943-

351 California Terrace

Clinton Kelly Judy, M.A.
Professor of English
Chairman of the Division of Humanities

M.A., University of California, 1907; M.A., Oxford University, 1913; A.M., Harvard University, 1917. California Institute, 1909-

1325 Woodstock Road, San Marino

Samuel Karlin, Ph.D.
Harry Bateman Research Fellow in Mathematics

B.S., Illinois Institute of Technology, 1944; M.S., 1945; M.A., Princeton University, 1946; Ph.D., 1947. California Institute, 1947-

1790 North Coolidge Ave., Altadena

Theodore von Kármán, Ph.D., Dr. Ing., Sc.D., LL.D., Eng.D.
Professor of Aeronautics
Director of the Daniel Guggenheim Laboratory

M.E., Budapest, 1902; Ph.D., Göttingen, 1908; Doctor of Engineering, University of Berlin, 1929; Doctor of Science, University of Brussels, 1937; LL.D., University of California at Los Angeles, 1943; Eng.D., Princeton University, 1947. Privatdozent, Göttingen, 1910-13; Professor of Mechanics and Aerodynamics, Director of the Aerodynamical Institute, University of Aachen, 1913-34; Rouse-Ball Lecturer at the University of Cambridge, 1937; C.R.B. Lecturer in Belgium, 1937; Wilbur Wright Lecturer of the Royal Aeronautical Society, 1937; Josiah Willard Gibbs Lecturer of the American Mathematical Society, 1939; Wright Brothers Lecturer of the Institute of the Aeronautical Sciences, 1946. California Institute, 1928-

1501 South Marengo Avenue

Geoffrey Lorrimer Keighley, Ph.D.

Senior Research Fellow in Biology

B.A., University of Toronto, 1926; M.S., California Institute, 1940; Ph.D., 1944. Research Assistant, California Institute, 1930-43; Instructor, 1943-46; Senior Research Fellow, 1946-

237 West Las Flores Drive, Altadena

John G. Kirkwood, Ph.D.

Arthur Amos Noyes Professor of Chemistry

B.S., University of Chicago, 1926; Ph.D., Massachusetts Institute of Technology, 1929. National Research Fellow, Harvard University, 1929-30; Research Associate in Physical Chemistry, Massachusetts Institute of Technology, 1930-31, 1932-34; International Research Fellow, Universities of Leipzig and Munich, 1931-32. Assistant Professor of Chemistry, Cornell University, 1934-37; Associate Professor, University of Chicago, 1937-38; Todd Professor of Chemistry, Cornell University, 1938-47; Visiting Professor of Chemistry, Columbia University, 1941; Visiting Professor of Mathematical Physics, Princeton University, 1947. California Institute, 1947-

Green Hotel

Arthur Louis Klein, Ph.D.

Associate Professor of Aeronautics

B.S., California Institute, 1921; M.S., 1924; Ph.D., 1925. Teaching Fellow in Physics, California Institute, 1921-25; Research Fellow in Physics and in Aeronautics, 1927-29; Assistant Professor, 1929-34; Associate Professor, 1934-

2771 Glendower Avenue, Los Angeles

Robert Talbot Knapp, Ph.D.

Associate Professor of Hydraulic Engineering

B.S., Massachusetts Institute of Technology, 1920; Ph.D., California Institute, 1929. Instructor, California Institute, 1922-30; Assistant Professor of Mechanical Engineering, 1930-36; Associate Professor of Hydraulic Engineering, 1936-

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Hartman P. R. Koechlin, Dr. Phil.

Research Fellow in Chemistry

Dr. Phil., University of Basle, 1947. California Institute, 1947-

Joseph Blake Koepfli, D.Phil.

Research Associate in Chemistry

A.B., Stanford University, 1924; M.A., 1925; D.Phil., Oxford University, 1928. Research Fellow in Organic Chemistry, California Institute, 1928-29; Instructor in Pharmacology, Johns Hopkins University School of Medicine, 1929-31; Research Associate, California Institute, 1932-

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Ph.D., University of Amsterdam, The Netherlands, 1946. Assistant in Organic Chemistry, University of Amsterdam, 1942-44; Institute of International Education Fellow, California Institute, 1947-

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Moises Kramer, Eng.Agr.

Research Fellow in Biology

Eng.Agr., University of Sao Paulo, 1932. Assistant in Zoology, School of Agriculture, University of Sao Paulo, 1933-35; Assistant, Biological Institute, University of Sao Paulo, 1935-45; Biologist, P., 1935-47. California Institute, 1947-

1549 Casa Grande St.

Edward Dunster Kremers, M.D.

Consulting Physician; Director of Student Health

M.D., University of Michigan, 1903; Graduate, Army Medical School, 1910. Lt. Col., United States Army, Retired; California Institute, 1930-

2125 Mar Vista Avenue, Altadena

Marshall Yates Kremers, M.D.

Assistant to the Consulting Physician

A.B., Occidental College, 1930; M.A., University of California, 1932; M.D., 1935. California Institute, 1936-

2045 Minoru Drive

Irving Parkhurst Krick, Ph.D.

Professor of Meteorology

A.B., University of California, 1928; M.S., California Institute, 1933; Ph.D., 1934. Teaching Fellow, California Institute, 1932-33; Instructor, 1933-35; Assistant Professor, 1935-38; Associate Professor, 1938-43; Professor, 1943-

3658 Mountain View Avenue

Peter Rudolf Kyropoulos, M.S.

Instructor in Mechanical Engineering

B.S., University of Göttingen, 1936; M. S., California Institute, 1938. California Institute, 1943-

1938 Mill Road, South Pasadena

Spiro Kyropoulos, Ph.D.

Research Fellow in Physics

Ph.D., University of Leipzig, 1911. Assistant in Physical Chemistry, Institute of Agriculture, University of Göttingen, 1912-13; Assistant in Physical Chemistry, Institute of Physical Chemistry, Göttingen, 1913-25; Research Fellow in Fluid Mechanics and Assistant in Physics, 1928-31; Assistant Professor of Applied Physics, 1931-35. California Institute, 1937-

1936-A Mill Road, South Pasadena

William Noble Lacey, Ph.D.

Professor of Chemical Engineering
Dean of Graduate Studies

A.B., Stanford University, 1911; Ch.E., 1912; M.S., University of California, 1913; Ph.D., 1915. Assistant in Chemistry, Stanford University, 1911-12; Assistant in Chemistry, University of California, 1912-15; Research Associate, Massachusetts Institute of Technology, 1916; Instructor, California Institute, 1916-17; Assistant Professor, 1917-19; Associate Professor, 1919-31; Professor, 1931-

2024 Minoru Drive, Altadena

Paco Lagerstrom, Ph.D.

Assistant Professor of Aeronautics

Fil. Kand., University of Stockholm, 1935; Fil. Lic., 1939; Ph.D., Princeton University, 1942. Instructor, Princeton University, 1941-44; Research Associate in Aeronautics, California Institute, 1946-47; Assistant Professor, 1947-

1001 Buena Vista, South Pasadena

Beach Langston, Ph.D.

Assistant Professor of English

A.B., The Citadel, 1933; M.A., Claremont Colleges, 1934; Ph.D., University of North Carolina, 1940. Instructor, University of North Carolina, 1935-40; Assistant Professor, Texas College of Mines, 1940-45; Associate Professor, 1945-46; Assistant Professor, University of New Hampshire, 1946-47. California Institute, 1947-

George Laties, Ph.D.

Research Fellow in Biology

B.S., Cornell University, 1941; M.S., University of Minnesota, 1942; Ph.D., University of California, 1947. Research Assistant, University of California, 1942-44. California Institute, 1947-

791 Woodland Drive, Sierra Madre

Charles Christian Lauritsen, Ph.D.

Professor of Physics

Graduate, Odense Tekniske Skole, 1911; Ph.D., California Institute, 1929. Assistant in Physics, California Institute, 1927-30; Assistant Professor, 1930; Associate Professor, 1931; Professor, 1935-

1444 Blanche Street

Thomas Lauritsen, Ph.D.

Assistant Professor of Physics

B.S., California Institute, 1936; Ph.D., 1939. Rockefeller Fellow at University of Copenhagen, 1940; Senior Research Fellow, California Institute, 1945; Assistant Professor, 1946-

620 East Punahou Street, Altadena

Robert B. Leighton, Ph.D.

Research Fellow in Physics

B.S., California Institute, 1941; M.S., 1944; Ph.D., 1947. California Institute, 1947-

1456 Paloma St.

JOSEPH LEIN, PH.D.
Research Fellow in Biology
B.S., City College of New York, 1941; Ph.D., Princeton University, 1947. Instructor, Syracuse University, 1946-47. Merck Fellow, California Institute, 1947-
419½ South Catalina Ave.

EDWARD B. LEWIS, PH.D.
Instructor in Genetics
B.A., University of Minnesota, 1939; Ph.D., California Institute, 1942. California Institute, 1946-
773 South Mentor Avenue

HANS WOLFGANG LIEPMANN, PH.D.
Associate Professor of Aeronautics
Ph.D., University of Zurich, 1938. Research Fellow, University of Zurich, 1938; Assistant Professor, California Institute, 1939-46; Associate Professor, 1946-
2595 Lambert Drive

FREDERICK CHARLES LINDVALL, PH.D.
Professor of Electrical and Mechanical Engineering
Chairman of the Division of Civil and Mechanical Engineering and Aeronautics
Member of the Executive Committee
B.S., University of Illinois, 1924; Ph.D., California Institute, 1928. Teaching Fellow, California Institute, 1925-28; Instructor in Electrical Engineering, 1930-31; Assistant Professor of Electrical Engineering, 1931-37; Associate Professor of Electrical and Mechanical Engineering, 1937-42; Professor of Electrical and Mechanical Engineering, 1942-
2006 Skyview Drive, Altadena

PAUL EUGENE LLOYD, PH.D.
Research Fellow in Physics
A.B., Stanford University, 1929; Ph.D., California Institute, 1937. Instructor, Oberlin College, 1938; Research Fellow, California Institute, 1938-
620 Burleigh Drive

ALBERT E. LONGLEY, PH.D.
Research Associate in Biology
B.S., Acadia University, 1920; M.A., Harvard University, 1922; Ph.D., 1923. Assistant, Acadia University, 1917-20; Austin Teaching Fellow, Harvard University, 1920-23; Assistant, Radcliffe College, 1923. Associate Cytologist, Associate Botanist and Cytologist, U. S. Department of Agriculture, 1923-. California Institute, 1947-
791 North Oak St., Temple City

HOWARD JOHNSON LUCAS, M.A.
Professor of Organic Chemistry
B.A., Ohio State University, 1907; M.A., 1908. Instructor in Chemistry, California Institute, 1913-15; Associate Professor of Organic Chemistry, 1915-40; Professor, 1940-
95 North Holliston Avenue

WERNER KARL MAAS, PH.D.
Gosney Fellow in Biology
B.A., Harvard University, 1943; Ph.D., Columbia University, 1946. Laboratory Instuctor in Zoology, Columbia University, 1943-46. California Institute, 1946-
173 South Meridith Ave.

JOHN ROBERTSON MACARTHUR, PH.D.
Professor of Languages, Emeritus
B.A., University of Manitoba, 1892; Ph.D., University of Chicago, 1903. Lecturer in Modern Languages, Manitoba College, 1893-98; Professor of English, New Mexico Agricultural College, 1903-10, 1911-13; Professor of English, Kansas State Agricultural College, 1914-20. Associate Professor, California Institute, 1920-23; Dean of Freshmen, 1923-37; Professor of Languages, 1923-
304 Ellis Street, Elsinore

GEORGE EBER MACGINITIE, M.A.
Associate Professor of Biology
A.B., Fresno State College, 1925; M.A., Stanford University, 1928. Instructor in Biology, Fresno State College, 1925-28; Instructor in Zoology, Hopkins Marine Station of Stanford University, 1928-29; Assistant Professor of Zoology, 1929-32. Assistant Professor, California Institute, 1932-46; Associate Professor, 1946-
Corona Del Mar

Samuel Stuart Mackeown, Ph.D.

Professor of Electrical Engineering

A.B., Cornell University, 1917; Ph.D., 1923. Instructor in Physics, Cornell University, 1920-23; National Research Fellow in Physics, California Institute, 1923-26; Assistant Professor, 1926-31; Associate Professor, 1931-42; Professor, 1942-

1240 Arden Road

George Rupert MacMinn, A.B.

Professor of English

A.B., Brown University, 1905. Instructor in English, Brown University, 1907-09; Iowa State College, 1909-10; University of California, 1910-18. Associate Professor, California Institute, 1918-45; Professor, 1945-

255 South Bonnie Avenue

Frank Joseph Malina, Ph.D.*

Assistant Professor of Aeronautics

B.S., Texas Agricultural and Mechanical College, 1934; M.S., California Institute, 1935 (M.E.) and 1936 (A.E.); Ph.D., 1940. Assistant and Teaching Fellow, California Institute, 1934-39; Research Assistant, 1939-40; Research Fellow, 1940-42; Assistant Professor, 1942-

Unesco, 19 Ave Kleber, Paris, 16, France

Romeo Raoul Martel, S.B.

Professor of Structural Engineering

S.B., Brown University, 1912. Instructor in Civil Engineering, Rhode Island State College, 1913-14; Instructor in Civil Engineering, Mechanics Institute, 1914-15; Instructor, California Institute, 1918-20; Assistant Professor, 1920-21; Associate Professor, 1921-30; Professor, 1930-

809 Fairfield Circle

Harold Clifford Martin, M.S.

Lecturer in Aeronautics

B.S., New York University, 1934; M.S., 1937. Instructor in Aeronautics, Princeton University, 1942-44; Assistant in Aeronautics, California Institute, 1944-46; Lecturer, 1946-

244 North Ivy Street, Monrovia

Max Mason, Ph.D., LL.D., Sc.D.

Chairman of the Observatory Council

Member of the Board of Trustees

B.L., University of Wisconsin, 1898; Ph.D., University of Göttingen, 1903. Instructor in Mathematics, Massachusetts Institute of Technology, 1903-04; Assistant Professor of Mathematics, Yale University, 1904-08; Associate Professor of Mathematics, University of Wisconsin, 1908; Professor of Mathematical Physics, 1910-25; President, University of Chicago, 1925-28; President of the Rockefeller Foundation, 1928-36. LL.D., University of Wisconsin, 1926; Yale University, 1926; Dartmouth College, 1927; Pomona College, 1937; Sc.D., Columbia University, 1926. Colloquium Lecturer, American Mathematical Society, 1906; Visiting Lecturer, Mathematical Physics, Harvard University, 1911-12. California Institute, 1936-

1035 Harvard Avenue, Claremont

Francis William Maxstadt, Ph.D.

Associate Professor of Electrical Engineering

M.E., Cornell University, 1916; M.S., California Institute, 1925; Ph.D., 1931. Instructor, California Institute, 1919-33; Assistant Professor, 1933-47; Associate Professor, 1947-

1626 North Grand Oaks Avenue

Gilbert D. McCann, Ph.D.

Professor of Electrical Engineering

B.S., California Institute, 1934; M.S., 1935; Ph.D., 1939. Westinghouse Corp., 1938-46; Associate Professor, California Institute, 1946-47; Professor, 1947-

1906 Pepper Drive, Altadena

Henry F. McCreery, Ph.D.

Assistant Professor of History

B.A., Princeton University, 1937; Ph.D., Stanford University, 1947. Tutor in English, Robert College, Istanbul, Turkey, 1937-40; Instructor, Stanford University, 1942-43. California Institute, 1947-

1729 Raymond Hill Road, South Pasadena

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HUNTER MEAD, PH.D.

Professor of Philosophy and Psychology

B.A., Pomona College, 1930; M.A., Claremont College, 1933; Ph.D., University of Southern California, 1936. Instructor, American Colleges in Turkey, Greece, 1930-32; Instructor, Glendale Junior College, 1938-39; Instructor, Los Angeles City College, 1939-41; Assistant Professor, San Diego State College, 1941-46; Associate Professor, 1946-47. California Institute, 1947-

626 North Chester Ave.

SALVATORE MERENDINO, M.A.

Visiting Lecturer in Industrial Design

A.B., San Jose State College, 1938; M.A., California Graduate School of Design, 1940. California Institute, 1945-

562 South Oak Knoll Avenue

ALBERT A. MERRILL

Instructor in Aeronautics

California Institute, 1918-30; 1940-

1172 North Michigan Avenue

MARGARETHA G. MES, PH.D.

Visiting Professor of Plant Physiology

B.S., Transvaal University College, 1924; Ph.D., University of Utrecht, 1930. Research Assistant, University of California, 1930-31; Lecturer in Botany, University of Pretoria, 1932-33; Senior Lecturer, 1934-43; Professor and Head of Department, 1944- . California Institute, 1947-

485 South Madison Ave.

WILLIAM W. MICHAEL, B.S.

Associate Professor of Civil Engineering

B.S., Tufts College, 1909. Instructor, Department of Drawing and Design, Michigan Agricultural College, 1914; Chief of Surveys, 200-inch Telescope, Palomar Mt. Summer, 1935. California Institute, 1918-

388 South Oak Avenue

ARISTOTLE DEMETRIUS MICHAL, PH.D.

Professor of Mathematics

A.B., Clark University, 1920; A.M., 1921; Ph.D., The Rice Institute, 1924. Teaching Fellow and Instructor of Mathematics, The Rice Institute, 1921-25; Instructor of Mathematics, University of Texas, Summer 1924; National Research Fellow in Mathematics, University of Chicago, Harvard University, and Princeton University, 1925-27; Assistant Professor of Mathematics, Ohio State University, 1927-29. California Institute, 1929-

2028 Amherst Drive, South Pasadena

CLARK BLANCHARD MILLIKAN, PH.D.

Professor of Aeronautics

Director of the Cooperative Wind Tunnel

Member of the Executive Committee

Ph.B., Yale University, 1924; Ph.D., California Institute, 1928. Teaching Fellow, California Institute, 1925-28; Assistant Professor, 1928-34; Associate Professor, 1934-40; Professor, 1940-

1500 Normandy Drive

ROBERT ANDREWS MILLIKAN, PH.D., LL.D., SC.D., Nobel Laureate

Professor of Physics, Emeritus

Vice-President of the Board of Trustees

A.B., Oberlin College, 1891; A.M., 1893; Ph.D., Columbia University, 1895. Instructor in Physics, University of Chicago, 1899-1902; Assistant Professor, 1902-07; Associate Professor, 1907-19; Professor, 1919-21; Professor of Physics and Director of the Norman Bridge Laboratory of Physics, California Institute, 1921-45; Chairman of the Executive Council, 1921-45; Vice-President of the Board of Trustees and Professor of Physics, Emeritus, 1945-

1640 Oak Grove Avenue, San Marino

JOHN MILLS, M.A.

Student Counselor

A.B., University of Chicago, 1901; M.A., University of Nebraska, 1904; B.S., Massachusetts Institute of Technology, 1909. Instructor, Western Reserve University, 1903-07; Professor, Colorado College, 1909-11; with Bell Telephone Laboratories (and its predecessor departments in the Bell Telephone System), 1911-45. California Institute, 1946-

Green Hotel

Mark Muir Mills, B.S.

Lecturer in Jet Propulsion

B.S., California Institute, 1940. Instructor in Physics, California Institute, 1941; Instructor in Jet Propulsion, 1943-47; Lecturer, 1947-

405 Northcliffe Road

Herschel K. Mitchell, Ph.D.

Senior Research Fellow in Biology

B.S., Pomona College, 1936; M.S., Oregon State College, 1938; Ph.D., University of Texas, 1941. Research Biochemist, University of Texas, 1941-43; Research Associate, Stanford University, 1943-46. California Institute, 1946-

600 South St. Johns Avenue

Beverly W. Morant

Instructor in Industrial Design

California Institute, 1941-

567 North Oakland Avenue

Lilian V. Morgan, M.A.

Research Associate in Biology

A.B., Bryn Mawr College, 1891; M.A., 1892. California Institute, 1947-

1149 San Pasqual St.

Seeley G. Mudd, M.D.

Research Associate in Medical Chemistry

B.S., Columbia University, 1917; M.D., Harvard University, 1924. Dean of the Medical School, University of Southern California, 1941-43; Professor of Experimental Medicine, 1941-; Research Associate, California Institute, 1931-

1550 Oak Grove Ave., San Marino

William Bennett Munro, Ph.D., LL.D., Litt.D.

Edward S. Harkness Professor of History and Government, Emeritus

Treasurer of the Board of Trustees

B.A., Queens University, 1895; M.A., 1896; LL.B., 1898; M.A., Harvard University, 1899; Ph.D., 1900; M.A. (hon.), Williams College, 1904; LL.D., Queens University, 1912; Litt.D., University of Southern California, 1930; LL.D., Mills College, 1931. Instructor in History and Political Science, Williams College, 1901-04; Instructor in Government, Harvard University, 1904-06; Assistant Professor of Government, 1906-12; Professor of Municipal Government, 1912-25; Jonathan Trumbull Professor of American History and Government, 1925-30; Chairman, Division of History, Economics and Government, Harvard University, 1920-28. California Institute, 1925-

268 Bellefontaine Street

Harold Z. Musselman, A.B.

Director of Athletics and Physical Education

A.B., Cornell College, 1920. Athletic Director, Sterling (Illinois) High School, 1920-21; Instructor, California Institute, 1921-24; Manager of Athletics, 1924-35; Assistant Director of Physical Education and Manager of Athletics, 1935-42; Acting Director of Physical Education, 1942-43; Director of Physical Education and Manager of Athletics, 1943-47; Director of Athletics and Physical Education, 1947-

1080 North Holliston Avenue

Henry Nagamatsu, M.S.

Lecturer in Aeronautics

B.S. (M.E.), California Institute, 1938; B.S. (A.E.), 1939; M.S. (A.E.), 1940. Graduate Assistant in Aeronautics, California Institute, 1939-41; Lecturer, 1946-

648 South Arroyo Boulevard

Herbert H. G. Nash

Assistant Secretary

University of Manitoba, 1919. Chief Accountant, California Institute, 1922-35; Assistant Secretary, 1935-

1261 San Pasqual Street

Henry Victor Neher, Ph.D.

Professor of Physics

A.B., Pomona College, 1926; Ph.D., California Institute, 1931. Instructor and Assistant Professor of Physics, California Institute, 1933-40; Associate Professor of Physics, 1940-44; Professor of Physics, 1944-

885 North Holliston Avenue

JAMES H. NERRIE, B.S.
Instructor in Physical Education

B.S., Rutgers University, 1941. California Institute, 1946-

1025 Raymond Avenue, Long Beach

CARL GEORGE NIEMANN, PH.D.
Professor of Organic Chemistry

B.S., University of Wisconsin, 1931; Ph.D., 1934. Research Assistant, University of Wisconsin, 1929-31; Fellow, 1931-34; Research Associate, 1934-35; Fellow of the General Education Board at the Rockefeller Institute for Medical Research, 1935-36; Assistant in Chemistry, 1936-37; Fellow of the Rockefeller Foundation at the University College Hospital Medical School, London, 1937-38; Assistant Professor, California Institute, 1937-43; Associate Professor, 1943-45; Professor, 1945-

400 South Berkeley Avenue

JAMES ALEXANDER NOBLE, PH.D.
Lecturer in Metalliferous Geology

A.B., Harvard College, 1920; S.B., Harvard Engineering School, 1922; M.A., Harvard University, 1936; Ph.D., 1939. Mine Engineer, American Zinc Company, 1922-24; Geologist, Cerro de Pasco Copper Corporation, 1924-31; Chief Geologist, Homestake Mining Company, 1931- . California Institute, 1947-

1460 Rose Villa Street

JOSEPH NYC, PH.D.
Research Fellow in Biology

B.S., Western Reserve University, 1943; Ph.D., 1946. California Institute, 1947-

5023 Bakman Avenue, North Hollywood

GUY C. OMER, JR., PH.D.
Research Fellow in Astrophysics

B.S., University of Kansas, 1936; M.S., 1937; Ph.D., California Institute, 1947. California Institute, 1947-

2372 Lambert Drive

GERTRUD OPPENHEIMER, PH.D.
Research Fellow in Biology

Ph.D., Frankfurt on Maine, Germany, 1918. Assistant, Munich University, 1919-22; Assistant, Kaiser Wilhelm Institute, 1923. California Institute, 1940-

1275 North Sierra Bonita

RAY D. OWEN, PH.D.
Associate Professor of Biology

B.S., Carroll College, 1937; Ph.M., University of Wisconsin, 1938; Ph.D., 1941. Assistant Professor of Genetics and Zoology, University of Wisconsin, 1944-47; Gosney Fellow, California Institute, 1946-47; Associate Professor, 1947-

1625 Raymond Hill Road, South Pasadena

RODMAN W. PAUL, PH.D.
Associate Professor of History

A.B., Harvard University, 1936; M.A., 1937; Ph.D., 1943. Assistant Dean, Harvard University, 1937-38, 1942-43; Instructor and Tutor in History, 1938-40; Instructor in History, Yale University, 1946-47. California Institute, 1947-

551 South Hill Ave.

LINUS PAULING, PH.D., SC.D.
Professor of Chemistry
Director of the Gates and Crellin Laboratories of Chemistry
Chairman of the Division of Chemistry and Chemical Engineering
Member of the Executive Committee

B.S., (Ch.E.), Oregon State College, 1922; Ph.D., California Institute, 1925; Sc.D., Oregon State College, 1933; Sc.D., University of Chicago, 1941; Princeton University, 1946; Cambridge University, 1947; University of London, 1947; National Research Fellow in Chemistry, 1925-26. Fellow of the John Simon Guggenheim Memorial Foundation, 1926-27; Lecturer in Physics and Chemistry, University of California, 1928-33; Massachusetts Institute of Technology, 1932; George Fisher Baker Lecturer, Cornell University, 1937-38. Assistant in Chemistry, California Institute, 1922-23; Teaching Fellow, 1923-25; Research Fellow, 1926-27; Assistant Professor, 1927-29; Associate Professor, 1929-31; Professor, 1931-

3500 East Fairpoint Street

Joseph E. Perry, Ph.D.

Research Fellow in Physics

B.S., Massachusetts Institute of Technology, 1939; Ph.D., University of Rochester, 1947. Assistant in Physics, University of Rochester, 1940-42; Graduate Instructor, 1945-46. California Institute, 1947-

Bernard O. Phinney, Ph.D.

Research Fellow in Biology

A.B., University of Minnesota, 1940; Ph.D., 1946. Assistant in Biology, University of Minnesota, 1940-46. California Institute, 1946-

1635 Lombardy Road

William Hayward Pickering, Ph.D.

Professor of Electrical Engineering

B.S., California Institute, 1932; M.S., 1933; Ph.D., 1936. Lecturer in Physics, University of Southern California, 1938. Teaching Fellow, California Institute, 1932-36; Instructor, 1936-40; Assistant Professor, 1940-45; Associate Professor, 1945-47; Professor, 1947-

425 South Craig Avenue

Willis Parkison Popenoe, Ph.D.

Research Fellow in Invertebrate Paleontology

B.S., George Washington University, 1930; M.S., 1933; Ph.D., California Institute, 1936. Curator in Invertebrate Paleontology, California Institute, 1929-45; Curator in Geology and Lecturer in Paleontology, University of California (Los Angeles), 1945. Research Fellow, California Institute, 1945-

1736 Vistillas Road, Altadena

Gennady W. Potapenko, Ph.D.

Associate Professor of Physics

C.Sc., University of Moscow, 1917; M.A., Ph.D., (Habilitation), 1920. Docent, University of Moscow, 1920-32; Lecturer and Professor of Physics, Moscow School of Mines, 1919-32; Professor of Physics, Moscow School of Agriculture, 1929-31; Research Associate, University of Berlin, 1927; Visiting Lecturer, University of Göttingen, 1929. California Institute, 1930-

1780 Oakdale Street

E. T. Preisler, B.A.

Instructor in Physical Education

B.A., San Diego State College, 1941. Coach, Carlsbad Union High School, 1941-43; Colton Union High School, 1946-47. California Institute, 1947-

Theodore Thomas Puck, Ph.D.

Senior Research Fellow in Biology

B.Sc., University of Chicago, 1937; Ph.D., 1940, University Fellow, University of Chicago, 1938-39; Augustavus F. Swift Fellow, 1939-40; Assistant Professor of Biochemistry, 1940- . California Institute, 1947-

141 North Madison Ave.

Allen E. Puckett, M.S.

Lecturer in Aeronautics

B.S., Harvard University, 1939; M.S., Graduate School of Engineering, Harvard University, 1941. Research Assistant, California Institute, 1941-45; Instructor, 1946-

1735 Maple Street

Simon Ramo, Ph.D.

Research Associate in Electrical Engineering

B.S., University of Utah, 1933; Ph.D., California Institute, 1936. Teaching Fellow, California Institute, 1934-36; General Electric Research Laboratory, 1936-46; Lecturer Union College, 1941-46; Director of Research, Hughes Aircraft Company, 1946- . California Institute, 1946-

2751 Midvale Avenue, Los Angeles

W. Duncan Rannie, M.A.

Assistant Professor of Mechanical Engineering

B.A., University of Toronto, 1936; M.A., 1937. Teaching Fellow, University of Toronto, 1936-38; Graduate Assistant in Aeronautics, California Institute, 1939-41; Northrup-Hendy Co., 1941-45; Jet Propulsion Laboratory, California Institute, 1946-47; Assistant Professor of Mechanical Engineering, 1947-

1106 West 41st Place, Los Angeles

BERNARD RASOF, M.S.

Instructor in Aeronautics

B.S., Illinois Institute of Technology, 1941; M.S., California Institute, 1944. Instructor in Aeronautics, California Institute, 1946-

1431½ Barry Ave., West Los Angeles

CHARLES FRANCIS RICHTER, PH.D.

Associate Professor of Seismology

A.B., Stanford University, 1920; Ph.D., California Institute, 1928. Research Assistant, Seismological Laboratory, Carnegie Institution of Washington, 1928-36; Assistant Professor, California Institute, 1937-47; Associate Professor, 1947-

1820 Kenneth Way

H. P. ROBERTSON, PH.D.

Professor of Mathematical Physics

B.S., University of Washington, 1922; M.S., 1923; Ph.D., California Institute, 1925; Loretta Denny Fellow in Mathematics, University of Washington, 1922-23; Fellow in Physics, California Institute, 1923-35; National Research Fellow in Mathematics, Göttingen, Munich, and Princeton University, 1925-28; Assistant Professor of Mathematics (on leave), California Institute, 1927-29; Assistant Professor, Mathematical Physics, Princeton University, 1928-31; Associate Professor, 1931-38; Professor, 1938-47; California Institute, 1947-

551 South Hill Ave.

BARBARA ROGERS-LOW, M.A.

Research Fellow in Chemistry

B.A., Oxford University, 1942; M.A., 1946. American Association of University Women Fellow, California Institute, 1947-

1525 Las Lunas Street

HERSCHEL K. ROMAN, PH.D.

Gosney Fellow in Biology

A.B., University of Missouri, 1936; Ph.D., 1942. Instructor in Botany, University of Washington, 1942-44; Assistant Professor, 1944-47; Associate Professor, 1947- . California Institute, 1947-

PAUL E. RUCH, M.S.

Associate Professor of Meteorology

B.S., Massachusetts Institute of Technology, 1928; M.S., California Institute, 1939. Instructor, California Institute, 1938-42; Associate Professor, 1942.

1924 North Craig Avenue, Altadena

R. DANA RUSSELL, PH.D.

(Visiting) Professor of Sedimentation

A.B., Pomona College, 1927; Ph.D., University of California (Berkeley), 1932. Teaching Fellow in Geology, University of California, 1928-30; Instructor, Louisiana State University, 1931-32; Assistant Professor, 1932-38; Associate Professor, 1938-47. California Institute, 1947-

553 Gravilla Place, La Jolla

BRUCE HORNBROOK SAGE, PH.D.

Professor of Chemical Engineering

B.S., New Mexico State College, 1929; M.S., California Institute, 1931; Ph.D., 1934. Teaching Fellow, California Institute, 1930-34; Research Fellow, 1934-35; Senior Fellow in Chemical Research, 1935-37; Assistant Professor, 1937-39; Associate Professor, 1939-44; Professor, 1944-

3216 Mt. Curve, Altadena

WILLIAM B. SCHALLEK, PH.D.

Research Fellow in Biology

A.B., Harvard University, 1941; M.A., 1942; Ph.D., 1945. Research Fellow, Washington University Medical School, 1945-46; Research Assistant, California Institute, 1946-47; Research Fellow, 1947-

541 South Madison Ave.

VERNER F. H. SCHOMAKER, PH.D.*

Associate Professor of Chemistry

B.S., University of Nebraska, 1934; M.S., 1935; Ph.D., California Institute, 1938. George Ellery Hale Fellow, California Institute, 1938-40; Senior Fellow in Chemical Research, 1940-45; Assistant Professor, 1945-46; Associate Professor, 1946-

418 South Michigan Avenue

*On leave of absence for the academic year 1947-48.

WALTER A. SCHROEDER, PH.D.

Instructor and Arthur Amos Noyes Senior Research Fellow in Chemistry

B.Sc., University of Nebraska, 1939; M.A., 1940; Ph.D., California Institute, 1943. Graduate Assistant, University of Nebraska, 1939-40. Graduate Assistant, California Institute, 1940-42; Research Assistant, 1942-43; Research Fellow, 1943-46; Instructor and Arthur A. Noyes Senior Research Fellow, 1946-

406 South Chester Avenue

JOHN ADOLPH SCHUTZ, PH.D.

Assistant Professor of History

A.B., University of California (Los Angeles), 1942; M.A., 1943; Ph.D., 1945. Fellow in History, University of California, 1944-45; Instructor in History, California Institute, 1945-47; Assistant Professor of History, 1947-

1100 White Knoll Drive, Los Angeles

ERNEST EDWIN SECHLER, PH.D.

Professor of Aeronautics

B.S., California Institute, 1928; M.S., 1929; Ph.D., 1933. Assistant in Engineering, California Institute, 1928-30; Instructor, 1930-37; Assistant Professor, 1937-40; Associate Professor, 1940-46; Professor, 1946-

2100 Dudley Street

HOWARD SEIFERT, PH.D.

Lecturer in Jet Propulsion

B.S., Carnegie Institute of Technology, 1932; M.S., 1934; Ph.D., California Institute, 1938. Teaching Fellow, California Institute, 1934-37; Assistant Professor of Physics, Kalamazoo College, 1937-40; Instructor, Carnegie Institute of Technology, 1940-42; Instructor in Jet Propulsion, California Institute, 1943-46; Lecturer, 1947-

382 South Grand Oaks

ROBERT PHILLIP SHARP, PH.D.

Professor of Geomorphology

B.S., California Institute, 1934; M.S., 1935; A.M., Harvard University, 1936; Ph.D., 1938. Austin Teaching Fellow in Geology, Harvard University, 1936-37; Instructor and Assistant Professor of Geology, University of Illinois, 1938-43; Associate Professor of Geology, University of Minnesota, 1944-46; Professor of Geology, 1946-47; Assistant Director, Stanford University Summer Field Camp, 1938; University of Michigan Summer Field Camp, 1946; Minnesota Geological Survey, 1946-47. California Institute, 1947-

1941 Milan Ave., South Pasadena

SEYMOUR JONATHAN SINGER, PH.D.

Research Fellow in Chemistry

A.B., Columbia University, 1943; A.M., 1945; Ph.D., Polytechnic Institute of Brooklyn, 1947. DuPont Research Fellow, Polytechnic Institute of Brooklyn, 1945-47; Abbott Fellow, California Institute, 1947-

415 Mariposa Avenue, Sierra Madre

HAMPTON SMITH, PH.D.

Lecturer in Petroleum Geology

B.S., California Institute, 1928; Ph.D., 1934. Geologist, Texas Company of California, 1929-45; Consulting Geologist, 1945- . California Institute, 1946-

1760 Elizabeth Street

THEODORE B. SMITH, M.S.

Instructor in Meteorology

A.B., Ohio State University, 1938; M.S. (Ph), California Institute, 1940; M.S. (My), 1942. California Institute, 1947-

1861½ Fairview Ave., San Gabriel

WILLIAM RALPH SMYTHE, PH.D.

Professor of Physics

A.B., Colorado College, 1916; A.M., Dartmouth College, 1919; Ph.D., University of Chicago, 1921. Professor of Physics, University of the Philippines, 1921-23; National Research Fellow, California Institute, 1923-26; Research Fellow, 1926-27; Assistant Professor, 1927-34; Associate Professor, 1934-40; Professor, 1940-

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Professor of Electrical Engineering

Chairman of the Division of Physical Education

B.S., University of Colorado, 1905; E.E., 1928; D.Sc., 1938. Associate Professor, Throop College, 1910-11; Professor, Throop College and California Institute, 1911-

384 South Holliston Avenue

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Associate Professor of English
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B.S., Colgate University, 1920; M.A., Princeton University, 1924; Ph.D., 1931. Instructor, Colorado College, 1924-25; Instructor, California Institute, 1925-31; Assistant Professor, 1931-47; Associate Professor, 1947-

551 South Hill Ave.

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(Visiting) Professor of Invertebrate Paleontology

B.S., Ohio State University, 1903; A.M., 1906; Ph.D., University of Chicago, 1909. Fellow, University of Chicago, 1907-09; Instructor in Geology, Ohio State University, 1906-07; Western Reserve University, 1909-10; Assistant Professor, School of Mining, Kingston, Ontario, 1910-11; Associate Professor, Western Reserve University, 1911-14; Associate Professor, University of Minnesota, 1914-17; Professor, 1917- . California Institute, 1947-

2247 Loma Vista

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Member of the Executive Committee

B.A., University of Toronto, 1927; M.A., University of Alberta, 1930; Ph.D., Stanford University, 1938. Lecturer in History, Regina College, 1927-28; Assistant in History and Director of Physical Education, University of Alberta, 1928-30; Research Staff, Hoover War Library, 1932-37; Instructor in History, Stanford University, 1935-37; Fellow, Social Science Research Council, 1939-40; Assistant Professor of History, California Institute, 1937-40; Associate Professor, 1940-42; Professor, 1942-

520 Jackson Street

Alfred Stern, Dr. of Phil.

Instructor in French and German

Dr. of Phil., University of Vienna, 1923. Professor, Sorbonne, University of Paris, 1933-40; Professor, Institute of Belgium, 1936-40; Professor of the New School for Social Research, 1945-46; Instructor, French and German, University College of University of Southern California, 1946-47; California Institute, 1947-

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B.AeroE., University of Minnesota, 1936; Ph.D., California Institute, 1940. Wind Tunnel Assistant, California Institute, 1936; Instructor, 1938-42; Assistant Professor, 1942-46; Associate Professor, 1946-

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B.S., University of California, 1914; Ph.D., 1917. Research Assistant, Department of Paleontology, University of California, 1917-19; Instructor, 1919-21; Assistant Professor, Department of Geological Science, 1921-25; Research Associate, Carnegie Institution of Washington; Senior Curator of Vertebrate Paleontology, Los Angeles Museum, Fellow of the John Simon Guggenheim Memorial Foundation, 1939-40; 1940-41. California Institute, 1926-

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B.Ed., Southern Illinois Teachers College, 1934; M.S., University of Illinois, 1935; B.S., California Institute, 1940; M.S., 1941. Head of Mathematics Department, Amboy Township High School, 1935-39. Instructor, California Institute, 1940-42; Assistant Professor, 1943-

214 South Wilson Avenue

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Director of Institute Band

B.S., University of Southern California, 1932; M.S., 1934. California Institute, 1931-

258 South Hudson Avenue

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Assistant Comptroller

B.A., Pomona College, 1931; M.B.A., Stanford University, 1940. Project Comptroller, California Institute, 1942; Assistant Comptroller, 1943-

551 South Hill Ave.

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Arthur G. R. Strickland, Ph.D.

Research Fellow in Biology

Dipl. Ing., Eidgen, Politechnikum, Zurich, 1908; Ph.D., Stanford University, 1939. Research Assistant in Biology, Stanford University, 1935-39. California Institute, 1939-

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B.S., University of Wisconsin, 1922; M.S., California Institute, 1937. Assistant Professor, California Institute, 1943-

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Professor of Chemistry

B.A., University of Texas, 1926; M.A., 1927; Ph.D., California Institute, 1930. Instructor, University of Texas, 1926-27; Teaching Fellow, California Institute, 1927-30; Research Fellow, 1930-35; Senior Fellow in Research, 1935-38; Assistant Professor, 1938-45; Associate Professor, 1945-47; Professor, 1947-

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A.B., Columbia University, 1912; Ph.D., 1914; D.Sc., Princeton University, 1947. Research Assistant, Carnegie Institution of Washington, 1915-28. California Institute, 1928- . *Chairman, Division of Biology, 1941-46.*

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B.S., *Murray State Teachers College, 1937; M.S., Louisiana State University, 1942; Ph.D., 1947.* Assistant in Zoology, Louisiana State University, 1942-43; Research Assistant in Cytogenetics, 1944-47. California Institute, 1947-

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Professor of Analytical Chemistry

B.S., University of Virginia, 1918; M.S., California Institute, 1920; Ph.D., 1924. Teaching Fellow, California Institute, 1920; Instructor, 1920-28; Assistant Professor, 1928-39; Associate Professor, 1939-43; Professor, 1943-

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B.S., Montana State College, 1939; Ph.D., California Institute, 1943. Arthur A. Noyes Fellow, California Institute, 1946-47; Senior Research Fellow, 1947-

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Lecturer in Jet Propulsion

B.S., California Institute, 1939; M.S. (A.E.), 1940; A.E., 1947. Instructor in Jet Propulsion, California Institute, 1945-47; Lecturer in Aeronautics, 1947-

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Instructor in History

A.B., Princeton University, 1943; M.A., Stanford University, 1947. California Institute, 1947-

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Dean of Students

B.E., University of Iowa, 1908; C.E., 1913. Instructor in Descriptive Geometry, University of Michigan, 1910-12; Associate Professor of Civil Engineering, California Institute, 1913-15; Professor, 1915-

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S.B., in Chemical Engineering, Massachusetts Institute of Technology, 1903; Ph.D., 1910; Sc.D., Princeton University, 1942. Dalton Fellow, Instructor in Theoretical Chemistry, and Research Associate in Physical Chemistry, Massachusetts Institute of Technology, 1905-10; Instructor in Physical Chemistry, University of Michigan, 1910-11; Assistant Professor of Physical Chemistry, University of Cincinnati, 1911-12; Assistant Professor of Chemistry, University of California, 1912-16; Professor of Physical Chemistry, University of Illinois, 1916-18; Chief, Dispersoid Section, Chemical Warfare Service, 1918; Associate Director and Director, Fixed Nitrogen Research Laboratory, Department of Agriculture, 1919-21; Vice-Chairman, National Defense Research Committee, 1940-46; Scientific Adviser to Commanding General, Manhattan Project, 1943-45; Scientific Adviser to United States Delegate to United Nations Atomic Energy Commission, 1946. California Institute, 1921-

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A.B., Harvard College, 1941; Ph.D., California Institute, 1947. California Institute, 1947-

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Associate Professor of Embryology

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B.S., Massachusetts Institute of Technology, 1920. Assistant Instructor in Thermodynamics, Massachusetts Institute of Technology, 1920-21; Managing Engineer, Industrial Engineering and Equipment Co., 1922. California Institute, 1936-

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Professor of Economics

A.B., University of Redlands, 1920; M.A., Harvard University, 1921; J.D., Mayo College of Law, 1925; Ph.D., Northwestern University, 1932. Instructor in Economics, Harvard University, 1921-23; Professor of Public Speaking, Huron College, 1923-24; Lecturer in Economics, Northwestern University, 1924-25. California Institute, 1925-

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Professor of Mathematics, Emeritus

Ph.B., Cornell University, 1897. Associate Professor, California Institute, 1904-15; Registrar, 1915-35; Professor, 1915-

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B.S., California Institute, 1936; M.B.A., Harvard University, 1938. Instructor and Research Assistant, California Institute, 1938-40; Teaching Assistant, Stanford University, 1940-41; Assistant Professor, California Institute, 1941-

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M.Sc., Hebrew University of Jerusalem, 1936; Ph.D., 1940. Visiting Investigator, Technical College, Delft, Holland, 1937-38; University of Utrecht, Holland, 1938-39; Assistant, Sieff Research Institute, Rehovoth, Palestine, 1940- . Research Fellow, University of California, 1946-47; Research Associate, Hopkins Marine Station, March, 1947-August, 1947; California Institute, 1947-

226 South Madison Ave.

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B.S., Loyola College, 1940. Research Assistant, University of Maryland Medical School, 1941-42; Instructor, United States Naval Hospital, Virginia, 1942- . California Institute, 1947-

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240 North Craig Avenue

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Ph.B., Lafayette College, 1914. Assistant in Physics, University of Chicago, 1914-17; Assistant Professor, California Institute, 1919-20; Associate Professor, 1920-30; Professor, 1930-

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Instructor in Industrial Design and Engineering Drafting

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A.B., University of Utrecht, 1922; M.S., 1925; Ph.D., 1927. Botanist, Botanic Gardens, Buitenzorg, Java, 1928-30; Director, Foreigners' Laboratory, Buitenzorg, Java, 1930-32. California Institute, 1933-

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B.A., University of Leiden, 1926; M.A., University of Utrecht, 1929; Ph.D., 1933. Assistant in Comparative Physiology, University of Utrecht, 1929, 1931; Dondersfonds Research Fellow, 1930-31; Chief Assistant in Medical Physiology, University of Utrecht, 1932-34; Associate Professor, California Institute, 1934-47; Professor, 1947-

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Börge Wille, M.S.

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Cand. Pharm., Royal Institute of Pharmacy of Copenhagen, 1939; M.S., University of Copenhagen, 1945. Research Assistant, Pharmaceutical Institute, 1939-44; Amanuensis, 1944. Fellow of the Danish Technical-Scientific Research Council, California Institute, 1947-

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B.S., Rice Institute, 1941; M.S., California Institute, 1942; Ph.D., 1947. California Institute, 1947-

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Charles H. Wilts, M.S.

Assistant Professor of Applied Mechanics

B.S., California Institute, 1940; M.S., 1941. National Research Council Predoctoral Fellow, California Institute, 1946-47; Assistant Professor, 1947-

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Research Associate in Seismology

A.B., Harvard University, 1902; A.M., 1904. Instructor in Mineralogy, Petrography and Geology, University of California, 1904-12; Research Associate in Seismology, Hawaiian Volcano Observatory of the Massachusetts Institute of Technology, 1919-20; Research Associate in Seismology, Carnegie Institution of Washington, 1921- . California Institute, 1947-

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Louis Booker Wright, Ph.D., Litt. D.

Associate in English Literature

A.B., Wofford College, 1920; M.A., University of North Carolina, 1924; Ph.D., 1926; Litt.D., Wofford College, 1941. Instructor in English, University of North Carolina, 1925-27; Johnston Research Scholar, Johns Hopkins University, 1927-28; Fellow of the John Simon Guggenheim Memorial Foundation, 1928-29; Visiting Professor, Emory University, winter quarter, 1929; Visiting Professor, University of Michigan, summer, 1935; Assistant Professor of English, University of North Carolina, 1929-30; Associate Professor, 1930-32; Visiting Professor on Walker-Ames Foundation, University of Washington, 1942; Visiting Professor, University of Minnesota, summer, 1946; Visiting Scholar of the Huntington Library, 1931-32; Member of the Research Staff, 1932- . California Institute, 1931-

580 South Berkeley Avenue, San Marino

Oliver Reynolds Wulf, Ph.D.

Research Associate in Chemistry

B.S., Worcester Polytechnic Institute, 1920; M.S., American University, 1922; Ph.D., California Institute, 1926. National Research Fellow, California Institute and University of California, 1926-28; Fellow of the John Simon Guggenheim Memorial Foundation, Berlin and Göttingen, 1932-33; Member of United States Weather Bureau; Research Associate, University of Chicago, 1941-45. California Institute, 1945-

81 El Nido Ave.

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-

1025 San Pasqual Street

Arthur Howland Young

Lecturer on Industrial Relations

Vice-President, United States Steel Corporation, 1934-37; Lecturer on Industrial Relations, Harvard Graduate School of Business Administration, 1929-31; and Wharton School of Commerce and Industry, 1930-37; Consulting Professor of Industrial Relations, Stanford University, 1937- . California Institute, 1939-

3 Rosemary Lane, Santa Barbara

J. Paul Youtz, M.S.

Lecturer in Industrial Design

Administrative Assistant

B.S. (TCT), California Institute, 1917; M.S., Union College, 1919. California Institute, 1932-

1477 North Holliston Avenue

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Research Fellow in Biology

Diploma in Philosophy, Ljubljana University, 1940; D.Sc., University of Geneva, 1944. Assistant in Zoology, University of Geneva, 1942-47. California Institute, 1947-

173 Meridith Ave.

László Zechmeister, Dr. Ing.

Professor of Organic Chemistry

Diploma of Chemist, 1911; Dr. Ing., 1913; Eidgenossische Technische Hochschule, Zurich, Switzerland. Assistant and Chief Assistant, Kaiser Wilhelm Institut für Chemie, 1912-14; Instructor, Danish Royal Veterinary and Agricultural Academy, Copenhagen, 1921-23; Professor of Chemistry and Director of the Chemical Laboratory, Medical School of the University of Pecs, Hungary, 1923-40. California Institute, 1940-

551 South Hill Ave.

Fritz Zwicky, Ph.D.

Professor of Astrophysics

B.S., Federal Institute of Technology, Zurich, Switzerland, 1920; Ph.D., 1922. Research Assistant, Federal Institute of Technology, Zurich, 1920-25; Research Fellow, International Education Board, California Institute, 1925-27; Assistant Professor of Theoretical Physics, California Institute, 1927-29; Associate Professor of Theoretical Physics, 1929-41; Professor of Astrophysics, 1942-

212 West California Street

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1946-1947

RAYMOND VOILES ADAMS, JR. . . . . N.R.C. Predoctoral Fellow, Physics
B.S., Kansas State College, 1941

ROBERT TRAIN ADAMS . . . . . Chemistry
B.S., University of California, 1942

DAVID MURRAY ALEXANDER . . . . . Meteorology
B.S., St. Andrews University, 1937

JACK LELAND ALFORD . . . . . Mechanical Engineering
B.S., California Institute, 1942; M.S., 1946

HARRY BERKELEY ALLEN . . . . . Geology
B.A., University of California at Los Angeles, 1939; M.A., 1942

THOMAS LOFTON ALLEN . . . . . Chemistry
B.S., University of California, 1944

MORTON ALPERIN . . . . . Aeronautics
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JOHN HENRY ALTSEIMER . . . . . Aeronautics
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ALAN H. ANDREW . . . . . N.R.C. Predoctoral Fellow, Physics
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HAROLD SEVERIN ANTHON . . . . . Civil Engineering
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HENRY ISRAEL ASHKENAS . . . . . Research Assistant, Aeronautics
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KURT BARNETT . . . . . Electrical Engineering
B.E.E., McGill University, 1946

SHIRLEY BARROWS . . . . . Research Assistant, Biology
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EDWARD RICE BARTLETT, JR. . . . . . Applied Mechanics
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B.S., California Institute, 1945

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. . . . . Amer. Chem. Soc. Predoctoral Fellow, Chemical Engineering
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John A. Brockman, Jr. .... Chemistry
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Richard Fremont Brooks .... Geology
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Frank Paul Buff .... Chemistry
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B.S., California Institute, 1943

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Jean Campbell .... Research Assistant, Biology
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Margaret Campbell .... Research Assistant, Biology

Richard Raymond Carhart .... Physics
B.A., University of California at Los Angeles, 1940

Marcella O. Carter .... Research Assistant, Biology
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B.S., California Institute, Feb., 1944; M.S., June, 1944

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William Tatem Collings .... Civil Engineering
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MAYETTE ELNER DENSON, JR. .... Geology
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WORTHIE LEFLER DOYLE .... Mathematics
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JAMES WILLIAM EDMUNDSON .... Geology
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JAMES CHIPMAN FLETCHER . . . . Physics
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CONRAD T. O. FONG . . . . Research Assistant, Biology
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ARIE JAN HAAGEN-SMIT, PH.D.	Bio-Organic Chemistry
ANTHONIE VAN HARREVELD, PH.D., M.D.	Physiology
ALFRED H. STURTEVANT, PH.D., D.SC.	Genetics
FRITS W. WENT, PH.D.	Plant Physiology
CORNELIS A. G. WIERSMA, PH.D.	Biology

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MARGARETHA G. MES, PH.D.	Plant Physiology

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LILIAN V. MORGAN, (MRS. T. H.), M.A.	Biology

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ALBERT TYLER, PH.D.	Embryology

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THEODORE C. PUCK[3], PH.D.	Biology
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Gerald C. Young

HISTORICAL SKETCH

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

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

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

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

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

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

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

For the five years beginning with the summer of 1940, the Institute devoted an increasingly large part of its personnel and facilities to the furthering of national defense and the war effort. The Institute's work during this period fell for the most part into two main categories: special instructional programs, and research on and development of the instrumentalities of war. The first included participation in the Engineering, Science and Management War Training Program, in which a total of over 24,000 students were enrolled in Institute-supervised courses; advanced meteorology for Army Air Force cadets; advanced work in aeronautics and ordnance for Army and Navy officer personnel; and the provision of instruction (as well as housing and subsistence) for a unit of the Navy V-12 Engineering Specialists. The research and development work was carried on for the most part under non-profit contracts with the Federal Office of Scientific Research and Development. These contracts had a total value of more than $80,000,000 and at their peak involved the employment of more than 4000 persons.

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

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

EDUCATIONAL POLICIES

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

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

The Institute offers two four-year undergraduate courses, one in Engineering and the other in Science, both leading to the degree of Bachelor of Science and both planned so that interchange between them is not unduly difficult. For the first year, the work of all undergraduates is identical. Differentiation between these two courses begins with the second year. The Engineering course is of a general, fundamental character, with a minimum of specialization in the separate branches of engineering. It includes an unusually thorough training in the basic sciences of physics, chemistry, and mathematics, as well as the professional subjects common to all branches of engineering. With minor exceptions, the student does not concentrate in his chosen field until the fourth year. The Engineering course also includes a large proportion of cultural studies, time for which is secured by eliminating the more narrowly particularized subjects commonly included in undergraduate engineering courses. Such a curriculum, it is hoped, will provide a combination of a fundamental scientific training with a broad human outlook. This is, in fact, the type of collegiate education endorsed by leading engineers—a training which avoids on one hand the narrowness often observed among students in technical schools and on the other hand the superficiality and lack of purpose noticeable in many of those taking academic college courses.

The course in Science affords, even more fully than is possible in the Engineering course, an intensive training in physics, chemistry, and mathematics. In the third and fourth years groups of optional studies are included which permit some measure of specialization in a chosen field of science. Instruction is also provided in French and German, with the object of giving the student a sufficient reading knowledge to follow the scientific and technical literature in those languages. This course includes the same proportion of cultural studies as the Engineering course, and for the same reason—to enlarge the student's mental horizon beyond the limits of his immediate professional interest and thus better qualify him to realize his opportunities and fulfill his responsibilities as a citizen and a member of his community.

The inclusion in the curriculum of a large proportion of non-scientific and non-technical subjects is one of the fundamental elements in the Institute's educational policy. The purpose which these studies is meant to achieve has already been indicated. Under the general designation of the Humanities, they include literature and composition, history and government, economics, philosophy, and psychology. To them the student devotes about one-fourth of his time during his undergraduate years (and if he proceeds for the degree of Master of Science he continues with elective subjects in the Humanities throughout his fifth year). Formal instruction in the Humanities is supplemented by lectures by, and opportunities for contact with, distinguished scholars who are attracted to Pasadena by the opportunities for research at the Huntington Library and Art Gallery. In addition to these academic and semi-academic pursuits, the Institute encourages a reasonable participation in student activities of a social, literary, or artistic nature, such as student publications, debating, dramatics, and music; and all undergraduates are required to take regular exercise, preferably in the form of intercollegiate or intramural sports. In short, every effort is made in the undergraduate section of the Institute to carry on a well rounded, well integrated program which will not only give the student sound training in his professional field but will also develop character, ideals, breadth of view, general culture, and physical well-being.

In the graduate section the Institute offers courses leading to the degree of Master of Science, which normally involves one year of graduate work; the professional degree in any of the branches of engineering and in meteorology and geophysics, with a minimum of two years; and the degree of Doctor of Philosophy. In all the graduate work, research is strongly emphasized, not only because of its importance in contributing to the advancement of science and thus to the intellectual and material welfare of mankind, but also because research activities add vitality to the educational work of the Institute. Graduate students constitute a comparatively large proportion (about forty per cent) of the total student body. Engaged themselves on research problems of varying degrees of complexity, and taught by faculty members who are also actively engaged in research, they contribute materially to the general atmosphere of intellectual curiosity and creative activity which is engendered on the Institute campus.

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

BUILDINGS AND FACILITIES

THROOP HALL, 1910.

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

GATES AND CRELLIN LABORATORIES OF CHEMISTRY: first unit, 1917; second unit, 1927; third unit, 1937.

The first two units were the gift of the late Messrs. C. W. Gates and P. G. Gates, of Pasadena; the third unit was the gift of Mr. and Mrs. E. W. Crellin, of Pasadena.

CULBERTSON HALL, 1922.

The Institute auditorium; named in honor of the late Mr. James A. Culbertson, trustee of the Institute and Vice-President of the Board 1908-1915.

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

The gift of the late Dr. Norman Bridge.

HIGH-POTENTIAL RESEARCH LABORATORY, 1923.

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

CHEMICAL ENGINEERING LABORATORY AND HEATING PLANT, 1926.

Erected with funds provided in part by the late Dr. Norman Bridge and in part from other sources.

DABNEY HALL OF THE HUMANITIES, 1928.

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

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

DANIEL GUGGENHEIM AERONAUTICAL LABORATORY, 1929.

Erected with funds provided by the Daniel Guggenheim Fund for the Promotion of Aeronautics.

WILLIAM G. KERCKHOFF LABORATORIES OF THE BIOLOGICAL SCIENCES: first unit, 1929; second unit, 1938.

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

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

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

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

ATHENÆUM, 1930.

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

STUDENT HOUSES, 1931.

Blacker House.

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

Dabney House.

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

Fleming House.

Erected with funds provided by some twenty donors, and named in honor of the late Mr. Arthur H. Fleming, of Pasadena, President of the Board of Trustees of the Institute 1918-1932.

Ricketts House.

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

ASTROPHYSICAL INSTRUMENT SHOP, 1931.

Erected with funds provided by the International Education Board and the General Education Board.

W. K. KELLOGG LABORATORY OF RADIATION, 1932.

The gift of Mr. W. K. Kellogg, of Battle Creek, Michigan.

HENRY M. ROBINSON LABORATORY OF ASTROPHYSICS, 1932.

Erected with funds provided by the International Education Board and the General Education Board.

HYDRAULIC STRUCTURES LABORATORY, 1932.

ASTROPHYSICAL OPTICAL SHOP, 1933.

Erected with funds provided by the International Education Board and the General Education Board.

SOIL CONSERVATION LABORATORY, 1936.

Provided by the Department of Agriculture of the United States Government.

CHARLES ARMS LABORATORY OF THE GEOLOGICAL SCIENCES, 1938.

The gift of the late Mr. and Mrs. Henry M. Robinson, of Pasadena, in memory of Mrs. Robinson's father, the late Mr. Charles Arms.

SEELEY W. MUDD LABORATORY OF THE GEOLOGICAL SCIENCES, 1938.

The gift of the late Mrs. Seeley W. Mudd, of Los Angeles, in memory of her husband.

BUILDINGS AND GROUNDS BUILDING, 1944.

HYDRODYNAMICS LABORATORY, 1944.

MECHANICAL ENGINEERING BUILDING, 1945.

Funds for the erection of this building were allocated from the income of the Eudora Hull Spalding Trust with the approval of Mr. Keith Spalding, Trustee.

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.

LIBRARIES

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

STUDENT LIFE

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

All four houses have attractive inner courts surrounded by portales. Most of the rooms are single, but there is a limited number of rooms for two. All the rooms are simply but adequately and attractively furnished. The buildings are so planned that within each of the four houses there are groupings of rooms for from twelve to twenty students, with a separate entry and toilet and kitchenette facilities for each.

The completion of this group of four residence halls marks the initial step in a plan to meet the housing and living problems of undergraduate students. The plan calls eventually for eight residence halls. Each of the four present houses has its own elected officers and is given wide powers in the matter of arranging its own social events, preserving its own traditions, and promoting the general welfare of the house. The houses are under the general supervision and control of a member of the Faculty known as the Master of the Student Houses.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

In addition to the national honorary fraternities there are four local honorary groups: the Beavers, membership in which is a recognition of service to the student body; the Varsity Club, which is composed of students who have earned letters in intercollegiate athletics; the Press Club, which elects members who are active in student publications; and the Drama Club, in which membership is conferred as an award for student dramatic talent.

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

Student Shop. The Student Shop is located in one of the service buildings on the campus near the Student Houses. It was equipped by the Institute, largely through donations, and is operated by the students under faculty supervision. It has no connection with regular Institute activities, and exists solely as a place where qualified students may work on private projects that require machinery.

All students are eligible to apply for membership in the Student Workshop organization. These applications are acted upon by a governing committee of students, and this committee is charged with the responsibility of admitting only those who can demonstrate their competence in the operation of the machines in the shop. Yearly dues are collected to provide for maintenance and replacement.

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

Y.M.C.A. The California Institute Y.M.C.A. is a service organization whose purpose is to supplement a technical and scientific education with a program emphasizing social and religious values. The "Y" is one of the most active student organizations on the campus and welcomes as members any student taking an active part in its regular program of activities. The program includes weekly luncheon clubs, discussion groups, forums and lectures, student-faculty firesides, inter-collegiate conferences and work with local church groups. It also sponsors an annual freshman tea dance and cooperates in planning the New Student Camp. The "Y" services to the student body include a used textbook exchange, a tutoring service, a loan fund, an all-year calendar of student events and the use of the lounge and offices. The executive secretary of the Y.M.C.A., Wesley L. Hershey, is always available to help students with their personal problems.

STUDENT HEALTH AND PHYSICAL EDUCATION

PHYSICAL EDUCATION

All undergraduate students are required to participate in some form of physical training a minimum of three days per week. This requirement may be satisfied by engaging in organized sports, which include both intercollegiate and intramural athletics, or by regular attendance at physical training classes.

Until September, 1948, war veterans, and men whose twenty-fourth birthday has occurred by the opening of the term, may be excused from the required work by action of the Physical Education Committee. After September, 1948, the following may be excused from the requirement of physical education by action of the Physical Education Committee:

1) Men over 24 years of age by the opening date of the academic year.

2) Juniors and seniors who have had a year of service in any branch of the Armed Forces, exclusive of time spent in educational programs.

It is the responsibility of students who wish to be excused and who are eligible under these rulings to make application for excuse at the Athletic Office.

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

HEALTH SERVICE

A. PHYSICAL EXAMINATION AND VACCINATION

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

B. HEALTH FEE

Each undergraduate and graduate student will pay a health fee of ($7.50) seven dollars, fifty cents per academic year, $4.00 of which is paid toward the Emergency Hospitalization Fund.

C. SERVICES OF THE INSTITUTE PHYSICIAN

1. The services of a part-time physician are available on the campus from 2:00 p.m. to 6:00 p.m., inclusive, every day except Saturday and Sunday. On Saturday the hours are from 1:00 p.m. to 2:00 p.m. The services of a Registered Nurse are available for eight hours during the day. The nurse will make calls on students in their rooms on the campus or in the city of Pasadena when her services are needed for illness or accident. First-aid service is also available at the Pasadena Emergency Hospital and at the Huntington Memorial Hospital.

2. There is no charge to the student for consultations in the office of the Institute Physician or for the services of the nurse except for certain medical treatment materials, such as vaccines. Charges for calls made upon students by the Institute Physician or by other physicians, however, are entirely the responsibility of the student.

3. The services of the Institute Physician are primarily for the student. Many students at present are married and the Institute has decided that the families of married students are to be given whatever service is possible at the medical office on the campus. A small fee is charged for this service to the family. Immunizations against infectious diseases, etc., can be given to the members of such families, for which the cost of the materials is added to the fee.

4. After the needs of the students and their families have been met, if time permits, members of the Institute staff, employees of the Institute working on the campus and their families also will be given service at the Medical Office at a moderate charge.

D. EMERGENCY HOSPITALIZATION FUND

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

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

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

2. In cases falling within the scope of the Emergency Hospitalization Fund, necessary hospital care will be allowed for a period not to exceed one month. Other necessary hospital expenses during this period of one month, such as the use of operating-room, surgical supplies and dressings, laboratory service, etc., will be allowed. Payment of surgical fees, anaesthetic fees and necessary special nursing fees will also be allowed whenever possible, provided the total amount of payments, exclusive of the hospital charge in any one case, shall not exceed one hundred dollars. The amount to be contributed from the Fund in any particular case shall be decided by the Faculty Committee on Student Health.

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

4. Whenever the expenses for emergency care in any one fiscal year are less than the total collected in fees for that year, the balance of money remaining shall be kept in the Emergency Hospitalization Fund, and shall remain deposited at interest to increase for the benefit of the Fund. A balance kept over from one year will be used to render emergency medical and surgical aid to the students in

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

5. Students are not required to accept the services of the Director of Student Health, but may choose physicians and surgeons privately. Whomever they choose, whether the Director of Student Health or another physician or surgeon, they must pay for such services themselves unless the illness or injury is covered by the Emergency Hospitalization Fund and if it is so covered they must pay any amount in excess of the amount contributed from the Fund in accordance with the above regulations.

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

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

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

E. RESPONSIBILITY OF THE PATIENT

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

Any expenses incurred in securing medical advice and attention in any case are entirely the responsibility of the patient. For instance: students who are ill and confined to their rooms in the dormitories or elsewhere, and are unable to visit the Institute Physician's office at the Institute, at the regular time, and who call in any physician, including the Institute Physician, are themselves solely responsible for the payment of all the bills incurred.

F. INSTITUTE INFIRMARY

A temporary but suitably equipped building has been installed on the campus as an Institute Infirmary. The Infirmary has a capacity of six beds, which can be increased to nine in emergencies. It is equipped with normal medical facilities and will provide nursing attendance.

Students living in the student houses will not be charged extra for board and room in the Infirmary. Students not living on the campus will be charged a fee of $2.00 a day for board while in the Infirmary.

REQUIREMENTS FOR ADMISSION TO UNDERGRADUATE STANDING

The academic year at the California Institute consists of one twelve-week term and two eleven-week terms, extending from late September until the middle of June. There are no summer sessions, except that graduate students are permitted to register for summer research. Undergraduates are admitted only once a year—in September.

I. ADMISSION TO THE FRESHMAN CLASS

Students are selected from the group of applicants on the basis of (a) high grades in certain required high school subjects, (b) satisfactory completion of entrance examinations in mathematics, physics, chemistry, and English, and (c) a personal interview. The specific requirements in each of these groups are described below.

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

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

Applicants who offer for entrance a total of fifteen recommended units, but whose list of subjects is not in accord with this table, may be admitted at the discretion of the faculty, if they are successful in passing the general entrance examinations; but no applicant will be admitted whose preparation does not include English 2 units, algebra 1½ units, geometry 1 unit, trigonometry ½ unit, physics 1 unit. 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 a foreign language, preferably Latin, a year of geology or biology, basic elementary shop work, and as much extra instruction in English grammar and composition as is available in the high school curriculum.

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

ENTRANCE EXAMINATIONS. In addition to the above credentials, all applicants for admission to the freshman class are required to take entrance examinations. These examinations do not take the place of the high school credentials, but serve to supplement them. The subjects covered are chemistry, physics, mathematics, and English. The examinations are general in character; they are intended to show the applicant's ability to think and express himself clearly, and his fitness for scientific and engineering training, rather than to test memorized information. Three hours are allotted for each examination. Specimens or samples of the examination questions for admission to the freshman class of the Institute are not available for distribution.

For admission September 21, 1948, entrance examinations will be held at the Institute on March 6 (English and chemistry) and March 13 (physics and mathematics). The examinations run from 9:00 a.m. to 12 noon and from 1:00 to 4:00 p.m. on each day. Applicants who are eligible to take the examinations will be notified of the place and should report there not later than 8:30 a.m. No other freshman entrance examinations will be given in 1948.

The examination in English includes a test of reading comprehension and the writing of a composition.

The chemistry examination is in four parts. Part one, for which two hours is allotted, covers the material taken in the usual high school general chemistry course and is to be taken by all applicants. Part two consists of further questions on general chemistry. Part three consists of questions on biology, and part four of questions on geology (including mineralogy). Applicants who have a special interest in, and some knowledge of, elementary biology or geology may, if they choose, substitute either part three or part four for the additional questions on chemistry in part two. Applicants are expected to complete part one and any *one* of the other parts.

The physics examination covers mechanics and heat. While a year of high school physics, including mechanics, heat, sound, light and electricity is required for admission, it is recognized that such a course is usually taken in the last year of high school, and that only mechanics and heat may have been completed by the time of the examination.

The mathematics examination includes plane geometry and algebra through simultaneous quadratic equations and determinants. Plane trigonometry is an absolute requirement for admission but does not appear on the examination because it is frequently taken in the last semester of high school after the date of the examination.

Students living at a distance from Pasadena may, upon request, be allowed to take the entrance examinations under the supervision of their local school authorities. Arrangements for examinations in absentia should include a letter to the Registrar from the individual directing the tests stating that the required supervision will be given.

Entrance examinations whether taken at the Institute or in absentia must be taken on the dates specified. In fairness to all applicants no exceptions to this rule can be permitted.

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

APPLICATION FOR ADMISSION. Blanks for application for admission to the Institute will be provided upon request.

Complete application blanks and high school records including courses that may be in progress must reach the Registrar's Office by February 1, 1948.

Applicants living outside the continental limits of the United States must submit their credentials by November 1, 1947.

Final selections are ordinarily made and the applicants notified of their admission or rejection by May 15. Upon receipt of a notice of admission an applicant should immediately send in the registration fee of $10.00, which covers the cost of the New Student Camp. See page 89. In the event of subsequent cancellation of application, the registration fee is *not* refundable unless cancellation is initiated by the Institute. Places in the entering class will not be held for more than ten days from the time an applicant could reasonably be expected to have received notice of acceptance. When the registration fee has been received, each accepted applicant will be sent a registration card which will entitle him to register, provided his physical examination is satisfactory. The registration card should be presented at the Dabney Hall Lounge on the date of registration.

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

PHYSICAL EXAMINATION. Prior to acceptance for admission, each applicant is required to submit a report of physical examination on a form which will be sent him at the time he is notified of admission. It is the applicant's responsibility to have this form filled out by a Doctor of Medicine (M.D.) of his own choosing. See page 83. Admission is tentative pending such examination, and is subject to cancellation if the results of the examinations are unsatisfactory.

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

NEW STUDENT CAMP. All undergraduate students entering the Institute for the first time, either as freshmen or as transfer students, are required to attend the New Student Camp as part of the regular registration procedure. This meeting occupies three days of registration week preceding the fall term, and is usually held at Camp Radford, a large well-equipped camp owned by the city of Los Angeles and located in the San Bernardino Mountains east of Redlands. The expenses of the camp are met in part by the $10 registration fee from new students and in part by a contribution of funds from the Institute.

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

II. ADMISSION TO UPPER CLASSES BY TRANSFER FROM OTHER INSTITUTIONS

The Institute admits to its upper classes (i.e., sophomore year and beyond) a limited number of able men who have made satisfactory records at other institutions of collegiate rank. In general only students whose grades, especially those in mathematics and science, are above average can expect to be permitted to take the entrance examinations.

A student who is admitted to the upper classes pursues a full course in one of the options in engineering or in science, leading to the degree of Bachelor of Science. The Institute has no special students. Men are admitted either as freshmen in accordance with the regulations set forth on pages 86-89 or as upper classmen in the manner described below. Those who have pursued college work elsewhere, but whose preparation is such that they have not had the substantial equivalent of the following freshman subjects, English, mathematics, physics and chemistry, will be classified as freshmen and must be admitted as such. (See freshman admission requirements on pages 86-89.) They may, however, receive credit for the subjects which have been completed in a satisfactory manner.

A minimum residence at the Institute of one scholastic year is required of all candidates for the degree of Bachelor of Science. See page 107.

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

Before their admission to the upper classes of the Institute all students are required to take entrance examinations in mathematics, physics, chemistry and English composition covering the work for which they desire credit, except that the examination in chemistry is required only of those desiring to pursue the course in science. Students must offer courses, both professional and general, substantially the same as those required in the various years at the Institute (see pages 162-178) or make up their deficiencies as soon as possible after admission (see Special Arrangements for Veterans, page 92). In case there is a question regarding either the quality or the extent of the previous work, examinations in the subjects concerned may be arranged.

It is not possible to answer general questions regarding the acceptability of courses taken elsewhere. The nature of the work at the

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

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

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

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

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

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

The schedule for the three-hour examinations for admission to upper classes September 23, 1948, is as follows:

Mathematics	9:00 a.m.	June 11, 1948
English	1:00 p.m.	June 11, 1948
Physics	9:00 a.m.	June 12, 1948
Chemistry	1:00 p.m.	June 12, 1948

No other examinations for admission to upper classes in 1948 will be given.

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

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

The attention of students planning to transfer to junior or senior standing is called to the fact that, until they have satisfactorily completed three full terms of residence at the Institute, they are subject to the same scholastic requirements as are freshmen and sophomores. See pages 105-108. 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 106.

Physical examinations and vaccination are required as in the case of students entering the freshman class. See page 83. 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 89.) In the event of subsequent cancellation of application, the registration fee is *not* refundable, unless cancellation is initiated by the Institute.

III. SPECIAL ADMISSION ARRANGEMENTS FOR VETERANS

It is recognized that veterans transferring to the Institute at the sophomore or junior level may not have had all courses required of regular Institute freshmen or sophomores. Such veteran transfers will be governed by the following regulations:

With the exception of requirements in mathematics, physics, chemistry, and English composition, the Institute curriculum requirements of the first year for an entering Sophomore, or of the first two years for an entering Junior—will be waived provided that (a) the transfer student has 32 acceptable college credits if a Sophomore or 64 if a Junior, the acceptability of such credits to be judged by the Engineering or Science Course Committees for engineers or scientists respectively; (b) he has satisfied all of the prerequisites of his option prior to the level at which he enters according to a list of such prerequisites selected from the curricula of the first two years at the Institute and certified to the Registrar by the head of each option; (c) if he is allowed credit for any courses of the year in which he enters or subsequent years, he may be required to complete his program by including such Institute courses of the year or years prior to his admission for which he may not have credit, as his adviser shall think wise. In any such requirement, courses prerequisite to the work in his option shall take precedence; (d) any department may prescribe the electives taken by the Transfer in its own department if it considers that his previous preparation has been lacking in a field under its jurisdiction. (For example, a transfer who had had no history might be required to take courses in history as his Senior Humanities elective.)

EXPENSES

The following is a list of student expenses at the California Institute of Technology for the academic year 1947-48, together with the dates on which the various fees are due. These charges are subject to change at the discretion of the Institute. In addition to the total amount given, approximately $50 a year should be allowed for books and supplies.

Date Due	*Fee*	*Amount*
Upon notification of admission	Registration Fee	$ 10.00[1]
At time contract for Student House reservation is signed or at time of registration for off campus students	General Deposit	25.00[2]
Sept. 23, 1947: Freshmen and transfer students; Sept. 26, 1947: All others	Tuition, 1st term	168.00
	1st installment of Board and Room, 21 meals per week	101.20[3]
	15 meals per week	97.50[3]
	Associated Student Body Dues, 1st term	3.95[5]
	Emergency Hospitalization Fee, 1947-48	4.00
	Student Health Fee, 1947-48	3.50
	Subscription to the California Tech, 1947-48	1.25
	Locker Rent, 1st term	1.00[4]
	Parking Fee, 1st term	1.50[4]
	Student House Dues, 1st term	4.00
November 9, 1947	2nd installment of Room and Board, 21 meals per week	96.10[3]
	15 meals per week	93.10[3]
January 5, 1948	Tuition, 2nd term	166.00
	3rd installment of Room and Board, 21 meals per week	84.05[3]
	15 meals per week	81.25[3]
	Associated Student Body Dues, 2nd term	5.20[5]
	Locker Rent, 2nd term	1.00[4]
	Parking Fee, 2nd term	1.50[4]
	Student House Dues, 2nd term	4.00
February 8, 1948	4th installment of Room and Board, 21 meals per week	102.90[3]
	15 meals per week	97.50[3]

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

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

[3]Rate for rooms will be adjusted for those assigned to rooms with double bunks. Rates for room and board subject to revision prior to the beginning of any term upon notice to students.

[4]Optional.

[5]Includes 20¢ Federal Tax on admissions.

March 29, 1948	Tuition, 3rd term	$ 166.00
	5th installment of Room and Board,	
	21 meals per week	84.05[3]
	15 meals per week	81.25[3]
	Associated Student Body Dues, 3rd term	5.20[5]
	Locker Rent, 3rd term	1.00[4]
	Parking Fee, 3rd term	1.50[4]
	Student House Dues, 3rd term	4.00
May 2, 1948	6th installment of Room and Board,	
	21 meals per week	102.90[3]
	15 meals per week	97.50[3]
	Total for academic year (less Registration Fee, Student House or General Deposits, and optional items).	
	With Room and Board in Student Houses (including Student House Dues):	
	21 meals per week	1,101.20
	15 meals per week	1,078.10
	Without Room and Board (excluding Student House Dues):	522.50
	Tuition fees for those carrying less than normal number of units.	
	Over 32 units	Full tuition
	32 to 25 units	$125 per term
	24 to 10 units	$5 per unit per term
	Minimum per term	$50.00

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 the time in attendance.

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 page 83).

ASSOCIATED STUDENT BODY FEE

The Associated Student Body Fee of $13.75 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, $1.25 each year, is collected from every undergraduate.

[3]Rate for rooms will be adjusted for those assigned to rooms with double bunks. Rates for room and board subject to revision prior to the beginning of any term upon notice to students.

[4]Optional.

[5]Includes 20¢ Federal Tax on admissions.

TELEPHONE FEE

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

GENERAL DEPOSIT

Each student is required to make a general deposit of $25, to cover possible loss and/or damage of Institute property used in connection with his work in regular courses of study. Upon his graduation or withdrawal from the Institute, any remaining balance of the deposit will be refunded.

STUDENT HOUSES

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

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

SPECIAL FEES

Students in the jet-propulsion option of Aeronautical Engineering pay $100 an academic year, and students in Meteorology pay $150 an academic year in addition to the regular $500 tuition fee.

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 102) is $10 per term, per lecture hour.

UNPAID BILLS

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

SCHOLARSHIPS, PRIZES, AND STUDENT AID*

FRESHMAN SCHOLARSHIPS

A number of freshman scholarships covering full tuition or half tuition are awarded each year to members of the incoming freshman class. The recipients of these scholarships are selected by the Freshman Admissions and Registration Committee from the candidates who have stood sufficiently high on the entrance examinations and have otherwise satisfied the entrance requirements of the Institute.

The scholarships are awarded 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. Financial need is taken into consideration. Applications for scholarships should be made on a form which may be obtained by writing to the Registrar or calling at the office.** Funds for these scholarships are provided in large part by the income from the various scholarship funds described below and by other gifts for scholarships.

Honor Standing: The Freshman Admissions and Registration Committee awards *Honor Standing* each year to those freshmen who stand in the top ten percent on the entrance examinations, except that those who have had previous college work or have previously tried the examinations may, at the discretion of the Committee, be passed over in granting this award. (See page 107 for Honor Standing for Upperclassmen.)

DRAKE SCHOLARSHIPS

In addition to the foregoing, 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.

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*For further information on Graduate Scholarships and Fellowships see page 152.

**Those attending under Public Laws 346 or 16, who would have difficulty meeting expenses in spite of government allowances, may apply for grants in aid on the same form as that used for scholarship applications.

INSTITUTE SCHOLARSHIPS AND GRANTS

The Institute has provided funds from which tuition awards or cash grants can be made. These grants are awarded at the end of each academic year to those students who, as the result of their work during the preceding year stand high in their respective classes. Financial need is taken into consideration, and application is made on a form obtainable in the Registrar's Office.**

Funds for these scholarships, as in the case of Freshman Scholarships, are provided in large part by special scholarship funds.

It is expected that all students awarded scholarships or grants will maintain high scholastic standing. Failure to do so at any time during the school year may result in the termination of the award.

HARRIET HARVEY SCHOLARSHIP
WALTER HUMPHRY SCHOLARSHIP

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.

DABNEY SCHOLARSHIPS

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

ELIZABETH THOMPSON STONE SCHOLARSHIP

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

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.

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

**Those attending under Public Laws 346 or 16, who would have difficulty meeting expenses in spite of government allowances, may apply for grants in aid on the same form as that used for scholarship applications.

Hunt Bennett, a former student at the Institute. The income of this fund is to be used to maintain scholarships and fellowships which shall be awarded to undergraduate and graduate students of the Institute, the holders of such scholarships and fellowships to be known as Meridan Hunt Bennett Scholars, in the case of undergraduates, and Meridan Hunt Bennett Fellows, in the case of graduates.

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.

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.

BLUMENTHAL SCHOLARSHIP IN PHYSICS

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

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.

LA VERNE NOYES SCHOLARSHIPS

Under the will of the late La Verne Noyes, of Chicago, funds are provided for paying the tuition, in part or in full, of 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 day 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.

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

LOAN FUNDS

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

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

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

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

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

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

The Roy W. Gray Fund.

The James R. Page Loan Fund.

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

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

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

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

THE CONGER PEACE PRIZE

Everett L. Conger, D.D., for the promotion of interest in the movement toward universal peace and for the furtherance of public speaking, established in 1912 the Conger Peace Prize. The income from one thousand dollars is given annually as a prize for the composition and delivery in public of the best essay on some subject related to the peace of the world. The general preparation for the contest is made under the direction of the department of English.

THE MARY A. EARL McKINNEY PRIZE

The Mary A. Earl McKinney prize, established in 1946, by Dr. Samuel P. McKinney of Los Angeles, a graduate in Civil Engineering of Rensselaer Polytechnic Institute, class of 1884, consists of the annual income from three thousand five hundred dollars.

It is awarded at Commencement in the form of a first and second prize, each consisting of a trophy and a sum of money, to the two students of the junior class, who show the greatest proficiency and improvement in English.

The department of English will announce each year the subject for an essay to be based on certain prescribed books. The three or four men presenting the best essays will engage in a discussion of the general subject, and the awards will be made by a panel of judges. The contest will be held in May.

STUDENT EMPLOYMENT

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

PLACEMENT SERVICE

The Institute, in cooperation with the Alumni Association, maintains a Placement Office, under the direction of a member of the Faculty. With the services of a full-time secretary, this office assists graduates and undergraduates to find employment. Students, both graduate and undergraduate, wanting part-time employment during the school year or during vacations, should register at the Placement Office. Assistance will be given whenever possible in securing employment for summer vacations. Graduates who are unemployed or desire improvement in their positions should register at the Placement Office.

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

REGISTRATION REGULATIONS

Registration Dates		*Fees Payable*	*Instruction Begins*
Freshmen and Transfer Students	Sept. 21, 1948	Sept. 21, 1948	Sept. 27, 1948
Upperclassmen and Graduate Students	Sept. 24, 1948	Sept. 24, 1948	Sept. 27, 1948

Fees for Late Registration

Registration is not complete until the student has filled out 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 two dollars is assessed for failure to register on the scheduled date, and a similar fee is assessed for failure to pay fees within the specified dates.

Change of Registration

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

General Regulations

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

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

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

Auditing of Courses

Persons not regularly enrolled in the Institute may, with the consent of the instructor in charge of the course and the Chairman of the Division concerned, be permitted to audit courses upon payment of a fee in the amount of $10 per term, per lecture hour. Registration cards for auditing of courses may be obtained in the Registrar's office. Regularly enrolled students are not charged for auditing. No grades for auditors are turned in to the Registrar's office, and no official record is kept of the result of the work done.

SCHOLASTIC GRADING AND REQUIREMENTS

SCHOLASTIC GRADING

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

A denotes Excellent,
B denotes Good,
C denotes Satisfactory,
D denotes Poor,
E denotes Conditioned,
F denotes Failed,
inc denotes Incomplete

In giving the grade *incomplete* the "inc" must be followed by a letter indicating the grade of work and by a number in parenthesis indicating approximately the percentage of the work completed. When so reported the grade of "inc" may, in summing grades, be provisionally considered to correspond to such a number of credits as the Registrar shall determine; but if reported without these specifications it shall not be counted. The instructor's reason for giving the grade and the manner by which the incomplete may be removed must be entered in the space provided for that purpose.

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

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

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

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

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. Leave of absence from examinations may be obtained only from the Deans, and will be granted only in the case of sickness or other emergency.

SCHOLASTIC REQUIREMENTS

All freshman and sophomore students are required to meet certain scholastic standards as outlined below. Students transferring from other colleges into the junior, senior, or Master of Science divisions are also subject to these restrictions until they have satisfactorily completed three full terms of residence at this Institute. In addition, students who have been reinstated to junior standing after having failed to make the required number of credits in the sophomore year are subject to these scholastic requirements in the junior year and also in the senior year if the junior work is not satisfactory.

Each course in the Institute is assigned a number of *units* corresponding to the total number of hours per week devoted to that subject, including classwork, laboratory, and the normal outside preparation.* *Credits* are awarded on the basis of the number of units multiplied by four if the grade received is "A," three if "B," two if "C," and one if "D"; thus, a student receiving a grade of "B" in a twelve unit course receives 36 credits for this course.

Credits are not given for work in physical education or in assembly.

Grade-point average is computed by dividing the total number of units taken in a term or in an academic year into the total number of credits earned in the corresponding period. Units for which a grade of "F" has been received are counted, even though the "F" may have subsequently been removed. (See above.)

Ineligibility for registration. Any student is ineligible to register

*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.

if he fails during any one term to receive at least 54 credits.** A freshman, sophomore, or new transfer student is ineligible to register:

(a) If he fails during any one term to receive at least 54 credits.

(b) If he fails for the school year to receive a total of at least 270 credits.

A student ineligible for registration because of failure to meet the requirements stated in the preceding paragraph may, if he desires, submit immediately to the Registrar a petition for reinstatement, giving any reasons that may exist for his previous unsatisfactory work and stating any new conditions that may lead to better results. Each such application will be considered on its merits. A reinstated student who again fails to fulfill the scholastic requirements for registration will be granted a second reinstatement only under very exceptional conditions.

Deficiency. Any freshman, sophomore, or new transfer student who fails to receive at least 72 credits during any one term will be required to report to the Dean before registering and may be requested to withdraw from all extra-curricular activities and outside employment or reduce the number of subjects he is carrying sufficiently to enable him to meet the scholastic requirements in succeeding terms.

Departmental regulations. Any student whose grade-point average (credits divided by units) is less than 1.9 in the subjects listed under his division* may, at the discretion of his department, be refused permission to continue the work of that option.‡ Thus, a student finishing his junior year in electrical engineering, whose grade-point average in the freshman, sophomore, and junior courses in his *division* (including physics, mathematics, and electrical engineering) was less than 1.9, could be refused permission by the electrical engineering department to continue with *senior* courses in the electrical engineering option. Such disbarment, however, does not prevent the student from continuing in some other option provided permission is obtained, or from repeating courses to raise his average in his original option.

Comprehensive Examinations. A student whose grade-point average in any of the following subjects—mathematics, physics, chem-

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**Students who take less than 45 units in any term or less than 135 units in an academic year must make at least a 1.5 grade-point average instead of the 54 credits, and at least a 1.8 grade-point average instead of the 270 credits mentioned in the above rulings regarding ineligibility for registration.

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

‡Any student whose grade-point average is less than 1.9 in freshman and sophomore physics and chemistry may, at the discretion of the Division of the Geological Sciences, be refused permission to register for the junior course in the Geological Sciences Option.

istry, English, history—is below 1.9 at the end of the sophomore year must take a comprehensive examination in each subject in which he is deficient, except that chemistry is not included in this requirement for students in engineering. Comprehensive examinations are held during the week preceding registration in September. Notices of deficiencies will be sent out by July 15 to the home addresses appearing on the third term registration cards. The examinations will cover the work of the first two years in each subject. Those in mathematics and physics are of the open book type. Failure of a comprehensive examination renders a student ineligible for registration, and his case will be reviewed by the Registration Committee on the date for registration of returning students.

Freedom from scholastic restrictions. After a student has completed at least three full terms of residence at the Institute and has been registered for his junior year, he shall no longer be subject to the scholastic regulation requiring that he make at least 270 credits during the school year, except that a student who is *reinstated* to enter the junior or senior year is subject to this requirement during his junior or senior year.

All undergraduate and Master's candidates are subject to the requirement that they must receive at least 54 credits each term to be eligible for subsequent registration. (Special note should be made of the graduation requirement in the following paragraph.)

Graduation requirement. To qualify for graduation a student must complete the prescribed work in some one option of the course in engineering or of the course in science with a grade point average of 1.9.

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

Honor standing. (See page 97 for *Honor Standing* for entering freshmen.) At the close of each academic year the Committee on Honors and Awards awards *Honor Standing* to approximately fifteen students in each of the three classes remaining in residence. These awards are based on the scholastic records of the students. Any holder of such an award who in any subsequent term fails to maintain a scholastic standard set by the Committee loses his honor standing for the remainder of the academic year.

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

A student will be *graduated with honor* who has received on the average throughout his course 130 credits per term which result from grades of "A" and "B", provided also that he maintains such an average throughout the three terms of the senior year. In addition, a student may be graduated with honor under joint recommendation of his department and the Committee on Honors and Awards, and approval of the Faculty.

Excess or less than normal units. Applications for registration in excess of the prescribed number of units, or for less than 33 units, must be approved by the Registration Committee.

Leave of absence. Prolonged leave of absence must be sought by written petition to the Registration Committee, and the student must indicate the length of time, and the reasons, for which absence is requested. In case of brief absences from any given exercise, arrangements must be made with the instructor in charge.

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

CANDIDACY FOR THE BACHELOR'S DEGREE

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

STUDY AND RESEARCH AT THE CALIFORNIA INSTITUTE

THE SCIENCES

ASTROPHYSICS

The Rockefeller Boards provided in 1928 for the construction by the Institute of an Astrophysical Observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, a 48-inch Schmidt wide-angle telescope and other auxiliary instruments and supplemented by an Astrophysical Laboratory, an Optical Shop and a Machine Shop on the Institute Campus. It is expected that this new observatory will begin operations during the academic year 1947-48.

It has been agreed between the Carnegie Institution of Washington and the California Institute of Technology that there shall be a unit research program for the observatories on Mount Wilson and Palomar Mountain, with Dr. I. S. Bowen as director of the combined observatories. This procedure continues and extends in a more formal way the cooperation which has been in progress between the California Institute and the Mount Wilson Observatory for several years, especially in the study of the astronomical, physical, and chemical aspects of the constitution of matter.

The purpose of the Astrophysical Observatory is thus to supplement, not to duplicate, the Mount Wilson Observatory. The increased light-collecting power of the 200-inch telescope will permit further studies of the size, structure and motion of the galactic system; of the distance, motion, radiation and evolution of stars; of the spectra of the brighter stars under very high dispersion; of the distance, motion and nature of remote nebulae; and of many phenomena bearing directly on the constitution of matter. The 48-inch Schmidt will make possible a systematic survey of the sky as well as an attack upon such problems as the structure of clusters of nebulae, the luminosity function of nebulae and absolutely faint stellar systems, intergalactic matter, nebulae as gravitational lenses, supernovae, and the stellar content of the milky way. These two unique instruments will supplement each other as well as the telescopes on Mount Wilson; the one will reach still further into space in a given direction, while the other will photograph upon a single plate an entire cluster of nebulae in its full geometrical and large scale material content.

The research program will be paralleled by undergraduate and graduate training in astronomy and astrophysics in which members of the Staff of the Mount Wilson Observatory will join with the Institute Faculty. This will be superimposed upon an especially thorough preparation in mathematics, physics and chemistry made possible by the strong work already being given at the Institute in these fields. It should be remembered, however, that the number of positions open to men trained in astrophysics and its related subjects is small. For this reason only those exceptionally well qualified for such work should undertake graduate study and research.

BIOLOGICAL SCIENCES

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

Adjacent to the campus there is a laboratory for plant physiology, with several greenhouses. Two of them are air-conditioned, allowing for exact control of temperature and humidity and partial control of light. They offer a unique opportunity for the study of plants under different synthetic climatic conditions and also enable complete reproducibility of experimental results.

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

About 50 miles from Pasadena, at Corona del Mar, is the William G. Kerckhoff Marine Laboratory. The building houses several laboratories for teaching and research in marine zoology, embryology, and physiology. It is equipped with its own shop, has boats and tackle for collecting marine animals, and running sea-water aquaria for keeping them. The proximity of the marine station to Pasadena makes it possible to supply the biological laboratories with living materials for research and teaching. The fauna at Corona del Mar and at Laguna Beach, which is near-by, is exceptionally rich and varied, and is easily accessible.

UNDERGRADUATE AND GRADUATE WORK

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

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

Graduate work leading to the Ph.D. degree is chiefly in the following fields: animal biochemistry, plant biochemistry, bio-organic chemistry, animal and plant genetics, chemical genetics, immunology, biophysics, mammalian physiology, comparative physiology, plant physiology, and experimental embryology. These represent the fields in which active research is now going on in the Division. The emphasis in graduate work is placed on research. This is supplemented by courses and seminars in advanced subjects aimed to develop the student's insight and critical ability as an investigator.

CHEMISTRY AND CHEMICAL ENGINEERING

The Gates and Crellin Laboratories of Chemistry consist of three adjacent units. The first two are the gift of the late Messrs. C. W. Gates and P. G. Gates. The third unit, which was completed in 1937 and which affords new space approximately equal to that of the first two units, is the gift of Mr. and Mrs. E. W. Crellin.

These three units include laboratories used for undergraduate instruction in inorganic, analytical, physical, and organic chemistry, and instrumental analysis; they also include class-rooms, demonstration lecture rooms, and a chemistry library. The remaining space in these buildings is largely devoted to facilities for research. There are numerous laboratories for inorganic, physical, organic, and immunological chemical research, providing space for about one hundred research fellows and advanced students.

With the Gates and Crellin Laboratories is associated the Chemical Engineering Laboratory, which is located in another building. This laboratory is well equipped for making the accurate measurements needed in engineering investigations of quantitative character. It is especially well provided with equipment for determination of the phase relations and thermodynamic properties of fluids at moderately high pressures. Research equipment is available for intensive study of transfers of matter and energy in systems involving fluids.

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

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

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

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

The supervision of the research work of graduate students is distributed among the members of the staff of the Division of Chemistry and Chemical Engineering. Some of the many fields in which researches are being actively prosecuted are listed on page 214-215.

The fifth-year course in chemical engineering leads to the degree of Master of Science in Chemical Engineering. This course contains an intensive problem study of chemical engineering, a laboratory course in engineering measurement and research methods, a course in business economics, and elective studies in science and engineering. Upon completion of the fifth-year course the student becomes eligible to be considered for sixth-year work leading to the degree of Chemical Engineer. Approximately one-half of the work of the sixth year is devoted to research either in chemical engineering or in applied chemistry, the other half being occupied with graduate course work arranged with the approval of the Division of Chemistry and Chemical Engineering.

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

GEOLOGICAL SCIENCES

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

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

Stratigraphic and faunal studies may be pursued in the Cenozoic and Mesozoic sedimentary rocks of the Southern Coast Range, and in the Mojave Desert region. Thick sections of Paleozoic sediments in southeastern California remain almost unexplored. Structural and physiographic problems in the Coast and Basin Ranges await critical investigation and frequently involve an interpretation of folding and faulting on a large scale. The many productive oil fields in southern California afford opportunity to students interested in petroleum geology. Many of the actively worked metallic and nonmetallic deposits of California and Arizona are within reach of week-end field parties. The world famous mineral localities of Crestmore and Pala are within a few hours' driving time from the Institute. Suites of ores, minerals and rocks from these localities are available for study in the Institute's collections, in addition to suites from many other parts of the world.

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

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

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

MATHEMATICS

UNDERGRADUATE WORK

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

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

Courses. The undergraduate option described on page 173 contains many electives. Their purpose is to enable the student to adapt his program to his needs and mathematical interests and to give him the opportunity to become familiar with creative mathematics early in his career. These electives may be chosen on consultation with the department either from the current graduate courses in mathematics which are open to undergraduates, or else from predominantly mathematical courses in allied fields such as physics or astronomy. Depending on the demand, elective courses in mathematics in addition to those listed explicitly in the catalogue will be offered.

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

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

GRADUATE WORK

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

Courses. The courses which carry a number between 100 and 199 cover fundamental general topics, those listed with a higher number are more special and more advanced and they include research seminars. Students are urged to take part in one or more of these seminars, and to make extensive use of the library facilities.

Requirements. The general requirements for the degree of Ph.D. are listed on pp. 139-142; additional requirements for mathematics are found on p. 143. The special prerequisites for the course requirements in the minor subject are listed under the separate departments. In particular those for physics are listed on pp. 260-261. A candidacy course requirement may be passed by examination if the student is sufficiently prepared.

As stated on p. 144 the student must submit his thesis before May 1, of the year in which his degree is to be granted. In addition he is required to present in person the work of his thesis before the staff in one of the research seminars before April 16 of the same year.

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

Master's degrees. Students initially planning to take only a Master's degree are accepted only under special circumstances. In the exceptional cases when the complete Ph.D. requirements cannot be met, a Master's degree will be awarded upon completion of all candidacy courses and submission of a thesis. The thesis requirement may be waived at the discretion of the department.

METEOROLOGY

With the conclusion of the semester ending in June, 1946, meteorology is again offered only in the Graduate School. Prerequisites for admission to meteorology will be a Bachelor's degree in Science or Engineering, or the equivalent, with credit in mathematics through differential and integral calculus and differential equations. A minimum of two years of college physics is required and a course in thermodynamics is desirable. In general, it is felt that an undergraduate major in mechanical engineering or in physics with a minor in mathematics constitute the best preparation for graduate study in meteorology.

The fifth year curriculum in meteorology is designed to give the student a well rounded training in basic meteorology and to qualify him for a position of assistant forecaster in an airline or for a junior meteorologist rating in the U. S. Weather Bureau. Students satisfactorily completing the fifth year curriculum will be granted the degree of Master of Science in Meteorology. Although fifth year students assist on research projects, no thesis is required for the Master's degree.

Students who have completed the fifth year curriculum at the Institute, or who have obtained essentially the same preparation elsewhere, may apply for admission to the sixth year course leading to the professional degree of Meteorologist. Whereas, the fifth year curriculum is devoted to basic meteorology and short term forecasting, the course plan of the second graduate year provides training in the technique of preparing extended forecasts. In the sixth year curriculum, considerable time is also allotted to Statistics and problems of applied meteorology as important subjects in the training of a consultant meteorologist. Sixth year students are required to devote considerable time to original research. An acceptable thesis is one of the sixth year requirements for the professional degree.

Qualified students will be accepted for further advanced study leading to the degree of Doctor of Philosophy.

Facilities of the Meteorology Department include a weather station, complete with instruments used in the making of routine observations, both surface and upper air. Fifth year students operate this weather station, as well as a forecasting office, in which Civil Aeronautics Administration teletype facilities permit the preparation of practice forecasts from current data.

PHYSICS

UNDERGRADUATE WORK

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

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

In order to provide the thorough training in physics required by those who are going into scientific or engineering work, two full years of general physics are required of all students. Those who desire to major in physics take during their junior, senior and fifth years intensive problem type courses that provide a more than usually thorough preparation for graduate work. For those who do not expect to go on into graduate work, an "applied physics option" is provided, in which some of the mathematics and problem courses are replaced by engineering subjects. Many of the undergraduate students who elect physics are given also an opportunity to participate in some of the thirty to sixty research projects which are always under way in the Norman Bridge Laboratory of Physics, and the graduate seminars are open to undergraduates at all times.

GRADUATE WORK

Graduate students should complete as soon as possible the courses required for admission to candidacy for the doctor's degree. (See page 143.) These provide an unusually thorough grounding in the fundamentals of physics, and the student learns to use these principles in the solution of problems of all kinds. In general, also, graduate students should begin research during their first year and continue it through their whole graduate period.

The Norman Bridge Laboratory of Physics is equipped to carry on research in all the principal fields of physics. Equipment for making liquid air, hydrogen, and helium has been installed, and liquid air and liquid hydrogen are available in sufficient quantities for low temperature researches. Special facilities for research in the field of radiation are provided in the W. K. Kellogg Laboratory of Radiation and the High-Potential Research Laboratory with their million-volt transformers, van de Graff machines, and high potential x-ray equipment. In both laboratories important work in nuclear physics and various phases of high-voltage x-rays is being carried on.

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

There is a general seminar or research conference each week which is regularly attended by all research workers and all graduate students. In addition, there is a weekly theoretical seminar conducted for the benefit of those interested primarily in mathematical physics and several seminars on special fields of work such as x-radiation, nuclear physics, metals, physics of solids, and ultra-short electromagnetic waves.

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

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

ENGINEERING

UNDERGRADUATE WORK

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

The plan of instruction in engineering embodies a four-year course for the degree of Bachelor of Science. The civil, electrical and mechanical engineering groups are not separated until the third year, all students following the same program of the fundamental subjects—mathematics, physics and chemistry—supplemented by their general applications in surveying, mechanism, mechanics, strength of materials, direct and alternate currents, heat engines and hydraulics. The divergence between the different branches occurs in the third and fourth years, when the study of the professional subjects of specialized nature is introduced. Subjects in the humanities—English, history, and economics—are included in each year of the curriculum.

The four-year undergraduate courses in engineering are well balanced foundations for entrance into many opportunities within the respective fields. However, those students who wish to prepare for careers in the more intensive technical phases of engineering, and who have shown capacity to do advanced work, are expected to take the fifth year, which represents additional professional subjects and work in both design and research. While the work of the fifth year is prescribed to a considerable extent, it offers time and encouragement for the student to engage in research in a field of his own selection under the guidance of a staff representing a wide range of experience and current activity.

GRADUATE STUDY AND RESEARCH IN ENGINEERING

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

AERONAUTICS

The graduate School of Aeronautics and Guggenheim Aeronautical Laboratory, widely known as the GALCIT, were established in 1928 at the California Institute with the aid of the Daniel Guggenheim Fund for the Promotion of Aeronautics. Since their inception the department and laboratory have been actively engaged in the fields of Aeronautics and the allied sciences. The following program of instruction at the post-graduate level and of advanced research is now in progress:

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

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

3. A series of courses in jet propulsion originally given for Army and Navy officers only, but now declassified and opened to a limited number of civilian students.

4. 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 performance, stability, and dynamical behavior of aircraft, guided missiles, and projectiles.
   d. Problems in jet propulsion with special emphasis on the underlying fluid mechanics, thermodynamics, dynamics, and chemistry.

The campus laboratory houses a wind tunnel of the closed circuit type with a working section 10 feet in diameter. A 750 horsepower motor and propeller produce test section wind velocities in excess of 200 miles per hour. A complete set of aerodynamical balances permits the rapid testing of aircraft models as well as the undertaking of many types of scientific investigation in this tunnel. A fluid mechanics laboratory contains several smaller wind tunnels and a considerable amount of auxiliary apparatus especially suitable for the study of the basic problems connected with turbulent flows. The problems of supersonic and transonic flow may be investigated in still other wind tunnels designed for this purpose. These tunnels are equipped with optical apparatus which can be used for the study of shock wave phenomena. A large structures laboratory is equipped with testing machines especially designed for researches related to stressed skin or monocoque structures. Photoelastic equipment is available for studying the stress distribution in complex structures by optical methods. The laboratory includes excellent shop facilities for students engaged in research problems.

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 is owned and sponsored by the Armed Services and operated by the California Institute. It is devoted to the study of the fundamental problems underlying jet propulsion and guided missiles. Among the subjects emphasized are supersonic aerodynamics, chemistry of fuels and combustion, high temperature materials, liquid and solid propellant rocket motors, ramjet and other air-consuming jet engines, missile guidance and control, etc.

The second off-campus facility is the Southern California Cooperative Wind Tunnel which is owned by four of the leading West Coast aircraft companies. The Laboratory with its equipment was constructed and is operated by the Aeronautics department under a management agreement. This tunnel has approximately 15,000 installed horsepower, an 8½ by 12 foot working section, and develops speeds up to the velocity of sound. It can be operated both above and below asmospheric pressure and is used for studying the aerodynamic problems of modern aircraft and guided missiles.

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

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

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

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

CHEMICAL ENGINEERING AND APPLIED CHEMISTRY

(See pp. 112-113)

CIVIL ENGINEERING

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

ELECTRICAL ENGINEERING

The Electrical Engineering Department offers instruction leading to the degrees of Bachelor of Science, Master of Science, Electrical Engineer, and Doctor of Philosophy.

The field of 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 by students from other colleges who have substantially the same preparation.

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

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

Of the several electrical engineering laboratories at the California Institute, the High-Potential Research Laboratory is the most outstanding. This building and the million-volt transformer were provided by the Southern California Edison Company, Ltd. The million-volt transformer, which was designed by Professor R. W. Sorensen has a normal rating of 1,000 kilovolt amperes but is capable of supplying several times the rated load at the above potential, with one end of the winding grounded. A 2,000,000 volt surge generator supplemented by cathode-ray oscillographs and other apparatus used in the study of electric surges (artificial lightning) and its effect upon electrical apparatus provides ample facility for the study of high voltage transients. This laboratory is used both for the pursuit of special scientific problems connected with the structure of matter and the nature of radiation, and for the conduct of the pressing engineering problems having to do with the improvement in the art of transmission at high potentials. It also provides opportunities for instruction in this field, such as are not at present easily obtainable elsewhere by students of science and engineering.

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

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

Though very new, this computer seems unsurpassed as a device for rapidly solving many very difficult equations. Its use has already indicated a number of development lines for other computation methods. These will provide research projects suitable for graduate students particularly in the field of electrical engineering and applied mechanics.

The computer also provides an important facility for extending certain lines of basic research in electric circuit theory, mechanics, aeronautics, thermodynamics and other fields where similar problems are encountered.

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

HYDRODYNAMICS

Due to the establishment of research laboratories at the Institute covering several of the broader fields of hydraulic engineering, the opportunities for advanced study and research are exceptionally good, especially for those graduate students able to pursue their studies to the point of obtaining a Ph.D. degree. Courses are available which, in connection with those in the allied departments of applied mathematics and aerodynamics, offer broad training in the entire field of fluid mechanics. Specialized research facilities are available in the following laboratories:

HYDRAULIC MACHINERY LABORATORY. This laboratory is designed for carrying out basic and precise research studies in the hydrodynamics of centrifugal and propeller pumps, turbines, and allied flow problems. Dynamometers with precision speed controls are available up to 450 horsepower output or input, and for speeds up to 5,000 r.p.m. Accurate instruments for measuring pressures, flow rates, speeds, and torques are provided. Special equipment for the study of cavitation has been developed.

HYDRODYNAMICS LABORATORY. This laboratory is a three-story wing adjoining the Hydraulic Machinery Laboratory. Its equipment is designed for the determination of the dynamics of the motion of underwater bodies. Major research programs are now being carried on under the sponsorship of the Bureau of Ordnance of the Navy. The facilities are also available for graduate research. The equipment includes (a) a High Speed Water Tunnel with a 14-inch working section and velocities above 70 feet per second, (b) a Free Surface Water Tunnel, (c) a large Controlled Atmosphere Launching Tank, and (d) a Polarized Light Flume. Force balance and pressure distribution measuring equipment are available for the tunnels. Much additional auxiliary equipment has been developed, including a flash-type motion picture camera for work up to 30,000 exposures per second. Well equipped photographic dark rooms and a precision instrument shop are part of the laboratory facilities.

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

Bureau of Yards and Docks to study the development of Apra Harbor at Guam, and is especially suitable for wave and surge problems.

SOIL CONSERVATION LABORATORY. This laboratory is a cooperative undertaking with the Soil Conservation Service of the United States Department of Agriculture. Its objective is the study of the mechanism of entrainment, transportation, and deposition of solid particles by flowing flluids. The equipment includes (a) the closed circuit suspended load flume with an adjustable gradient, (b) a special flume for the study of rate of reduction of bed load, (c) an outdoor model basin for studying field problems requiring either clear or silt laden flows, and (d) sediment analysis laboratory. Facilities of this installation are also available to qualified graduate students.

MECHANICAL ENGINEERING

The Mechanical Engineering Department offers instruction and research leading to the degrees of Bachelor of Science, Master of Science, Mechanical Engineer, and Doctor of Philosophy.

The general program of instruction in mechanical engineering is organized on a five year basis in which the fifth year schedule is open to qualified students who have completed the four year mechanical engineering option for the Bachelor of Science degree from the Institute, or have had substantially the same preparation in other colleges. The first four years at the Institute are concerned with basic subjects in science and engineering and in the humanities. The fifth year, therefore, is somewhat more specialized, but yet basic in the field of mechanical engineering. A set schedule of subjects is specified for the fifth year covering the more specialized and advanced phases of mechanical engineering.

Greater specialization is provided by the work for the professional or doctor's degrees. 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. Research work leading to a thesis is required for the professional degree and for the doctor's degree.

In advanced work the Mechanical Engineering Department provides facilities in four general areas: (1) hydrodynamics, (2) design, mechanics, and dynamics, (3) physical metallurgy and mechanics of materials, and (4) thermodynamics and heat power. In hydrodynamics extensive facilities are available as described under a separate section of the catalogue. A Dynamics Laboratory is provided for the study of problems in vibration, transient phenomena in mechanical systems, and experimental stress analysis by means of special mechanical and electronic equipment. Instruction and research in physical metallurgy is made possible by a well equipped metallography laboratory in which alloys may be prepared, heat treated, analyzed, and studied microscopically. Extensive laboratory facilities have been developed for the study of the mechanics of materials, particularly under conditions of dynamic loading, which are located in a special laboratory. Work in the field of thermodynamics and heat power is implemented by laboratories containing internal combustion engines, heat transfer apparatus, and refrigeration equipment. Work is in progress on certain phases of gas turbines which provides problems and facilities for research in this field.

An additional activity of interest to all advanced students in engineering is the Analysis Laboratory. (See page 125.) This laboratory is built around an analog computer which merges the various interests in applied mechanics, applied mathematics, and electrical engineering in the solution of problems. The computer is valuable not only for solution of specific research problems but also as a field of research in itself in the development of new elements to extend the usefulness of the computer to more general mathematical analysis.

The 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.

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.

INDUSTRIAL DESIGN

THE INDUSTRIAL DESIGN SECTION was established at the California Institute of Technology in 1941 to fill a need for advanced training in the field of Industrial Design. This training combines the study of function and appearance with that of new materials, recent developments in production methods and merchandising techniques as a basis for a thorough and well rounded approach to contemporary design. Current developments in new materials, new processes, and in the buying habits of the consumer public are closely observed with the objectives of predicting future trends and furthering the design of improved products for better living. The student in Industrial Design is offered the opportunity to supplement his basic pre-requisite undergraduate study to a point where the professional level is reached in the solution of complex problems in design.

The program of instruction and research includes:

1. Study of historical and contemporary developments in the arts, technical and socialogical trends, buying psychology, cost and market analysis along with the development of the student's approach to design and aesthetic abilities through a carefully integrated two year course leading to a professional degree.
2. Lectures by experts, seminars and discussions with practicing industrial designers on class problems assigned throughout the course of study.
3. Visits to design studios, industrial plants, sales, and advertising organizations.
4. Research development in close collaboration with industry.

To be admitted to graduate standing, an applicant must in general have received a bachelor's degree representing the completion of a basic undergraduate course in science or engineering substantially equivalent to comparable courses 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 success advanced study and research.

Upon successful completion of the two-year graduate course, students are awarded the professional degree of Industrial Designer.

THE HUMANITIES

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

Ample quarters for the work in humanities are provided in Dabney Hall, which was given to the Institute by the late Mr. and Mrs. Joseph B. Dabney of Los Angeles as an evidence of their interest in the humanities program of the Institute and their desire to support it.

Besides the usual class and lecture rooms, Dabney Hall of the Humanities contains a divisional library and reading room, offices for members of the humanities faculty, a room for the exhibition of pictures and other works of art, and a student lounge which opens upon a walled garden of olive trees.

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

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

THE INDUSTRIAL RELATIONS SECTION

The Industrial Relations Section, which was established in 1939 as a part of the Division of the Humanities, is supported by special contributions from a substantial number of individuals, companies, and labor unions. The Section operates under the general direction of the Committee on the Industrial Relations Section, Professor William B. Munro, Chairman, appointed by the Board of Trustees.

The program of the Industrial Relations Section is fourfold: (1) it provides instruction in industrial relations for seniors and graduate students; (2) it holds periodic conferences and meetings with industrial executives and labor union officials for the discussion of current labor problems; (3) it conducts surveys and research studies on problems of industrial relations; and (4) it maintains a comprehensive reference library on this subject in its quarters in Culbertson Hall on the campus.

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 professional degrees of Aeronautical Engineer, Chemical Engineer, Civil Engineer, Electrical Engineer, Geological Engineer, Geophysical Engineer, Industrial Designer, Mechanical Engineer, and Meteorologist, 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 those courses 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. 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 courses at the Institute, he may be admitted subject to satisfactory completion of such undergraduate subjects as may be assigned. Admission sometimes may have to be refused solely on the basis of limited facilities in the department concerned. Students applying for assistantships or fellowships need not make separate application for admission to graduate standing. (See pages 152-156). For requirements in regard to physical examination, see page 83.

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

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

II. GRADUATE RESIDENCE

One term of residence shall consist of one term's work of not less than 45 units of advanced work in which a passing grade is recorded. If less 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.

Graduate students are encouraged to continue their research during the whole or a part of the summer, but in order that such work may count in fulfilment of the residence requirements, the student must file a registration card for such summer work in the office of the Registrar. When circumstances warrant, students who are registered for summer research but not for course work, will not be required to pay tuition therefor.

III. TUITION FEES

The tuition charge for all students registering for graduate work is $500 per academic year, (see page 96 for special fees in jet propulsion and meteorology) payable in three installments at the beginning of each term. Graduate students who cannot devote full time to their studies are allowed to register only under special circumstances. Students desiring permission to register for less 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 $125 a term for 32 to 25 units, and at the rate of $5 a unit for less than 25 units, with a minimum of $50 a term. If the courses registered for do not correspond to the full educational facilities made available to the student, additional tuition will be charged.

The payment of tuition by graduate students is required (a) without reference to the character of the work of the student, which may consist in the prosecution of research, in independent reading, or in the writing of a thesis or other dissertation, as well as in attendance at regular classes; (b) without reference to the number of terms in which the student has already been in residence; and (c) without reference to the status of the student as an appointee of the Institute, except that members of the academic staff of rank of Instructor or higher are not required to pay tuition.

There is a fee of $7.50 per academic year to assist in defraying expenses for medical care and emergency hospitalization. (See page 83.) Each graduate student is required to make a general deposit of $25 to cover any loss of or damage to Institute property used in connection with his work in regular courses of study. Upon completion of his graduate work, or upon withdrawal from the Institute, any remaining balance of the deposit will be refunded.

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

In regard to *fellowships and assistantships*, see pages 152-156 of this catalogue. In addition, to students with high scholastic attainments there may be awarded *graduate scholarships* covering one-half or the whole 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 179-194) as well as in the schedule of the four-year course in science or in engineering, except that, in the case of students transferring from other institutions, equivalents will be accepted in subjects in which the student shows by examination or otherwise that he is proficient, and except in so far as substitutions may be approved by special vote of the committee in charge.

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

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

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

II. REGISTRATION

1. The regulations governing registration and student responsibilities as given for undergraduate students on page 102 of the catalogue apply also to students working toward the master's degree.

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

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

4. Students registering for more than 50 units but less 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 or for a professional degree, and holding a position as graduate asssitant, 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. 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 is completed. Courses used to fulfill requirements for the Bachelor's degree may not be counted as graduate residence.

2. Scholastic requirements for undergraduate students (see page 105) also apply to students working toward the Master's degree. In meeting the graduation requirement as stated on page 107, the following rule will apply for Master's degree candidates: Only those courses shown on the candidacy blank and approved by the department representative shall be counted in figuring the grade-point average. Changes on the candidacy blank which are not initialed by the proper authority are not to be recognized. No course which appears on the candidacy blank and for which the candidate is registered may be removed after the last date for dropping courses as listed in the catalogue.

3. Candidates for the degree of Master of Science who have completed the senior year at the Institute are subject to the same regulations as are juniors and seniors, as listed on page 107.

4. Candidates for the degree of Master of Science who have completed their undergraduate work at other institutions are subject to the same scholastic regulations applying to new transfer students as listed on pages 105-106.

IV. THESIS

In the case of a required thesis two final copies must be filed with the Division concerned ten days before the degree is to be conferred. In the Division of the Geological Sciences and in the Department of Mathematics, a complete first draft of a thesis presented in partial fulfilment of the requirements for the degree of Master of Science must be submitted to the supervising instructor not later than six weeks before the date on which the degree is to be conferred.

C. REGULATIONS CONCERNING WORK FOR THE PROFESSIONAL DEGREE

1. The work for a professional 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.

2. *Residence.* At least six terms of graduate residence subsequent to a baccalaureate degree equivalent to that given by the California Institute are required for a professional 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.

3. *Admission to Candidacy.* Before the end of the second week of the first term of the academic year in which the student expects to receive the degree he must file in the office of the Dean of Graduate Studies an application for admission to candidacy for the degree desired. Upon receipt of this application, the Dean, in consultation with the chairman of the appropriate division, will appoint a committee of three members of the faculty to supervise the student's work and to certify to its satisfactory completion. One of the members of the committee must be in a field outside of the student's major field of study. The student should then consult with this committee in planning the details of his work.

The student will be admitted to candidacy for the degree when his supervising committee certifies

(a) That all the special requirements for the desired degree have been met, with the exception that certain courses of not more than two terms in length may be taken after admission to candidacy.

(b) That the thesis research has been satisfactorily started and can probably be finished at the expected time.

Such admission to candidacy must be obtained by the end of the second week of the term in which the degree is to be granted.

4. *Thesis.* At least two weeks before the degree is to be conferred, the student is required to submit to the Dean of Graduate Studies two copies of a satisfactory thesis describing his research, including a one-page digest or summary of the main results obtained. In form, the thesis must satisfy the requirements for theses for the degree of Doctor of Philosophy. (See page 142).

The use of "classified" research as thesis material for the doctorate or other 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.

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.

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.

Special Requirements for the Professional Degree of Mechanical Engineer

The Candidate must take at least 48 units of advanced work per term for two years subsequent to the Bachelor's degree. Not less than a total of 35 units of this work shall be for research and thesis, the exact number of units to be left to the discretion of the Supervising Committee appointed by the Dean of Graduate Studies. The courses shall be closely related to Mechanical Engineering, and the specific courses to be taken and passed with a grade of "C" or better by each candidate shall be determined by the Supervising Committee, but must include:

ME 125 abc	Engineering Laboratory
and one of the following:	
EE 226 abc	Engineering Mathematical Physics
Ph 92 abc	Introduction to Mathematical Physics and Differential Equations
AE 257 abc	Engineering Mathematical Principles
Ma 114 abc	Mathematical Analysis

Each candidate shall be required to pass a final examination as prescribed by a board to be appointed by the Supervising Committee.

A list of possible courses from which a program of study may be organized will be found on page 192.

Special Requirements for the Professional Degree of Electrical Engineer

See top of page 144.

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 in science or engineering. In addition, the candidate must have acquired the power of expressing himself clearly and forcefully both orally and in written language, and he must have a good reading knowledge of French and German*.

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

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

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

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

With the approval of the Committee on Graduate Study, students are admitted to graduate standing by the department in which they choose their major work toward the doctor's degree. In some cases, applicants for the doctor's degree may be required to register for the master's degree first. The master's degree, however, is not a general prerequisite for the doctor's degree. Students who have received the master's degree and wish to pursue further studies leading towards the doctor's degree must file a new application for admission to graduate standing to work towards that degree.

III. REGISTRATION

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

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

3. A student will not receive credit for a course unless he is properly registered, and at the first meeting of each class 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. 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. Students on part time teaching appointments will not be allowed to register for so many units. When admitted for work leading to the Doctor's degree, Graduate Assistants with duties in either teaching or research will be allowed to register for not more than 45 units.

IV. GRADES IN GRADUATE COURSES

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

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

3. The following system of grades is used to indicate class standing in graduate courses: "A" excellent, "B" good, "C" satisfactory, "D" poor, "E" conditioned, "F" failed. In addition to these grades, which are to be interpreted as having the same significance as for undergraduate courses, (See page 104) the grade "P," which denotes passed, may be used at the discretion of the instructor, in the case of seminar, research, or other work which does not lend itself to more specific grading.

V. GENERAL REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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

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

2. *Residence:* At least three academic years of work in residence subsequent to a baccalaureate degree equivalent to that given by the Institute are required for the doctor's degree. Of this at least one year must be in residence at the Institute. It should be understood that these are minimum requirements, and students must usually count on spending a somewhat longer time in residence. However, no student will be allowed to continue work toward the doctor's degree for more than five years of graduate residence, or more than 18 terms of full- or part-time academic work, except by special action of the Committee on Graduate Study.

Graduate students are encouraged to continue their research during the whole or a part of the summer, but in order that such work may count in fulfilment of the residence requirements, the student must comply with the above regulations and file in advance a registration card for such summer work in the office of the Registrar. When circumstances warrant, students who are registered for summer research but not for course work, will not be required to pay tuition therefor.

A graduate student who, by special arrangement, is permitted to conduct a portion of his research in the field, in government laboratories, or elsewhere off the campus, must file a registration card for this work in the office of the Registrar, in order that it may count in fulfilment of residence requirements. The number of units to be credited for such work shall be determined by the Dean of Graduate Studies in consultation with the Chairman of the Division in which the student is carrying his major work; and a recommendation as to the proportion of the full tuition to be paid for such work shall be made by the Dean to the Assistant Comptroller.

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

3. *Admission to Candidacy:* Any student admitted to work for the doctor's degree who has been in residence one term* or more, who has satisfied the several departments concerned by written or oral examination or otherwise that he has a comprehensive grasp of his major and minor subjects as well as of subjects fundamental to them, who has satisfied the department of modern languages that he can read with reasonable facility scientific literature in German and one other approved language (see page 137), who has shown ability in carrying on research and whose research subject has been approved

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

by the Chairman of the Division concerned, and whose program of study has been approved by both his major and minor departments may, on recommendation of the Chairman of the Division in which he is working, be admitted by the Committee on Graduate Study to candidacy for the degree of Doctor of Philosophy. Members of the permanent Institute staff of rank higher than that of Assistant Professor are not admitted to candidacy for a higher degree. For special departmental regulations concerning admission to candidacy, see Section VI.

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

4. *Examinations:* (a) The language examinations, prerequisite to admission to candidacy for the degree of Doctor of Philosophy, will be given at three times in the year, these times to be announced by the Registrar's Office. Candidates may in place of the above take the advanced undergraduate examinations offered at the end of each term. Students who have credit for courses in languages taken at the Institute and who have a grade above average may be exempted from further requirements after consultation with the language department.

Graduate students are permitted to audit all courses in the department of languages. In general, however, it is desirable for students without previous study in required languages to take these subjects in class for at least the first term rather than to depend upon studying them by themselves. Students are advised to take examinations as long as possible before they expect to file application for candidacy, so that, if their preparation is inadequate, they may enroll in one of the language courses.

(b) Final examinations in their major and minor subjects are required of all candidates for the doctor's degree. These examinations, subject to the approval of the Committee on Graduate Study, may be taken at such time after admission to candidacy as the candidate is prepared, except that they must take place at least two weeks before the degree is to be conferred. The examinations may be written or oral, or both, and may be divided into parts or given all at one time at the discretion of the departments concerned. The student must petition for these examinations on a form obtained from the Dean of Graduate Studies. For special departmental regulations concerning candidacy and final examinations, see Section VI.

5. *Thesis:* The candidate is required to submit to the Dean of Graduate Studies two weeks before the degree is to be conferred two copies of a satisfactory thesis describing his research.

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 special departmental regulations concerning theses, see Section VI.

The first copy of the thesis must be a typewritten original on paper of good quality, 8½ by 11 inches, or, with the requisite approval, it may consist in part of pages taken from a published article and pasted on paper of the above size. Each sheet, including figures, must have a clear margin of at least one inch on the left-hand side for binding. Other margins should be at least one-half inch for good appearance. The second copy of the thesis may consist of first carbon copies on paper of good quality, or may be reproduced by use of photosensitized paper.

The thesis should be preceded by a title page containing the following items: Title, Thesis by *(full name of candidate)*, In Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy, California Institute of Technology, Pasadena, California, Date *(year only)*. Following the title page there shall be a one-page abstract or digest of the main results obtained. This page may be followed in turn by a page of Acknowledgment and by the Table of Contents. For regulations regarding use of "classified" material, see page 136.

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

6. *Grades on Degree:* The doctor's degree is awarded with the designations "*summa cum laude,*" "*magna cum laude,*" "*cum laude,*" or without designation, in the Division of Physics, Mathematics, and Electrical Engineering, and in the Division of Civil and Mechanical Engineering and Aeronautics. It is awarded without designation in the Divisions of Biology, Chemistry and Chemical Engineering, and the Geological Sciences.

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

A. DIVISION OF PHYSICS, ASTROPHYSICS, MATHEMATICS, AND ELECTRICAL ENGINEERING

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

Ph 101 abc	Electricity and Magnetism
Ph 103 abc	Analytical Mechanics
Ph 105 ab	Optics
Ph 107	Spectroscopy
Ph 109 abc	Atomic and Nuclear Physics

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

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

and one of the following subjects:

Ph 101 abc	Electricity and Magnetism
Ph 103 abc	Analytical Mechanics
Ph 109 ab	Nuclear Physics
	together with
Ph 113	Quantum Mechanics

The attention of prospective graduate students in mathematics is particularly called to the undergraduate prerequisites in physics for these courses.

1c. *Electrical Engineering.* To be recommended for candidacy for the doctor's degree in electrical engineering the applicant must pass the following subjects with a grade of C or better:

Ph 101 abc	Electricity and Magnetism
EE 226 abc	Engineering Mathematical Physics

and one of the following subjects:

Ph 103 abc	Analytical Mechanics
AM 1 abcd	Applied Mechanics

and one of the following subjects:

Ph 5 abc	Introduction to Mathematical Physics (shorter course)
Ph 6 abc	Introduction to Mathematical Physics (longer course)
AM 115 abc	Engineering Mathematics
Ma 8 abc	Methods of Advanced Calculus

and 30 units from the following:

EE 120 abc	Advanced Electric Power System Analysis
EE 152	Dielectrics
EE 158 abc	Circuit Analysis
EE 190 abc	Electromagnetic Fields

To be recommended for the professional degree in electrical engineering the applicant must pass with a grade of C or better (with the exception of Ph 101) the same subject requirements as listed above for the doctorate degree.

2. An applicant may also satisfy any of the course requirements described above by taking an examination in the subject with the instructor in charge. Every examination of this type will cover the *whole* of the course specified and the student will not be permitted to take it either in parts (e.g. term by term) or more than twice. These so-called candidacy examinations will be given early in the first term of each academic year and the student must apply for permission to take them before the end of the second week of the term. Such application must be in writing and, if approved, will be regarded as one of the two permitted trials, whether or not the student actually takes the examination. (Note: The above regulations are not to be interpreted as preventing the student, with the permission of the instructor in charge, from satisfying the candidacy requirements by taking the examinations in a course without actual class attendance.)

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

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

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

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

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

5. A candidate for the degree of Doctor of Philosophy with a major in mathematics must deliver a typewritten or printed copy of

his completed thesis, in final form, to the professor in charge on or before May 1 of the year in which the degree is to be conferred.*

6. A student in electrical engineering 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 college residence.

B. DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

1. To be recommended for candidacy for the doctor's degree in Chemistry the applicant must give satisfactory evidence of proficiency by satisfying the following requirements:

a. Candidacy examination in physical chemistry,
b. Candidacy examination in inorganic chemistry,
c. Candidacy examination in organic chemistry,
d. Candidacy examination in colloid and surface chemistry,
e. Written report on the progress of research.

In Chemical Engineering the corresponding requirements consist of the following:

a. Candidacy examination in physical chemistry,
b. Candidacy examination either in inorganic chemistry or in organic chemistry,
c. Candidacy examination in chemical engineering unit operations.
d. Candidacy examination in engineering thermodynamics,
e. Written report on the progress of research.

The examinations are written, except for that in inorganic chemistry, which is usually oral, and that in engineering thermodynamics, which may be partly oral. They cover their respective subjects substantially to the extent that these are treated in the undergraduate chemistry and applied chemistry options and in the fifth-year chemical engineering course; the proficiency expected is not less than that acquired by the abler undergraduates. A detailed informational knowledge is not so much desired as an understanding of general principles and a power to apply these to concrete problems. These examinations are ordinarily given once a year.

Each of the examinations is graded as a whole. A grade of A or B is accepted as passing in each of the examinations; in addition C is accepted as passing in organic chemistry for students working mainly in physical or inorganic chemistry, and in physical chemistry for students working in organic chemistry. A grade of C is accepted as passing in chemistry examinations for students working in chemical engineering.

A student registered for the Ph.D. degree who fails to pass at least two of the above candidacy requirements during his first year of resi-

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

dence, or who fails to complete the candidacy requirements by the end of his second year of residence will not be allowed to register in a subsequent academic year except by special permission of the Division of Chemistry and Chemical Engineering.

The written report must be a satisfactory description of the applicant's research up to the date of his application. By this report and his laboratory work the applicant must have given evidence of his industry and ability in research, and of his power to present his results in clear, forceful language and with discrimination as to what is essential in scientific papers.

2. It is expected that the applicant shall have studied mathematics and physics substantially to the extent that these subjects are covered in the first two years of the Institute undergraduate courses. In cases where the applicant's training is less extensive than this, the Division of Chemistry and Chemical Engineering may prescribe additional work in these subjects prior to recommending him as a candidate.

3. The 45 units of study offered for satisfaction of a minor requirement are to consist in general of graduate courses other than research; however, the Division of Chemistry and Chemical Engineering may, by special action, permit up to 23 units to consist of appropriate research.

4. After admission to candidacy a student must in general pursue advanced study and research for not less than 4 terms before he will be recommended by the Division of Chemistry and Chemical Engineering for the final examination for the doctor's degree.

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

6. 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 not immediately related to his research or propositions.

The propositions should be about ten in number, of which about four should relate to the minor subject and to general branches of chemistry, and about six to the branch of chemistry of major interest to the candidate, including his research. For students in chemical engineering about three propositions should relate to the minor subject, two to chemistry if this is not the minor subject or to mechanical engineering if chemistry is the minor subject, and about five to chemical engineering. The candidate may also include propositions not relating to his major and minor fields. The propositions, prepared by the candidate himself, should display his originality, breadth of interest, and soundness of training; the candidate will be judged on his selection and formulation of the propositions as well as on his defense of them. It is recommended that the candidate begin the formulation of his set of propositions early in his course of graduate study.

A copy of the set of propositions must be submitted to the Division of Chemistry and Chemical Engineering at least two weeks before the date set for the examination. A copy of the set of propositions must be submitted to the Dean of Graduate Studies with each of the two copies of the thesis.

C. DIVISION OF CIVIL AND MECHANICAL ENGINEERING, AND AERONAUTICS

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

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

ME 125 abc	Engineering Laboratory

and one of the following:

EE 226 abc	Engineering Mathematical Physics
Ph 92 abc	Introduction to Mathematical Physics and Differential Equations
Ae 257 abc	Engineering Mathematical Principles
Ma 114 abc	Mathematical Analysis

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

Candidates are required to take two oral examinations after admission to candidacy. The first, termed the general examination, may be taken at any convenient time 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.

1c. *Aeronautics.* To be recommended for candidacy for the doctor's degree in aeronautics the applicant must pass the following subjects with a grade of C or better for each term:

	AE 257 abc or	Engineering Mathematical Principles
	Ma 114 ab	Mathematical Analysis
and		
	AE 251 abc	Aerodynamics of the Airplane
	AE 266 abc	Theoretical Aerodynamics
	AE 270 abc	Elasticity Applied to Aeronautics

and one of the following subjects:

AE 252 abc	Airplane Design
Ph 103 abc	Analytical Mechanics

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

2. In general a student will find it necessary to continue his graduate study and research for two years after admission to candidacy, and will be expected to have had six months or more of practical work.

D. DIVISION OF THE GEOLOGICAL SCIENCES

1. To be admitted to candidacy for the doctor's degree in the Division of the Geological Sciences the applicant must have shown more than average ability in mastering the previous geological, paleontological, and geophysical subjects.

2. A student must have a minimum of three terms' residence at the California Institute before applying for admission to candidacy.

3. The applicant for admission to candidacy may be required to take a qualifying examination which may be oral, written, or both.

4. After admission to candidacy, students must in general pursue advanced study and research for a minimum of six terms or approximately two years (counting each summer of field work as a term).

5. Candidates are required to take two oral examinations after admission to candidacy. The first, termed the general examination, tests knowledge in a specified number, but not all, of the various branches of geology, paleontology, and geophysics, and may be taken at any convenient time after admission to candidacy. The second, or final examination, is principally, but not entirely, a defense of the doctoral thesis and a test of the candidate's knowledge in the specialized fields of his major and minor subjects.

6. The first draft of the complete doctoral thesis containing all pertinent data, maps, and illustrations must be submitted to the

Division Secretary not later than February 1. A paper prepared for publication, embodying the results of the research in whole or in part, must be submitted to the Division Secretary not later than March 1. Two copies of the final, revised thesis must be filed with the Division Secretary by May 1 for subsequent circulation among members of the examining committee.

7. Special requirement in Field Geology for graduate students in the Division of the Geological Sciences.

If, in the judgment of the Division, additional technical training in geologic mapping is desirable, a graduate student may be required to take Ge 21 or Ge 121, and/or Ge 123.

Students with adequate technical background in geologic mapping may be required to gain familiarity with California geology by taking Ge 123, or an appropriate problem in areal geologic research.

METEOROLOGY

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

My 251 abc	Extended Forecasting, Theory and Practice
My 252 abc	Meteorological Laboratory
My 207 abc	Dynamical Meteorology
My 258	Meteorological Statistics
My 259	Applied Meteorology
AE 266 ab	Theoretical Aerodynamics
Ph 211	Thermodynamics

and one of the following subjects:

Ma 114 ab	Introduction to Mathematical Analysis
Ph 92 abc	Introduction to Mathematical Physics

In general a student will find it necessary to continue his graduate study and research for two years after admission to candidacy, and will be expected to have had six months or more of practical work.

E. DIVISION OF BIOLOGY

1. *Admission.* To be admitted to graduate study in Biology:— a) The applicant should have a satisfactory undergraduate record. b) He should have shown (as judged by the confidential reports of his instructors) a genuine interest in Biology and promise of development into an independent investigator. c) He should have studied the subjects required of undergraduate students majoring in Biology at the California Institute of Technology (see curriculum for Biology Option), or their equivalent. Applicants otherwise acceptable may be admitted with deficiencies in some of these

subjects, but will be expected to make up such deficiencies early in the course of their graduate study. Applicants wishing to specialize in fields bordering between Biology and Chemistry (or Physics) may be admitted on the basis of a curriculum equivalent to the Chemistry (or Physics) Option at the California Institute of Technology, in which case they are expected to prepare themselves in the fundamental fields of Biology early in their graduate course; otherwise they should make application for admission to graduate study in the Division of Chemistry (or Physics). The student must consult with his advisory committee at the start of his graduate work in order to determine which of the undergraduate courses he will be required to complete, as well as to obtain approval of his program of advanced study. d) The applicant must be acceptable to the staff member expected to be in charge of his major field of study. This decision will be based on the instructor's opinion that the ensuing relationship will be mutually advantageous to both student and instructor. e) Students may be admitted to Graduate Study (1) leading to the Degree of Doctor of Philosophy, (2) leading to the Degree of Master of Science, or (3) as Special Graduate Students not studying towards a degree. As a rule, only students studying for the doctor's degree will be admitted in Biology. A course of study leading to the master's degree is not considered sufficient preparation for the development of original investigators, and hence lies outside the scope of graduate instruction in Biology. In the immediate postwar years, students who have been out of school for a number of years may be admitted as Special Graduate Students until they and the Biology Staff have decided upon a change of status. Such a student, later registering for study towards a degree, receives full credit towards that degree for work done as a Special Student. Special Students must reapply for admission to graduate study at the beginning of each academic year. f) The fields in which a student may pursue major work leading towards the doctor's degree in Biology consist at present of:—Animal Physiology, Biochemistry, Bio-organic Chemistry, Biophysics, Embryology, Genetics, Invertebrate Zoology and Plant Physiology. g) One or more minors may be selected from the above list with the addition of Immunology, or in other Divisions of the Institute. The choice of the minor(s) must be approved by the student's advisory committee. h) While the Division of Biology has "departments" of specialization, the student selects one instructor under whose direction he carries on his major study, and not a department. The choice of the staff member with whom the student works is entirely up to the student, except that the staff member is free to refuse to accept him as a student. During the course of graduate study, a student may change his major or minor fields. The initiative in such changes is left to the student himself, but he must secure the approval of his committee.

2. *Advisory Committees.* At the start of his graduate work each student will have an advisory committee consisting of the instructor who supervises his major work, and the members of the Biology Committee on Graduate Study (at present constituted by Drs. Sturtevant, Bonner, and Emerson).

3. *Admission to Candidacy.* To be recommended for admission to Candidacy to the Doctor's Degree by the Division of Biology, the student must satisfactorily pass the appropriate Candidacy examinations and have a satisfactory report from the instructors in charge of the major and minor subjects. Recommendations are made by a vote of the Biology Staff in regular meeting. The Candidacy examinations consist of comprehensive written or oral examinations in four of the following fields including (a) or (b), or both, the selection of which must be approved by the advisory committee:— a) General Botany, b) General Zoology, c) Animal Physiology, d) Biochemistry, e) Bio-organic Chemistry, f) Embryology, g) Genetics, h) Immunology, i) Plant Physiology, j) Biophysics. Each examination will be three hours in length and will usually be given only once a year, usually in the fifth week of the fall term. The student should make application to take the examinations, in whole or in part, at least two weeks before the scheduled date. This application should be made to the Biology Committee on Graduate Study (Dr. Emerson, chairman). Those examinations that are in the student's major and minor fields must be passed with a grade of B or better. For the others a grade of C is accepted as passing. The factual information required is more than that required of undergraduate students selecting the Biology Option, but emphasis will be placed especially on the student's ability to make reasonable inferences and deductions from this information, and to show how it relates to his subjects of specialization. In the field of his major, the student is expected to be informed on current developments and to know the pertinent current literature. Except in the field of his major, the student may, with the consent of his instructor, satisfy the examinations c to i that he selects by passing (with the grades specified above) final examinations in the respective graduate courses, namely:—for c) Bi 260; d) Bi 107; e) Bi 214; f) Bi 220; g) Bi 225; h) Bi 114 and Ch 258; i) Bi 240. In place of one or two of the above examinations, c to i, students may substitute one-fourth or one-half, respectively, of the candidacy examinations re-

quired in the Division of Chemistry, the Division of Physics, or the Division of Geology. A student majoring in another Division and taking a minor in Biology, must pass examinations a or b and that one of c to i that is in the field of his minor. A student who fails any one of these examinations twice will not be allowed to register in the subsequent academic year except with special permission of the Division of Biology. The student must present a written report of his research and an outline of his future plan of work which must be approved by those in charge of his major work before admission to candidacy.

4. *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. Two copies of the candidate's thesis must be submitted at least two weeks before the date of the final examination. The Examining Committee will consist of the instructors in charge of the major and minor work and such other individuals as may be designated by the chairman of the division.

F. OPPORTUNITIES FOR GRADUATE AND SCIENTIFIC WORK AT THE INSTITUTE

I. 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.

Provision is made so that appointees may secure for themselves board in the Athenaeum (see page 75), and when space is available lodging as well. This affords the possibility of contact not only with fellow graduate students but also with others using the Athenaeum, including the Associates of the Institute, distinguished visitors, and members of the professional staffs of the Mount Wilson Observatory, the Huntington Library, and the California Institute.

Students from any university or college who have completed their undergraduate work satisfactorily (see page 131) are eligible to apply for graduate assistantships, scholarships, and fellowships. In the award of such appointments preferred consideration will be given to students who have been accepted as candidates for the degree of Doctor of Philosophy.

Graduate Assistants devote during the school year not more than fifteen hours a week to teaching, laboratory assistance, or research of a character that affords them useful experience. This time includes that required in preparation and in marking note-books and papers, as well as that spent in classroom and laboratory. Of the remaining time at least one-half must be devoted to research, unless otherwise arranged by the division or department concerned; and the obligation to prosecute the research earnestly is regarded as no less binding than that of showing proper interest in the teaching and in the advanced study, which is also pursued so far as time permits.

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.

II. RESEARCH FELLOWSHIPS AND SCHOLARSHIPS

Fellowships and scholarships are available at the Institute to aid men of outstanding ability who desire to pursue research work. Some of these are restricted to men who have received the doctor's degree, while others are given to graduate students working toward advanced degrees.

(A). Post-doctoral Fellowships

1. A number of 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 those administered by the National Research Council, John Simon Guggenheim Memorial Foundation, Commonwealth Fund, American Chemical Society, Lalor Foundation, Bell Telephone Laboratories, E. I. du Pont de Nemours and Company, various national governments, and other agencies.

2. Institute Research Fellowships: The Institute each year appoints as Research Fellows a number of men holding the degree of Doctor of Philosophy who desire to pursue further research work.

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

being similar to those of Guggenheim Fellowships. The stipend varies with the experience of the Fellow.

4. Harry Bateman Research Fellowship: In honor of the late Professor Harry Bateman, the Institute offers a research fellowship in pure mathematics to a candidate holding the doctorate. The recipient will devote the major part of his time to research, but will be expected to teach one upper class course in mathematics. The stipend is $3000 for the academic year, and appointment is normally made for one year, but may be renewed for a second year.

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

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

(B). Predoctoral Scholarships and Fellowships

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

2. Cole Scholarships: The income from the Cole Trust, established by the will of the late Mary V. Cole in memory of her husband, Francis J. Cole, is used to provide three scholarships annually, one in each of the following fields: electrical engineering, mechanical engineering, and physics. The recipients are designated as Cole Scholars.

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

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

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

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

7. Meriden Hunt Bennett Fellowships: These fellowships for graduate students are granted from the Meriden Hunt Bennett Fund as stated on page 98.

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

9. Special Fellowship and Research Funds: A considerable group of governmental units, industrial organizations, and private individuals have contributed funds for the support of Fellows and Assistants engaged in fundamental researches related to their interests and activities. These include Abbot Laboratories, Allied Chemical and Dye

Corporation, American Cancer Society, American Petroleum Institute, American Telephone and Telegraph Company, California Ship Building Corporation, Cancer Research Foundation of California, Carbide and Carbon Chemicals Corporation, Childs Frick Corporation, Consolidated Vultee Aircraft Corporation, Douglas Aircraft Company, Inc., E. I. du Pont de Nemours and Company, Earhart Foundation, Eastman Kodak Company, John G. Ellis, Essick Manufacturing Company, Frasch Foundation, C. B. Gentry Company, Dr. Harriet Allen Heath, Clarence J. Hicks Memorial Fund, Lane Publishing, Eli Lilly and Company, Mr. and Mrs. F. S. Markham, Merck and Company, Charles E. Merrill, National Advisory Committee for Aeronautics, Nutrition Foundation, Inc., Pineapple Producers Cooperative Association, Pioneer Hi-Bred Corn Company, Polymerization Process Corporation, Procter and Gamble Company, Purdue University Corn Research Fund, Radio Corporation of America, Research Corporation, Shell Fellowship Committee, Socony-Vacuum Oil Company, Standard Oil Company of California, Stanolind Oil and Gas Company, Sugar Research Foundation, Texaco Development Corporation, Times-Mirror Company, United States Army (Army Air Forces, Engineer Corps, Ordnance Department, Quartermaster Corps), United States Navy (Bureau of Yards and Docks, Bureau of Ordnance, Office of Naval Research), United States Public Health Service, United States Soil Conservation Service, United States Rubber Company, Alexander B. van Leer, Wescar Investment Company, Western Growers Association, Westinghouse Educational Foundation.

The Rockefeller Foundation Fund for Research on Basic Problems of Biology: 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.

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

III. INSTITUTE GUESTS

Members of the faculties of other educational institutions and Research Fellows already holding the doctor's degree, who desire to carry on special investigations, may be invited to make use of the facilities of the Institute. Arrangement should be made in advance with the chairman of the division of the Institute concerned. Such guests are requested to file a card in the Registrar's office at the beginning of their work, giving Institute and home address, degrees, nature of work planned, etc.

IV. GRADUATE LIFE

The Athenaeum (see page 75) affords opportunity for contact between the Associates of the Institute, distinguished foreign visitors, and members of the staffs and graduate students at the three adjacent institutions, the Mount Wilson Observatory, the Huntington Library and the California Institute. It also provides living quarters for a limited number of men associated with the foregoing institutions.

DESCRIPTION OF THE UNDERGRADUATE AND FIFTH-YEAR COURSES

THE COURSE IN SCIENCE

The course in science prepares for those scientific and engineering professions in which an extensive training in the basic sciences and in research is of more importance than a knowledge of the principles and practice of engineering. Accordingly, the four-year course in science, while including the same historical, literary and economic subjects as the course in engineering, requires much more extended study of the three sciences of chemistry, physics, and mathematics. In its junior and senior years there are offered a series of options which, when supplemented by the corresponding graduate courses, afford definite preparation for various scientific professions, as outlined in the following statement.

The option in chemistry and the option in physics and the graduate courses in chemistry and physics prepare students, on the chemical and physical sides respectively, for research and teaching in universities, colleges, and high schools, and for research positions in governmental laboratories and especially in the reasearch and development departments of the larger chemical, metallurgical, and electrical companies.

The option in applied chemistry and the fifth-year and sixth-year courses in chemical engineering differ from those in chemistry in that they include, in place of some of the science work, general subjects in mechanical and electrical engineering, and (in the fifth year) an extended treatment of chemical engineering itself. This course is designed to fit men for the installation, operation, and the research development of industrial chemical processes.

The geology, paleontology, and geophysics options and the graduate courses in these fields prepare students for teaching and research positions in colleges and universities, for government posts in connection with geological and mining surveys, for places as investigators and field explorers for museums and for professional work as geologists, paleontologists, and geophysicists in the petroleum and mining industries.

The biology option and the graduate course in biology prepare for teaching and research in colleges and universities, for government service in agriculture and public health, and for field studies and laboratory research in connection with museums. The option of the undergraduate course affords a preliminary training, with emphasis on the fundamental sciences, for those who desire to pursue graduate studies in medicine, sanitation, and public health.

THE COURSE IN ENGINEERING

The five-year plan of engineering instruction is based on recognition of the fact that a four-year period of study is inadequate to give satisfactorily the combination of cultural, basic scientific, and engineering studies essential to the highest type of engineer, and to afford at the same time leisure for the development of the physical well-being and human interests of the students. The four-year course trains, more broadly and fundamentally than the engineering courses now given at most institutions, the large proportion of students who study engineering not to make themselves engineering experts in a specialized sense, but to fit themselves to fill satisfactorily administrative positions in the utilities and manufacturing industries, and to serve as operating and constructing engineers in such industries. The fifth-year courses, based on this broad fundamental preparation, and co-ordinated with it so as to constitute a harmonious, unified, five-year period of study, with no sharp breaks between the undergraduate and graduate periods, will afford the more intensive training required by the engineer who is to do creative work in his field.

The four-year course in engineering includes an unusually thorough training in physics and mathematics, and instruction in chemistry and geology; also extended courses, continuing throughout the four years, in humanistic studies, including English writing and speaking, literature, evolutionary science, history of civilization, current social and political problems, and economics; and, finally, those engineering subjects common to all branches of engineering, such as surveying, mechanism, descriptive geometry, machine drawing, applied mechanics, engineering materials, hydraulics, and preliminary courses in civil, mechanical, and electrical engineering.

Laboratory facilities are available for experimental work in hydraulics, thermodynamics, metallography, materials of construction, soil mechanics, and electricity, including a high-voltage laboratory with a maximum rating of one million volts.

The fifth-year courses in civil, mechanical, and electrical engineering, and aeronautics consist mainly of the engineering subjects that are fundamental in these separate branches of engineering. Thus the civil engineering course deals largely with the analysis, design and construction of water systems, sanitation works and structures; the mechanical engineering course, with machine design, steam and gas engineering, and power-plant design and operation; the electrical engineering course with the generation, transmission and utilization of electric power and the communication of intelligence by electrical means; and the aeronautics course with the principles of aerodynamics, the design and construction of airplanes, their engines and instruments. Of all these courses, engineering research or design forms an important part.

SCHEDULES OF THE UNDERGRADUATE COURSES

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

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

KEY TO ABBREVIATIONS

Aeronautics	AE
Applied Chemistry	A Ch
Applied Mechanics	AM
Applied Physics	A Ph
Assembly	As
Astronomy	Ay
Biology	Bi
Chemistry	Ch
Civil Engineering	CE
Drafting and Drawing	D
Economics	Ec
Electrical Engineering	EE
English	En
Geology	Ge
History and Government	H
Hydraulics	Hy
Industrial Design	ID
Languages	L
Mathematics	Ma
Mechanical Engineering	ME
Meteorology (Aerology)	My
Philosophy	Pl
Physical Education	PE
Physics	Ph
Thesis	Th

*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.

**See page 83 for rule regarding excuse from physical education.

FIRST YEAR, ALL OPTIONS

The subjects listed below are taken by all students during their first year. Differentiation into the various options begins in the second year.

		Units per Term 1st	2nd	3rd
Ma 1abc	Plane Analytic Geometry, Differential and some Principles of Integral Calculus (4-0-8)	12	12	12
Ph 1abc	Mechanics, Molecular Physics, Heat, Sound (3-3-6)	12	12	12
Ch 1abc	Inorganic Chemistry, Qualitative Analysis (3-6-3)	12	12	12
En 1abc	English: Reading, Writing and Speaking (3-0-3)	6	6	6
H 1abc	History of European Civilization (3-0-2)	5	5	5
D 1abc	Freehand and Engineering Drafting (0-3-0)	3	3	3
		50	50	50

ASTRONOMY AND ASTROPHYSICS OPTION

(For First Year see above)

(For Second and Third Years see Physics Option, page 176.)

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 106.

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	----
H 10	The Constitution of the United States (1-0-1)	----	----	2
Ay 2 abc	General Astronomy (2-1-5)	8	8	8
Ec 2	General Economics and Economic Problems (3-0-7)	----	----	10
Ph 109 abc	Atomic and Nuclear Physics (3-0-6)	9	9	9
Ph 105 ab	Optics (3-0-6)	9	9	----
Ph 106 ab	Optics Laboratory (0-3-0)	3	3	----
Ph 107	Spectroscopy (3-0-6)	----	----	9
Ph 108	Spectroscopy Laboratory (0-3-0)	----	----	3
EE 60 ab	Electronics and Circuits (3-0-6; 2-3-4)	9	9	----
		49	49	50

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

Pl 1	Philosophy
Pl 4	Ethics
Pl 5	Sociology
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
L 5	French Literature
L 40	German Literature
Ec 48	Introduction to Industrial Relations
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 Since 1789
H 17	The Far West and the Great Plains
H 18	The Old South: A Study in Persistence
H 19	Modern America

BIOLOGY OPTION

(For First Year see page 162.)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 106.

SECOND YEAR*

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)†	12	12	12
Ph 2 abc	Electricity and Optics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ch 12 ab	Analytical Chemistry (2-6-2)	10	10	—
Ge 1 a	Physical Geology (4-1-4)	9	—	—
Bi 1	Elementary Biology (3-3-3)	—	9	—
Bi 2	Genetics (2-4-3)	—	—	9
Bi 3 a	General Botany (2-6-2)	—	—	10
		49	49	49

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
L 32 abc	Elementary German (4-0-6)	10	10	10
Ch 41 abc	Organic Chemistry (3-0-5)	8	8	8
Ch 47	Organic Chemistry Laboratory (0-6-0)	—	—	6
Ch 21 abc	Chemical Principles (4-0-6)	10	10	10
Bi 3 b	General Botany (3-8-2)	13	—	—
Bi 5 ab	Plant Physiology (3-8-2; 2-4-1)	—	13	7
		49	49	49

*Students taking the Biology option are required to take Bi 4 (20 units), Invertebrate and Vertebrate Zoology, at the Marine Laboratory for six weeks starting the Monday following the end of their sophomore year. This course is taken without payment of additional tuition, and living quarters are provided at the Laboratory.

†See page 106 for rule governing comprehensive examinations.

FOURTH YEAR

		1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
Bi 14	Immunology (2-4-4)	10	—	—
Bi 7 ab	Biochemistry (3-4-5)	—	12	12
Ec 2	General Economics and Economic Principles (3-0-7)	10	—	—
Bi 11	Histological Technique (1-3-1)	5	—	—
Bi 12	Histology (1-3-2)	—	6	—
Bi 13	Mammalian Anatomy (1-3-1)	5	—	—
Bi 16 abc	Animal Physiology (2-3-3)	8	8	8
Bi 6	Embryology (2-6-4)	—	12	—
Bi 8	Advanced Genetics (1-6-2)	—	—	9
	Biology Electives**	—	—	9
		49	49	49

*For the list of Humanities electives, see footnote, page 162.

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

Bio-organic Chemistry Laboratory
Biophysics
Biostatistics
Entomology
Invertebrate and Experimental Embryology
Marine Ecology
Paleontology (Ge 1b)

CHEMISTRY OR APPLIED CHEMISTRY OPTIONS

(For First Year see page 162.)

Students of the Chemistry or Applied Chemistry Option whose grade point average (credits divided by units) in the required subjects of their division is less than 1.9 will be admitted to the required chemistry subjects of the following year only with the special permission of the Division of Chemistry and Chemical Engineering.

SECOND YEAR

		Units per Term		
		1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)*	12	12	12
Ph 2 abc	Electricity and Optics (3-3-6)	12	12	12
Ch 12 abc	Analytical Chemistry (2-6-2)	10	10	10
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1 a	Physical Geology (4-1-4)	9	—	—
Bi 1	Elementary Biology (3-3-3)	—	9	—
Bi 2	Genetics (2-4-3)	—	—	9
	or			
Ay 1	Introduction to Astronomy (3-1-5)	—	—	9
		49	49	49

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 3 ab	Current Economic Problems (3-0-3)	6	6	—
Ch 21 abc	Chemical Principles (4-0-6)	10	10	10
Ch 41 abc	Organic Chemistry (3-0-5)	8	8	8
Ch 46 abc	Organic Chemistry Lab. (0-6-0; 1-9-0)	6	6	10
L 32 abc	Elementary German (4-0-6)	10	10	10
		48	48	46

CHEMISTRY OPTION

FOURTH YEAR

		Units per Term		
		1st	2nd	3rd
	Humanities Electives (3-0-6)†	9	9	9
H 5 ab	Current History (1-0-1)	2	2	—
H 10	Constitution of the United States (1-0-1)	—	—	2
Ch 13 ab	Inorganic Chemistry (2-0-4)	6	6	—
Ch 22	Thermodynamic Chemistry (2-0-4)	—	6	—
Ch 29	Colloid and Surface Chemistry (3-0-5)	—	—	8
Ch 16	Instrumental Analysis (0-6-2)	8	—	—
Ch 26 ab	Physical Chemistry Laboratory (0-6-2)	—	8	8
L 35	Scientific German (4-0-6)	10	—	—
	Elective Subjects**	13	17	21
		48	48	48

*See page 106 for rule governing comprehensive examinations.

†For the list of Humanities electives, see footnote, page 162.

**Professional elective subjects include the following: Chemical Research Ch 80-86, Inorganic Chemistry Ch 13c, Radioactivity and Isotopes Ch 27 ab, Photochemistry Ch 30, Advanced Organic Chemistry Ch 48 abc, Advanced Organic Chemistry Laboratory Ch 49 abc, Industrial Chemistry Ch 61 ab, Introduction to Mathematical Physics Ph 5 abc, Biochemistry Bi 7 ab.

APPLIED CHEMISTRY OPTION

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
Ch 16	Instrumental Analysis (0-6-2)	8	—	—
Ch 26 ab	Physical Chemistry Lab. (0-6-2; 0-3-1)	—	8	4
Ch 29	Colloid and Surface Chemistry (3-0-5)	—	—	8
Ch 61 ab	Industrial Chemistry (4-0-8; 2-0-4)	12	6	—
Ch 63 ab	Chemical Engineering Thermodynamics (2-0-4; 4-0-8)	—	6	12
AM 2 abc	Applied Mechanics (3-0-5)	8	8	8
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0)	3	3	—
		48	48	49

*For the list of Humanities electives, see footnote, page 162.

CIVIL ENGINEERING OPTION

(For First Year see page 162)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 106.

SECOND YEAR

		Units per Term 1st		2nd	3rd
Ma 2abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)*	12		12	12
Ph 2abc	Electricity and Optics (3-3-6)	12		12	12
H 2abc	History of the United States (2-0-4)	6		6	6
CE 1	Surveying (2-4-3)	9	or	9	—
ME 3	Materials and Processes (3-3-3)	9	or	9	—
Ge 1a	Physical Geology (4-1-4)	9		—	—
AM 1a	Applied Mechanics (Statics) (3-3-6)	—		—	12
D 2	Descriptive Geometry (0-6-0)	—		6	—
ME 1ab	Empirical Design (0-3-0; 0-6-0)	—		3	6
		48		48	48

THIRD YEAR

		1st	2nd	3rd
En 7abc	Introduction to Literature (3-0-5)	8	8	8
AM 1bcd	Applied Mechanics (Strength of Materials, Dynamics) (3-3-6)	12	12	12
CE 2	Advanced Surveying (2-7-3)	—	—	12
EE 1abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2ab	Basic Electrical Engineering Laboratory (0-3-0)	3	3	—
Ec 2	General Economics and Economic Problems (3-0-7)	—	10	—
Hy 2ab	Hydraulics (3-0-6)	9	9	—
CE 7	Curves and Earthwork (2-0-5)	7	—	—
Ge 110	Engineering Geology (2-3-4)	—	—	9
CE 14a	Engineering Conference (0-4-0)	4	—	—
		49	48	47

*See page 106 for rule governing comprehensive examinations.

CIVIL ENGINEERING OPTION

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
Ec 18	Industrial Organization (3-0-6)	—	9	—
CE 4	Highways & Airports (2-4-4)	—	10	—
CE 6	Transportation Engineering (2-0-4)	6	—	—
CE 8	Route Surveying (0-7-0)	7	—	—
CE 10abc	Theory of Structures (3-3-6; 3-0-6)	12	12	9
CE 12	Reinforced Concrete (3-3-6)	—	—	12
AM 3	Testing Materials Laboratory (1-6-1)	—	—	8
Ec 25	Business Law (3-0-3)	—	—	6
Hy 11	Hydraulic Laboratory (0-6-0)	—	6	—
ME 20	Heat Engineering (3-0-6)	9	—	—
CE 14bc	Engineering Conference (1-0-2; 1-0-1)	3	—	2
		48	48	48

*For the list of Humanities electives, see page 162.

ELECTRICAL ENGINEERING OPTION

(For First Year see page 162)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 106.

SECOND YEAR

		Units per Term 1st		2nd	3rd
Ma 2abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)†	12		12	12
Ph 2abc	Electricity and Optics (3-3-6)	12		12	12
H 2abc	History of the United States (2-0-4)	6		6	6
CE 1	Surveying (2-4-3)	9	or	9	----
ME 3	Materials and Processes (3-3-3)	9	or	9	----
Ge 1a	Physical Geology (4-1-4)	9		----	----
AM 1a	Applied Mechanics (Statics) (3-3-6)	----		----	12
D 2	Descriptive Geometry (0-6-0)	----		6	----
ME 1ab	Empirical Design (0-3-0; 0-6-0)	----		3	6
		48		48	48

THIRD YEAR

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

†See page 106 for rule governing comprehensive examinations.

‡Electrical and mechanical engineering students with scholastic records that warrant the excess load may take Ph 5abc, Introduction to Mathematical Physics (4-0-8) as an alternate for Engineering Mathematics.

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
Ec 2	General Economics and Economic Problems (3-0-7)	10	—	—
Ec 18	Industrial Organization (3-0-6)	—	9	—
Ec 25	Business Law (3-0-3)	—	—	6
EE 6ab	Electrical Machinery (2-0-4; 3-0-6)	—	6	9
EE 7	Electrical Engineering Laboratory (0-6-1)	—	—	7
EE 12	Electric Circuits (4-0-8)	12	—	—
Ph 7abc	Electricity and Magnetism (2-0-4)†	6	6	6
Ph 9	Electrical Measurements (0-6-0)	—	6	—
EE 70ab	Engineering Conference (1-0-1)	2	2	—
AM 3	Materials Testing Laboratory (1-6-1)	8	—	—
EE 62ab	Electron Tubes (2-3-5)	—	10	10
		49	50	49

*For the list of Humanities electives, see page 162.

†Electrical engineering students who have completed Ph 5abc will, as an alternate for Ph 7abc, take the following:

Ph 8	Electricity and Magnetism (3-0-6)	9	—	—
EE 15ab	High Frequency Circuits (2-0-4; 0-3-3)	—	6	6
		52	50	49

GEOLOGICAL SCIENCES OPTION

(For First Year see page 162)

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

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 ab	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)*	12	12	----
Ph 2 abc	Electricity and Optics (3-3-6)	12	12	12
Ch 11	Qualitative Chemical Analysis (2-6-2)	----	----	10
H 2 abc	History of the United States (2-0-4)	6	6	6
CE 1	Surveying (2-4-3)	9	----	----
Ge 1 a	Physical Geology (4-1-4)	9	----	----
Bi 1	Elementary Biology (3-3-3)	----	9	----
Ge 3 ab	Mineralogy (3-3-2; 3-6-1)	----	8	10
	Options A and B†			
Ge 1 b	Elementary Paleontology (4-1-4)	----	----	9
		48	47	47
	Option C			
Ma 2 c	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)	----	----	12
		48	47	50

*See page 106 for rule governing comprehensive examinations.

†Students taking Option B are required to take Bi 4 (20 units) Invertebrate and Vertebrate Zoology, at the Marine Laboratory for six weeks starting the Monday following the end of their sophomore year. This course is taken without payment of additional tuition, and living quarters are provided at the Laboratory.

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

GEOLOGICAL SCIENCES OPTION

THIRD YEAR*

		Units per Term 1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
CE 3	Plane Table Surveying (1-6-1)	8	----	----
Ge 4 ab	Petrology (2-3-1; 2-4-2)	6	8	----
Ge 1 c	Historical Geology (4-2-6)	----	12	----
Ge 107	Stratigraphy (4-2-6)	----	----	12
Ge 21 abc	Introduction to Field Geology (2-7-1; 2-7-1; 0-7-3)	10	10	10
Ge 175	Introduction to Applied Geophysics (3-0-3)	6	----	----
Ge 176	Elementary Seismology (3-0-3)	----	----	6
Ge 102	Oral Presentation (1-0-0)	1 or	1	----
	Option A			
Ch 24 ab	Physical Chemistry (4-0-6)	10	10	----
Ge 14	Geologic Illustration (0-3-2)	----	----	5
D 5	Descriptive Geometry (0-6-0)	----	----	6
		49	49	47
	Option B			
Ge 111 ab	Invertebrate Paleontology (2-6-2)	10	10	----
Ge 14	Geologic Illustration (0-3-2)	----	----	5
D 5	Descriptive Geometry (0-6-0)	----	----	6
		49	49	47
	Option C			
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 abc	Basic Electrical Engineering Laboratory (0-3-0)	3	3	3
		48	48	45

*Spring Field Trip, Ge 122, 1 unit, required in third and fourth years. Summer Field Geology, Ge 123, 12 units, required after third and fourth years.

GEOLOGICAL SCIENCES OPTION

FOURTH YEAR*

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)†	9	9	9
H 5 ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
Ec 2	General Economics and Economic Problems (4-0-6)	—	—	10
Ge 100	Geology Club (1-0-0)	1	1	1
Ge 109	Structural Geology (4-0-6)	10	—	—
	*Option A***			
Ge 105	Optical Mineralogy (2-6-2)	10	—	—
Ge 106 ab	Petrography (2-6-2)	—	10	10
Ge 111 ab	Invertebrate Paleontology (2-6-2)	10	10	—
Ge 121 ab	Field Geology (1-9-0; 0-6-4)	—	10	10
	and *either*			
L 32 abc	Elementary German (4-0-6)	10	10	10
	or			
Ge 126	Geomorphology (4-0-6)	10	—	—
Ge 128	Introduction to Economic Geology (4-0-3)	—	7	—
Ge 125	Geology of Western America (4-0-3)	—	—	7
		52	49 or 52	49 or 52
	*Option B***			
Bi 6	Embryology (2-6-4)	—	12	—
Ge 115	Micropaleontology (1-3-4)	8	—	—
Ge 121 ab	Field Geology (0-10-0; 1-5-4)	10	10	—
Ge 112 ab	Vertebrate Paleontology (2-6-2)	—	10	10
	and *either*			
L 32 abc	Elementary German (4-0-6)	10	10	10
	or			
Ge 126	Geomorphology (4-0-6)	10	—	—
Ge 128	Introduction to Economic Geology (4-0-3)	—	7	—
Ge 125	Geology of Western America (4-0-3)	—	—	7
		50	51 or 54	39 or 42
	Option C			
Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	15
L 32 abc	Elementary German (4-0-6)	10	10	10
Ge 128	Introduction to Economic Geology (4-0-3)	—	7	—
Ge 165	Introduction to General Geophysics I (2-0-4)	—	6	—
		47	50	47

*Spring Field Trip, Ge 122, 1 unit, required in third and fourth years. Summer Field Geology, Ge 123, 12 units, required after third and fourth years.

**Those Option A and Option B students who intend to go on to graduate work, either at the California Institute or at other institutions should take L 32 abc, since Ge 126, 128, and 125 may be taken at the graduate level. It is recommended that those who expect to terminate their education with the B.S. degree take Ge 126, 128, and 125 in the senior year.

†For the list of Humanities electives, see page 162.

MATHEMATICS OPTION

(For First Year see page 162)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller *statement of this regulation will be found on page 106.*

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)*	12	12	12
Ph 2 abc	Electricity and Optics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
Ge 1 a	Physical Geology (4-1-4)	9	----	----
Bi 1	Elementary Biology (3-3-3)	----	9	----
Ay 1	Introduction to Astronomy (3-1-5)	----	----	9
Ma 3	Theory of Equations (4-0-6)	10	----	----
Ma 16	Matrices and Quadratic Forms (4-0-6)	----	10	----
	Schedule A (1948-49, and alternate years thereafter)			
Ma 10	Differential Equations (4-0-6)	----	----	10
	Schedule B (1947-48, and alternate years thereafter)			
Ma 4	Geometry (4-0-6)	----	----	10
		49	49	49

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ec 3 ab	Current Economic Problems (3-0-3)	6	6	----
Ph 6 ab	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	----
Ph 5 c	Introduction to Mathematical Physics (4-0-8)	----	----	12
L 32 abc	Elementary German (4-0-6)	10	10	10
Ma 8 abc	Advanced Calculus (4-0-5)	9	9	9
	Schedule A (1947-48, and alternate years thereafter)			
Ma 4	Geometry (4-0-6)	----	----	10
	Schedule B (1948-49, and alternate years thereafter)			
Ma 10	Differential Equations (4-0-6)	----	----	10
		48	48	49

*See page 106 for rule governing comprehensive examinations.

MATHEMATICS OPTION

FOURTH YEAR

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
L 35	Scientific German (4-0-6)	10	—	—
L 1 ab	Elementary French (4-0-6)	—	10	10
Ma 12	Elementary Statistics (3-0-6)	9	—	—
Ma 111	Elementary Theory of Tensors (3-0-6)	9	—	—
	Approved Mathematics Electives	9	27	27
		48	48	48

*For the list of Humanities electives, see footnote, page 162.

MECHANICAL ENGINEERING OPTION

(For First Year see page 162)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 106.

SECOND YEAR

		Units per Term 1st	2nd	3rd
Ma 2 abc	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8)*	12	12	12
Ph 2 abc	Electricity and Optics (3-3-6)	12	12	12
H 2 abc	History of the United States (2-0-4)	6	6	6
CE 1	Surveying (2-4-3)	9 or	9	---
ME 3	Materials and Processes (3-3-3)	9 or	9	---
Ge 1 a	Physical Geology (4-1-4)	9	---	---
AM 1 a	Applied Mechanics (Statics) (3-3-6)	---	---	12
D 2	Descriptive Geometry (0-6-0)	---	6	---
ME 1 ab	Empirical Design (0-3-0; 0-6-0)	---	3	6
		48	48	48

THIRD YEAR

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

FOURTH YEAR

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

*See page 106 for rule governing comprehensive examinations.

†Electrical and mechanical engineering students with scholastic records that warrant the excess load may take Ph 5 abc, Introduction to Mathematical Physics (4-0-8) as an alternate for Engineering Mathematics.

‡For the list of Humanities electives, see footnote, page 162.

PHYSICS, APPLIED PHYSICS, OR ASTROPHYSICS OPTION

(For First Year see page 162)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue the work of that option. A fuller statement of this regulation will be found on page 106.

SECOND YEAR

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

THIRD YEAR

		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5)	8	8	8
Ch 21 abc	Chemical Principles (4-0-6)	10	10	10
Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)	15	15	15
EE 1 abc	Basic Electrical Engineering (2-0-4)	6	6	6
EE 2 b	Basic Electrical Engineering Laboratory (0-3-0)	—	3	—
Ma 8 abc	Advanced Calculus (4-0-5)	9	9	9
		48	51	48

PHYSICS OPTION

FOURTH YEAR (1947-1948)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)**	9	9	9
H 5 ab	Current History (1-0-1)	2	2	—
H 10	The Constitution of the United States (1-0-1)	—	—	2
L 32 abc	Elementary German (4-0-6)†	10	10	10
Ph 9	Electrical Measurements (0-6-0)	6	—	—
Ph 10	High Frequency Measurements (0-6-2)	—	8	—
Ph 101 abc	Electricity and Magnetism (3-0-6; 4-0-8)	9	9	12
EE 12	Electric Circuits (4-0-8)	12	—	—
EE 62 a	Electron Tubes (2-3-5)	—	10	—
Ma 57	Introduction to Analysis (5-0-10)†	—	—	15
		48	48	48

*See page 106 for rule governing comprehensive examinations.

**For the list of Humanities electives, see footnote page 162.

†*Students who plan no Ph.D. work may substitute Ph 109* abc Atomic and Nuclear Physics or Ph 103 abc Analytical Mechanics for L 32 abc; and EE 62 b Electron Tubes and EE 200 Advanced Work in Electrical Engineering for Ma 57.

FOURTH YEAR (1948-1949)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	---
H 10	The Constitution of the United States (1-0-1)	---	---	2
Ec 2	*General Economics and Economic Problems* (3-0-7)	---	10	---
Ph 109 abc	Atomic and Nuclear Physics (3-0-6)	9	9	9
Ph 101 abc	Electricity and Magnetism (3-0-6)	9	9	9
Ph 113	Principles of Quantum Mechanics (3-0-6)	---	---	9
Ph 9 ab	Electrical Measurements (0-3-0)	3	3	---
EE 60 abc	Electronics and Circuits (3-0-6; 2-3-4; 2-3-4)	9	9	9
Ma 12	Elementary Statistics (3-0-6)	9	---	---
		50	51	47

*For the list of Humanities electives, see footnote, page 162.

APPLIED PHYSICS OPTION

FOURTH YEAR (1947-1948)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	----
H 10	The Constitution of the United States (1-0-1)	----	----	2
Ph 8	Electricity and Magnetism (3-0-6)	9	----	----
Ph 9	Electrical Measurements (0-6-0)	----	6	----
Ph 109 abc	Atomic and Nuclear Physics (3-0-6)	9	9	9
AM 2 abc	Applied Mechanics (3-0-5)	8	8	8
EE 12	Electric Circuits (4-0-8)	12	----	----
EE 15 ab	High Frequency Circuits (2-0-4; 0-3-3)	----	6	6
EE 62 ab	Electron Tubes (2-3-5)	----	10	10
EE 200	Advanced Work in Electrical Engineering (0-6-0)	----	----	6
		49	50	50

FOURTH YEAR (1948-1949)

		1st	2nd	3rd
	Humanities Electives (3-0-6)*	9	9	9
H 5 ab	Current History (1-0-1)	2	2	----
H 10	The Constitution of the United States (1-0-1)	----	----	2
Ec 2	General Economics and Economic Problems (3-0-7)	----	----	10
Ph 8	Electricity and Magnetism (3-0-6)	9	----	----
Ph 9 ab	Electrical Measurements (0-3-0)	3	3	----
AM 2 abc	Applied Mechanics (3-0-5)	8	8	8
EE 60 abc	Electronics and Circuits (3-0-6; 2-3-4; 2-3-4)	9	9	9
EE 15 ab	High Frequency Circuits (2-0-4; 0-3-3)	----	6	6
Ec 25	Business Law (3-0-3)	----	----	6
Ph 109 ab	Nuclear Physics (3-0-6)	9	9	----
		49	46	50

ASTRONOMY AND ASTROPHYSICS OPTION

(First three years same as Physics Option.
For Fourth Year see page 162.)

*For the list of Humanities electives, see footnote, page 162.

SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

AERONAUTICS

FIFTH YEAR

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

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

JET PROPULSION

FIFTH YEAR

		Units per Terms 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
AE 251 abc	Aerodynamics of the Airplane (3-0-6)	9	9	9
AE 257 abc	Engineering Mathematical Principles (3-0-6)**	9	9	9
AE 258 abc	Introductory Mechanics and Thermodynamics of Fluids (3-0-6)	9	9	9
AE 281 abc	Jet Propulsion Systems (4-0-8)	12	12	12
AE 282 abc	Jet Propulsion Laboratory (0-3-0)	3	3	3
AE 290 abc	Aeronautical Seminar (1-0-0)	1	1	1
		52 or 53	52 or 53	52 or 53

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

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

H 100	Seminar in International Problems
En 100	English Literature
Pl 100	Philosophy
Ec 100	Business Economics
Ec 110	Introduction to Industrial Relations

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

†See page 96 for extra fee for this option.

AERONAUTICS

SIXTH YEAR

(Leading to the professional degree of Aeronautical Engineer)

		Units per Term 1st	2nd	3rd
AE 260 abc	Aeronautics Research	15	15	15
AE 266 abc	Theoretical Aerodynamics of Real and Perfect Fluids (3-0-6)	9	9	9
AE 270 abc	*Elasticity Applied to Aeronautics* (2-0-4)	6	6	6
AE 272 abc	Precision Measurements (1-0-2)	3	3	3
AE 290 abc	Aeronautical Seminar (1-0-0)	1	1	1
	Electives as below	16	16	16
		50	50	50

Structures Option

AE 254 abc	Advanced Problems in Airplane Design (2-0-2)	4	4	4
AE 271 abc	Vibration and Flutter Problems (2-0-4)	6	6	6
AE 273 abc	Photoelasticity and Structural Testing Methods (2-0-4)	6	6	6
		16	16	16

Aerodynamics and Compressibility Option

AE 261 abc	Hydrodynamics of Compressible Fluids (3-1-6)	10	10	10
AE 265 abc	Advanced Problems in Aerodynamics (2-0-4)	6	6	6
		16	16	16

JET PROPULSION*

SIXTH YEAR

(Leading to the degree of Aeronautical Engineer—Jet Propulsion)

		Units per Terms 1st	2nd	3rd
AE 260 abc	Aeronautics Research	15	15	15
AE 265 abc	Advanced Problems in Aerodynamics (2-0-4)	6	6	6
AE 270 abc	Elasticity Applied to Aeronautics (2-0-4)	6	6	6
AE 280 abc	Materials and Chemistry Problems in Jet Propulsion (2-0-4)	6	6	6
AE 281 abc	Jet Propulsion Systems (4-0-8)	12	12	12
AE 282 abc	Jet Propulsion Laboratory (0-3-0)	3	3	3
AE 290 abc	Aeronautical Seminar (1-0-0)	1	1	1
		49	49	49

*See page 96 for extra fee. If AE 281 and AE 282 have previously been taken in the 5th year, other 6th year courses may be substituted.

ASTRONOMY AND ASTROPHYSICS OPTION

FIFTH YEAR

As nearly all Astronomy and Astrophysics majors work for the doctor's degree, no specific graduate curricula have been outlined. Instead each student arranges his program in consultation with the members of his division, selecting from the courses of instruction offered in Astronomy and Astrophysics, Physics, Mathematics, Chemistry, Meteorology, etc. In general, students with special interests in observational and applied astrophysics will carry different programs from students interested primarily in theoretical astrophysics. All are required to acquire the working knowledge of mathematics, physics and chemistry necessary for an understanding of and effective work in present-day astrophysics. Among the courses recommended for this purpose are the following:

Ph 103 abc	Analytical Mechanics
Ph 101 abc	Electricity and Magnetism
Ph 113 ab	Principles of Quantum Mechanics
Ph 236 abc	Theory of Relativity
Ph 211	Thermodynamics
Ph 223	Theory of Electromagnetic Waves
Ph 225	Theory of Electrons
Ph 226, 228, 229	Quantum Mechanics
Ma 114 abc	Mathematical Analysis
Ma 255 abc	Methods of Mathematical Physics
Ma 12	Elementary Statistics
Ch 130	Photochemistry
Ch 234	Introduction to the Spectra of Molecules
EE 65	Electronics Laboratory
EE 62 ab	Electron Tubes

BIOLOGY

As nearly all Biology majors are working for the doctor's degree and following programs arranged by the student in consultation with members of the Division, no specific graduate curricula can be outlined. The professional degree is not given in Biology.

CHEMISTRY

FIFTH YEAR

(Leading to the degree of Master of Science in Chemistry. The professional degree is not given in Chemistry.)

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

The Humanities requirement for a master's degree will be found on page 179. Candidates who have not had courses substantially equivalent to Inorganic Chemistry Ch 113 ab, Thermodynamic Chemistry Ch 122 ab, and Surface and Colloid Chemistry Ch 129, must take these courses. In addition not less than 30 units of courses of science subjects chosen from fifth-year and advanced courses and not less than 40 units of Chemical Research must be offered for the master's degree.

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

CHEMICAL ENGINEERING

FIFTH YEAR

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

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

Elective subjects approved by a member of the Division to be chosen from advanced subjects in Chemistry, Chemical Engineering, Physics, Mathematics and Mechanical Engineering, or from the following subjects: Ma 10 Differential Equations, AM 15 Engineering Mathematics, ME 5 Machine Design, ME 10 Metallurgy.

SIXTH YEAR

(Leading to the professional degree of Chemical Engineer)

Programs are selected from a comprehensive list of available subjects and are arranged by the student in consultation with members of the Division. At least half of the student's time will be spent on research.

*For the list of Humanities Electives, see footnote, page 179.

CIVIL ENGINEERING

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
Ec 100 abc	Business Economics (4-0-6)	10	10	10
CE 120 a	Statically Indeterminate Structures (4-3-5)	12	—	—
CE 121 abc	Structural and Civil Engineering Design (0-12-0; 0-9-0)	12	9	9
CE 125	Irrigation and Water Supply (4-0-8)	—	—	12
CE 126	Masonry Structures (2-3-4)	—	9	—
CE 127	Sewerage and Sewage Treatment (2-3-4)	—	—	9
AM 115 abc	Engineering Mathematics (3-0-6)	9	9	9
AM 105 ab	Soil Mechanics (2-0-4; 1-3-2)	6	6	—
CE 130 abc	Engineering Seminar (1-0-1)	2	2	2
	Research or Thesis as arranged	—	5	—
		51	50	51

SUPPLEMENTARY SUBJECTS*

CE 120 bc	Statically Indeterminate Structures (2-0-4)	—	6	6
CE 122	Earthquake Effects upon Structures	—	—	—
CE 131	Sewage Treatment Plant Design	—	—	—
CE 132	Water Power Plant Design	—	—	—
CE 133	Water Treatment Plant Design	—	—	—
CE 134	Ground Water Investigations	—	—	—
CE 135	Geodesy and Precise Surveying	—	—	—
CE 136	Irrigation Investigations	—	—	—
CE 141	Structural Engineering Research	—	—	—
CE 142	Sanitation Research	—	—	—
CE 143	Highway Research	—	—	—
CE 144	Airport Design	—	—	—
CE 150	Foundations (2-3-4)	—	—	9
Ge 110	Engineering Geology (2-3-4)	—	—	9
AM 110 a	Introduction to the Theory of Elasticity (2-0-4)	6	—	—
AM 110 b	Theory of Plates and Shells (2-0-4)	—	6	—
AM 110 c	Mechanics of Materials (2-0-4)	—	—	6
AE 270 abc	Elasticity Applied to Aeronautics (2-0-4)	6	6	6
Hy 100	Hydraulics Problems	—	—	—
Hy 101 ab	Advanced Fluid Mechanics (2-0-4; 3-0-6)	—	6	9
My 105	Climatology (2-0-2)	—	—	4
My 201 abc	Weather Forecasting and Practice (3-0-6; 2-0-4)	9	9	6

SIXTH YEAR

(Leading to the professional degree of Civil Engineer)

Programs are arranged by the student in consultation with members of the Department.

Note: No deviations from the prescribed 5th-year work will be permitted unless the student has had equivalent work in one or more of the subjects listed under the above 5th-year curriculum, in which case courses may be elected from the supplementary subjects.

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

ELECTRICAL ENGINEERING

FIFTH YEAR

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

		Units per Terms 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
EE 120 abc	Advanced Electric Power System Analysis (4-0-8)	12	12	12
EE 121 abc	Alternating Current Laboratory (0-6-0)	6	6	6
EE 158 abc	Circuit Analysis (3-0-6)	9	9	9
		36 or 37	36 or 37	36 or 37
	Electives	12	12	12

SIXTH YEAR

(Leading to the professional degree of Electrical Engineer)

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

*For the list of Humanities Electives, see footnote, page 179.

GEOLOGICAL SCIENCES

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
Ge 100	Geology Club	1	1	1
Ge 102	Oral Presentation	1	or 1	----
Ge 295	Master's Thesis Research (units and subject by arrangement)			
	Elective units from groups A and B below to total	50	50	50

A. Geology and Paleontology

FIFTH AND SIXTH YEARS

(Leading to the degree of Geological Engineer)

		Units per Term 1st	2nd	3rd
Ge 105	Optical Mineralogy	10	----	----
Ge 106 ab	Petrography	----	10	10
Ge 107	Stratigraphy	----	----	12
Ge 109	Structural Geology	10	----	----
Ge 110	Engineering Geology	----	----	9
Ge 111 ab	Invertebrate Paleontology	10	10	----
Ge 112 ab	Vertebrate Paleontology	----	10	10
Ge 115	Micropaleontology	8	----	----
Ge 121 ab	Field Geology	10 &/or	10 &/or	10
Ge 122	Spring Field Trip	----	----	1
Ge 123	Summer Field Geology	----	----	12
Ge 125	Geology of Western America	----	----	7
Ge 126	Elementary Geomorphology	10	----	----
Ge 128	Introduction to Economic Geology	----	7	----
Ge 200	Mineragraphy	10	----	----
Ge 202	Metalliferous Deposits	----	10	----
Ge 209	Sedimentary Petrology**	----	8	----
Ge 210	Metamorphic Petrology†	----	8	----
Ge 211	Petrology (Seminar)	----	----	5
Ge 212	Non-metalliferous Deposits	----	----	10
Ge 213	Mineral Deposits (Seminar)	----	5	----
Ge 215	Mineralogy (Seminar)	5	----	----
Ge 220	History of the Geological Sciences (Summer reading)	----	----	5
Ge 226	Advanced Geomorphology†	10	----	----
Ge 228	Geomorphology of Arid Regions**	----	10	----
Ge 229	Glacial Geomorphology†	----	10	----
Ge 230	Geomorphology (Seminar)	----	----	5
Ge 232	Petroleum Geology	10	----	----
Ge 233	Petroleum Geology Practices	----	10	----
Ge 235	Petroleum Geology (Seminar)	----	----	5
Ge 237	Tectonics	----	----	10
Ge 238	Structural Geology (Seminar)	5	----	----
Ge 245 ab	Vertebrate Paleontology (Seminar)	----	5	5

*For the list of Humanities Electives, see footnote, page 179.

**1947-1948

†1948-1949

		Units per Term 1st	2nd	3rd
Ge 248	Fossils of the California Tertiary	—	5	—
Ge 249	Stratigraphy of the Coast Ranges	—	—	5
Ge 250	Invertebrate Paleontology (Seminar)	5	—	—
Ge 295	Master's Thesis Research (units by arrangement)	—	—	—
Ge 297	Advanced Study (units and subject by arrangement)	—	—	—
Ge 299	Research (units and subject by arrangement)	—	—	—

B. GEOPHYSICS

FIFTH AND SIXTH YEARS

(Leading to the degree of Geophysical Engineer)

		Units per Term 1st	2nd	3rd
Ge 165	Introduction to General Geophysics I*	—	6	—
Ge 166	Introduction to General Geophysics II**	—	6	—
Ge 175	Introduction to Applied Geophysics	6	—	—
Ge 176	Elementary Seismology	—	—	6
Ge 261	Theoretical Seismology*	6	—	—
Ge 262	Interpretation of Seismograms of Teleseisms*	—	4	—
Ge 263	Field Work in Earthquake and Interpretation of Seismograms of Local Earthquakes*	—	—	4
Ge 273	Applied Geophysics I**	5	—	—
Ge 274 ab	Applied Geophysics II**	5	5	—
Ge 275 ab	Applied Geophysics III*	5	5	—
Ge 278	Interpretation of Field Seismograms**	—	4	—
Ge 279	Laboratory and Field Work in Electrical Methods of Prospecting**	—	7	—
Ge 280	Laboratory and Field Work in Gravitational and Magnetic Methods of Prospecting*	—	7	—
Ge 282 abc	Geophysics (Seminar)	1	1	1
Ge 297	Advanced Study (units and subject by arrangement)	—	—	—
Ge 299	Research (units and subject by arrangement)	—	—	—
CE 2	Advanced Surveying	—	—	12
CE 122	Earthquake Effects Upon Structures (units by arrangement)	—	—	—
EE 1 abc	Basic Electrical Engineering	6	6	6
EE 2 abc	Basic Electrical Engineering Laboratory	3	3	3
EE 156	Electrical Communication	6	—	—
EE 62 ab	Electron Tubes	—	10	10
Ma 98 abc	Advanced Calculus	6	6	6
Ma 60	Mathematical Probability and Statistics	9	—	—
Ph 9	Electrical Measurements	6	or 6	—
Ph 92 abc	Introduction to Mathematical Physics	10	10	10
Ph 101 abc	Electricity and Magnetism	9	9	9

*1947-1948
**1948-1949

INDUSTRIAL DESIGN

FIFTH YEAR

(The master's degree is not given in the Industrial Design Option)

		Units per Term 1st	2nd	3rd
ID 101 abc	Industrial Design I (2-9-4)	15	15	15
ID 111 abc	Experimental Laboratory (0-8-0)	8	8	8
ID 121 abc	Design Techniques I (0-3-0)	3	3	3
ID 131	Design Trends (1-0-2)	----	3	----
ID 141 abc	Non-Metallic Materials (3-0-6)	9	9	9
ID 151	Cost Analysis (2-0-3)	----	----	5
ID 161	History of Art (1-0-2)	3	----	----
ID 171 abc	Weekly Seminar (1-0-0)	1	1	1
Ec 100 abc	Business Economics (4-0-6)	10	10	10
		49	49	51

Elective for some students:

ME 3 Materials and Processes (3-3-3)

SIXTH YEAR

(Leading to the professional degree of Industrial Designer)

ID 201 abc	Industrial Design II (Thesis) (2-15-4)	21	21	24
ID 211 abc	Production Methods (1-6-1)	8	8	8
ID 221 abc	Design Techniques II (0-7-0; 0-4-0)	7	7	4
ID 231 abc	Technical Trends in Design (2-0-4)	6	6	6
ID 241 abc	Merchandising Analysis (2-3-4)	9	9	9
ID 271 abc	Weekly Seminar (1-0-0)	1	1	1
		52	52	52

MATHEMATICS

As nearly all mathematics majors are working for the doctor's degree and following programs arranged by the student in consultation with members of the Division, no specific graduate curricula can be outlined. The professional degree is not given in mathematics.

MECHANICAL ENGINEERING

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
ME 101 ab	Advanced Machine Design (2-6-2)	—	10	10
ME 105	Mechanical Vibrations (4-0-8)	12	—	—
ME 110	Physical Metallurgy (4-0-8)	12	—	—
ME 115 ab	Thermodynamics (3-0-6; 2-0-4)	—	9	6
ME 125 abc	Engineering Laboratory (2-6-4)	12	12	12
ME 150 abc	Mechanical Engineering Seminar (1-0-1)	2	2	2
Hy 101 ab	Advanced Fluid Mechanics (2-0-4; 3-0-6)	—	6	9
		47 or 48	48 or 49	48 or 49

Note: Students who have not had a course in Advanced Engineering Mathematics, Advanced Calculus, or the equivalent in their undergraduate work should substitute AM 115 abc for the equivalent amount of professional work. Engineering Laboratory is required of candidates for advanced degrees.

Note: All candidates for advanced degrees are required to take Engineering Laboratory. Students who plan advanced study past the fifth year, and who have had AM 115 abc or an equivalent course in their undergraduate work may substitute one of the following courses for professional courses, subject to the approval of the Mechanical Engineering Department:

EE 226 abc Engineering Mathematical Physics
AE 257 abc Engineering Mathematical Principles

*For the list of Humanities Electives, see footnote, page 179.

MECHANICAL ENGINEERING

SIXTH YEAR

(Leading to the professional degree of Mechanical Engineer)

Specific requirements for the professional degree of Mechanical Engineer are given on page 137. The following list will suggest possible subjects from which a program of study may be organized:

ME 200	Advanced Work in Mechanical Engineering
ME 206	Vibrations Laboratory
ME 210 abc	Science of Metals
ME 211 abc	Metallography Laboratory
ME 215	Internal Combustion Engines
ME 216 ab	Refrigeration and Air Conditioning
ME 217 ab	Steam and Gas Turbines
ME 218 ab	Aircraft Power Plants
ME 219	Experimental Background of Engine Research
ME 220	Lubrication
ME 300	Thesis—Research
Hy 200	Advanced Work in Hydraulic Engineering
Hy 201 abc	Hydraulic Machinery
Hy 202 ab	Hydraulics of Free Surface Phenomena
Hy 203	Cavitation Phenomena
Hy 210 ab	Hydrodynamics of Sediment Transportation
Hy 300	Thesis
AE 261 abc	Hydrodynamics of Compressible Fluids
AE 266 abc	Theoretical Aerodynamics of Real and Perfect Fluids
AE 267	Turbulence
AE 270 abc	Elasticity Applied to Aeronautics
Ch 63 ab	Chemical Engineering Thermodynamics
Ch 227 abc	The Structure of Crystals
Ch 229	Diffraction Methods of Determining the Structure of Molecules
Ch 262 ab	Thermodynamics of Multi-Component Systems
Ph 211	Thermodynamics

METEOROLOGY*

FIFTH YEAR

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

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)**	9 or 10	9 or 10	9 or 10
My 201 abc	Weather Forecasting and Practice (3-0-6; 3-0-6; 2-0-4)	9	9	6
My 202 abc	Meteorology Laboratory (0-15-0)	15	15	15
My 203 abc	Meteorological Instruments and Observations (1-3-0)	4	4	4
My 207 ab	Meteorological Thermodynamics and Kinematics (1-0-2) (2-0-4)	3	6	—
My 208	Oceanography (1-0-2)	—	—	3
My 230 abc	Seminar	1	1	1
My 240 abc	Research (and/or electives)	—	6	8
My 105	Climatology (2-0-2)	—	—	4
AM 115a	Engineering Mathematics† (3-0-6)	9	—	—
		50 or 51	50 or 51	50 or 51

SIXTH YEAR

(Leading to the professional degree of Meteorologist)

		1st	2nd	3rd
My 251 abc	Extended Forecasting, Theory and Practice (3-0-6; 2-0-4; 2-0-4)	9	6	6
My 252 abc	Advanced Meteorology Laboratory (0-15-0)	15	15	15
My 203 bc	Meteorological Instruments and Observations (1-3-0)	—	4	4
My 230 abc	Seminar	1	1	1
My 240 abc	Research	4	9	12
My 255	Climatology (2-0-4)	6	—	—
My 257 abc	Dynamical Meteorology (2-0-4)	6	6	6
My 258	Meteorological Statistics (3-0-6)	—	9	—
My 259	Applied Meteorology (2-0-4)	—	—	6
Ma 12	Elementary Statistics (3-0-6)	9	—	—
		50	50	50

*For extra fee see page 96.

**For the list of Humanities Electives, see footnote page 179.

†9 units graduate credit. Fifth-year students who expect to take sixth year work leading to the professional degree must elect Ph 92 abc (5-0-10) Introduction to Mathematical Physics (10 units allowed Graduate Students) in place of AM 115a, My 203 bc, and My 240 abc.

PHYSICS

FIFTH YEAR

(Leading to the degree of Master of Science in Physics. The professional degree is not given in Physics.)

		Units per Term 1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6)*	9 or 10	9 or 10	9 or 10
Ph 103 abc	Analytical Mechanics (4-0-8)	12	12	12
	Electives as below	27	27	27
		48 or 49	48 or 49	48 or 49
Ph 92 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10)**	10	10	10
Ph 101 abc	Electricity and Magnetism (3-0-6)***	9	9	9
Ph 105 ab	Optics (3-0-6)	9	9	—
Ph 106 ab	Optics Laboratory (0-3-0)	3	3	—
Ph 107	Spectroscopy (3-0-6)	—	—	9
Ph 108	Spectroscopy Laboratory (0-3-0)	—	—	3
Ph 109 abc	Atomic and Nuclear Physics (3-0-6)	9	9	9
Ph 110 ab	Kinetic Theory of Matter (3-0-6)	9	9	—
Ph 113 a	Principles of Quantum Mechanics (3-0-6)	—	—	9
Ph 117 ab	X-Rays (3-0-6)	9	9	—
Ph 119	History of Modern Physics (3-0-6)	9	—	—
Ma 98 abc	Advanced Calculus (3-0-6)†	6	6	6
Ma 114 abc	Mathematical Analysis (4-0-8)	12	12	12

*For the list of Humanities Electives, see footnote, page 179.

**Prerequisite for most other fifth-year courses. Two-thirds credit allowed graduate students.

***Students who have not had Ph 101 abc may substitute it for Ph 103 abc.

(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. Those who have taken Ph 101 abc and Ph 109 abc as undergraduates may take L 32 abc (4-0-6) Elementary German, and EE 62 ab (2-3-5) Electron Tubes, for credit toward a master of science degree.)

†Prerequisite for Ma 114. Two-thirds credit allowed graduate students.

SUBJECTS OF INSTRUCTION

AERONAUTICS

FIFTH YEAR AND ADVANCED SUBJECTS

AE 251 abc. **Aerodynamics of the Airplane.** 9 units (3-0-6); each term.
Prerequisites: AM 15 abc, Hydraulics.
Airfoil lift, drag and moment characteristics. Boundary layers. Effects of compressibility. Calculation of spanwise lift distribution on finite wings. Performance of complete airplane. Static stability. Dynamic stability. Maneuverability.

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

AE 252 abc. **Airplane Design.** 9 units (2-1-6); each term.
Prerequisites: Applied Mechanics, Strength of Materials, and Machine Design.
The solution of problems connected with the structural design and analysis of airplane structural components. Special emphasis is placed on the problems dealing with monocoque construction. A modern airplane is considered and the key structural elements are designed and analysed.

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

AE 253 abc. **Design of Aircraft Components.** 4 units (2-0-2); each term.
A study of the non-structural components of airplanes including control and flap systems, landing gears, power plants, electrical, radio, and instrument installations, heating and ventilating problems, hydraulic systems and acoustics.
Instructor: Klein, assisted by engineers from aircraft companies.

AE 254 abc. **Advanced Problems in Airplane Design.** 4 units (2-0-2); each term.
Prerequisites: AE 252, AE 253.
The application of basic mathematical methods to structural problems. A study of advanced design methods for airplane structural components.
Instructors: Sechler, Martin.

AE 255. **Wind Tunnel Operation and Technique.** 6 units (0-3-3); one term.
A one-term course covering pressure and velocity measuring instruments, balances, model suspensions, wind tunnel calibrations and correction factors, data reduction and presentation, extrapolation of model results to full scale. Experiments on various aerodynamic phenomena are carried out by the students in a special wind tunnel constructed for instruction purposes.

AE 256. **Flight Test Techniques.** 6 units (2-0-4); second term only.
Prerequisites: AE 251 abc.
The methods of obtaining aerodynamic data by means of flight testing. Instrumentation, types of flight testing, and flight test procedures. The reduction of flight test data and their correlation with wind tunnel data and airplane performance.
Instructor: Williams.

AE 257 abc. **Engineering Mathematical Principles.** 9 units (3-0-6); each term.
Prerequisite: AM 15, or 115.

A study of the fundamental principles of vector and tensor analysis, Green's and Stoke's integral theorems. Functions of a complex variable, contour integration, conformal mapping. Schwarz-Christoffel transformation. Operational calculus and Laplace transforms, Bessel functions. Equilibrium and vibration problems of systems of finite and infinitely many degrees of freedom. Graphical, numerical, Rayleigh-Ritz, and perturbation methods.

Text: *Mathematical Methods in Engineering,* Kármán and Biot.

Instructor: DePrima.

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

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

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

Instructor: Stewart.

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

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

AE 261 abc. **Hydrodynamics of Compressible Fluids.** 10 units (3-1-6); each term.

Prerequisites: AE 251, AE 258.

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

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

Instructor: Liepmann.

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

Prerequisites: AE 251, AE 257, AE 258.

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

Instructor: Bell.

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

Prerequisites: AE 251, AE 257, AE 258.

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

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

Instructor: Millikan.

AE 267. **Turbulence.** To be offered on request. Units to be arranged.

Phenomenological and other modern theories of turbulence, conception of mixing length, similarity hypothesis, statistical theory of isotropic turbulence, laminar stability, experimental methods in turbulence research, hot-wire technique, etc.

Instructors: Liepmann, Millikan.

AE 268 abc. **Advanced Problems in Fluid Mechanics.** 6 units (2-0-4); each term.

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

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

Instructor: Lagerstrom.

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

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

Instructors: Liepmann, Millikan.

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

Prerequisites: Applied Mechanics, AE 257.

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

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

Instructor: Sechler.

AE 271 abc. **Vibrations and Flutter Problems.** 6 units (2-0-4); each term.

Prerequisites: Applied Mechanics, AE 257.

Fundamentals of vibration analysis, vibration problems occurring in airplane design with particular reference to the problems of flutter.

Instructor: Rasof.

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

Prerequisites: Applied Mechanics, Mechanisms.

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

Instructor: Klein.

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

Prerequisites: AE 270. (May be taken simultaneously)

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

Instructor: Martin.

AE 280 abc. **Material and Chemistry Problems in Jet Propulsion.** 6 units (2-0-4); each term.

Prerequisites: ME 3, ME 10.

Chemical properties of propellants and fuels. Chemical equilibrium, combustion temperature. Combustion as a chemical kinetic problem. High temperature materials.

Instructors: Seifert and other JPL staff members.

AE 281 abc. **Jet Propulsion Systems.** 12 units (4-0-8); each term.
Prerequisites: AM 15.

Fundamentals of rockets, solid propellant rocket design, liquid propellant rocket design. Under water jet propulsion systems. Impulse duct engine. General combustion chamber design for thermal jets. Ramjet, turbojet, turbofan, turboprop. Design principles of centrifugal and axial compressors. Design principles of gas turbines.

Instructors: Seifert and other JPL staff members.

AE 282 abc. **Jet Propulsion Laboratory.** 3 units (0-3-0); each term.

Laboratory demonstrations of the operation of jet propulsion systems and the reduction and interpretation of observed data.

Instructors: Seifert and other JPL staff members.

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

Study and critical discussion of current contributions to aerodynamic and aeronautical engineering.

APPLIED MECHANICS

UNDERGRADUATE SUBJECTS

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

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

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.

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

Prerequisite: AM 1 a.

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

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

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

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

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

Prerequisite: AM 1 c.

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

Instructors: Converse and Assistants.

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

Prerequisites: Ma 1 abc, Ma 2 abc.

A course in the advanced mathematical treatment of engineering and physics problems. About half of the time is spent on the mathematical techniques, the remainder being devoted to the solution of problems in dynamics, structures, the vibrations of particles, strings, and plates, the flow of heat, fluids, and electricity, and the transient response of various physical systems to the appropriate kind of impulse. The mathematical topics include the usual methods of solving standard ordinary and partial differential equations, including the use of infinite series, elliptic integrals, Fourier series, Gamma and Bessel functions, vector analysis, functions of a complex variable, and the Laplace transform.

ADVANCED SUBJECTS

AM 105 a. **Soil Mechanics.** 6 units (1-3-2); first term.

Prerequisites: AM 1 abcd.

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

Texts: *Soil Mechanics,* Krynine; *Procedures for Soil Testing,* A.S.T.M.

Instructor: Converse.

AM 105 b. **Soil Mechanics.** 6 units (1-3-2); second term.

Prerequisites: AM 105 a.

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

Texts: *Soil Mechanics,* Krynine; *Procedures for Soil Testing,* A.S.T.M.

Instructor: Converse.

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

Prerequisites: AM 1 abc.

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

Instructor: Housner.

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

Prerequisites: AM 1 abc.

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

Instructor: Housner.

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

Prerequisites: AM 1 abc.

Experimental methods of stress determination. Theories of failures of stressed materials. Non-linear stress-strain relations. Plastic deformations.

Instructor: Housner.

AM 115 abc. **Engineering Mathematics.** 9 units (3-0-6); first, second, third terms.

Prerequisites: Ma 1 abc, Ma 2 abc.

Similar to AM 15 abc described above, for fifth year graduate students who have not taken a course in advanced calculus or advanced engineering mathematics in their undergraduate work.

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

ASTRONOMY AND ASTROPHYSICS

UNDERGRADUATE SUBJECTS

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

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

Text: *Astronomy*, Baker.

Instructor: Johnson.

Ay 2 abc. **General Astronomy.** 8 units (2-1-5); first, second and third terms.

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

This course is intended to give the general preparation necessary for specialized study in astronomy.

ADVANCED SUBJECTS

Ay 101 abc. **Astrophysics I.** 9 units (3-0-6); first, second and third terms. Offered only in alternate years.

Prerequisites: Ay 2 abc; Ph 105 ab, 107.

Stellar atmospheres and the interpretation of stellar spectra, the solar chromosphere and the corona, radiative equilibrium, etc.

Ay 102 abc. **Astrophysics II.** 9 units (3-0-6); first, second and third terms. Offered only in alternate years.

Prerequisites: Ay 2 abc; Ph 109 abc.

Stellar interiors, internal constitutions of stars and sources of stellar energy, atomic and nuclear theories applied to astronomical phenomena, theories of the constitution and evolution of stars.

Ay 103 abc. **Celestial Mechanics.** 6 units (2-0-4); first, second and third terms. Offered only in alternate years.

Prerequisites: Ay 2 abc; Ph 103 abc.

Theory of planetary motion, perturbation theory, periodic orbits, two-body problem, double stars, etc.

Ay 104 abc. **Galactic Dynamics.** 6 units (2-0-4); first, second and third terms. Offered only in alternate years.

Prerequisites: Ay 2 abc; Ph 103 abc.

Stellar dynamics, positions and motions of stars, clusters and nebulae in space, star streaming, galactic rotation, nebular red shift, etc.

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 of clusters of nebulae. Hydrodynamic and statistical mechanical analysis of the morphology of nebulae. Theory and discussion of observational data obtained from observations on stars of special interest, such as supernovae, novae, white dwarfs, variable stars, and emission line stars. Theory and practice of new types of telescopes and other observational devices. Practical work of reduction of data obtained with the Schmidt telescopes on Palomar Mountain. Only students, assitants, 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 Astrophysics.** 2 units; first, second and third terms.

Meets once a week for report and discussion of the work appearing in the literature and that in progress on Mount Wilson and Palomar. Advanced students in astrophysics and members of the staff take part.

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

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

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

Ay 201. The Sun and Planetary System

Ay 202. Sun Spots and the Solar Atmosphere

Ay 203. Zeeman Effect in Solar and Stellar Spectra

Ay 204. Classification of Stellar Spectra

Ay 205. Peculiar Stellar Spectra

Ay 206. Stellar Radial Velocities

Ay 207. Stellar Absolute Magnitudes

Ay 208. Microphotometry of Stellar Spectra

Ay 209. Spectra of Gaseous Nebulae

Ay 210. Structure of the Galaxy

Ay 211. Observational Cosmogony

Ay 212. Theoretical Cosmogony.

BIOLOGY

UNDERGRADUATE SUBJECTS

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

An introductory subject intended to give the student of general science some information about the fundamental properties of living organisms. Special emphasis is placed on the study of the human body and its functions.

Instructors: Sturtevant, van Harreveld, Lewis.

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

Prerequisite: Bi 1.

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

Instructor: Sturtevant.

Bi 3 ab. **General Botany.** 10 units (2-6-2), third term; 13 units (3-8-2), first term.

Prerequisite: Bi 1.

A general survey of the water relations of plants in connection with their morphology. The classification and life histories of plants.

Instructor: Went.

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

Prerequisite: Bi 1.

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

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

Instructor: MacGinitie.

Bi 5 ab. **Plant Physiology.** 13 units (3-8-2), second term; 7 units (2-4-1), third term.

Prerequisite: Bi 3.

A general survey of growth and the chemical processes taking place in the living plant.

Instructor: Went

Bi 6. **Embryology.** 12 units (2-6-4), second term.

Prerequisite: Bi 4.

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

Instructor: Tyler.

Bi 7 ab. **Biochemistry.** 12 units (3-4-5), second, third terms.

Prerequisites: Bi 16 a, Ch 41.

A lecture course on the chemical constitution of living matter; and the chemical changes in animals, with laboratory work illustrating principles and methods in current use.

Instructor: Borsook.

Bi 8. **Advanced Genetics.** 9 units (1-6-2), third term.

Prerequisite: Bi 2.

A course dealing especially with Neurospora genetics.

Instructors: Beadle, Horowitz.

Bi 11. **Histological Technique.** 5 units (1-3-1), first term.

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

Instructor: Tyler.

Bi 12. **Histology.** 6 units (1-3-2), second term.
Prerequisite: Bi 4.
A course in the microscopic anatomy of vertebrates.
Instructor: Tyler.

Bi 13. **Mammalian Anatomy.** 5 units (1-3-1), first term.
Prerequisite: Bi 4.
The dissection of a mammal.
Instructors: van Harreveld, Keighley.

Bi 14. **Immunology.** 10 units (2-4-4), first term.
Prerequisites: Bi 2, Ch 41 abc.
A course on the principles and methods of immunology and their application to various biological problems. Some previous knowledge of biochemistry and embryology is desirable.
Instructors: Emerson, Owen.

Bi 16 abc. **Animal Physiology.** 8 units (2-3-3), first, second and third terms.
Prerequisites: Bi 4, Bi 13, Ch 41. To be taken simultaneously or previously.
A survey of comparative and mammalian physiology.
Instructors: Wiersma, van Harreveld.

Bi 18. **Review in Botany.** 3 units (1-0-2). No graduate credit.
A short review course of general botany and plant physiology required of graduate students who take a minor in plant physiology, but have had no previous courses in botany.
Instructor: Went.

ADVANCED SUBJECTS

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

Bi 102 abc. **Biological Assays.** 8 units (1-6-1); first, second, third terms.
A course with lectures and laboratory practice, on certain biological tests for physiologically active substances.
Instructors: Went, Haagen-Smit, Bonner.

Bi 106. **Embryology.** 12 units (2-6-4); second term.
Prerequisite: Bi 4.
A subject in vertebrate embryology, including some experimental and cytological material.
Instructor: Tyler.

Bi 107 ab. **Biochemistry.** 12 units (3-4-5); second, third terms.
Prerequisites: Bi 16 a, Ch 41.
A lecture course on the chemical constitution of living matter; and the chemical changes in animals, with laboratory work illustrating principles and methods in current use.
Instructor: Borsook.

Bi 108. **Advanced Genetics.** 9 units (1-6-2); third term.
Prerequisite: Bi 2.
A course dealing especially with neurospora genetics.
Instructors: Beadle, Horowitz.

Bi 111. **Histological Technique.** 5 units (1-3-1); first term.
A course in the preparation of biological material for microscopic examination; includes electron microscopy.
Instructor: Tyler.

Bi 112. **Histology.** 6 units (1-3-2); second term.
Prerequisite: Bi 4.
A course in the microscopic anatomy of vertebrates.
Instructor: Tyler.

Bi 113. **Mammalian Anatomy.** 5 units (1-3-1); first term.
Prerequisite: Bi 4.
The dissection of a mammal.
Instructors: van Harreveld, Keighley.

Bi 114. **Immunology.** 10 units (2-4-4); first term.
Prerequisites: Bi 2, Ch 41 abc.
A course on the principles and methods of immunology and their application to various biological problems. Some previous knowledge of biochemistry and embryology is desirable.
Instructors: Emerson, Owen.

Bi 116 abc. **Animal Physiology.** 8 units (2-3-3); first, second, third terms.
Prerequisites: Bi 4, Bi 13, Ch 41 to be taken simultaneously or previously.
A survey of comparative and mammalian physiology.
Instructors: Wiersma, van Harreveld.

B. Subjects that may be counted toward either a major or a minor for the degree of Doctor of Philosophy:

Bi 201. ***Biology Seminar.*** *1 unit.*
Meets weekly for reports on current research of general biological interest by members of the Institute Staff and visiting scientists.
In charge: Bonner.

Bi 202. **Biochemistry Seminar.** 1 unit.
A seminar throughout the academic year on special selected topics and on recent advances.
In charge: Bonner, Horowitz.

Bi 204. **Genetics Seminar.** 1 unit.
Reports and discussion on special topics.
In charge: Anderson.

Bi 205. **Experimental Embryology Seminar.** 1 unit.
Reports on special topics in the field; meets twice monthly.
In charge: Tyler.

Bi 206. ***Immunology Seminar.*** *1 unit.*
Reports and discussions; meets twice monthly.
In charge: Tyler, Owen.

Bi 207. **Biophysics Seminar.** 1 unit.
A seminar throughout the academic year on the application of physical concepts to selected biological problems. Reports and discussions. Open also to graduate students in physics who contemplate minoring in Biology.
In charge: Delbrück.

Bi 214 abc. **Chemistry of Bio-Organic Substances.** 3 units (1-0-2); first, second and third terms.
Prerequisite: Ch 41 ab.
A series of lectures on selected topics of organic chemistry which have special interest from a biological viewpoint.
Instructor: Haagen-Smit.

Bi 217. **Quantitative Organic Microanalysis.** Units based on work done (0-20-0), second term.
Laboratory practice in the methods of quantitative organic microanalysis required for structure determination of organic compounds. Students must obtain permission from the instructor before registering for this subject as the enrollment is necessarily limited.
Instructor: Haagen-Smit.

Bi 220 abc. **Experimental Embryology.** 6 units (2-0-4); first, second and third terms.

Lectures and discussion of the problems of embryonic development, including such topics as growth of the ovary, breeding habits of animals, fertilization, cleavage, organ formation, metamorphosis, regeneration, tissue culture, embryonic metabolism, etc. The subject may be taken for two consecutive years since the subject matter will be duplicated only in alternate years.

Instructor: Tyler.

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

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

Instructor: Tyler.

Bi 225 abc. **Graduate Genetics.** 6 units (2-0-4); first, second and third terms.

In the first term a systematic survey of the field will be presented. In the second and third terms special subjects will be treated more in detail. The material in the second and third terms will not ordinarily be duplicated in a period of three years, and students majoring in Genetics will be expected to register for at least five terms.

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

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

Reading and discussion of the problems of plant physiology.

Instructors: Went, Bonner, Wildman, Galston.

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

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

Instructor: Bonner.

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

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

Instructors: Wiersma, van Harreveld.

Bi 280-288. **Biological Research.**

Students may register for research in the following fields, the number of units to be determined by consultation with those in charge:

Animal physiology (280), biochemistry (281), bio-organic chemistry (282), embryology (283), genetics (284), immunology (285), marine zoology (286), plant physiology (287), biophysics (288).

CHEMISTRY AND CHEMICAL ENGINEERING

UNDERGRADUATE SUBJECTS

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

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

Instructors: Pauling, Davidson and Assistants.

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

Prerequisite: Ch 1 c.

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

Text: *Chemical Analysis,* Swift.

Instructor: Swift.

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

Prerequisite: Ch 1 c.

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

Text: *Chemical Analysis,* Swift.

Instructor: Swift.

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

Prerequisite: Ch 12 b.

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

Instructor: Swift.

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

Prerequisites: Ch 12 b, 21 ab.

The chemical and physical properties of the elements are discussed with reference to the periodic system and from the view-points of atomic structure and radiation effects. Such topics as coordination compounds, the liquid ammonia system, the compounds of nitrogen, the halides, and selected groups of metals are taken up in some detail. The class work is supplemented by problems which require a study of current literature.

Instructor: Yost.

Ch 16. **Instrumental Analysis.** 8 units (0-6-2); first term.

Prerequisite: Ch 12 c.

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

Instructor: Sturdivant.

Ch 21 abc. **Chemical Principles.** 10 units (4-0-6); first, second, third terms.

Prerequisites: Ch 12 ab or Ch 11; Ph 2 abc; Ma 2 abc.

Conferences and recitations dealing with the general principles of chemistry from an exact, quantitative standpoint, and including studies on the pressure-volume relations of gases; on thermodynamics, on vapor-pressure, boiling point, freezing point, and osmotic pressure of solutions; on the molecular and ionic theories; on electrical transference and conduction; on chemical and phase equilibria; on thermochemistry, and the elements of thermodynamic chemistry and electro-chemistry. A large number of problems are assigned to be solved by the student.

Text: *Chemical Principles,* Noyes and Sherrill.

Instructors: Bates, Badger, Hughes.

Ch 22. **Thermodynamic Chemistry.** 6 units (2-0-4); second term.

Prerequisite: Ch 21 abc.

A continuation of subject Ch 21, given in much the same way. The topics considered include a further study of electrochemistry and thermodynamic chemistry. Practice is given in the computation of free energies, activities and entropies of typical substances.

Text: *Chemical Principles,* Noyes and Sherrill.

Instructor: Bates.

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

Prerequisites: Ch 12 ab; Ma 2 ab; Ph 2 abc.

A discussion of selected topics in physical chemistry, adapted to the needs of *Science Course students in the Geology Option.*

Ch 26 ab. **Physical Chemistry Laboratory.** 8 units (0-6-2); second term; and 8 units (0-6-2) or 4 units (0-3-1); third term.

Prerequisites: Ch 12 ab, Ch 21 a.

Text: *Laboratory Experiments on Physico-Chemical Principles,* Sherrill.

Instructor: Badger.

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

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

Instructors: Yost, Davidson.

Ch 29. **Colloid and Surface Chemistry.** 8 units (3-0-5); third term.

Prerequisite: Ch 21 abc.

Classroom exercises with outside reading and problems, devoted to the properties of surfaces and interfaces, and to the general principles relating to disperse systems with particular reference to the colloidal state. Supplementary laboratory work can be provided if desired.

Text: *Colloid Chemistry,* Weiser.

Instructor: Badger.

Ch 30. **Photochemistry.** 6 units (2-0-4); third term.

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

Prerequisite: Ch 12.

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

Text: *Organic Chemistry,* Lucas.

Instructor: Lucas.

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

Prerequisite: Ch 1.

A discussion of selected topics in organic chemistry, adapted to the needs of science course students in the physics option.

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

Prerequisite: Ch 12.

Laboratory exercises to accompany Ch 41 abc. The preparation and purification of carbon compounds and the study of their characteristic properties. Qualified students may pursue research work.

Text: *Mimeographed Notes,* Lucas and Pressman.

Instructors: Lucas and Assistants.

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

Prerequisite: Ch 12.

Similar to 46. Selected experiments for students of biology.

Text: *Mimeographed Notes,* Lucas and Pressman.

Instructors: Lucas and Assistants.

Ch 48 abc. **Advanced Organic Chemistry.** 4 units (2-0-2); first, second, third terms.

Prerequisites: Ch 41, Ch 46.

Lectures and recitations emphasizing the analytical methods of organic chemistry. Consideration of the general problem of the characterization of organic compounds by qualitative and quantitative procedures.

Instructor: Niemann.

Ch 49 abc. **Advanced Organic Chemistry Laboratory.** 6 units (0-6-0); first, second, third terms.

Prerequisites: Ch 41, Ch 46, and consent of instructor.

Laboratory exercises to accompany Ch 48. 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 61 ab. **Industrial Chemistry.** 12 units (4-0-8) first term; 6 units (2-0-4) second term.

Prerequisite: Ch 21 a.

A study of the most important industrial chemical processes, from the point of view not only of the chemical reactions, but of the conditions and equipment necessary to carry on these reactions.

Text: *Chemical Process Industries,* Shreve.

Instructor: Lacey.

Ch 63 ab. **Chemical Engineering Thermodynamics.** 6 units (2-0-4) second term; 12 units (4-0-8) third term.

Prerequisite: Ch 21 a.

Class exercises and problems in engineering thermodynamics studied from the point of view of the chemical engineer.

Text: *Thermodynamics of One-Component Systems,* Lacey and Sage.

Instructor: Lacey.

Ch 80-86. **Chemical Research.**

Opportunities for research in analytical and inorganic chemistry (80), physical chemistry (82), and organic chemistry (83) are offered to candidates for the degree of Bachelor of Science.

FIFTH-YEAR AND 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 physico-chemical view-points; thus with reference to their physical properties, their thermodynamic constants (their heat-contents, free-energies, and entropies), their rates of conversion into one another (including effects of catalysis and energy radiations), and their molecular structure and valence relations.

Instructor: Yost.

Ch 122 ab. **Thermodynamic Chemistry.** 6 units (2-0-4) first and second terms.

This subject is open to students who have had a course in physical chemistry. During the first term the elements of thermodynamics are reviewed. The second term is the same as Ch 22.

Text: *Chemical Principles,* Noyes and Sherrill.

Instructor: Bates.

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

This course is the same as Ch 27.

Instructors: Yost, Davidson.

Ch 129. **Colloid and Surface Chemistry.** 8 units (3-0-5); third term.

This course is the same as Ch 29.

Instructor: Badger.

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

Lectures and discussions on photochemical processes, especially in their relations to quantum phenomena. The following topics will be included: the photochemical absorption law; the processes—excitation, dissociation, ionization—accompanying the absorption of radiation; subsequent processes including fluorescence and collisions of the second kind; photosensitization; quantum yield and its relation to photochemical mechanism; kinetics of homogeneous thermal and photochemical reactions; catalysis and inhibition; temperature coefficients of photochemical reactions.

Instructor: Wulf.

Ch 148 abc. **Advanced Organic Chemistry.** 4 units (2-0-2); first, second, third terms.

Same as Ch 48 abc.

Instructor: Niemann.

Ch 149 abc. **Advanced Organic Chemistry Laboratory.** 6 units (0-6-0); first, second, third terms.

Same as Ch 49 abc.

Instructor: Niemann.

Ch 163 ab. **Chemical Engineering Thermodynamics.** 4 units second term; 8 units third term.

Prerequisites: Ch 21 a or ME 15.

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

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

Prerequisites: Ch 61, Ch 63 ab.

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

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

Instructor: Lacey.

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

Prerequisites: Ch 21, Ch 61, Ch 63.

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

Instructors: Sage, Hough.

Ch 168 ab. **Mechanics of Fluid Flow.** 8 units (2-0-6); second, third terms. Prerequisite: Ch 166 a.

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

Instructor: Sage.

Ch 180-186. **Chemical Research.**

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

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

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

Given every third year. Offered in 1948-49.

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

In Charge: Pauling.

Ch 222 ab. **Seminar on Statistical Mechanics, with Chemical Applications.** 6 units; first and second terms.

A thorough discussion of the fundamental principles and methods of thermodynamics and statistical mechanics, followed by their application to the practical problems of modern chemistry, including the calculation of thermodynamic properties of substances from spectroscopic and structural data.

Given every third year. Not offered in 1947-48.

In charge: Yost, Badger.

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 probabilities, the equilibrium theory of statistical mechanics is developed and used to interpret the laws of thermodynamics from the molecular standpoint. A detailed study of the relationships between the thermodynamic functions of gases, liquids, and solids and their structure on the molecular scale follows. The interpretation of phase transitions as cooperative phenomena in aggregates of molecules is presented. In the third term the statistical mechanics of systems departing from equilibrium is developed, and the transport processes, diffusion, heat transfer, and viscous fluid flow are analyzed in the light of current theories.

Given every other year. Offered in 1947-48.

Instructor: Kirkwood.

Ch 224 abcd. **Statistical Mechanics** (Seminar). 6 units; four terms.

A discussion of statistical mechanics and its applications to physics and chemistry. The topics treated will include a sufficient exposition of classical and quantum theory mechanics to serve as a foundation for statistical mechanics and the relations between statistical mechanics and thermodynamics.

Text: *Principles of Statistical Mechanics,* Tolman.

In charge: Tolman.

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

A review of Lagrangian and Hamiltonian mechanics and of the old quantum theory is first given, followed by the discussion of the development and significance of the new quantum mechanics and the thorough treatment of the Schrödinger wave equations, including its solution for many simple systems such as the rotator, the harmonic oscillator, the hydrogen atom, etc. During the second and third terms various approximate methods of solution (perturbation theory, the variation method, etc.) are discussed and applied in the consideration of the resonance phenomenon, the structure of many-electron atoms and of simple molecules, the nature of the covalent chemical bond, the structure of aromatic molecules, and other recent chemical applications.

Given every third year. Offered in 1946-47.

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

Instructor: Pauling.

Ch 227 abc. **The Structure of Crystals.** 9 units (3-0-6); first, second, third terms.

The following topics are discussed:

The nature of crystals and X-rays and their interaction. The various experimental methods of investigation—Bragg, Laue, oscillation, Weissenberg, etc. The theory of space groups and the use of symmetry in the determination of the structures of crystals. The detailed study of representative structure investigations. The quantitative treatment of X-ray diffraction. Fourier-series methods of structure investigation.

Given every third year. Offered in 1947-48.

Instructor: Sturdivant.

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

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

Given every third year. Offered in 1948-49.

Instructors: Schomaker, Hughes, Sturdivant.

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

The physical, electrical, and magnetic as well as the structural, chemical, and thermodynamic properties of metals and alloys considered from modern viewpoints.

Instructor: Yost.

Ch 234. **Introduction to the Spectra of Molecules.** 6 units; first term.

The theory of the structure of the spectra of both the diatomic and the simpler polyatomic molecules is presented, and the transition rules and their relation to the symmetry elements of molecules are discussed. Emphasis is laid on the methods of interpreting and analyzing molecular spectra, and it is shown how from an analysis one obtains information regarding the structure and other properties of a molecule of interest to the chemist. Problems are given in the interpretation of actual data.

Given every third year. Offered in 1946-47.

Instructor: Badger.

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

Prerequisite: Consent of instructor.

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

Instructor: Haagen-Smit.

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

Prerequisites: Ch 41, Ch 46.

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

Given every third year. Offered in 1948-49.

Instructors: Lucas, Niemann.

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

Prerequisite: Ch 41.

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

Instructor: Zechmeister.

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

Prerequisites: Ch 41, Ch 46.

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

Given every third year. Offered in 1947-48.

Instructor: Niemann.

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

Prerequisites: Ch 41, Ch 46.

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

Given every third year. Offered in 1946-47.

Instructor: Niemann.

Ch 255 abc. **Chemistry of Bio-organic Substances.** 3 units (1-0-2); first, second, third terms.

Lectures on selected subjects of organic chemistry such as alkaloids, essential oils, and other major groups of natural products.

Instructor: Haagen-Smit.

Ch 258. **Immunochemistry.** 8 units (3-3-2); second term.

Prerequisite: Consent of instructor.

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

Instructor: Campbell.

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

Prerequisite: Ch 21.

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

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

Instructor: Sage.

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

Prerequisites: Ch 21, Ch 61.

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

Instructor: Lacey.

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

Prerequisite: Ch 166, AM 15 ab or equivalent.

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

Instructor: Sage.

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

Given in alternate years. Offered in 1947-48.

Prerequisites: Ch 166, AM 15 ab or equivalent.

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

Instructor: Sage.

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

Given in alternate years. Offered in 1948-49.

Prerequisites: Ch 166, AM 15 ab or equivalent.

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

Instructor: Sage.

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

Given in alternate years. Offered in 1947-48.

Prerequisites: Ch 166, Ch 262.

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

Instructors: Hough and Sage.

Ch 280-286. **Chemical Research.**

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

The main lines of research now in progress are:

(In physical and inorganic chemistry)

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

(In organic chemistry and immunochemistry)

Chemotherapy of parasitic diseases.

Isolation and structure of alkaloids.

The synthesis of cyclobutadiene and related substances.

The chemistry of carotenoids and other plant pigments.

The use of chromatographic methods of analysis and separation of stereoisomers.

Diphenylpolyenes.

Configuration and vitamin A potency.

Fluorescing compounds in the vegetable kingdom including micro organisms.

The Walden inversion.

Kinetics and equilibria involving addition to unsaturated compounds.

Coordination reactions of alkenes.

Sulfinyl and phosphinyl chlorides.

The chemistry of protozoa.

The study of plant hormones and related substances of physiological importance.

Studies on the constitution of the phosphatides and cerebrosides.

The chemistry of amino acids and peptides.

Studies on mammalian and bacterial polysaccharides including the blood group specific substances.

Studies on the enzymatic cleavage and formation of amide bonds.

The mechanism of antigen-antibody reactions and the structure of antibodies.

The isolation and characterization of cellular antigens.

The functional significance of antibodies.

The chemical and physical properties of blood.

(In applied chemistry and chemical engineering)

The influence of turbulence upon heat transfer in fluids.

The influence of turbulence on the transfer of material through fluids.

Phase and thermodynamic behavior of hydrocarbons and other fluids.

Gas phase combustion.

Ch 290 abc. **Chemical Research Conference.** First, second, third terms.

These conferences consist of reports on investigations in progress in the chemical laboratories and on other researches which are of current interest. Every graduate student in chemistry is expected to attend these conferences. Seminars in special fields (immunochemistry, inorganic chemistry, crystal structure, organic chemistry) are also held.

CIVIL ENGINEERING

UNDERGRADUATE SUBJECTS

CE 1. **Surveying.** 9 units (2-4-3); first or second terms.

A study of the elementary operations employed in making surveys for engineering work, including the use, care, and adjustment of instruments, linear measurements, angle measurements, note keeping, stadia surveys, calculation and balancing of traverses, use of calculating machines, topographic mapping and field methods.

Text: *Elementary Plane Surveying,* Davis.

Instructor: Michael.

CE 2. **Advanced Surveying.** 12 units (2-7-3); third term.

Prerequisite: CE 1.

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

Instructor: Michael.

CE 3. **Plane Table Surveying.** 8 units (1-6-1); first term.

A subject offered primarily for students in geology but may be elected by arrangement with the department. Theory and use of the plane table as applied to geological surveys. The class devotes one entire day a week to field surveys over typical terrain completing a topographic and geological map of the region covered.

Text: *Elementary Plane Surveying,* Davis.

Instructor: Michael.

CE 4. **Highways and Airports.** 10 units (2-4-4); second term.

A comparison of various types of highway construction; the design, construction and maintenance of roads and pavements. An introduction to airport design.

Instructor: Michael.

CE 6. **Transportation Engineering.** 6 units (2-0-4); first term.

Prerequisites: CE 1, 2.

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

Text: *Elements of Railroad Engineering,* Raymond.

Instructor: Thomas.

CE 7. **Curves and Earthwork.** 7 units (2-0-5); first term.

Prerequisite: CE 1.

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

Text: *Railway Curves and Earthwork,* Allen.

Instructor: Michael.

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

Prerequisite: CE 7.

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

Text: *Railway Curves and Earthwork,* Allen.

Instructor: Michael.

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

Prerequisite: AM 1 c.

Methods used in the calculation of stresses in beams, girders, and columns; study of the effects of moving load systems; graphic statics applied to roofs and bridges. A study of arch, cantilever, and continuous bridges; and deflection of trusses.

Texts: *Structural Theory,* Southerland and Bowman; *Structural Design in Steel,* Shedd.

Instructor: Martel.

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

Prerequisites: AM 1 c, CE 10 a.

The theory of reinforced concrete design, with a study of the applications of this type of construction to various engineering structures.

Text: *Reinforced Concrete,* Caughey.

Instructor: Martel.

CE 14 abc. **Engineering Conferences.** 4 units (0-4-0) first term junior year; 3 units (1-0-2) first term senior year; 2 units (1-0-1) third term senior year.

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 junior year, students will visit and inspect engineering projects.

Instructors: Michael, Eagleson.

FIFTH-YEAR AND ADVANCED SUBJECTS

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

Prerequisites: CE 10 abc, 12.

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

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

Instructor: Martel.

CE 120 bc. **Statically Indeterminate Structures.** Units to be based upon work done; any term.

A continuation of the study of indeterminate structures as begun in CE 120 a with the use of analytical and instrumental methods of solution.

Instructor: Martel.

CE 121 a. **Structural Design.** 12 units (0-12-0); one term.

Prerequisites: CE 10 abc, 12.

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

Instructor: Thomas.

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

Prerequisites: CE 10 abc, 12.

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

Instructors: Thomas, Martel.

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

Prerequisite: CE 125.

Special problems including preliminary investigations of irrigation or water power projects; study of stream flow data, the effect of reservoir storage upon distributed flow, determination of size and type of economic development.

Instructor: Thomas.

CE 122. **Earthquake Effects upon Structures.** Units to be based upon work done; any term.

A comparison of the analytical study and the experimental effects of vibrations on simple structures with the actual effects of earthquakes upon buildings.

Instructor: Martel.

CE 125. **Irrigation and Water Supply.** 12 units (4-0-8); third term.

Prerequisite: Hy 1.

A study of modern practice of the collection, storage, purification and distribution of water for municipal, domestic and irrigation uses; design, construction and operation of systems; consideration of the conditions adapted to irrigation developments, dams, reservoirs, canals; laws pertaining to irrigation; the economic aspects of projects.

Text: *Water Supply and Utilization,* Baker and Conkling.

Instructor: Thomas.

CE 126. **Masonry Structures.** 9 units (2-3-4); second term.

Prerequisite: CE 12.

Theory of design and methods of construction of masonry structures; foundations, dams, retaining walls, and arches.

Text: *Design of Masonry Structures,* Williams.

Instructor: Martel.

CE 127. **Sewerage and Sewage Treatment.** 9 units (2-3-4); second or third terms.

Prerequisite: Hy 1.

A study of systems for the collection and treatment of sewage, the design of sewers and storm drains; characteristics of various treatment processes; factors affecting treatment plant design; inspection of local plants.

Text: *Sewerage and Sewage Disposal,* Metcalf and Eddy.

Instructor: Banta.

CE 130 abc. **Engineering Seminar.** 2 units (1-0-1); first, second, third terms.

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.

CE 131. **Sewage Treatment Plant Design.** Units to be based upon work done; any term.

A design of treatment works for a selected community and site involving special conditions of location, volume, and requirements for disposal. Includes selection of type of treatment, arrangement of tanks and equipment, and general design of structures.

Instructor: Banta.

CE 132. **Water Power Plant Design.** Units to be based upon work done; any term.

A design of a power plant in conformity with the conditions of head, flow, and load fluctuations at a particular site. Includes selection of number and type of units, design of water passages and general structural features.

Instructor: Thomas.

CE 133. **Water Treatment Plant Design.** Units to be based upon work done; any term.

Preparation of a layout and design of the general features of a plant to effect the purification and softening of water as may be required in specific circumstances. Includes design of typical structural features of the plant.

Instructor: Thomas.

CE 134. **Ground Water Investigations.** Units to be based upon work done; any term.

A study of the relation between rainfall, runoff, percolation, and accumulations of ground water. Investigation of the location, extent, and yield of underground reservoirs.

Instructor: Thomas.

CE 135. **Geodesy and Precise Surveying.** Units to be based upon work done; any term.

Methods of triangulation and surveying over extended areas. The adjustment of triangulation systems, the adjustment of observations by the method of least squares. Map projections, precise leveling determination of a true meridian.

Instructor: Michael.

CE 136. **Irrigation Investigations.** Units to be arranged.

Prerequisite: CE 125.

Investigation of irrigation methods and practices and the presentation of reports.

Instructor: Thomas.

CE 141. **Structural Engineering Research.** Units to be based upon work done; any term.

Selected problems and investigations to meet the needs of advanced students.

Instructor: Martel.

CE 142. **Sanitation Research.** Units to be based upon work done; any term.

Exceptional opportunities for advanced study in the fields of water and sewage treatment are available at the numerous plants located in this locality.

Instructor: Banta.

CE 143. **Highway Research.** Units to be based upon work done; any term.

Cooperating with the Highway Research Board of the National Research Council, opportunities are offered for advanced studies in highway engineering. Arrangements may be made for special studies on subgrade materials, wearing surfaces, economics of vehicle operation, and allied subjects.

Instructor: Michael.

CE 144. **Airport Design.** Units to be based upon work done; any term.

Prerequisite: CE 4.

Preparation of a layout and design of an airport, including studies of a proposed site, surface and subsurface drainage; runway, and taxiway. Design of base courses and runways surfaces. Accessory structures and lighting.

Instructor: Michael.

CE 150. **Foundations.** 9 units (2-3-4); third term.

Prerequisite: AM 105 ab.

Types and methods of construction of foundations for buildings, bridges, and other major structures. Spread footings and foundation slabs, piles and pile driving equipment, open and pneumatic caissons, cofferdams, underpinning, methods of exploration.

Instructor: Converse.

ELECTRICAL ENGINEERING

UNDERGRADUATE SUBJECTS

EE 1 abc. **Basic Electrical Engineering.** 6 units (2-0-4); EE 1 a first term only, EE 1 bc second or third terms.

Prerequisites: Ma 2 abc; Ph 2 abc.

An introductory study of electric and magnetic fields and circuits, electromagnets, direct and alternating current machinery and electronic devices.

Instructors: Maxstadt, Pickering, Drake, and Assistants.

EE 2 abc. **Basic Electrical Engineering Laboratory.** 3 units (0-3-0); first, second, third terms.

Prerequisites: Ma 2 abc; Ph 2 abc.

This course is the laboratory for the corresponding EE 1 course. Use of measuring instruments, operation of direct and alternating current machinery and determination of their characteristics and instrumentation of electronic circuits.

Text: *Laboratory Notes.*

Instructors: Maxstadt and Assistants.

EE 6 ab. **Electrical Machinery.** 6 units (2-0-4) second term; 9 units (3-0-6) third term.

Prerequisites: EE 1 abc; EE 2 abc.

Windings, special characteristics, graphical methods, commutation, machine reactances, and short circuit currents. System stability; short transmission lines.

Instructor: Sorensen.

EE 7. **Electrical Engineering Laboratory.** 7 units (0-6-1); third term.

Prerequisites: EE 1 abc; EE 2 abc; Ph 7 ab and enrollment in EE 6.

A continuation of EE 2 abc. Efficiency tests of alternating current machinery. Graphic analysis of alternator performance; operation of transformers, alternators and direct current machines in parallel; communication circuit testing; use of electronic devices; writing of engineering test reports.

Text: *Laboratory Notes.*

Instructors: Maxstadt, Drake, and Assistants.

EE 12. **Electric Circuits.** 12 units (4-0-8); first term.

Prerequisites: EE 1 abc; EE 2 abc; EE 6 ab; EE 7.

A course of study relating to the calculation of voltage, current, and power in electrical power and electronic circuits, including an introductory study of filter circuits. In all of these studies free use is made of the symbolic or complex method of solving problems using Kirchoff's laws, Thevenin's theorem and other special methods of calculation.

Texts: *Alternating Current Circuits,* Kerchner and Corcoran; *Problems in Alternating Currents,* Lyon.

Instructors: Sorensen and Assistants.

EE 15 ab. **High Frequency Circuits.** 6 units (2-0-4) second term; (0-3-3) third term.

Prerequisites: Ph 7 a, Ph 8; EE 62 to be taken concurrently.

Maxwell's equations, electromagnetic fields, generation and propagation of microwaves. Laboratory experiments illustrating microwave phenomena.

Instructors: Mackeown and Pickering.

EE 60 abc. **Electronics and Circuits.** 9 units (3-0-6; 2-3-4; 2-3-4); first, second, third terms.

Basic physics of vacuum tubes, electron ballistics, thermionic emission, space charge effects, etc. Application of tubes and circuits to physical measurements.

Instructors: Mackeown and Pickering.

EE 62 ab. **Electron Tubes.** 10 units (2-3-5); second, third terms.
Prerequisites: EE 1 abc; EE 12.
Fundamental theory of electron tubes in radio, communication and control circuits.
Instructors: Mackeown and Pickering.

EE 65. **Electronics Laboratory.** 6 units (0-3-3); third term.
Prerequisite: EE 62, or to be taken concurrently.
Laboratory measurements at audio- and radio-frequencies using modern electronic devices.
Instructors: Pickering and Assistants.

EE 70 ab. **Engineering Conference.** 2 units (1-0-1); first, second terms.
Prerequisites: EE 2 ab, EE 3 ab.
Presentation and discussion of new developments in the industry. Review of current literature.
Instructors: Mackeown, Maxstadt, Pickering, Sorensen.

FIFTH-YEAR SUBJECTS

EE 120 abc. **Advanced Electric Power System Analysis.** Three terms.
This course is devoted to the study of electric circuit theory as applied to the basic problems encountered in the design and operation of modern power transmission and distribution systems.

EE 120 a. 12 units (4-0-8); first term.
Prerequisites: EE 6 ab; EE 7; EE 12; Ph 7 abc.
Theory of symmetrical components and basic circuit theorems for reduction and simplification of power system networks. System fault calculations supplemented by a comprehensive power system fault study with the Electric Analog-Computer used as an AC-Network Analyzer.

EE 120 b. 12 units (4-0-8); second term.
Prerequisite: EE 120 a.
Analysis of transformer characteristics including development of sequence circuits for two and three winding transformer banks. Theory of synchronous and induction motors including transient analysis during system faults. Calculation of transmission line constants and their equivalent sequence circuits. General principles of circuit breaker and relay application.

EE 120 c. 12 units (4-0-8); third term.
Prerequisite: EE 120 b.
Development of generalized circuit constants for transmission lines and integrated systems. Application of power circle diagrams and other techniques for steady state power flow and regulation problems. Treatment of the steady state and transient stability problem. Transient circuit analysis as applied to switching surge calculations. General discussion of the effects of system grounding on switching surge voltages. Basic principles of overvoltage protection against switching surges and lightning. AC-Network Analyzer techniques will be applied to actual calculations of transient stability and switching surge problems.

Texts: Electrical Transmission and Distribution Reference Book and Course Notes.
Instructors: McCann, Lindvall, and Sorensen.

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

EE 128. **Electric Transportation.** 9 units supervised reading course by assignment.

Prerequisites: EE 1 abc, EE 6 ab.

Modern electric and oil-electric railways, studies of the motive power, train requirements, frictional and other resistances, schedules, acceleration and braking; the portable power plant vs. substations and contact conductor. Safe speeds and riding qualities are studied.

Text: *Electric Transportation,* Thompson.

Instructors: Lindvall, Maxstadt.

EE 130. **Electric Lighting and Power Distribution.** 6 units supervised reading course by assignment.

Prerequisites: EE 1 abc, EE 6 ab.

Electric distribution and wiring; calculation of simple alternating current circuits; installation and operation costs and selling price of electric power.

Text: *Generating Stations,* Lovell.

Instructor: Maxstadt.

EE 148. **Specifications and Design of Electrical Machinery.** 6 units (3-0-3); first term.

Prerequisites: EE 7, and preceding subjects.

Preparation of specifications and design calculations for alternating and direct current machinery.

Text: *Electrical Machine Design,* Gray.

Instructor: Sorensen.

EE 152. **Dielectrics.** 6 units (2-0-4); third term.

Prerequisites: EE 120 ab, and preceding subjects.

A study of electric fields in insulations, particularly air, and the effects on sparking voltage of the sparking distance, atmospheric pressure and humidity; corona phenomena; high frequency voltages, characteristics of commercial insulations.

Text: *Theory of Dielectrics,* Schwaiger and Sorensen.

Instructor: Sorensen.

EE 156. **Electric Communication.** 6 units (2-0-4); first term.

Prerequisites: EE 12, EE 62 ab.

A study of modern means of communication with special emphasis on recent developments.

Instructor: Mackeown.

EE 157. **Communications Laboratory.** 6 units (0-3-3); first term.

Prerequisite: Must be taking or have taken EE 156.

Laboratory assignments in advanced communications problems.

Instructors: Pickering and Assistants.

EE 158 abc. **Circuit Analysis.** 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 12, EE 62 ab.

Transient analysis of linear networks; Laplace transform methods; feed back amplifiers; network analysis.

Instructor: Pickering.

EE 162 ab. **Electron Tubes.** 7 units; second and third terms.

Same as EE 62 ab with reduced units for chemical engineers.

EE 165. **Electronics Laboratory.** 4 units; third term.

Same as EE 65 with reduced units for chemical engineers.

EE 170. **Feed Back Amplifiers and Servo Mechanism.** 9 units (3-0-6); second term.

Prerequisites: AM 15 abc, EE 62 ab.

Theory and analysis of electrical, hydraulic and mechanical feed back and servo mechanism systems.

Instructors: Pickering, Mackeown.

EE 190 abc. **Electromagnetic Fields.** 9 units (3-0-6); first, second, third terms.

Prerequisites: EE 62, EE 156, Ph 8.

Application of Maxwell's equations to equipment used at ultra-high frequencies. Includes wave guides, cavity resonators, velocity modulated tubes, magnetrons, etc.

Instructor: Mackeown.

EE 191. **Ultra High Frequency Laboratory.** 6 units (0-3-3); third term.

Prerequisite: EE 190, or be enrolled for it.

Laboratory measurements and use of ultra-high frequency equipment.

Instructors: Pickering and Assistants.

ADVANCED SUBJECTS

EE 200. **Advanced Work in Electrical Engineering.**

Special problems relating to electrical engineering will be arranged to meet the needs of students wishing to do advanced work in the field of electricity. The Institute is equipped to an unusual degree for the following lines of work: Theory of Electrical Machine Design, Electric Transients, and High Voltage Engineering Problems, under the direction of Professors R. W. Sorensen, F. C. Lindvall, and G. D. McCann; Electrical Engineering Problems relating to electronic devices and their applications under the direction of Professors S. S. Mackeown and W. H. Pickering; Engineering Analysis problems requiring large scale computer techniques, A.C. network techniques, Analog and Transient studies, etc., under the direction of Professor G. D. McCann. Problems relating to the distribution and uses of electric power for lighting and industrial uses; Studies of light sources and illumination under the direction of Professor F. W. Maxstadt.

EE 220. **Research Seminar in Electrical Engineering.** 2 units.

Meets once a week for discussion of work appearing in the literature and in industry. All advanced students in electrical engineering and members of the electrical engineering staff are expected to take part.

In charge: Sorensen, Mackeown, Lindvall, Pickering, Maxstadt.

EE 223 ab. **Electric Strength of Dielectrics.** 15 units; second and third terms.

A study of the effect of high potentials applied to dielectrics.

Text: *Theory of Dielectrics*, Schwaiger and Sorensen.

Instructor: Sorensen.

EE 224 abc. **Vacuum Tube and Radio Frequency Circuits.** Units to be based on work done; first, second, third terms.

A study of the literature on vacuum tubes and associated circuits. Experimental work with oscillators, transmitters, and receivers.

Instructor: Mackeown.

EE 226 abc. **Engineering Mathematical Physics.** 15 units (3-0-12); first, second, third terms.

Prerequisites: Differential Equations or AM 15 or 115.

This subject is designed to develop the correlation of mathematics and physics with problems in engineering design and application. The following subjects will be treated in detail: mechanical vibrations, oscillations in electro-mechanical systems, short circuit forces, power system transients, electric motors applied to variable or pulsating loads, heat transfer and transient heat flow. The principle of constant flux linkage in electrical transient analysis; solution of mechanical problems by electrical methods; application of Heaviside operational calculus to mechanical and thermal problems.

Instructor: Lindvall.

EE 227. **Operational Circuit Analysis.** 6 units (2-0-4); third term. Not given every year.

An introduction to the solution of circuit problems by the operational method.

Instructor: Mackeown.

EE 228. **Conduction of Electricity in Gases.** Units to be arranged; first, second, third terms. Not given every year.

Selected topics in glow, arcs, and spark discharges.

Instructor: Mackeown.

EE 230. **Microwave Electronics.** 9 units (3-0-6); third term.

The behavior of vacuum tubes at ultra-high frequencies, electron transit time effects, microwave oscillators.

Instructor: Pickering.

EE 232 abc. **Advanced Problems in Modern Radio Engineering.** 8 units (2-0-6); first, second, third terms.

Prerequisites: EE 15 ab, EE 62 ab, Ph 7, Ph 8; or Ph 101 abc.

A case-problem course treating frontier problems in antennas, electron tubes, random phenomena and signal-noise ratio, and complex radio systems. Order-of-magnitude estimates are emphasized for many important phenomena not yet susceptible to complete analytical solution.

Instructor: Ramo.

ENGINEERING DRAFTING

D 1a. **Freehand Drawing.** 3 units (0-3-0); first term.

The study of geometrical forms and their representation by means of freehand orthographic and perspective. Training in pencil rendering is given and the fundamental principles of perspective are illustrated by simple engineering studies and the use of machine parts. Emphasis is placed on careful observation and accurate drawing.

Instructors: Wilcox and Assistants.

D 1b. **Engineering Drafting.** 3 units (0-3-0); second term.

This course is designed to give the student a general knowledge of the most important types of engineering drawings. Instruction is given in the proper use of drafting equipment and in the fundamental principles of drafting and lettering. Elementary detail drawings are included.

Text: *Engineering Drawing,* French.

Instructors: Wilcox and Assistants.

D 1c. **Engineering Drafting.** 3 units (0-3-0); third term.

Prerequisite: D 1b.

A continuation of D 1b. Emphasis is placed on the elementary geometry of engineering drawing and visualization in three dimensions. Elementary principles of design are discussed and the accepted standards of machine drafting are applied in the making of simple working drawings.

Text: *Engineering Drawing,* French.

Instructors: Wilcox and Assistants.

D 2. **Descriptive Geometry.** 6 units (0-6-0); second term.

Prerequisites: D 1 abc.

The course is designed to supplement the study of shape description as given in D 1 abc, and to present a graphical means of solving the more difficult three-dimensional problems. Special emphasis is placed on the ability to visualize and analyze three-dimensional structures. Analytical solution of the simpler problems is discussed. The work includes problems covering the geometrical relationship of straight lines and planes, curved lines, single curved surfaces, double curved surfaces, warped surfaces, intersections, and developments. The course stresses the practical application of descriptive geometry in the various fields of engineering.

Text: *Geometry of Engineering Drawing,* Hood.

Instructors: Tyson, Wilcox, Campbell.

D 5. **Descriptive Geometry.** 6 units (0-6-0); third term.

Prerequisites: D 1 abc.

This course is planned primarily for geology students and is designed to cover the fundamentals of descriptive geometry as given in the first part of D 2. Emphasis is placed, throughout the course, on practical problems in mining and earth structures.

Text: *Geometry of Engineering Drawing,* Hood.

Instructors: Tyson, Welch.

D 7. **Advanced Engineering Drafting.** Maximum of 6 units. Elective; any term.

Prerequisites: D 1 abc; D 2; ME 1 ab.

The study and execution of layout drawings involving further applications of machine mechanisms.

Instructor: Tyson.

GEOLOGICAL SCIENCES

UNDERGRADUATE SUBJECTS

Ge 1 a. **Physical Geology.** 9 units (4-1-4); first term.

Prerequisites: Ch 1 abc; Ph 1 abc.

A consideration of the composition and structure of the Earth and the internal and external processes which modify the crust and the surface. Dynamical and structural geology. Lectures, recitations, laboratory, and field trips.

Text: *Textbook of Geology,* Part I, Longwell, Knopf, and Flint.

Instructors: Sharp and Teaching Fellows.

Ge 1 b. **Elementary Paleontology.** 9 units (4-1-4); third term.

Prerequisite: Ge 1 a.

A discussion of the principles on which the history of life is based. Illustrations of evolution taken from certain groups of animals for which the fossil record is essentially complete. Occasional field trips.

Text: *Organic Evolution,* Lull.

Instructor: Stock.

Ge 1 c. **Historical Geology.** 12 units (4-2-6); second term.

Prerequisite: Ge 1 a.

A consideration of the geologic history of the Earth, as shown by the changing patterns of land and sea and by the succession of faunas and floras. Conferences, lectures, and occasional field trips.

Text: *Textbook of Geology,* Part II, Schuchert and Dunbar.

Instructor: Stock.

Ge 3 ab. **Mineralogy.** 8 units (3-3-2), second term; 10 units (3-6-1), third term.

Prerequisites: Ge 1 a, Ch 1 abc.

A study of the physical and chemical properties of minerals, of their associations and modes of occurrence; of their industrial applications; with training in their identification.

Text: *Introduction to the Study of Minerals,* Rogers.

Ge 4 a. **Petrology.** 6 units (2-3-1); first term.

Prerequisites: Ge 1 a, Ge 3 ab.

A study of the origin and occurrence, and training in the megascopic identification of the more important igneous rocks.

Text: *Principles of Petrology,* Tyrell; or *Rocks and Rock Minerals,* Pirrson-Knopf.

Instructor: Jahns.

Ge 4 b. **Petrology.** 8 units (2-4-2); second term.

Prerequisites: Ge 1 a, Ge 3 ab.

A study of the principal sedimentary and metamorphic rocks.

Text: *Principles of Petrology,* Tyrell; or *Rocks and Rock Minerals,* Pirrson-Knopf.

Instructor: Campbell.

Ge 14. **Geologic Illustration.** 5 units (0-3-2); third term.

Classroom training in the drawing of block diagrams. Problems in perspective, projection, and the rendering of topographical features and stratigraphy. Exercises, using various mediums, in freehand and mechanical drawing as applied to geologic illustration. Freehand sketching of landscape forms and visible geologic structures in the field.

Text: *Block Diagrams,* Lobeck.

Instructor: Willoughby.

Ge 21 abc. **Introduction to Field Geology.** 10 units (2-7-1), first, second terms; 10 units (0-7-3), third term.

Prerequisites: Ge 1 ab, Ge 3 ab.

An introduction to the interpretation of geologic features in the field, and to the fundamental principles and techniques of geologic mapping. Classroom and field studies include the interpretation of geologic maps, megascopic investigation of rock types, the solution of simple field problems in structure and stratigraphy, geologic computations, and an introduction to the use of aerial photographs and of the plane table for field mapping. To these ends, small areas are mapped in great detail and reports are prepared in professional form.

Text: *Field Geology,* Lahee.

Instructor: Jahns.

UNDERGRADUATE OR GRADUATE SUBJECTS

Ge 100. **Geology Club.** 1 unit (1-0-0); all terms.

Presentation of papers on research in geological science by the students and staff of the Division of the Geological Sciences, and by guest speakers.

Required of all senior and graduate students in the Division; optional for juniors.

Ge 102. **Oral Presentation.** 1 unit (1-0-0); first or second 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 105. **Optical Mineralogy.** 10 units (2-6-2); first term.

Prerequisite: Ge 3 ab.

The principles of optical crystallography; training in the use of the petrographic microscope in identification of crystalline substances, especially natural minerals.

Instructor: Jahns.

Ge 106 ab. **Petrography.** 10 units (2-6-2); second and third terms.

Prerequisites: Ge 105, Ch 24 ab.

A systematic study of rocks; identification of their constituents by means of the polarizing microscope; interpretation of textures; problems of genesis; qualitative and quantitative classifications.

Text: *Petrology for Students,* Harker.

Instructor: Campbell.

Ge 107. **Stratigraphy.** 12 units (4-2-6); third term.

General principles of stratigraphy. Correlation and description of sedimentary deposits. Type sections of the stratigraphic column. Stratigraphy of California.

Text: *Principles of Sedimentation,* Twenhofel.

Ge 109. **Structural Geology.** 10 units (4-0-6); first term.

Prerequisite: Ge 21 ab.

A consideration of the structural features of the Earth's crust; folds, faults, joints, foliation.

Text: *Structural Geology,* Billings.

Instructor: Buwalda.

Ge 110. **Engineering Geology.** 9 units (2-3-4); third term.

Prerequisite: Ge 1 a.

A discussion of those geological conditions that affect particular engineering operations, such as tunnelling, the building of dams, the retention of water in reservoirs, foundation excavation, harbor work, control of erosion and landslides, materials of construction, etc. Lectures, assigned reading, weekly field trips.

The course is planned primarily for civil engineers.

Text: *Elements of Engineering Geology,* Ries and Watson.

Instructor: Buwalda.

Ge 111 ab. **Invertebrate Paleontology.** 10 units (2-6-2); first, second terms.

Prerequisites: Ge 1 ab.

Morphology and geologic history of the common groups of fossil invertebrates, with emphasis on progressive changes in structures and their significance in evolution and in adaptive modifications. Laboratory, conferences, lectures, and occasional field trips.

Texts: *Tertiary Faunas,* Davies; *Invertebrate Paleontology,* Twenhofel and Shrock.

Instructor: Stauffer.

Ge 112 ab. **Vertebrate Paleontology.** 10 units (2-6-2); second, third terms.

Prerequisite: Ge 1 b.

Osteology, affinities, and history of the principal groups of fossil mammals and reptiles. History of vertebrate life with special reference to the region of western North America.

Instructor: Stock.

Ge 115. **Micropaleontology.** 8 units (1-3-4); first term.

Prerequisite: Ge 111 ab.

Introduction to the morphology and classification of the foraminifera. Their use in stratigraphic correlation with special reference to the Tertiary of California.

Texts: *The Foraminifera, their Classification and Economic Use,* Cushman; *A Manual of the Foraminifera,* Galloway.

Ge 121 ab. **Field Geology.** 10 units (0-10-0), first term; (1-5-4 or 1-9-0), second term; (0-6-4), third term.

Prerequisites: Ge 3 ab, Ge 21 ab.

The student investigates a limited geologic problem in the field. Individual initiative is developed, principles of research are acquired, and practice is gained in technical methods. The student prepares a report setting forth the results of the research and their meaning. This report constitutes the Senior Thesis.

Instructor: Jahns.

Ge 122. **Spring Field Trip.** 1 unit (0-1-0); week between second and third terms.

Brief studies of various localities in the Southwest representative of important geologic provinces. Trips are conducted in successive years to Owens and Death Valleys where excellent Paleozoic sections are exposed, and Basin Range structure and morphology may be observed; to the Salton Basin and Lower California where the San Andreas fault and the Peninsular Range may be studied; to the San Joaquin Valley and the mountains to the west where important Tertiary formations are exposed and typical Coast Range structure may be seen; and to the Grand Canyon of the Colorado River where a fascinating record of Archean, Algonkian and Paleozoic geologic history may be investigated.

Required of junior, senior, and graduate students in the Division of the Geological Sciences.

Instructors: Buwalda, Sharp.

Ge 123. **Summer Field Geology.** 12 units (0-12-0).

Prerequisites: Ge 3 ab, Ge 21 ab.

Intensive field mapping of a selected area from a centrally located field camp. Determination of the stratigraphy, fossil content, structure, and geologic history. The area chosen will probably lie in the California Coast Ranges in odd-numbered years and in the Great Basin in even-numbered years. As an occasional alternative an expedition will be conducted to localities important in California geology. The interpretations of classical localities afforded in the literature will be studied in the field. The course begins immediately after Commencement (about June 12th), and lasts for about five weeks. Required at the end of both the Junior and Senior year for the bachelor's degree in the Geology course.

Ge 125. **Geology of Western America.** 7 units (4-0-3); third term.
Presents an organized concept of the geologic history of the Rocky Mountains, the Colorado Plateau, Basin and Range, and Coast Range Provinces. Lectures, mainly by staff members personally familiar with the regions discussed, and assigned reading.
Instructors: Buwalda, Campbell, Jahns, Noble, Sharp.

Ge 126. **Geomorphology.** 10 units (4-0-6); first term.
Prerequisites: Ge 109, Ge 121 ab.
Origin and evolution of land features produced by weathering, mass movements, wind, running water, glaciers, shore processes, vulcanism, and diastrophism.
Text: *Geomorphology*, 4th edition, revised, Cotton.
Instructor: Sharp.

Ge 128. **Introduction to Economic Geology.** 7 units (4-0-3); second term.
A survey course of geology applied to coal, oil and gas, industrial minerals, metalliferous deposits, water resources, and engineering.
Text: *Economic Mineral Deposits*, Bateman.
Instructor: Noble.

Ge 165. **Introduction to General Geophysics, I.** 6 units (2-0-4); second term, 1947-48.
Prerequisites: Ma 2 ab, Ph 2 abc.
Structure of the Earth; gravity and isostasy; tides; movement of the poles; elastic properties; temperature; density.
Instructor: Gutenberg.

Ge 166. **Introduction to General Geophysics, II.** 6 units (2-0-4); second term, 1948-49.
Prerequisites: Ma 2 ab, Ph 2 abc.
Structure of the ocean and the atmosphere, tides, propagation of sound waves, temperature, density.
Instructor: Gutenberg.

Ge 175. **Introduction to Applied Geophysics.** 6 units (3-0-3); first term.
A survey of pure and applied geophysics designed mainly for geological, engineering, and other students who do not expect to enroll in specialized subjects in this field.
Text: *Geophysical Prospecting for Oil*, Nettleton.
Instructor: Potapenko.

Ge 176. **Elementary Seismology.** 6 units (3-0-3); third term.
A survey of the geology and physics of earthquakes.
Instructor: Richter.

GRADUATE SUBJECTS

Courses given in alternate years are so indicated. Courses in which the enrollment is less than five may, at the discretion of the instructor, not be offered.

GEOLOGY

Ge 200. **Mineragraphy.** 10 units (2-6-2); first term.
Prerequisite: Ge 106 ab.
Methods of identification of opaque minerals in crushed samples and polished sections, together with applications to research and practical problems.
Texts: *Microscopic Determination of Ore Minerals,* M. N. Short; U. S. G. S. Bull., 914; *Mineral Deposits,* 4th edition, Lindgren.
Instructor: Noble.

Ge 202. **Metalliferous Deposits.** 10 units (2-6-2); second term.
Prerequisites: Ge 106 ab, Ge 200.
A study of metalliferous deposits with respect to geographic distribution, structure, alteration, and mode of formation. The laboratory work will consist of a study of ore suites and altered rocks in hand specimens, polished and thin sections.
Text: *Mineral Deposits,* 4th edition, Lindgren.
Instructor: Noble.

Ge 209. **Sedimentary Petrology.** 8 units, second term 1947-48.
Prerequisite: Ge 106.
Discussion, reports and conferences on sediments, particularly from the petrographic viewpoint. The work in the laboratory affords an introduction to the various quantitative methods for detailed analysis of sediments.
Text: *Sedimentary Petrography,* 3rd edition, Milner.

Ge 210. **Metamorphic Petrology.** 8 units; second term 1948-49.
Prerequisite: Ge 106.
A study of metamorphic processes.
Text: *Metamorphism,* Harker.
Instructor: Campbell.

Ge 211. **Petrology** (Seminar). 5 units; third term.
Discussion of classic and current literature with consideration of recent advances in the field of petrology. Occasional conferences on research problems are included.
In charge: Campbell.

Ge 212. **Non-Metalliferous Deposits.** 10 units (2-6-2); 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 ores, but also to problems involving processed and fabricated materials. Occasional field trips.
Text: *Industrial Minerals and Rocks,* Seeley W. Mudd Series (A.I.M.E.)
Instructor: Campbell.

Ge 213. **Mineral Deposits** (Seminar). 5 units; second term.
Discussion of problems and current literature concerning mineral deposits.
In charge: Noble.

Ge 215. **Mineralogy** (Seminar). 5 units; first term.
Discussion of current literature and special problems related to mineralogy.
In charge: Jahns.

Ge 220. **History of the Geological Sciences.** 5 units, summer reading course.
Development of basic concepts and specialized fields by great geologists of the past. Intended to provide historical background and understanding of growth of the science.
Assigned reading during summer, examination second week of fall term.
Instructor: Stock.

Ge 226. **Advanced Geomorphology.** 10 units (3-0-7); first term 1948-49.
Prerequisites: Ge 109, Ge 121 ab, Ge 126.
Detailed analysis of geological processes acting on the earth's crust, and of the land forms they produce, with emphasis on humid regions. Lectures, assigned reading, field trips to the San Gabriel Mountains, the Coast Ranges, and the coast of California.
Instructor: Sharp.

Ge 228. **Geomorphology of Arid Regions.** 10 units (3-0-7); second term 1947-48.
Prerequisite: Ge 126.
Processes of erosion in an arid climate. Land forms of arid regions and their modes of origin. The arid cycle of erosion in the Basin and Range Province.
Lectures, assigned reading, field trips to the Mojave Desert and Death Valley.
Text: *Climatic Accidents,* Cotton.
Instructor: Sharp.

Ge 229. **Glacial Geology.** 10 units (3-0-7); second term 1948-49.
Prerequisite: Ge 126.
Origin of glaciers, existing glaciers, glaciology and glacial mechanics, erosional and depositional features of mountain and continental glaciers, chronology of the Pleistocene.
Text: *Glacial Geology and the Pleistocene Epoch,* Flint.
Instructor: Sharp.

Ge 230. **Geomorphology** (Seminar). 5 units; third term.
Discussion of research and current literature in geomorphology.
In charge: Sharp.

Ge 232. **Petroleum Geology.** 10 units (3-0-7); first term.
Prerequisites: Ge 109, 121 ab.
Theories of origin, principles of movement and accumulation of oil and gas; types of reservoir structures.

Ge 233. **Petroleum Geology Practices.** 10 units (3-4-3); second term.
Prerequisites: Ge 109, 121 ab.
Studies of individual oil fields involving discussion of structural conditions, preliminary estimates of reservoir capacity, practical methods of surface and sub-surface mapping, and sub-surface correlation.

Ge 235. **Petroleum Geology** (Seminar). 5 units; third term.
Problems of petroleum geology. Current literature and discussion of new discoveries.

Ge 237. **Tectonics.** 10 units (3-0-7); third term.
Prerequisites: Ge 109, or equivalent, and Ge 121 ab, or equivalent.
Advanced structural and tectonic geology. Structure of some of the great mountain ranges; theories of origin of mountains, mechanics of crustal deformation; isostasy; continental drift.
Instructor: Buwalda.

Ge 238. **Structural Geology** (Seminar). 5 units; first term.
Critical review of literature dealing with some part of the field of structural geology.
In charge: Buwalda.

PALEONTOLOGY

Ge 245 ab. **Vertebrate Paleontology** (Seminar). 5 units; second and third terms.

Discussion of progress and results of research in vertebrate paleontology.
Critical review of current literature.
In charge: Stock.

Ge 248. **Fossils of the California Tertiary.** 5 units; second term.

Study of some of the more important invertebrate fossils of the California Tertiary with especial emphasis on their use as horizon markers in field geology.

Ge 249. **Stratigraphy of the Coast Ranges** (Seminar). 5 units; third term.

Review, discussion and criticism of literature of the California Coast Ranges, with especial emphasis on correlation and fauna.

Ge 250. **Invertebrate Paleontology** (Seminar). 5 units; first term.

Critical review of classic and current literature in invertebrate paleontology. Study of paleontologic principles and methods.
Instructor: Stauffer.

GEOPHYSICS

Ge 261. **Theoretical Seismology.** 6 units (2-0-4); first term 1947-48.
Prerequisites: Ma 8, or Ma 10, or Ph 6 abc.
Studies and conferences on the principles of physical seismology.
Instructor: Gutenberg.

Ge 262. **Interpretation of Seismograms of Teleseisms.** 4 units (0-3-1); second term, 1947-48.
Prerequisite: Ge 261.
Instructor: Gutenberg.

Ge 263. **Field Work in Earthquakes and Interpretation of Seismograms of Local Earthquakes.** 4 units (0-3-1); third term 1947-48.
Prerequisite: Ge 261.
Instructor: Richter.

Ge 273. **Applied Geophysics, I.** 5 units (2-0-3); first term 1948-49.
Prerequisites: Ma 8, or Ma 10, or Ph 6 abc.
Methods of seismology applied to geological problems and prospecting.
Instructor: Gutenberg.

Ge 274 ab. **Applied Geophysics, II.** 5 units (2-0-3); first, second terms 1948-49.
Prerequisites: Ma 8, or Ma 10, or Ph 6 abc.
Theory of methods of electrical prospecting.
Text: *Geophysical Exploration,* Heiland.
Instructor: Potapenko.

Ge 275 ab. **Applied Geophysics, III.** 5 units (2-0-3); first, second terms 1947-48.
Prerequisites: Ma 8, or Ma 10, or Ph 6 abc.
Theory of gravitational and magnetic methods of prospecting.
Text: *Geophysical Exploration,* Heiland.
Instructor: Potapenko.

Ge 278. **Interpretation of Field Seismograms.** 4 units (0-3-1); second term 1948-49.
Prerequisite: Ge 273.
Instructor: Gutenberg.

Ge 279. **Laboratory and Field Work in Electrical Methods of Prospecting.** 7 units (0-4-3); second term 1948-49.
Prerequisite: Ge 274.
Instructor: Potapenko.

Ge 280. **Laboratory and Field Work in Gravitational and Magnetic Methods of Prospecting.** 7 units (0-4-3); second term 1947-48.
Prerequisite: Ge 275.
Instructor: Potapenko.
Ge 282 abc. **Geophysics** (Seminar). 1 unit; first, second, third terms.
Prerequisite: At least two subjects in geophysics.
Discussion of papers in both general and applied geophysics.
In charge: Gutenberg, Buwalda, Potapenko.

GENERAL

Ge 295. **Master's Thesis Research.** Units to be assigned. Listed as to field according to the letter system under Ge 299.

Ge 297. **Advanced Study.**
Students may register for 8 units or less of advanced study in fields listed under Ge 299. Occasional conferences; final examination.

Ge 299. **Research.**
Original investigation, designed to give training in methods of research, to serve as theses for higher degrees, and to yield contributions 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) non-metalliferous 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.

Special requirement in Field Geology for graduate students in the Division of the Geological Sciences.

If, in the judgment of the Division, additional technical training in geologic mapping is desirable, a graduate student may be required to take Ge 21 or Ge 121, and/or Ge 123.

Students with adequate technical background in geologic mapping may be required to gain familiarity with California geology by taking Ge 123, or an appropriate problem in areal geologic research.

SUBJECTS IN THE HUMANITIES

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.

UNDERGRADUATE SUBJECTS

Ec 2. **General Economics and Economic Problems.** 10 units (3-0-7); any term.

The purpose of this subject is to describe in as great detail as possible the economic life of the community. It includes a study of production, distribution, and exchange of goods, the nature of money and credit, the development of economic institutions, and an analysis of a number of pressing economic problems.

Instructors: Brockie, Untereiner.

Ec 3 ab. **Current Economic Problems.** 6 units (3-0-3); first and second terms.

A course in economic principles, approached through a study of current problems, national and international. An exploration of the causes and significance of inflation, unemployment, labor unrest, government controls, international trade and finance, and other headline topics.

Instructor: Untereiner.

Ec 18. **Industrial Organization.** 9 units (3-0-6); second term.

After outlining the historical background of industry with the economic changes involved, this subject surveys the major problems facing management, especially in factory operations. The principal topics included are organization, plant layout, costs and budgets, methods, time and motion study, production control, labor relations, and wage scales.

Instructors: Brockie, Untereiner.

Ec 25. **Business Law.** 6 units (3-0-3); third term.

The principles of law as applied to business affairs; a study of the law governing contracts, negotiable instruments, agency, partnership, corporations, and employer's liability. Studies will be made of engineering specifications.

Instructor: Untereiner.

Ec 48. **Introduction to Industrial Relations.*** 9 units (3-0-6).

Senior elective.

An examination of the causes of, and the proposed remedies for, some of the labor problems present in our modern industrial economy: unemployment, industrial accidents, illness, old age, wages, hours of work, and industrial disputes. In appraising solutions to these problems, consideration is given to (a) the history and functions of organized labor, (b) the efforts of employers to solve labor problems, especially through some of the techniques of personnel administration, and (c) the role of government in regulating labor conditions.

Instructor: Gray.

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

FIFTH-YEAR AND ADVANCED SUBJECTS

Ec 100 abc. **Business Economics.** 10 units (4-0-6); first, second, third terms. Open to graduate students.

This course endeavors to bridge the gap between engineering and business, especially industry. It is intended for two groups of technically trained students: 1) those who wish sooner or later, to take advantage of opportunities in industry beyond their strict technical fields, and 2) those who will be engaged in teaching and in scientific research, but who wish to get an understanding of industry in both its technical and philosophical aspects. The broad assumptions in the course are that technical training is an excellent approach to positions of general responsibility in business and industry, and that technically trained men going into industry can make significant contributions to the improved functioning of the economy.

The principal divisions of the subject matter of the course 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. Special permission to register for this course must be secured from the instructor.

Instructor: Gilbert.

Ec 110. **Industrial Relations.** 10 units (4-0-6); third term.

Not open to students who have taken Ec 48, Introduction to Industrial Relations. An introductory course dealing with the basic problems of employer-employee relationships and covering the internal organization of an enterprise, the organization and functions of unions, and the techniques of personnel administration with emphasis on the problem of setting wage rates. Two book reports are required.

Instructors: Gray, Arthur H. Young.

ENGLISH

English composition is prescribed for all students in the freshman year, and an introduction to literature is prescribed for all students in the junior year. In the senior year the students are offered a number of options in English, American, and European literature.

The instruction in composition is intended to give a thorough training in both writing and speaking. The instruction in literature is intended to provide an appreciative acquaintance with some of the chief works of major authors, past and present, and to foster the habit of self-cultivation in books.

The regular courses in English do not exhaust the attention given at the Institute to the student's use of the language, all writing, in whatever department of study, is subject to correction with regard to English composition.

UNDERGRADUATE SUBJECTS

En 1 abc. **English: Reading, Writing, and Speaking.** 6 units (3-0-3); first, second, third terms.

A thorough review of the principles of composition; constant practice in writing and speaking; and an introduction to the critical reading of essays, biographies, short stories, novels and plays.

Instructors: Clark, Eagleson, Eaton, Huse, Langston, MacMinn, Stanton.

En 7 abc. **Introduction to Literature.** 8 units (3-0-5); first, second, third terms.

Prerequisite: En 1 abc.

This course is designed to give the student a discriminating acquaintance with a selected group of principal literary works. The reading for the first term is concentrated on Shakespeare; for the second and third terms, on representative British and American authors.

Instructors: Clark, Eagleson, Eaton, Huse, Jones, Judy, Langston, MacMinn, 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. 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. 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: MacMinn.

En 10. **Modern Drama.*** 9 units (3-0-6).

Senior elective. Prerequisite: En 7.

A study of leading European, British, and American dramatists from Ibsen to writers of the present. Special attention is given to dramatic technique, and to the plays both as types and as critical comments upon life in the late nineteenth and twentieth centuries.

Instructors: Huse, Stanton.

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

En 11. **Literature of the Bible.*** 9 units (3-0-6).
Senior elective. Prerequisite: En 7.
A study of the Old and New Testaments, and the Apocrypha, exclusively from the point of view of literary interest. The history of the English Bible is reviewed, and attention is brought to new translations. Opportunity is offered for reading modern fiction, poetry, and drama dealing with Biblical subjects.
Instructor: MacMinn.

En 12 abc. **Debating.** 4 units (2-0-2).
Elective, with the approval of the Registration Committee.
A study of the principles of argumentation; systematic practice in debating; preparation for intercollegiate debates.
Instructor: Schutz.

En 13. **Reading in English and History.** Units to be determined for the individual by the department.
Elective, with the approval of the Registration Committee, in any term.
Collateral reading in literature and related subjects, done in connection with regular courses in English or history, or independently of any course, but under the direction of members of the department.

En 14. **Special Composition.** 2 units (1-0-1).
This subject may be prescribed for any student whose work in composition, general or technical, is unsatisfactory.

En 15 abc. **Journalism.** 3 units (1-0-2); first, second, third terms.
Elective, with the approval of the Registration Committee.
A study of the elementary principles of newspaper writing and editing, with special attention to student publications at the Institute.
Instructor: MacMinn.

En 16. **Spelling.** No credit.
This subject may be prescribed for any student whose spelling is unsatisfactory.

En 17. **Technical Report Writing.*** 9 units (3-0-6).
Senior elective. Prerequisite: En 7.
Practice in writing reports and articles in engineering, science, or business administration. The course includes some study of current technical and scientific periodicals. The major project is the preparation of a full-length report.
Instructors: MacMinn, Stanton.

En 20. **Summer Reading.** Maximum 16 credits.
Credits are allowed to the maximum number of 16 for vacation reading from a selected list of books in various subjects, and written report thereon.

FIFTH-YEAR AND ADVANCED SUBJECTS

En 100 abc. **Seminar in Literature.** 9 units (3-0-6).
A study of some selected group of writers chosen to illustrate modern trends in literary and social history.
First term: The Revolution in Thought, Rousseau to Darwin. A consideration of some of the landmarks in literature which influenced the social and intellectual development of the modern world. The continuing influence upon present-day thought of nineteenth century ideas will receive special attention.
Instructor: Wright.
Second term: The westward expansion in America.
Instructor: Wright.
Third term: To be announced.

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

HISTORY AND GOVERNMENT

UNDERGRADUATE SUBJECTS

H 1 abc. **History of European Civilization.** 5 units (3-0-2); first, second, third terms.

Lectures on and discussions of the civilizations of the Ancient World, the institutions of the Middle Ages, and the foundations and development of the modern state system, with emphasis throughout on the commanding problems of the period since 1914. Required of all freshmen.

Instructor: McCreery.

H 2 abc. **History of the United States.** 6 units (2-0-4); first, second, third terms.

Lectures on and discussions of the History of the United States since colonial times with due attention to constitutional development and the changing aspect of the country's foreign policy, and with special emphasis on the history of the twentieth century. Required of all sophomores.

Instructors: Paul, Schutz.

H 4. **The British Empire Since 1815.*** 9 units (3-0-6).

Senior elective.

A study in the evolution of empire. Discussion of the changing political philosophy and methods by which Britain has adjusted her imperial policy to new conditions created by modern industrialism, humanitarianism, and shifts in the international balance of power.

Instructor: Schutz.

H 5 ab. **Current History.** 2 units (1-0-1); first, second terms.

This subject is given collaterally with senior humanities electives, and is articulated with a selected weekly journal of general information and opinion. Its purpose is to direct attention to outstanding problems in current national and international affairs. Required of all seniors.

Instructors: McCreery, Sterling.

H 7. **Modern and Contemporary Germany.*** 9 units (3-0-6).

Senior elective.

A study of what is sometimes called "The German Problem." The course will direct attention to the rise of Prussia in Europe and to Prussian leadership in the unification and direction of Germany, to the relation of the German to the European economy, and particularly to German experience since the first world war.

Instructor: McCreery.

H 8. **The History of Russia.*** 9 units (3-0-6).

Senior elective.

A study of the rise of Russia as a national state; of Russian national expansion in Eurasia and of the long struggle to secure warm water outlets for the land empire. Special emphasis will be placed on Russian economic development both under the Tsars and under the Soviets, and on the revolutionary movements of the 19th and 20th centuries.

Instructor: Sterling.

H 10. **The Constitution of the United States.** 2 units (1-0-1); third term.

A study of the principles and provisions of the national constitution in the light of interpretation by the courts. Required of all seniors.

Instructor: Schutz.

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

H 15. **The World Since 1914.*** 9 units (3-0-6).
Senior elective.

A survey of recent international relations. Its purpose is to study: the machinery by which nations conduct their foreign relations; the foreign policies of the great powers; the causes of war; political philosophies; problems of imperialism; the United Nations.

Instructor: Sterling.

H 16. **American Foreign Relations Since 1789.*** 9 units (3-0-6).
Senior elective.

A study of the foreign relations of the United States from new nation to world power. Attention will be directed to problems concerning: The Monroe Doctrine, neutrality, freedom of the seas, manifest destiny, acquisition of overseas possessions, isolationism vs. world leadership.

Instructor: Schutz.

H 17. **The Far West and the Great Plains.*** 9 units (3-0-6).
Senior elective.

A study of the development of the great regions that compose the western half of the United States. Especial attention will be paid to the influence of the natural environment on the men who settled the West, and the exploitation of natural resources, through such industries as mining, ranching, oil, and farming.

Instructor: Paul.

H 18. **The Old South: A Study in Persistence.*** 9 units (3-0-6).
Senior elective.

A study of life in the Old South, of the sectional crisis and Civil War, of "Reconstruction" and of the "unreconstructed South."

Instructor: Paul.

H 19. **Modern America.*** 9 units (3-0-6).
Senior elective.

The course will focus attention on the main social and economic forces which have shaped present-day American life since the Civil War. A considerable part of the discussion will be based on original source material.

Instructor: Paul.

FIFTH-YEAR AND ADVANCED SUBJECTS

H 100 abc. **Seminar in History and Government.** 9 units (3-0-6).

A study of recent developments in national and international history.

First and second terms: English and American foreign policy considered in its political, social, and economic aspects.

Instructor: Davies.

Third term: To be announced.

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

LANGUAGES

The subjects in modern languages are arranged primarily to meet the needs of science students who find it necessary to read books, treatises, and articles in French, German, and Russian. In the study of these languages correct pronunciation and the elements of grammar are taught, but the emphasis is laid upon the ability to translate from them into English.

UNDERGRADUATE SUBJECTS

L 1 ab. **Elementary French.** 10 units (4-0-6); second, third terms.

A subject in grammar, pronunciation, and reading that will provide the student with a vocabulary and with a knowledge of grammatical structure sufficient to enable him to read at sight French scientific prose of average difficulty. Accuracy and facility will be insisted upon in the final tests of proficiency in this subject. Students who have had French in the secondary school should not register for these subjects without consulting the department of modern languages.

Instructors: Bowerman, Stern.

L 5 abc. **French Literature.*** 9 units (3-0-6); first, second, third terms.

Senior elective. Prerequisite: L 1 ab, or the equivalent.

The reading of selected classical and modern literature, accompanied by lectures on the development of French literature. Elective and offered when there is sufficient demand.

Instructors: Bowerman, Stern.

L 32 abc. **Elementary German.** 10 units (4-0-6); first, second, third terms.

This subject is presented in the same manner as the Elementary French. Students who have had German in the secondary school or junior college should not register for these subjects without consulting the department of modern languages.

Instructors: Bowerman, Stern.

L 35 a. **Scientific German.** 10 units (4-0-6); first term.

Prerequisite: L 32 abc, or equivalent.

This is a continuation of L 32 abc, with special emphasis on the translation of scientific material in the student's field.

Instructor: Bowerman.

L 39 abc. **Readings in French or German.** Units to be determined for the individual by the department. Elective, with the approval of the Registration Committee, in any term.

Reading in scientific or literary French or German under the direction of the department.

L 40 abc. **German Literature.*** 9 units (3-0-6); first, second, third terms.

Senior elective. Prerequisite: L 35 a, or L 32 abc with above average grades.

The reading of selected classical and modern literature, accompanied by lectures on the development of German literature.

Instructors: Bowerman, Stern.

L 50 abc. **Elementary Russian.** 10 units (4-0-6); first, second, third terms.

A subject in pronunciation, grammar, and reading that is intended to enable a beginner to read technical prose in his field of study. Students are expected to become familiar with a basic scientific vocabulary. Articles from current Russian scientific periodicals are used in the second and third terms.

Instructor: Chaitkin.

FIFTH-YEAR AND ADVANCED SUBJECTS

L 105 abc. Same as L 5 abc. For graduate students.

L 140 abc. Same as L 40 abc. For graduate students.

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

PHILOSOPHY, PSYCHOLOGY, AND SOCIOLOGY

UNDERGRADUATE SUBJECTS

Pl 1. **Introduction to Philosophy.*** 9 units (3-0-6); second term.
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.

Instructor: Mead.

Pl 4. **Ethics.*** 9 units (3-0-6); third term.
Senior elective.

The principal concepts and conflicts of man's ethical thought, studied in terms of the major ethical systems. The problems of the good life, the nature of obligation, and the sources of moral authority are considered at length, particularly in relation to modern life and its ethical tensions.

Instructor: Mead.

Pl 5. **Sociology.*** 9 units (3-0-6).
Senior elective.

The genesis and evolution of human society. The influence of economic, religious and social forces. The nature of social control and the analysis of mores, morals, and legal codes. The development of social institutions and the nature of change in these institutions.

(Not offered in 1947-48.)

Pl 6. **General Psychology.*** 9 units (3-0-6); first term.
Senior elective.

A study of modern psychological theory and practice. Among topics considered are: the nature and measurement of intelligence; human and animal learning; feeling, emotion, attitude; nervous structures and functions; sense organs and functions; imagination, dreams; memory and forgetting; current psychological doctrines, etc.

Instructor: Mead.

FIFTH-YEAR AND ADVANCED SUBJECTS

Pl 100 abc. **Seminar in Philosophy.** 9 units (3-0-6); each term.

First term: Science and Philosophy. The relations between science and philosophy and their mutual influences upon each other. The principal contributions of science to the general history of thought, particularly since Galileo and Descartes.

Second term: **Science and Logic.** A study of the general methodology and logic of science. Induction, casuality and the central role of the hypothesis.

Third term: **Science and Society.** The place of science and scientific thought in the larger setting of modern society. The social implications of scientific method and the knowledge it produces, together with some conflicting views regarding the scientist's responsibility to society as a whole.

Instructor: Mead.

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

HYDRAULICS

UNDERGRADUATE SUBJECTS

Hy 1. **Hydraulics.** 9 units (3-0-6); first term.
Prerequisites: AM 1 abcd, ME 15 abc.
Application of basic principles of fluid mechanics to engineering problems in laminar and turbulent flow, flow in closed conduits, flow in open channels, flow around immersed bodies, cavitation; analysis and study of hydraulic turbines and centrifugal pumps.

Hy 2 ab. **Hydraulics.** 9 units (3-0-6); first and second terms. (For Civil Engineers).
Prerequisite: AM 1 ab.
Kinematics and dynamics of fluid motion with particular emphasis on the properties of water. Hydrostatics, flow of water in pipes, nozzles, channels; hydraulic turbines; centrifugal pumps and other hydraulic equipment.

Hy 11. **Hydraulic Laboratory.** 6 units (0-6-0); second term.
Prerequisite: AM 1 abcd.
Experiments on the characteristics of fluid flow and tests of hydraulic machines.

ADVANCED SUBJECTS

Hy 100. **Hydraulics Problems.** Units to be based upon work done, any term.
Special problems or courses may be arranged to meet individual needs.

Hy 101 a. **Advanced Fluid Mechanics.** 6 units (2-0-4); second term.
Prerequisites: Hy 1 ab or Hy 2 ab and Hy 11.
Dimensional analysis; hydraulic similitude, theory and use of hydraulic models; elementary principles of flow; principles of energy, continuity and momentum; theory and use of the flow net; development of generalized equations of flow; circulation and vorticity; velocity and force potentials; stream function; conformal transformation; cavitation; equations of viscous motion; laminar flow; lubrication; percolation.
Instructor: Wagner.

Hy 101 b. **Advanced Fluid Mechanics.** 9 units (3-0-6); third term.
Prerequisite: Hy 101 a.
Fluid turbulence; boundary layer; separation; resistance of immersed bodies; flow in closed conduits; resistance and roughness; flow in open channels; hydraulic jump; sub- and super-critical flow phenomena; weirs and spillways; erosion; transportation of sediment; wave phenomena; and miscellaneous topics.
Instructor: Wagner.

Hy 110. **Hydraulics.** 7 units (3-0-6); first term.
Prerequisites: AM 1 abcd, ME 15 abc.
This subject is the same as Hy 1, but with reduced credit for graduate students in all departments except AE, CE, and ME. No graduate credit is given for this subject to students in AE, CE, and ME.

Hy 200. **Advanced Work in Hydraulic Engineering.** Units to be based upon work done; any term.
Special problems in hydraulics will be arranged to meet the needs of students wishing to do advanced work in this field.

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.

Hy 202 ab. **Hydraulics of Free Surface Phenomena.** 6 units (2-0-4).

A study of the hydrodynamics of a fluid having a free surface with special reference to gravity wave phenomena. Fields studied will include low and high velocity in open channels and wave phenomena in enclosed bodies of fluid.

Hy 203. **Cavitation Phenomena.** 6 units (2-0-4).

Study of the experimental and analytical aspects of cavitation and allied phenomena. Problems will be considered from the field of hydraulic machinery and also for bodies moving in a stationary fluid.

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.

Hy 300. **Thesis.**

INDUSTRIAL DESIGN

FIFTH-YEAR SUBJECTS

ID 101 abc. **Industrial Design I.** 15 units (2-9-4); first, second, third terms.

Basic elements in industrial design. Analysis of interdependence of function, construction, or manufacturing process, material and appearance. Abstract and practical form problems. Selected problems in product design.

Instructors: Welch, Greene.

ID 111 abc. **Experimental Laboratory.** 8 units (0-8-0); first, second, third terms.

Training in carrying design concepts from the drawing through a working model. Instruction in shop procedures as applied in industry to production in metallic and non-metallic materials.

Instructor: Morant.

ID 121 abc. **Design Techniques I.** 3 units (0-3-0); first, second, third terms.

Instruction in the methods of two and three dimensional presentations, including free-hand and mechanical drawing, lettering, perspective, color rendering, model construction, montages, and use of photography in presentation.

Instructors: Merendino, Welch.

ID 131. **Design Trends.** 3 units (1-0-2); second term.

The evolution of industrial design through the various phases of machine age styles.

Instructors: Greene, Welch.

ID 141 abc. **Non-Metallic Materials.** 9 units (3-0-6); first, second, third terms.

A study of plastics, fibres, and the developments of the chemical laboratory as related to modern manufacturing and design.

Instructor: Youtz.

ID 151. **Cost Analysis.** 5 units (2-0-3); third term.

Instruction in specialized accounting practice of value to the designer in controlling, analyzing, and estimating production costs and in cooperating with the needs of industry.

Instructor: Huston.

ID 161. **History of Art.** 3 units (1-0-2); first term.

A survey of the development of forms through the ages with the correlation of aesthetic expression and theory with the cycles of political, social, and economic change.

Instructors: Visiting Lecturers and Members of the Faculty.

ID 171 abc. **Weekly Seminar.** 1 unit (1-0-0); first, second, third terms.

A critical presentation and discussion of current Industrial Design problems including conferences with selected members of industry and the design profession. Opportunity is given for the individual oral presentation of the students' work before selected juries as a part of the training in the demonstration and presentation of design solutions.

ADVANCED SUBJECTS

ID 201 abc. **Industrial Design II** (Thesis). 21 units (2-15-4), first, second terms; 24 units, third term.

Selected advanced problems in industrial design and a major problem selected individually by the student, giving an opportunity and the encouragement for the exercise of personal initiative in the solution. This class is conducted as a seminar. The third term is devoted largely to thesis work.

Instructors: Visiting Lecturers and Members of the Faculty.

ID 211 abc. **Production Methods.** 8 units (1-6-1); first, second, third terms.

Tool engineering, tool planning, and tool design. Industrial practices and research.

Instructor: Morant.

ID 221 abc. **Design Techniques II.** 7 units (0-7-0) first, second terms; 4 units (0-4-0) third term.

Production illustration, breakdown-diagrams, and advanced training in presentation through color rendering.

Instructors: Merendino, Greene, Welch.

ID 231 abc. **Technical Trends in Design.** 6 units (2-0-4); first, second, third terms.

Analysis of industrial design problems as they appear from the standpoint of technological development and current manufacturing trends. Review of patent and trademark regulations as affecting the work of the professional designer.

Instructor: Youtz.

ID 241 abc. **Merchandising Analysis.** 9 units (2-3-4); first, second, third terms.

A study of the broader implications of the work of the designer in controlling and analyzing public demand and needs as related to manufacturing, marketing, and pricing problems.

Instructor: Youtz.

ID 271 abc. **Weekly Seminar.** 1 unit (1-0-0); first, second, third terms.

A critical presentation and discussion of current industrial design problems including conferences with selected members of industry and the design profession.

Supplementary lectures by visiting designers and engineers, and seminars are offered as occasion permits. (See page 129.)

MATHEMATICS

UNDERGRADUATE SUBJECTS

Note: Students intending to take the Mathematics Option must indicate their choice at the beginning of their sophomore year.

Ma 1 abc. **Freshman Mathematics.** 12 units (4-0-8); first, second, third terms.
Prerequisites: High school algebra and trigonometry.
An introduction to differential and integral calculus and the fundamentals of plane analytic geometry.
Text: *Analytic Geometry and Calculus,* Phillips.

Ma 2 abc. **Sophomore Mathematics.** 12 units (4-0-8); first, second, third terms.
A continuation of the freshman calculus, through partial differentiation, multiple integration and the use of series. The course includes as well topics in solid analytic geometry and vector analysis.
Texts: *Calculus* and *Analytic Geometry,* Middlemiss; *Analytic Geometry and Calculus,* Phillips.

Ma 3. **Theory of Equations.** 10 units (4-0-6); first term.
Includes topics in algebra of interest to mathematicians, physicists and applied mathematicians. Topics treated: numerical solution of equations, the fundamental algebraic operations, properties of number fields and polynomials, linear equations and determinants with application to vector spaces, symmetric functions.
Text: *Introduction to Theory of Equations,* Weiner.
Instructor: Wear.

Ma 4. **Geometry.** 10 units (4-0-6); third term.
A treatment of the classical metric, affine, and projective geometries of two and three dimensions.
Text: *Higher Geometry,* Graustein.
Instructor: Wear.

Ma 8 abc. **Advanced Calculus.** 9 units (4-0-5); three terms.
Prerequisites Ma 1, 2.
This course will deepen and extend the student's knowledge of the technique and methods of the calculus and in addition to covering the topics outlined under Ma 57, the course will include elementary functions of a complex variable, line integrals, gamma functions, elliptic functions and calculus of variations. This course or its equivalent is a prerequisite to graduate mathematics courses in analysis.
Text: *Methods of Advanced Calculus,* Franklin.

Ma 10. **Differential Equations.** 10 units (4-0-6); third term.
Prerequisites: Ma 1, 2.
This course will stress the rigorous development of the subject rather than formal methods of solution. Topics treated will include the general existence theorems, systems of differential equations, solutions of equations by means of operators, series, and iteration methods, treatment of non-linear differential equations and perturbation methods.
Text: *Differential Equations,* Agnew.
Instructors: Goldsworthy, Ward.

Ma 12. **Elementary Statistics.** 9 units (3-0-6); first term.
Prerequisites: Ma 1, 2.
This course is intended for anyone interested in the applications of statistics to science and engineering, and is a prerequisite to all other courses in statistics. The topics treated will include the preparation and systematization of experimental

data, the fundamental statistical concepts; population, sample, mean and dispersion, curve fitting and least squares, significance tests and problems of statistical estimation.

Text: Selected references.

Instructor: Dilworth.

Ma 16. **Matrices and Quadratic Forms.** 10 units (4-0-6); third term.

This course is intended for mathematicians and those physicists and engineers who must use the methods and techniques of modern linear algebra. It will cover the more frequently used parts of matrix algebra, linear transformations, quadratic forms and linear spaces.

Instructors: Bell, Ward.

Ma 57. **Introduction to Analysis.** 15 units (5-0-10); third term.

Prerequisites: Ma 1, 2; and either Ma 8 or Ph 15.

This course will give a rigorous treatment of the fundamentals of classical real variable theory. Among the topics treated will be: the real number system, the concept of a function, continuity, differentiability, Hiemann integrability, double limits and uniform convergence, infinite series and integrals, orthegonal functions, general properties of functions defined by definite integrals, the classical conditions for Fourier series expansions. To be given only in 1948. Juniors and Seniors planning to take more analysis should take Ma 8 abc if possible.

Ma 60. **Mathematical Probability and Statistics.** 9 units (3-0-6).

Prerequisites: Ma 12.

This course will give the mathematical development underlying modern statistical methods. Topics treated will include: characteristic functions, properties of the binomial, Poisson and normal distributions, the fundamental sampling statistics and their distributions, stochastic convergence and the central limit theorem.

Instructor: Dilworth.

UNDERGRADUATE OR GRADUATE SUBJECTS

Ma 98 abc. **Advanced Calculus.** 6 units; three terms.

Prerequisites: Ma 1, 2.

This subject is the same as Ma 8, but with reduced credit for graduate students. Graduate students in mathematics receive no credit for taking this subject.

Ma 101 abc. **Modern Algebra.** 9 units; three terms.

Prerequisites: Ma 8 abc, reading knowledge of German.

Abstract algebra as developed since about 1910.

Instructors: Bell, Dilworth.

Ma 102 abc. **Introduction to Higher Geometry.** 12 units; three terms.

Prerequisites: Ma 1 ab, 2 abc, 4 ab.

The course covers selected topics in metrical differential geometry and in algebraic geometry.

Instructor: Wear.

Ma 106 abc. **Introduction to Theory of Functions of Real Variables.** 9 units; three terms. Required for graduation (B.S.) in mathematics.

Prerequisite: Ma 8 ab.

Postulational treatment of real number system, descriptive properties of point sets, continuous and discontinuous functions, derivatives and differentials. Riemann integration, functions of several real variables, implicit functions. Modern integration theory. Topological spaces, metric spaces and normed spaces with special emphasis on function spaces, Hilbert spaces and Banach spaces. Existence theorems for differential equations. Theory of functionals and functional transformations. Polynomials and power series in normed linear spaces. Differentials in normed linear spaces. Integral equations and other functional equations.

Instructor: Michal.

Ma 111 ab. **Elementary Theory of Tensors.** 9 units; two terms.
Prerequisites: Ma 8 abc, 10.
Fundamental properties of tensors, differential forms, covariant differentiation, geodesic coordinates, Riemannian differential geometries. Applications to dynamics, fluid mechanics, elasticity theory and other physical and engineering subjects.
Instructor: Michal.

Ma 113 abc. **Geometry.** 12 units; three terms.
Prerequisite: Ma 2 abc.
Algebraic geometry; projective geometry; differential geometry; tensor analysis and its applications to numerous geometrical problems; non-Euclidean geometry; Riemannian differential geometry; geometry of dynamics; hyperspace; elementary group theory and its geometrical applications.
Texts: *Applications of the Absolute Differential Calculus,* McConnell; *Riemannian Geometry,* Eisenhart; collateral reading.
Instructor: Michal.

Ma 114 abc. **Mathematical Analysis.** 12 units; three terms.
Prerequisites: Ma 8 abc, 57; Ma 10 or its equivalent.
Theory of convergence, integration and residues, expansions of functions in infinite series, asymptotic and divergent series. Fourier series. Differential equations and function theory, integral equations, the gamma function and the zeta function, the hyper-geometric function and related functions of mathematical physics, elliptic functions, ellipsoidal harmonics.
This course will be offered every alternate year.
Text: *Functions of a Complex Variable,* Copson.
Instructors: Bohnenblust, Ward, Robertson.

Ma 119 abc. **Introduction to Theory of Numbers.** 9 units; three terms.
Prerequisites: Ma 1 abc, 2 abc.
The fundamental theorem of arithmetic, continued fractions, congruences, Bernouilli numbers, quadratic residues, quadratic forms and other topics in elementary number theory.
Instructor: Ward.

Ma 137 abc. **Real Variables.** 9 units; three terms.
Prerequisites: Ma 8 abc or its equivalent.
The real number system; the fundamental concepts of topology and point-set theory; types of abstract spaces and mappings of spaces, set functions, functionals and sequences, continuous and discontinuous functions, series and summability methods, measure of sets, Lebesgue and Stieltjes integration, differentiability, function spaces and Hilbert space, linear operators.
Instructors: Bohnenblust, Ward.

Ma 138 abc. **Applied Mathematics.** 12 units; three terms.
Prerequisites: Ma 8 abc or Ma 10.
Matrix calculus, tensor calculus and operational calculus—including Laplace transform theory and numerical methods. Most of the course will be devoted to applications of the subjects to vibrations, circuit theory, flutter theory in aeronautics, fluid mechanics, elasticity theory, classical dynamics of particles and rigid bodies, and to modern physics. A brief but adequate introduction to analytic functions of a complex variable and conformal mapping will be given. The applications will include airfoil theory and the more advanced portions of Laplace transform theory.
Instructor: Michal.

Ma 139 abc. **Topology and Modern Geometry.** 9 units; three terms.
Prerequisites: Ma 8 and Ma 10.
An introduction to topology, topological algebra and topological spaces. Applications to various mathematical domains, especially to the foundations of Euclidean and Non-Euclidean geometries, and to the foundations of differential geometry.
Instructor: Michal.

Ma 140 abc. **Combinatorial Topology.** 9 units (3-0-6); three terms.
Introduction to combinatorial topology by a study of two-dimensional manifolds. Their classification. Applications to Riemann surfaces. General homology and co-homology theory. Invariance under homomorphisms. Application to Analysis.
Instructor: Bohnenblust.

GRADUATE SUBJECTS

Note: For all subjects numbered above 200, a reading knowledge of French and German is required.

Ma 202 abc. **Modern Theory of Differential Equations.** 9 units; three terms.
Prerequisites: Ma 10, 114.
Expansion of functions in series, asymptotic expansions. Linear differential equations in complex domain. Elementary methods of integration. General theory of linear differential equations and their solution by definite integrals and contour integrals. Classification of linear differential equations of the second order.
Instructor: Ward.

Ma 205 abc. **Theory of Functions.** 15 units; three terms.
Theory of convergence and infinite processes, properties of continuous and discontinuous functions, functions of limited variation, selected topics on analytic functions, point sets, measure of point sets, Stieltjes integrals, Lebesgue integrals, Fourier series and integrals, orthogonal functions, convergence in the mean, geometry of Hilbert Space. Function theory in abstract spaces.
Text: *The Theory of Functions*, Titchmarsh.
Instructor: Michal.

Ma 209 abc. **Functionals and Functional Equations.** 15 units; three terms.
Prerequisite: Graduate standing in Mathematics, including a course in Analysis.
Functional operations; permutable functions, functions of composition; integral equations, integro-differential equations; differentials of functions, functional equations with functional derivatives; infinite matrices; Stieltjes and Lebesgue integrals; abstract spaces; partial differential equations and their characteristics; calculus of variations. Applications to the sciences. Analytic functionals.
Instructor: Michal.

Ma 218 abc. **Advanced Mathematical Statistics.** 9 units; three terms.
Prerequisite: Ma 60.
Characteristic function methods, the moment problem, limit theorems of probability theory, selected topics in sampling theory.
Instructor: Dilworth.

Ma 251 a. **Seminar in Algebra and the Theory of Numbers.** 6 units; first term.
Prerequisite: Graduate standing.
Topics selected to suit the class.
In charge: Bell.

Ma 251 b. **Mathematical Logic.** 6 units; second term.
Instructor: Bell.

Ma 251 c. **Theory of Algebraic Numbers.** 6 units; third term.
Prerequisite: Graduate standing.
Instructor: Bell.

Ma 252 abc. **Seminar in Continuous Groups.** 9 units; three terms.
Prerequisite: Graduate standing in Mathematics.
Lie's theory of r-parameter groups; differential geometry of the group manifold. Groups of functional transformations; invariant functionals; differential geometries of function spaces. Topological groups.
In charge: Michal.

Ma 253 abc. **Seminar in Foundations of Abstract Algebra.** 6 units; three terms.

Prerequisite: Graduate standing.

Lattice theory, Boolean rings and algebras. Decomposition theorems in rings and hypercomplex systems.

In charge: Ward.

Ma 254 abc. **Seminar in Modern Theories of Integration.** 6 units; three terms.

Prerequisite: Graduate standing in Mathematics, including a course in Function Theory.

Stieltjes and Lebesgue integrals with applications to the algebra and geometry of functionals.

In charge: Michal.

Ma 255 abc. **Methods of Mathematical Physics.** 10 units; three terms.

Prerequisites: Ma 8 abc, Ma 10.

Matrices and bilinear forms, spectral analysis of quadratic forms in Hilbert space. Fourier series, integrals, and expansions in terms of orthogonal function systems. Integral Equations the methods of Volterra, Fredholm, Hilbert. Introduction to the Calculus of Variations. Partial Differential Equations of the Elleptic Type —Green's Function. Vibration and Quantum Mechanical Problems—equations of the Sturm-Louiville type. Spectral Resolution of differential operators. Asymptotic distribution of eigen-values. Perturbation Methods.

Instructors: Ward, de Prima, Robertson.

Ma 256 abc. **Modern Differential Geometry.** 9 units; three terms.

Prerequisite: Graduate standing.

Riemannian and Non-Riemannian geometries. Theory of parallel displacement of tensors. Affine differential geometry. Projective differential geometry. Continuous groups and their applications to geometry. Contemporary researches in differential geometry.

Instructor: Michal.

Ma 257 abc. **Seminar in Abstract Spaces.** 6 units; three terms.

Prerequisite: Graduate standing.

Metric spaces, linear vector spaces; topological spaces; abstract polynomials; general function theories; analysis and geometry in abstract spaces; connections with abstract algebra and the theory of functionals; analysis of selected papers of Frechet, Riesz and Banach; contemporary researches; applications to mathematical problems in modern theoretical physics.

In charge: Michal.

Ma 260. **Reading.**

Occasionally advanced work is given by a reading course under the direction of an instructor. Hours and units by arrangement.

Ma 261. **Research.**

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

Ma 270 abc. **Seminar in Applied Mathematics.** 6 units; three terms.

Prerequisite: Graduate standing.

Subjects selected according to the interest of the members of the seminar.

In charge: Michal.

Ma 271 abc. **Seminar in Mathematical Analysis.** 3 or 6 units; three terms.

A fortnightly seminar open to anyone who has taken or is taking a course in analysis or functional theory.

In charge: Michal.

Ma 272 abc. **Seminar in Normed Rings.** 6 units; three terms.

Prerequisites: Ma 114 and Ma 137 or their equivalents.

Representation theory, integrations over rings, operators over rings. The seminar will cover the current literature and research problems of this field.

In charge: Karlin. To be given 1947-48 only.

MECHANICAL ENGINEERING

UNDERGRADUATE SUBJECTS

ME 1 a. **Empirical Design.** 3 units (0-3-0); second term.
Prerequisites: D 1 abc.
This course is designed to supplement D 1 bc with the more advanced drafting and layout techniques, and to introduce elementary principles of design. Drafting room problems are formulated to incorporate these principles and to introduce the use of design reference material.
Instructors: Tyson, Welch, Campbell.

ME 1 b. **Empirical Design.** 6 units (0-6-0); third term.
Prerequisites: D 1 abc, D 2, ME 1 a.
This course is a continuation of ME 1 a. Problems involving simple design features, the use of reference material and a consideration of materials, are stressed. Machine mechanisms including the transfer of velocities and accelerations through linkages by graphical methods, gearing applications, gear trains and cams are studied in relation to layout and machine design.
Instructors: Tyson, Welch, Campbell.

ME 3. **Materials and Processes.** 9 units (3-3-3); first or second term.
Prerequisites: Ph 1 abc, Ch 1 abc.
A study of the materials of engineering and of the processes by which these materials are made and fabricated. The fields of usefulness and the limitations of alloys and other engineering materials are studied, and also the fields of usefulness and limitations of the various methods of fabrication and of processing machines.
The class work is combined with inspection trips to many industrial plants. The student is not only made acquainted with the technique of processes but with their relative importance industrially and with the competition for survival which these materials and processes continually undergo.
Text: *Materials and Processes,* Clapp and Clark.
Instructor: Clark.

ME 5 abc. **Machine Design.** 9 units (2-3-4); first, second, third terms.
Prerequisites: ME 1, AM 1 abcd.
Application of the mechanics of machinery and strength of materials, which are reviewed and extended, to practical design and construction. Fastenings: riveting, welding, screws, bolts and keys. Power transmission: shafting, sleeve and rolling bearings, belts, chains, gears, couplings, and clutches. Elements of power machinery: cylinders, cylinder heads, piping and valves, springs, crankshafts, flywheels, packing and seals. Variety in design is explained by pointing out the different requirements of every application.
Instructor: Hollander.

ME 10. **Metallurgy.** 12 units (3-3-6); third term.
Prerequisite: ME 3.
A study of the properties of ferrous and non-ferrous metals and alloys with respect to their application in engineering; the principles of heat treatment for a proper understanding by engineers for application in specification of alloys for design. The microstructures of ferrous and non-ferrous metals and alloys are studied in the laboratory.
Text: *Engineering Physical Metallurgy,* Heyer.
Instructor: Clark.

ME 15 abc. **Thermodynamics and Fluid Mechanics.** 11 units (3-3-5); first, second, third terms.
Prerequisites: Ma 2 abc, ME 1 ab.
A study of the first and second laws of thermodynamics and their application to flow and non-flow processes both with and without friction. Emphasis will be

placed on single component systems. Fluid motion treated from the point of view of thermodynamics and of mechanics for flow with and without friction. Steady flow versus non-steady flow. Introduction to the detailed mechanics of fluid motion and its relation to energy dissipation.

Application of the basic principles to the main types of fluid motions encountered in engineering problems and to the main classes of industrial heat engines, thermodynamic processes, and hydraulic machinery.

Laboratory demonstrations of thermodynamic and fluid mechanic principles. Tests of industrial heat engines and hydraulic machinery.

Instructor: Daugherty.

ME 16 ab. **Thermodynamics.** 9 units (3-0-6) first term; 6 units (2-0-4) second term.

Prerequisite: ME 15 abc.

Further discussion of engineering applications of thermodynamics, including more detailed analyses of the examples included in ME 15, and additional items such as the following: Combustion processes and flue gas analysis; heat transfer (correlate conduction and convection discussion with fluid mechanics discussion of turbulence); gas and vapor mixtures.

Instructor: Daugherty.

ME 20. **Heat Engineering.** 9 units (3-0-6); first term.

An abridgement of ME 15 and 16 for students in civil engineering.

ME 25. **Mechanical Laboratory.** 9 units (0-6-3); third term.

Prerequisite: ME 15 abc.

Tests of steam engine, steam turbine, blower and gas engine, etc., for efficiency and economy.

Text: *Power Plant Testing,* Moyer.

ME 50 ab. **Engineering Conferences.** 2 units (1-0-1); first, third terms.

A course in public speaking for engineers, on engineering topics.

Instructor: Daugherty.

FIFTH-YEAR AND ADVANCED SUBJECTS

ME 100. **Advanced Work in Mechanical Engineering.**

The staff of the mechanical engineering department will arrange special courses or problems to meet the needs of fifth-year students or qualified under-graduate students.

ME 101 ab. **Advanced Machine Design.** 10 units (2-6-2); second, third terms.

Prerequisites: ME 5 abc, ME 10.

The application of machine elements to specific problems of design by combining them to form a self-contained unit for a definite purpose. Attack of such a design problem by setting up the different requirements of the specified unit, and showing how they may vary, according to the number of such units to be made, the methods of manufacture, space, weight, and cost limitations, required life, wear, and duty. Selection of materials and of permissible stresses and strains for various conditions. Examination and justification of established constructions, with a consideration of possible improvements and of different methods of approach.

Examples in the design course are chosen to broaden the students' knowledge of sound practice, and to show that for a good solution of such design problems a fundamental knowledge of mechanics, thermodynamics, and hydraulics is essential as well as a knowledge of the strength and properties of materials and the methods of forming them by casting, forging, welding, machining, and other processes.

Instructor: Hollander.

ME 104 abc. **Machine Design.** 7 units (2-3-4); first, second, third terms.
Prerequisites: ME 1, AM 1 abcd.
This subject is the same as ME 5 abc, but with reduced credit for graduate students in all departments except AE, CE, and ME. No graduate credit is given for this subject to students in AE, CE, and ME.

ME 105. **Mechanical Vibrations.** 12 units (4-0-8); first term.
Prerequisites: AM 1 abcd, Ma 10 or AM 15 abc.
A study of the theory of vibrating systems, and the applications of such theory to problems of mechanical design. Subjects considered include theory of resonant systems; elimination of undesirable vibrations; vibration instrumentation; periodic disturbing forces, such as in engine vibration problems; critical speed phenomena; transient excitations; self-excited vibrations and instability in mechanical systems; introduction to non-linear systems.
Instructor: Hudson.

ME 110. **Physical Metallurgy.** 12 units (4-0-8); first term.
Prerequisite: ME 10.
A study of phase equilibria, the fundamental structure of metals and alloys, the transformations in steel, hardenability of steel, the function of alloying elements in steel, grain size and grain growth, precipitation hardening, and powder metallurgy.
Text: References and lecture notes.
Instructor: Clark.

ME 114. **Metallurgy.** 9 units (3-3-6); third term.
Prerequisite: ME 3.
This subject is the same as ME 10, but with reduced credit for graduate students in all departments except AE and ME. No graduate credit is given for this subject to students in AE and ME.

ME 115 ab. **Thermodynamics.** 9 units (3-0-6) second term; 6 units (2-0-4) third term.
Prerequisites: ME 15 abc, ME 16 ab.
Advanced work in engineering thermodynamics and application to practical engineering problems.
Instructor: Daugherty.

ME 124 ab. **Thermodynamics.** 7 units (3-0-6), first term; 4 units (2-0-4), second term.
This subject is the same as ME 16 ab, but with reduced credit for graduate students in all departments except AE, ChE, and ME. No graduate credit is given for this subject to students in AE, ChE, and ME.

ME 125 abc. **Engineering Laboratory.** 12 units (2-6-4); first, second, third terms.
The techniques of making measurements encountered in engineering practice and research, with the use of special and standard measuring instruments, and the recognition of precision and accuracy of data secured. The planning of tests and research, and the analysis of data.
Instructors: ME Department Staff.

ME 150 abc. **Mechanical Engineering Seminar.** 2 units (1-0-1); first, second, third terms.
Attendance required of graduate students in mechanical engineering. Conference on research work and reviews of new developments in engineering.
Instructor: Daugherty.

ME 200. **Advanced Work in Mechanical Engineering.**
The staff of the mechanical engineering department will arrange special courses on problems to meet the needs of students beyond the fifth year.

ME 206. **Vibrations Laboratory.** 6 units (0-3-3).

Prerequisites: One of the following courses; ME 105, AE 258 abc, AE 271 abc.

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 strain in a machine member subjected to impact loads. The measurement 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 various types of instruments used for the experimental analysis of dynamics problems.

Instructor: Hudson.

ME 210 abc. **Science of Metals.** 9 units (3-0-6); first, second, third terms.

Prerequisites: ME 110.

A study of the atomic structure of metals in relation to properties, criteria for the formation of intermetallic compounds and solid solutions, plastic properties of single crystals and polycrystalline media, creep, internal friction, diffusion in metals, recrystallization, crystal structure, and special studies.

Text: References and lecture notes.

Instructor: Clark.

ME 211 abc. **Metallography Laboratory.** 8 units (1-6-1); first, second, third terms.

Prerequisite: ME 110.

Pyrometry, thermal analysis, preparation of metallographic specimens, photomicrography, macroscopy, carburizing, heat treatment, grain size, hardenability, structure of welded and brazed joints, and special problems.

Text: *Principles of Metallographic Laboratory Practice,* Kehl.

Instructor: Clark.

ME 215. **Internal Combustion Engines.** 9 units (3-0-6); one term.

Prerequisites: ME 15 abc, ME 16.

Advanced study of: engine cycles with real fuel-air mixtures, combustion processes, fuels, detonation, octane and cetane rating, engine performance, and design.

Instructor: Daugherty.

ME 216 ab. **Refrigeration and Air Conditioning.** 9 units (2-3-4); two terms.

Prerequisites: Heat Power (class and laboratory)

Principles of vapor and absorption refrigeration; composite cycles. Deep freezing and liquifaction of gases. Reversed cycles.

Principles of air conditioning: properties of air-water vapor mixtures, air conditioning cycles. Comfort air conditioning (residence, trains, airplanes), industrial air conditioning (food, photographic, textile, paper industries).

Instructor: Kyropoulos.

ME 217 ab. **Steam and Gas Turbines.** 9 units (3-0-6); two terms.

Prerequisites: ME 15 abc, ME 16.

(a) Steam Turbines: cycles, reheat factor, condition curve, construction features, operating characteristics, and design. (b) Gas Turbines: cycles, compressor design and performance, fuels and combustion chamber design nozzles, blading, cooling problems, and plant output and overall efficiency.

Instructor: Daugherty.

ME 218 ab. **Aircraft Power Plants (Reciprocating Engines).** 9 units (3-0-6); two terms.

Prerequisites: Heat power and internal combustion engines (class and laboratory).

Range of application of reciprocating aircraft engines. Thermodynamics and performance of spark ignition engines at altitude. Blower and exhaust turbine performance. Cruising contact. Flight testing cooling and cowling. Special design problems (injection, carburetion, lubrication, ignition).

Instructor: Kyropoulos.

ME 219. **Experimental Background of Engine Research.** 4 units (2-0-2); one term.

Prerequisites: ME 215, or to be taken concurrently.

Survey of combustion research in spark and ignition engines. Flame front observation. High speed indicators, detonation indicators. Study of experimental methods of fuel injection problems and droplet formation. Carburetion and direct injection in spark ignition engines. Hydrocarbon thermodynamics. Reaction kinetics. Measurement of ignition quality of spark and compression ignition fuels. Standard methods (ASTM-CFR). Power measurement at sea level and altitude. Preparation of power charts and cruising charts. Measurement of exhaust composition and temperature. Measurement of cooling requirements and performance.

Texts: *Science of Petroleum* (Oxford Press). *I. C. Engines,* Pye (Oxford Press), *The Chemical Background of Engine Research* (Interscience Publishers).

Instructor: Kyropoulos.

ME 220. **Lubrication.** 6 units (2-0-4); one term.

Prerequisites: Internal combustion engines, machine design, hydrodynamics.

Hydrodynamic theory of lubrication. Application to actual bearings. Boundary lubrication. Interaction between bearing surface and lubricant. Extreme pressure lubricants, detergent oils. Lubricant performance in the engine.

Flow of viscous fluids (Reynolds, Sommerfeld) viscosity and friction. Pressure distribution and load carrying capacity of theoretical and actual bearing. Dimensional analysis of the problem. Partial bearings, thrust bearings. Temperature rise and heat dissipation. Bearings for high speed. Clearances. Gear tooth lubrication.

Boundary lubrication, problem, theory experiment. Interaction between surface and lubricant. Constitution of lubricating oils. Addition agents, detergents, extreme pressure lubricants. Property control of lubricants. Lubricant behaviour in the engine, corrosion, sludge formation.

Bearing metals; tin, lead, silver, etc.

Texts: *Theory of Lubrication,* M. D. Hersey (Wiley, 1939); *Lubrication,* A. E. Norton, (McGraw-Hill, 1942).

Instructor: Kyropoulos.

ME 300. **Thesis Research.**

METEOROLOGY

My 105. **Climatology.** 4 units (2-0-2); third term.

Climatic controls and elements; general circulation, temperatures, precipitation, evaporation, condensation forms, the hydrologic cycle. Uses and sources of climatic data. Climatic classifications.

My 201 abc. **Weather Forecasting and Practice.** 9 units (3-0-6) first, second terms; 6 units (2-0-4) third term.

A course in basic meteorology coordinated with My 202 abc. Techniques used in the preparation of 8, 24 and 48 hour short term forecasts. Modern theory on structure of extratropical cyclone, general circulation of the atmospheric air mass. Use of upper air soundings in synoptic analysis and forecasting. Detailed discussion of weather forecasting by means of frontal and air mass analysis supplemented by upper constant pressure analyses. Forecasting local weather phenomena such as fog, thunderstorms and icing with particular emphasis on their relationship to aircraft operations. Trans-oceanic forecasting.

Instructor: Ruch.

My 202 abc. **Meteorological Laboratory.** 15 units (0-15-0); first, second, third terms.

Decoding of synoptic and radiosonde reports; plotting and analysis of synoptic and constant pressure charts. Current data available through C.A.A. teletype facilities are used to simulate actual forecasting practice. Students prepare forecasts for various localities and airways routes.

Instructor: Stone.

My 203 abc. **Meteorological Instruments and Observations.** 4 units (1-3-0); first, second, third terms.

A thorough course in meteorological instruments and their use in addition to instruction in the making of visual observations and station operation. In the second and third terms students operate the weather station on a regular schedule. Thermometers, psychrometers, barometers, altimeters, anemometers, precipitation gages, nephoscopes, recorders. Theodolites and radiosonde transmitter-recorders.

My 207 ab. **Meteorological Thermodynamics and Kinematics.** 6 units (2-0-4) first term; 3 units (1-0-2) second term.

Atmospheric hydrostatics, barometric altimetry, stability of dry and moist air masses, thermodynamic diagrams, energy of thermal currents. Kinematics of the surface pressure chart, velocity and acceleration of isobars, highs, lows, fronts, frontogenesis.

Instructor: Smith.

My 208. **Oceanography.** 3 units (1-0-2); third term.

Physical properties of ocean water; temperature, salinity in the oceans; tides, waves, currents.

Instructor: Elliott.

My 230 abc. **Meteorological Seminar.** 1 unit; first, second, third terms.

Reviews and discussions of current meteorological literature and problems.

In charge: Krick, Ruch.

My 240. **Meteorological Research.**

Selected problems in meteorology research assigned to meet the needs of advanced students.

In charge: Elliott.

My 251 abc. **Extended Forecasting, Theory and Practice.** 9 units (3-0-6) first term; 6 units (2-0-4) second, third terms.

Prerequisite: My 201 abc.

Modern methods used in the preparing of 5 and 7 day extended forecasts. Application of extended forecasts to problems of Industry, Agriculture, Commerce and Conservation.

Instructors: Elliott, Krick, Stone.

My 252 abc. **Advanced Meteorology Laboratory.** 15 units (0-15-0); first, second, third terms.

Prerequisite: My 202 abc.

Application of modern methods in the preparing of extended forecasts. Utilization of the Northern Hemisphere Synoptic Weather Types in the selection of analogues. Application of the 5 day method in the preparing of extended forecasts. Students prepare and verify extended practice forecasts.

Instructors: Elliott, Krick, Ruch, Smith, Stone.

My 255. **Climatology.** 6 units (2-0-4); first term.

Prerequisite: My 105.

Climates of the continents. Micro-climatology. Methods of analysis of climatic data.

My 257 abc. **Dynamic Meteorology.** 6 units (2-0-4); first, second, third terms.

The application of hydrodynamics to the study of atmospheric motions. Equations of motion and continuity, circulation and vorticity, geostrophic winds, gradient winds, surfaces of discontinuity, wave motion in the atmosphere, tendency equation, effects of viscosity, effects of turbulence, atmospheric diffusion, thermal winds, dissipation of kinetic energy.

Instructors: Elliott, Smith.

My 258. **Meteorological Statistics.** 9 units (3-0-6); second term.

Prerequisite: Ma 12.

Studies in time series: Periodicities, harmonic analysis, correlation spectra and the application to forecasting. Analytical treatment of time series. Multivariate statistical analysis and stochastic processes in meteorology.

Instructor: Smith.

My 259. **Applied Meteorology.** 6 units (2-0-4); third term.

Prerequisites: My 201 abc; My 202 abc; My 105; My 207 ab.

Application of modern short and extended forecast techniques and climatological studies to the problems of engineering, industry, commerce and agriculture. Function of the consultant meteorologist in the capacity of a professional engineer to analyze particular problems and to organize a specialized meteorological service for varied operations. Study of representative case problems in different fields. Organization of the consultant weather service and the maintenance of professional standards.

Instructors: Krick, and special lecturers.

PHYSICS

UNDERGRADUATE SUBJECTS

Ph 1 abc. **Mechanics, Molecular Physics, Heat and Sound.** 12 units (3-3-6); first, second, third terms.

Prerequisites: A high school course, or its equivalent, and trigonometry.

The first year of a general college course in physics extending through two years. It is a thorough analytical course, in which the laboratory carries the thread of the work, and the problem method is largely used. A bi-weekly demonstration lecture, participated in by all members of the department, adds the inspirational and informational element, and serves for the development of breadth of view.

Text: *Mechanics, Molecular Physics, Heat and Sound,* Millikan, Roller and Watson.

Instructors: Watson, Strong and Graduate Assistants.

Ph 2 abc. **Electricity and Optics.** 12 units (3-3-6); first, second, third terms.

Prerequisites: Ph 1 abc, Ma 1 abc, or their equivalents.

A continuation of Ph 1 abc to form a well-rounded two-year course in general physics.

Text: Vols II and III, Principles of Physics, Sears.

Instructors: Neher and Graduate Assistants.

Ph 5 abc. **Introduction to Mathematical Physics.** 12 units (4-0-8); first, second, third terms.

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

An introduction to the application of mathematics to physics, and practice in the solution of problems.

Text: *Principles of Mathematical Physics*, Houston.

Instructor: Leighton.

Ph 6 abc. **Introduction to Mathematical Physics and Differential Equations.** 15 units (5-0-10); first, second, third terms.

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

An introduction to the application of mathematics, including vector analysis and differential equations, to physics; and practice in the solution of problems.

Text: *Principles of Mathematical Physics,* Houston.

Instructor: Anderson.

Ph 7 abc. **Electricity and Magnetism.** 6 units (2-0-4); first, second, third terms.

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

A course in theoretical electricity and magnetism, primarily for electrical engineering students. Ph 9 (Electrical Measurements) must accompany this course.

Instructor: T. Lauritsen.

Ph 8. **Electricity and Magnetism.** 9 units (3-0-6); first term.

Prerequisite: Ph 6 abc.

A special course open only to students who have completed Ph 5 abc or Ph 6 abc.

Ph 9. **Electrical Measurements.** Offered both as a 6 unit course (0-6-0) first or second term; and as a 3 unit course (0-3-0) first and second terms.

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

An advanced course in precision electrical measurements at d.c. and low frequencies, measurement of impedance, voltage, current, frequency, etc.

Text: *Advanced Electrical Measurements*, Michels.

Instructors: Pickering and Graduate Assistants.

Ph 10. **High Frequency Measurements.** 8 units (0-6-2); second term.
A continuation of Ph 9 at radio frequencies.
Instructors: Pickering and Graduate Assistants.

UNDERGRADUATE OR FIFTH YEAR SUBJECTS

Ph 92 abc. **Introduction to Mathematical Physics and Differential Equations.** 10 units; first, second, third terms.
Prerequisites: Ph 1 abc, 2 abc; Ma 2 abc.
This subject is the same as Ph 6 abc but with reduced credit for graduate students.
Instructor: Anderson.

Ph 100 abc. **Methods of Mathematical Physics.** 12 units (4-0-8); first, second, third terms.
Selected topics from the fields of mechanics, elasticity, hydrodynamics, heat conduction and quantum mechanics, presented with emphasis on the mathematical structure of the physical theories.
Instructor: Robertson.

Ph 101 abc. **Electricity and Magnetism.** In 1947-48, 9 units (3-0-6); first, second terms; 12 units (4-0-8) third term. In 1948-49, 9 units (3-0-6) three terms.
Prerequisite: An average grade of C in Ph 5 abc, or Ph 6 abc.
A problem course in electricity, magnetism and electromagnetic waves, intended primarily as a preparation for graduate work in science.
Text: *Static and Dynamic Electricity*, Smythe.
Instructor: Smythe.

Ph 103 abc. **Analytical Mechanics.** 12 units (4-0-8); first, second, third terms.
Prerequisite: Ph 5 abc, or Ph 6 abc.
A study of the laws of motion as formulated by Newton, d'Alembert, Lagrange, Euler, Jacobi, Hamilton, etc. Integration of the differential equations of mechanics by exact methods and by methods of successive approximations. Theory of small oscillations around statically and dynamically stable states; normal modes. Elementary theory of hydrodynamics and elasticity. Applications of the tensor calculus to mechanical problems.
Text: *Dynamics*, Webster.
Instructor: Davis.

Ph 105 ab. **Optics.** 9 units (3-0-6); first, second terms.
Prerequisite: Ph 5 abc, or Ph 6 abc.
A problem subject dealing with the fundamental principles of geometrical optics, of diffraction, interference, etc., and their experimental verification.
Text: *Theory of Optics*, Drude.
Instructor: Fowler.

Ph 106 ab. **Optics Laboratory.** 3 units (0-3-0); first, second terms.
Advanced laboratory work in light, consisting of accurate measurements in diffraction, dispersion, interference, polarization, spectrophotometry.
Text: *Manual of Advanced Optics*, Taylor.
Instructor: Fowler.

Ph 107. **Spectroscopy.** 9 units (3-0-6); third term.
Prerequisite: Ph 5 abc, or Ph 6 abc.
A discussion of observed spectra in terms of atomic structure theory.
Instructor: Bowen.

Ph 108. **Spectroscopy Laboratory.** 3 units (0-3-0); third term.

Laboratory work in the measurement and classification of spectral lines to accompany Ph 107.

Instructor: Bowen.

Ph 109 abc. **Atomic and Nuclear Physics.** 9 units (3-0-6); first, second, third terms.

Prerequisite: Ph 5 abc, or Ph 6 abc.

A problem and lecture course in the experimental and theoretical basis of modern atomic and nuclear physics. The properties of the fundamental particles are treated in detail as well as current concepts of the structure of atoms and nuclei. Nuclear disintegrations are considered at some length.

Instructors: Lauritsen and Fowler.

Ph 110 ab. **Kinetic Theory of Matter.** 9 units (3-0-6); first and second terms.

Prerequisites: Ph 1 abc, Ma 2 abc.

During the first term, the fundamental concepts of the molecular theory of matter are treated from the theoretical, experimental and technical viewpoints (Clausius, Maxwell, Boltzman, van der Waals, Knudsen equations). During the second term, advance problems of the constitution of matter as well as practical applications are discussed (such as the thermodynamics of low temperature phenomena, liquifaction of gases, phase relations, specific heats, crystallization, plasticity.)

Instructor: Goetz.

Ph 113 ab. **Principles of Quantum Mechanics.** 9 units (3-0-6); third (a) and first (b) terms.

Prerequisites: Ph 5 abc, or Ph 6 abc; Ph 109 ab or equivalent, concurrently or previously.

An outline developed by means of problems, of the experimental and theoretical basis of quantum mechanics, including the idea of states, principle of indetermination, the Schroedinger equation, perturbation theory, collision theory, electron spin and Pauli principle.

Instructor: Christy.

Ph 117 ab. **X-Rays.** 9 units (3-0-6); first and second terms.

Prerequisite: Ph 5 abc, or Ph 6 abc.

A course covering the generation of X-rays and their interactions with matter in theory and in practical applications to research physics; including the early history of X-rays in atomic research, X-ray tubes and high voltage power supplies, generation of continuous and characteristic X-rays in targets, X-ray intensity measurements, polarization, absorption, diffraction, refraction, scattering, X-ray spectroscopy spectroscopic methods and instrumentation, the X-ray photoelectric effect, Compton effect, dynamical theory of X-ray diffraction, the Auger effect, scattering by liquids and gases, metallurgical applications, and relation of X-rays to atomic constants. During the latter part of the course, class members will be assigned topics to report from the literature.

Instructor: DuMond.

Ph 119. **History of Modern Physics.** 9 units (3-0-6); first term.

Prerequisites: Ph 1 abc, Ph 2 abc.

Instructor: Millikan.

Ph 142. **Research in Physics.** Units in accordance with the work accomplished. Approval of the department must be obtained before registering.

GRADUATE SUBJECTS

Ph 211. **Thermodynamics.** 12 units (4-0-8); first term.

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

The two fundamental laws of thermodynamics. Entropy and the thermodynamic potentials. Equations of reciprocity. Applications to gases, perfect and imperfect, and to dilute solutions. Phase rule and chemical equilibrium. Nernst's theorem.

Instructor: Epstein.

Ph 212 ab. **Mechanics of Continuous Media.** 12 units (4-0-8); second and third terms.

Prerequisite: Ph 103 abc.

Hydrodynamics of non-viscous fluids. Equations of Euler and Lagrange. General integrals and special problems. Tensor theory of deformations and of stresses. Hydrodynamics of viscous fluids. Equations of Stokes-Navier with applications to special problems. Fundamental equations of the theory of elasticity. Applications to static deformations of solids. Theory of elastic oscillations in space and in plates.

Instructor: Epstein.

Ph 215. **Theoretical Nuclear Physics.** 9 units (3-0-6); second term.

Prerequisite: Ph 113 ab, or equivalent.

The subject matter may vary from year to year. The course may include Stability of nuclei; Theory of nuclear reactions, radiation and beta-decay; Theory of nuclear forces and its connection with cosmic rays; Neutron physics.

Instructor: Christy.

Ph 220. **Applications of Maxwell's Equations.** 12 units (4-0-8); third term.

Prerequisite: Ph 101 abc.

A mathematical problem course in the use of retarded potentials and orthogonal solutions of the electromagnetic propagation equations. It includes the radiation patterns and impedances of antennas; diffraction; surface waves; coupling, input impedances and attenuation in wave guides and cavities.

Instructor: Smythe.

Ph 223. **Theory of Electromagnetic Waves.** 12 units (4-0-8); second term.

Prerequisite: Ph 101 abc.

Mathematical study of Maxwell's equations, propagation of waves, absorption and reflection, approximate and rigorous treatment of diffraction, theory of dispersion, electro- and magneto-optics.

Instructor: Epstein.

Ph 225. **Theory of Electrons.** 12 units (4-0-8); third term.

Prerequisites: Ph 101 abc, Ph 223.

Retarded potentials. Radiation of a point charge. Theory of dielectrics. Electron theory of dia-, par- and ferromagnetism. Phenomena in moving bodies and experimental foundations of the theory of relativity.

Instructor: Epstein.

Ph 226. **Heat Radiation and Quantum Theory.** 12 units (4-0-8); second term.

Prerequisites: Ph 103 abc, Ph 211.

Historical treatment of the development of the mathematical theory of heat radiation and of the application of the theory of quanta to the phenomena of specific heats of solid and gaseous bodies, photoelectricity, photochemistry, chemical constants, etc.

Instructor: Epstein.

Ph 228. **Modern Aspects of the Quantum Theory.** 12 units (4-0-8); third term.

Prerequisites: Ph 103 abc, Ph 109 abc, Ph 229.

This course is devoted to review of recent developments in the quantum theory, especially in the fields of the theory of radiation and of the electron theory of metals. The subject matter varies from year to year.

Instructor: Epstein.

Ph 229 ab. **Quantum Mechanics.** 12 units (4-0-8); second and third terms.

Prerequisites: Ph 103 abc, Ph 109 abc.

Schrodinger's equation and matrix calculus. Applications to spectroscopy and atomic structure. Transformation theory. Dirac's electron equation. Fundamentals of the theory of the electromagnetic field and second quantization.

Instructor: Epstein.

Ph 232. **Dispersion and Absorption of Ultra-Short Electromagnetic Waves.** 6 units (2-0-4); first term.

Propagation of waves. Maxwell's dispersion and absorption in semi-conductors and metals. Electronic and dipolar dispersion and absorption in dielectrics. Dispersion and absorption in electrolytes. Waves along wires and dispersion in magnetic substances.

Experimental results on dispersion and absorption of ultra-short waves in dielectrics, electrolytes and magnetic substances.

Instructor: Potapenko.

Ph 233. **High Frequency Measurements.** 6 units (2-0-4); first term.

Methods of measurements in the field of high and ultra-high frequencies.

Instructor: Potapenko.

Ph 236 abc. **Introduction to the Theory of Relativity.** 6 units (2-0-4); first, second and third terms.

The special theory of the relativity of motion in free space, with applications to mechanical and electromagnetic problems. Use of four dimensional language for expressing the results of relativity. Introduction to tensor analysis. The general theory of relativity and the theory of gravitation. Applications to thermodynamics and cosmology.

Text: *Relativity, Thermodynamics and Cosmology*, Tolman.

Instructor: Tolman.

Ph 237 abc. **Selected Topics in Thermodynamics.** First, second, third terms.

Prerequisite: Previous work in thermodynamics.

Introduction to thermodynamics. Relation of thermodynamics to statistical mechanics. Thermodynamic properties of matter and radiation. Applications to steady and other non-equilibrium states.

Instructor: Tolman.

Ph 238 abc. **Seminar on Theoretical Physics.** 4 units; first, second and third terms.

Recent developments in theoretical physics for specialists in mathematical physics.

In charge: Epstein.

Ph 239 abc. **Seminar on the Solid State.** 4 units; first, second and third terms.

Meets once a week for the report and discussion of problems and selected current publications on the physics of the solid state. The field covered concerns especially low temperature phenomena (every second week), the physics of photographic emulsions and biophysical problems (each every fourth week).

In charge: Goetz.

Ph 240. **Seminar on X-Radiation.** 4 units; second and third terms.

Meets once a week for reports and discussions of problems in X-Radiations. Standard texts on X-rays are followed in the first term as an outline only; the reports being amplifications and additions to the material of the text as drawn from the original papers of workers in the field. During the second and third terms advanced reports are made on current problems and on fundamental classical work.

In charge: DuMond.

Ph 241. **Research Conferences in Physics.** 4 units; first, second and third terms.

Meets twice a week for a report and discussion of the work appearing in the literature and that in progress in the laboratory. Advanced students in physics and members of the physics staff take part.

In charge: Epstein.

Ph. 242. **Research in Physics.** Units in accordance with work accomplished.

Opportunities for research are offered to graduate students in all the main branches of physics. The students should consult the department and have a definite program of research outlined before registering.

DEGREES AND CERTIFICATES CONFERRED JUNE 21, 1946

Doctor of Philosophy

Howard Baller *(Electrical Engineering)*, B.S., California Institute of Technology, 1940; M.S., California Institute of Technology, 1941
Walter Daniel Bonner, Jr. *(Biology)*, B.S., University of Utah, 1940
Clyde Andrew Dubbs *(Biology)*, B.S., California Institute of Technology, 1943
Conrad Tuck Onn Fong *(Biology)*, B.S., University of Hawaii, 1939
William Nunn Lipscomb *(Chemistry)*, B.S., University of Kentucky, 1941
William Shand, Jr. *(Chemistry)*, A.B., Princeton University, 1940

Aeronautical Engineer

John Berwick Anderson, B.S., United States Naval Academy, 1939
Frank Horace Browning, Jr., B.S., University of Washington, 1936
Kenan Clark Childers, Jr., B.S., United States Naval Academy, 1939
Julian D. Cole, M.E., Cornell University, 1944
Edmond Stephen Gillette, Jr., B.S., United States Naval Academy, 1940
George Grandchamp Halvorson, B.S., United States Naval Academy, 1941
Charles Calvin Hoffman, B.S., Northwestern State Teachers College, 1936
Stanley William Kerkering, B.S., United States Naval Academy, 1939
Norman Jack Kleiss, B.S., United States Naval Academy, 1938
George Hannibal Kronmiller, B.S., United States Naval Academy, 1940
Frederick William Maxwell, Jr., B.S., United States Naval Academy, 1941
James William McConnaughhay, B.S., United States Naval Academy, 1939
Leslie Richard Olsen, B.S., United States Naval Academy, 1941
James Frederick Parker, B.S., Georgia School of Technology, 1938
Edward Cress Sledge, B.S., United States Naval Academy, 1940
Robert James Trauger, B.S., United States Naval Academy, 1939
Richard McClellan Tunnell, B.S., United States Naval Academy, 1939
Harry Lansing Vincent, Jr., B.S., United States Naval Academy, 1941
Daniel Kehr Weitzenfeld, B.S., United States Naval Academy, 1939
Jonathan Winson, B.M.E., College of the City of New York, 1943; M.A.E., New York University, 1944

Civil Engineer

Carl B. Johnson, B.S., California Institute of Technology, 1937; M.S., California Institute of Technology, 1944

Mechanical Engineer

David Holbrook Jarvis, B.S., University of Utah, 1937; M.S., University of Colorado, 1942

Meteorologist

Chung Pen Ho, B.S., National Tsing-Hua University, China, 1932; M.S., California Institute of Technology, 1945

Master of Science in Science

CHEMISTRY

Theodore Silkman Gilman, B.A., Williams College, 1940
Fern Wood Mitchell, Jr., A.B., University of Alabama, 1938

GEOLOGICAL SCIENCES

Victor Ari A., B.S., Tomas Frias University, Bolivia, 1943; M.S. (C.E.), California Institute of Technology, 1945
William Thomas Holser, B.S., California Institute of Technology, 1942
John Oscar Nigra, A.B., University of Texas, 1937

METEOROLOGY

Ralph William Allen, B.B.A., University of Cincinnati, 1942
Patrick Robert Jamele, A.B., Columbia College, 1927
Byron Ordway Lowery, A.B., Whitman College, 1938
Robert Herb Reece, B.S., University of New Mexico, 1942
Dansy Trite Williams, B.S., Wisconsin State Teachers College, 1940

PHYSICS

George Lee Bate, A.B., Princeton University, 1945
Dwain Burns Bowen, B.S., California Institute of Technology, 1942
Charles Bullard Dougherty, B.S., Iowa State College, 1945
Lawrence D'Arle Hindall, B.S., Carnegie Institute of Technology, 1942

Master of Science in Engineering

AERONAUTICS

John Henry Altseimer, B.S., University of Wisconsin, 1941
John Berwick Anderson, B.S., United States Naval Academy, 1939
Harry Israel Ashkenas, B.S., University of California, 1944
John Winthrop Barnes, B.S., United States Military Academy, 1942
Boris Bresler, B.S., University of California, 1941
Frank Horace Browning, Jr., B.S., University of Washington, 1936
Patrick Stanley Chase, B.S., California Institute of Technology, 1943
Kenan Clark Childers, Jr., B.S., United States Naval Academy, 1939
William Loring Clay, B.S., United States Military Academy, 1940
Charles W. Cole, B.A.E., University of Minnesota, 1940
Julian D. Cole, M.E., Cornell University, 1944
Thomas Frederick Coleman, B.S., University of Michigan, 1943
John Oliver Crum, B.S., Massachusetts Institute of Technology, 1940
William Edgar Davis, III, B.S., University of Pennsylvania, 1942
Frank John Dore, B.S., California Institute of Technology, 1945
Guy Humphrey Drewry, Jr., B.S., Virginia Military Institute, 1941
Mike Walter Fossier, B.S., Louisiana State University, 1945
Richard Bruce Foster, B.S., Newark College of Engineering, 1939
Harry Lane Gephart, B.S., New Mexico State Teachers College, 1937
Edmond Stephen Gillette, Jr., B.S., United States Naval Academy, 1940
Richard Joseph Gifford, B.S., Iowa State College, 1942
Theodore Robert Goodman, B.A., Rensselaer Polytechnic Institute, 1945
Carl Frederick Hagenmaier, B.S., Purdue University, 1945
Douglas Warwick Hege, B.S., Duke University, 1942
Charles Calvin Hoffman, B.S., Northwestern State Teachers College, 1936
John Stanley Ingham, B.S., Worcester Polytechnic Institute, 1941
John Ralph Jacobsen, B.S., Purdue University, 1941
Stanley William Kerkering, B.S., United States Naval Academy, 1939
Charles Henry King, Jr., B.S., Massachusetts Institute of Technology, 1941

William Edward Kinney, B.S., University of Dayton, 1940
Norman Jack Kleiss, B.S., United States Naval Academy, 1938
John N. Kleissas, B.S., University of Pittsburgh, 1943
George Hannibal Kronmiller, B.S., United States Naval Academy, 1940
Harold Cecil Larsen, B.S., University of Utah, 1941
Morris Lebovits, B.S., University of Illinois, 1940
Bernard Barclay Levitt, B.S., University of Colorado, 1941
Frederick James Lewis, B.S., St. Edward's University, 1940
Charles Coleman Martin, Jr., B.S., United States Military Academy, 1944
Edmund Blake Maske, Jr., B.S., Louisiana State University, 1942
Frederick William Maxwell, Jr., B.S., United States Naval Academy, 1941
James William McConnaughhay, B.S., United States Naval Academy, 1939
John William McCurdy, B.S., University of Pittsburgh, 1943
John Charles Nickerson, B.S., United States Military Academy, 1938
George Marshall Palmer, B.S., Purdue University, 1945
Robert Grier Parke, B.S., University of Pittsburgh, 1942
James Frederick Parker, B.S., Georgia School of Technology, 1938
Charles Clifford Pinkerton, Jr., B.S., United States Military Academy, 1943
Henry Thomas Ponsford, A.B., Stanford University, 1944
Audre Richardson, B.S., California Institute of Technology, 1943
Webster Charles Roberts, B.S., Case School of Applied Science, 1940; M.S., Lehigh University, 1942
Charles Roberts Russell, B.S., State College of Washington, 1936; M.S., University of Wisconsin, 1939; Ph.D., University of Wisconsin, 1941
John Carl Siltanen, B.A.E., New York University, 1938
John Gilbert Small, B.S., California Institute of Technology, 1941
Natesan Srinivasan, B.S., Madras University, India, 1938
Basil George Stergis, B.S., Drexel Institute of Technology, 1943
Robert James Trauger, B.S., United States Naval Academy, 1939
Leon Trilling, B.S., California Institute of Technology, 1944
Richard McClellan Tunnell, B.S., United States Naval Academy, 1939
Mahinder Singh Uberoi, B.S., Forman Christian, India, 1944
Harry Lansing Vincent, Jr., B.S., United States Naval Academy, 1941
Stuart Allen Warren, B.S., Oregon State College, 1941
Daniel Kehr Weitzenfeld, B.S., United States Naval Academy, 1939
Thomas Franklin Weldon, B.S., College of the Holy Cross, 1941
David Hugh Whitlow, B.S., University of Washington, 1943
Melvin Noble Wilson, B.S., California Institute of Technology, 1945

CIVIL ENGINEERING

José Antonio Arguedas, B.S., Georgia School of Technology, 1944
José Daniel Cortés-Guzmán, Agr. Eng., National Agricultural School, Mexico, 1945
Richard Horton Cox, B.S., California Institute of Technology, 1942
Munson White Dowd, B.S., California Institute of Technology, 1938
Claudio Federico Stegmann, C.E., University of Buenos Aires, Argentina, 1936

ELECTRICAL ENGINEERING

Morton Michael Astrahan, B.S., Northwestern Technological Institute, 1945
William Walker Butler, B.S., Iowa State College, 1940
Robert Fairbank Cline, B.A., University of Toronto, Canada, 1936
Charles Melville Davids, B.S., California Institute of Technology, 1945
George Samuel Fenn, B.S., California Institute of Technology, 1945
Eric Gilbert Laue, B.S., California Institute of Technology, 1940
Richard Alan Montgomery, B.A., University of British Columbia, Canada, 1940
Robert Leroy Schrag, B.S., Kansas State College, 1945
Yu-Siu Tung, B.S., Nankai University, China, 1936
Carl Paul Wiedow, A.B., Occidental College, 1933; M.S., University of Southern California, 1935; M.S. (Phys.) California Institute of Technology, 1945

MECHANICAL ENGINEERING

Robert Dilworth Bonner, B.S., Rice Institute, 1943
John T. Bowen, B.S., California Institute of Technology, 1942
Francis Barton Brown, A.B., Stanford University, 1935
Howard Norman Farmer, Jr., B.S., California Institute of Technology, 1943
Hassan Fatholmolk Fateh, M.E., Honar Sara University, Iran, 1944
Richard A. Fayram, A.B., Stanford University, 1945
Jack Raymond Kettler, B.S., California Institute of Technology, 1944
Harold Lambertus, B.S., Purdue University, 1942
Carl Richardson, B.E., Yale University, 1943

Bachelor of Science

SCIENCE

Dennis Joseph Ahern
Dale Edward Bement
Edward Elmer Carr
Lloyd William Chamberlain
Bernard Emile Dethier
David R. Esner
Donn Emery Hopkins
Wilbur Atwood Ingram
Frank Carl Jorgensen
Thomas Woodward Kelly
David Richard Lewis
Walter Alfred Long
Norman Joseph Macdonald
William Griffin Misner
William Mojé
Howard Wall Morgan, Jr.
Robert Lee Newbrough
David Butterfield Sheldon
Robert Charles Siegel
Milton Arthur Strauss
Herbert William Strong, Jr.
Robert Ernest Tucker
Robert Campbell Wise
Howard Russell Woods

ENGINEERING

Robert Francis Blocker
Bennett Bovarnick
Phillip Nolen Buford
John Peter Calligeros
Donovan Chester Davis
Richard Herbert DeLano
Jerome Packard Dyson
William Frederick Evenson
Peter Fagan
Frank Sumner Gates
Norman Robert Greve
Robert Harry Grube
Laurence Oliver Haupt, Jr.
Benjamin Stiles Hayne, III
Edward Stanley Ida
David Colvill Lincoln
Glynn Husted Lockwood
Paul Cardon Ricks, Jr.
Fred Phillip Robins
Louis Vincent Schmidt
Jerome William Schneider
Conrad P. Stensgaard, Jr.
James Benjamin Stichka
John Van Benthuysen
Jerry Apostoles Zagorites

Senior Certificate

Wayne Sturge Blackman
Joseph Page Colley
Chresten Mills Knudsen
Robert Lee Peeler, Jr.

DEGREES CONFERRED SEPTEMBER 27, 1946

Doctor of Philosophy

Barbarin Arreguin-Lozano *(Plant Physiology)*, M.S., California Institute of Technology, 1945
Joseph Vincent Charyk *(Aeronautics)*, B.Sc., University of Alberta, 1942; M.S., California Institute of Technology, 1943
Robert Clarke James, *(Mathematics)*, B.A. University of California at Los Angeles, 1940
Frank Lanni *(Immunology)*, B.S., Rensselaer Polytechnic Institute, 1940
John Michael O'Gorman *(Chemistry)*, B.S., University of California College of Chemistry, 1940
Allen Eugene Senear *(Chemistry)*, B.A., Williams College, 1941
Robert Earl Wallace *(Geology)*, B.S., Northwestern University; M.S., California Institute of Technology, 1940

Master of Science in Science

BIOLOGY

John Daniel Spikes, B.S., California Institute of Technology, 1941

CHEMICAL ENGINEERING

Hugh Adamson Baird, B.S., California Institute of Technology, 1942
Anthony Briglio, Jr., B.S., California Institute of Technology, 1943
James William Glanville, B.S., The Rice Institute, 1944
Warren Gleason Schlinger, B.S., California Institute of Technology, 1944

GEOLOGICAL SCIENCES

Erwin Jacob Poizner, B.S., Texas Technological College, 1940

METEOROLOGY

John Howland Barber, B.A., Stanford University, 1941
Mark Edward Bowen
Robert Yost Dean, A.B., Willamette University
Charles Hadley Lewis, A.B., Whittier College, 1944
John Osmer Montgomery, B.A., University of Southern California, 1942

Master of Science in Engineering

AERONAUTICS

Clyde Cecil Andrews
Kenneth Perrin Barden
James Monfort Bowie
Glenn William Burger
Jerry Forest Daniels, Jr.
Joseph Benjamin Deodati, B.S., Agricultural and Mechanical College of Texas, 1939
William Earl Ditch
Paul Christian Durup
Charles Wing Griffing, B.S., University of Florida, 1940
Gerald Stephen Huestis
Jack Naylor Miller, B.S., University of Missouri, 1940
Edward Berlendis Monteath, B.S.M.E., Washington University, 1940

Leo Wayne Mullane, B.Ch.E., University of Minnesota, 1940
Donald John O'Meara, B.S., United States Naval Academy, 1939
Albert David Pollock, Jr., B.A., Santa Barbara State, 1938
Floyd Francis Reck
Russell Lawrence Reiserer
Orlan Alton Soli, B.S., River Falls State Teachers College, 1940
Joseph Oscar Weisenberg, B.S., Rockhurst College, 1940
William Clarence Wilburn, A.B., Birmingham Southern College, 1941

CIVIL ENGINEERING

Santiago H. Rodriguez Rozo

ELECTRICAL ENGINEERING

Charles Graydon Beatty, B.S., Massachusetts Institute of Technology, 1942
Khosrow Behroon
Kenneth Orlando Cartwright, B.S.E.E., Purdue University, 1941
Ke Yuan Chen, B.S., Northeastern University, 1933
Richard Herbert DeLano, B.S., California Institute of Technology, 1946
Willis E. Dobbins, B.S., California Institute of Technology, 1941
Yoshiyuki J. Fujimura, B.S., University of Nebraska, 1943
Marion Elbert Gillihan, B.E., University of Southern California, 1945
Marion Ernest Hines, B.S., California Institute of Technology, 1940
Robert South Neiswander, B.S., California Institute of Technology, 1940
Kadaba Krishna Prasad, B.S., University of Mysore, Bangalore, India, 1943, M.S., University of Mysore, 1944
Morris Skurka, B.S., Illinois Institute of Technology, 1939
Marcius Curtis Smith, B.S., California Institute of Technology, 1943
William Snyder, B.S., California Institute of Technology, 1943
Robert Eldon Stephenson, B.S., University of Utah, 1941
Egbert Moore Tingley, Jr., B.S., Purdue University, 1942
Rev. L. Clyde Werts, S.J., B.S., California Institute of Technology, 1946; A.B., Gonzaga University, 1935; M.A., Gonzaga University, 1936; S.T.B., Alma College, 1942

MECHANICAL ENGINEERING

Jack Leland Alford, B.S., California Institute of Technology, 1942
Ali Bulent Cambel, B.S., Robert College, 1942
Arthur Fletcher Gebhart, Jr., B.S., University of Utah, 1943
Walter Hardenbroecke Goodwin, B.A., University of British Columbia, 1942; B.Sc., University of British Columbia, 1943
Daniel Nathan Hendricks, Jr., B.S., Agricultural and Mechanical College of Texas, 1942
David S. Wood, B.S., California Institute of Technology, 1941

Bachelor of Science in Science

Richard William Davies
George Finlay Simmons, II
George Charles Standart
Sherman Kopald Babe Stein

Bachelor of Science in Engineering

Max Merton Aydelott
Richard A. Bernatis
William George Bongardt
John Junior Burke
Andrew Berrien Campbell
James Ferguson Chalmers
Joseph Page Colley
James Frederick Drake
Frederick Charles Essig
Jerome Sidney Field
Luis Eduardo Freire
Tsung-Hsiung Huang
Gordon Lloyd Johnson
Glenn Robert Jones
Richard Gerald Kuck
Paul Leonard Pecchenino
Edwin Pounder
John Edward Richter
William Julius Russell, Jr.
Harry Max Steele, Jr.
Dean Putnam Stone
Jay William Stuart, Jr.
William Clifford Taylor
Charles Williams

DEGREES CONFERRED JUNE 13, 1947

Doctor of Philosophy

William Francis Ballhaus *(Aeronautics)*, A.B., Stanford University, 1940; M.E.A., 1942
Stanley Corrsin *(Aeronautics)*, B.S., University of Pennsylvania, 1940; M.S., California Institute of Technology, 1942; Ae.E., 1942
Donald Allan Darling *(Mathematics)*, A.B., University of California at Los Angeles, 1941
Jerry Donohue *(Chemistry)*, B.A., Dartmouth College, 1941; M.A., 1943
James Wightman Follin, Jr. *(Physics)*, B.S., Massachusetts Institute of Technology, 1940
David William Hagelbarger *(Physics)*, A.B., Hiram College, 1942
Wallace Dean Hayes *(Physics)*, B.S., California Institute of Technology, 1941; Ae.E., 1943
Paul Bennett Johnson *(Mathematics)*, A.B., University of Washington, 1938; M.S., 1944
Robert B. Leighton *(Physics)*, B.S., California Institute of Technology, 1941; M.S., 1944
Kurt Martin Mislow *(Chemistry)*, B.S., Tulane University, 1944
Samuel Pope Morgan, Jr. *(Physics)*, B.S., California Institute of Technology, 1943; M.S., 1944
Sam Naiditch *(Chemistry)*, B.A., University of California at Los Angeles, 1939
Robert Horner Olds *(Physics)*, B.S., California Institute of Technology, 1938; M.S., 1939
Guy Clifton Omer, Jr. *(Physics)*, B.S., University of Kansas, 1936; M.S., 1937
Arthur Beck Pardee *(Chemistry)*, B.S., University of California, 1942; M.S., California Institute of Technology, 1943
Donald Harry Potts *(Mathematics)*, B.S., California Institute of Technology, 1943
David Cook Regnery *(Genetics)*, B.A., Stanford University, 1941
Sylvan Rubin *(Physics)*, B.S., California Institute of Technology, 1939
Richard Schamberg *(Aeronautics)*, B.S., California Institute of Technology, 1943; M.S., 1944
David Powell Shoemaker *(Chemistry)*, B.A., Reed College, 1942
Alexander Smith *(Petrology)*, B.A., University of British Columbia, 1943; M.A., 1933
Jonathan Dean Swift *(Mathematics)*, A.B., University of California, 1939
Howard Jones Teas, Jr. *(Genetics)*, A.B., Louisiana State University, 1942; M.A., Stanford University, 1946
E. Arthur Trabant *(Mathematics)*, B.A., Occidental College, 1940
Kenneth Nyitray Trueblood *(Chemistry)*, A.B., Harvard College, 1941
Donald Bingham Wheeler, Jr. *(Physics)*, B.S., Lehigh University, 1938
Albert George Wilson *(Mathematics)*, B.S., Rice Institute, 1941; M.S., California Institute of Technology, 1942

Aeronautical Engineer

Roy Gene Anderson, B.S., United States Naval Academy, 1940
Clyde Cecil Andrews, M.S., California Institute of Technology, 1946
Kenneth Perrin Barden, M.S., California Institute of Technology, 1946
James Monfort Bowie, M.S., California Institute of Technology, 1946
Edward George Bull, B.S., University of Michigan, 1941
Glenn William Burger, M.S., California Institute of Technology, 1946
Fredric "B" Clarke, B.S., United States Naval Academy, 1939

Robert Emmett Clements, B.S., United States Naval Academy, 1940
Charles Willard Cole, B.Ae., University of Minnesota, 1940; M.S., California Institute of Technology, 1946
Hugh "L" H. Collins, B.S., Spring Hill College, 1940
Jerry Forest Daniels, Jr., M.S., California Institute of Technology, 1946
Joseph Benjamin Deodati, B.S., Agricultural and Mechanical College of Texas, 1939; M.S., California Institute of Technology, 1946
William Earl Ditch, M.S., California Institute of Technology, 1946
Frank John Dore, B.S., California Institute of Technology, 1945; M.S., California Institute of Technology, 1946
Paul Christian Durup, M.S., California Institute of Technology, 1946
Mike Walter Fossier, B.S., Agricultural and Mechanical College of Louisiana, 1945; M.S., California Institute of Technology, 1946
Charles W. Griffing, B.S., University of Florida, 1940; M.S., California Institute of Technology, 1946
R. Richard Heppe, A.B., Stanford University, 1944; A.M., Stanford University, 1945
Gerald Stephen Huestis, M.S., California Institute of Technology, 1946
Thomas Frederick Kirkwood, A.B., Stanford University, 1943; A.M., *Ibid.*, 1944
Bernard Barclay Levitt, B.S., University of Colorado, 1941; M.S., California Institute of Technology, 1946
Ting Yi Li, B.S., National Central University, 1940
Frank Earl Marble, B.S., Case School of Applied Science, 1940; M.S., *Ibid.*, 1942
Robert L. Mastin, B.S., United States Naval Academy, 1939
Thomas Rufus McClellan, B.S., United States Naval Academy, 1942
Earl Wilson McLaughlin, B.S., United States Naval Academy, 1940
Edward Berlendis Monteath, B.S., Washington University, 1940; M.S., California Institute of Technology, 1946
Ralph Earl Moyer, Jr., B.S., Maryville State Teachers College, 1941
Leo Wayne Mullane, B.ChE., University of Minnesota, 1940; M.S., California Institute of Technology, 1946
Donald John O'Meara, B.S., United States Naval Academy, 1939
George Marshall Palmer, Jr., B.S., Purdue University, 1945; M.S., California Institute of Technology, 1946
Albert David Pollock, Jr., B.S., Santa Barbara State College, 1938
Henry Thomas Ponsford, A.B., Stanford University, 1944; M.S., California Institute of Technology, 1946
David Purdon, B.S., United States Naval Academy, 1940
Floyd Francis Reck, B.S., Hamline University, 1941
Russell Lawrence Reiserer, M.S., California Institute of Technology, 1946
Harold Egbert Rice, B.S., United States Naval Academy, 1941
Charles Wesley Rush, Jr., B.S., United States Naval Academy, 1941
Lewis B. Sanders, Nebraska State Teachers College, 1936-37, 1939-41
Merrill Homer Sappington, B.S., United States Naval Academy, 1942
Loys Malcolm Satterfield, B.S., Trinity College, 1940
Robert Walton Shackford, B.S., Northeastern University, 1942
John Gilbert Small, B.S., California Institute of Technology, 1941; M.S., California Institute of Technology, 1946
Orlan Alton Soli, B.S., River Falls State Teachers College, 1940; M.S., California Institute of Technology, 1946
Jean Barrieu Stevens, B.S., California Institute of Technology, 1940
Robert Fulton Tangren, B.S., California Institute of Technology, 1939; B.S., in Ae., *Ibid.*, 1940
Leon Trilling, B.S., California Institute of Technology, 1944; M.S., California Institute of Technology, 1946
Joseph A. Tvedt, B.A., University of North Dakota, 1939
Joseph Oscar Weisenberg, B.S., Rockhurst College, 1940; M.S., California Institute of Technology, 1946

Thomas Franklin Weldon, B.S., Holy Cross College, 1941; M.S., California Institute of Technology, 1946
Alonzo Holbrook Wellman, Jr., B.S., United States Naval Academy, 1940
John Paul Wheatley, B.S., University of Washington, 1938; M.S., Harvard University, 1939
Quentin Robert Whitmore, A.B., Nebraska State Teachers College, 1941
William Clarence Wilburn, A.B., Birmingham-Southern College, 1941; M.S., California Institute of Technology, 1946

Industrial Designer

Lee Martin Griswold, B.S., Principia College, 1943
Herman Heidt, B.S., University of Colorado, 1944
Mundkur Vasudev Kamath, B.S., Madras University, 1938
Henry Chapman Keck, B.A., Dartmouth College, 1943
Emmett Thomas King, B.S., University of California, 1933; M.S., *Ibid.*, 1936
Orville Samuel Powell, B.S., Purdue University, 1942
Paul C. Yankauskas, Jr., B.S., Rhode Island State College, 1943

Chemical Engineer

Russell Albert Thompson, Jr., B.S., Massachusetts Institute of Technology, 1942; M.S., Massachusetts Institute of Technology, 1943

Mechanical Engineer

Walter Hardenbroecke Goodwin, B.A., University of British Columbia, 1942; B.S., *Ibid.*, 1943; M.S., California Institute of Technology, 1946

Meteorologist

Charles Hadley Lewis, A.B., Whittier College, 1944
John Omer Montgomery, B.A., University of Southern California, 1942; M.S., California Institute of Technology, 1946

Master of Science in Science

CHEMISTRY

Raymond Allen Brown, B.S., Wagner College, 1941
Edward Woodrow Hammock, A.B., Lynchburg College, 1937
Charles Norman Scully, B.S., California Institute of Technology, 1941
Dudley Watson Thomas, A.B., University of California, 1942
Warren Scriver Wooster, Sc.B., Brown University, 1943

CHEMICAL ENGINEERING

Charles Edward Auerbach, B.S., University of California, 1942
Harold Herbert Bradley, Jr., B.S., California Institute of Technology, 1943
Paul Stephen Farrington, B.S., California Institute of Technology, 1941
Arthur Henry Gardner, B.S., California Institute of Technology, 1943
Walter D. Harrington, Jr., B.S., University of California, 1939
Louis Edward Klein, B.S., Lehigh University, 1942
David Malcolm Mason, Jr., B.S., California Institute of Technology, 1943
Stanley Fox Newman, B.S., California Institute of Technology, 1944
John Burton Opfell, B.S., University of Wisconsin, 1945
Jarvis Larson Schwennesen, B.S., Michigan College of Mining and Technology, 1943

GEOLOGICAL SCIENCES

Prabhat Kumar Bhattacharya, M.S., Calcutta University, 1942
Edwin Conger Buffington, B.A., Carleton College, 1941
Leendert DeWitte, B.S., Goringen University
James William Edmundson, A.B., Stanford University, 1941
Luis Flores Covarrubias, C.E., National University of Mexico, 1937
Joseph Stewart Martin, B.S., California Institute of Technology, 1944
Henry William Menard, Jr., B.S., California Institute of Technology, 1942
Robert Carleton White, A.B., Dartmouth College, 1942

METEOROLOGY

David Murray Alexander, B.S., St. Andrews University, 1938
Arthur Frederick Blight, Jr., B.S., California Institute of Technology, 1947
Ta-San Chung, B.S., Tsing-Hwa University, 1938
Brian David Dagnall, B.S., University of London, 1942
Fernand Petregille de Percin, B.S., Rutgers University, 1943
Bernard Emile Dethier, B.S., California Institute of Technology, 1946
Byrne Eggenberger, Certificate in Meteorology, University of California
Eric Gillam, B.S., University of London, 1945
Donnell Hunting Gould, B.S., Berea College, 1943
Walter John Hamming, B.S., California Institute of Technology, 1947
Chi-Hsun Hsueh, B.S., National Central University, 1937
Norman Joseph Macdonald, B.S., California Institute of Technology, 1946
John Manoukian, B.S., Imperial College of Science, 1942
Arnold Allen McCarley, B.S., Austin State Teachers College
Clifford A. Olsen, B.A., Montana State University
John Pettley, B.A., University of London, 1935
Eugene Porter Richey, B.S., University of Alaska, 1941
Pao-Kang Wan, B.S., National South West Associated University, 1938
Norris Woerner, B.S., Tri-State College, 1943
Lai-chao Ying

PHYSICS

Alfred Bruce Brown, Jr., B.S., Lehigh University, 1942
Richard H. Davis, B.S., Purdue University, 1943
William Richard Davis, B.S., California Institute of Technology, 1944
Robert Briggs Day, A.B., Haverford College, 1943
Albert Tromly Ellis, B.S., California Institute of Technology, 1943
Hussein Mohammed Amin El-Sum, B.S., Fouad' University, 1941
Frank Behle Estabrook, A.B., Miami University, 1943
Louis Adams Giamboni, B.S., University of California at Los Angeles, 1941
Robert Max Ilfeld, B.S., Massachusetts Institute of Technology, 1944
David Lockhart Judd, A.B., Whitman College, 1943
Herman Kahn, B.A., University of California at Los Angeles, 1946
Fiorello Rannzo Leo, B.S., National Chio-Tun University, 1937
Alfred Lewis Mendenhall, B.A., Miami University, 1937
Maurice Rattray, Jr., B.S., California Institute of Technology, 1944
Leland Perley Robinson, Jr., B.S., University of New Hampshire, 1939; M.S., University of New Hampshire, 1940
Malvin Avram Ruderman, A.B., Columbia College, 1945
Robert G. Thomas, B.S., California Institute of Technology, 1944
Richard Davidson Young, B.A., Princeton University, 1945

Master of Science in Engineering

AERONAUTICS

Jerry Frederick Louis Aldrich, A.B., University of California at Los Angeles, 1944
Morton Alperin, B.S., New York University, 1939
Warren Amster, B.S., California Institute of Technology, 1944

Norman Carl Appold, B.S., University of Michigan, 1940; M.S., University of Michigan, 1941
Adolfo Jose Atencio, B.S., Buenos Aires University, 1944
Paul Gregory Atkinson, Jr., B.S., United States Military Academy, 1943
John Wray Bennett, B.S., University of Florida, 1942
Zegmund Oscar Bleviss, B.S., University of California, 1944
William Crockett Cooley, B.S., Massachusetts Institute of Technology, 1944
Sudbodh Chandra Das, B.S., Presidency College, 1937
Harold H. DeGroff, Jr., B.S., Rensselaer Polytechnic Institute, 1946
James Alexander Gwilym Diack, B.S., University of Toronto, 1943
William Henry Eisele, B.S., Rensselaer Polytechnic Institute, 1946
Morris Feigen, B.S., University of California, 1940
Luis Eduardo Freire, B.S., California Institute of Technology, 1946
Robert David Fusfeld, B.S., Columbia University, 1942
Jack Alban Gibbs, B.S., Oregon State College, 1936
George Edward Gompf, B.S., Virginia Polytechnic Institute, 1942
Jean Glen Goppert, B.S., Texas Agricultural and Mechanical College, 1943
William D. Graziano, B.S., New York University, 1943
Albert Henry Hall, B.S., University of Alberta, 1942
Wendell William Harter, B.S., California Institute of Technology, 1942
Ea-Qua Huang, Technische Hochschule, Berlin
Harry Frederick Imster, B.S., University of Michigan, 1946
Arnold Axtell Jensen, B.S., University of Minnesota, 1939
Felix Andrew Kalinski, B.S., United States Military Academy, 1943
John Andrew Kelly, B.S., University of Colorado, 1946
Warren Gottlieb Koerner, B.S., Purdue University, 1942
Seymour Lampert, B.S., Georgia School of Technology, 1943
James Steven Lesko, B.S., Rensselaer Polytechnic Institute, 1943
Bernard Walter Marschner, B.S., University of Minnesota, 1942
George Bert Melrose, Jr., B.S., Brown University, 1945
Irving Michelson, B.S., California Institute of Technology, 1943
Curtis Edward Miller, B.S., University of Minnesota, 1943
Thomas Guy Monroe, Jr., B.S., North Carolina State College, 1943
Antony John Andrew Morgan, B.S., California Institute of Technology, 1944
William Edward Morley, B.A.Sc., University of Toronto, 1945
Clyde Richard Murtaugh, B.E.E., Ohio State University, 1943
Conrad Nathaniel Nelson, B.S., Massachusetts Institute of Technology, 1941
John Lewis Orr, B.A.Sc., University of Toronto, 1939
Telford Wilbert Oswald, A.B., Stanford University; S.M., Harvard University
Norman Charles Peterson, B.S., University of Michigan, 1943
Ernest I. Pritchard, B.S., Antioch College, 1943
Anatol Roshko, B.S., University of Alberta, 1945
Donald Barstow Seager, B.S., University of California, 1942
Thor Eyolfur Stephenson, B.A.Sc., University of Toronto, 1942
James Leonard Summers, B.S., University of Washington, 1942
Calhoun Winfred Sumrall, B.S., Louisiana State University, 1945
George Renzo Vanden Heuvel, B.S., Georgia School of Technology, 1939
Milton Denman Van Dyke, B.S., Harvard University, 1943
Wilbert Gayton Wheldon, B.S., United States Naval Academy, 1941
Max L. Williams, Jr., B.S., Carnegie Institute of Technology, 1942
Eugene Frank Wyszpolski, B.A.E., Rensselaer Polytechnic Institute, 1945

CIVIL ENGINEERING

Harold Severin Anthon, B.S., Illinois Institute, 1939
James Henderson Beddow, B.S., West Virginia University, 1938
Richard Arns Boettcher, B.S., University of Wisconsin, 1938
Raymond Maurice Clock, B.S., United States Military Academy, 1940
William Tatem Collings, B.S., California Institute of Technology, 1944
John Pinna Craven, B.S., Cornell University, 1946

Thomas V. Davis, B.S., California Institute of Technology, 1937
Charles Marsden Duke, B.S., United States Military Academy, 1939
Edward Aiken Flanders, B.S., United States Military Academy, 1940
John Edward Fritz, C.E., University of Cincinnati, 1937
Richard Carl Gerke, B.S., University of Colorado, 1946
Richard Hall Gilman, III, B.S., California Institute of Technology, 1944
John A. Graf, B.S., United States Military Academy, 1940
Elmer Ernest Hall, Jr., B.S., University of California, 1944
Robert Blynn Harris, B.S., University of Colorado, 1940
William Edwin Heller, B.S., California Institute of Technology, 1945
William Miles Linton, B.S., United States Naval Academy, 1941
Sidney Taylor Martin, B.S., United States Military Academy, 1939
Myron Ellsworth Page, Jr., B.S., University of California, 1938
Adrian Pauw, B.S., University of Washington, 1937
Joseph Mansfield Phelps, B.S., California Institute of Technology, 1944
Patrick Michael Quinlan, B.E., University College, 1941; B.Sc., University College, 1942; M.Sc., University College, 1943
Guruvayur Subramanyam Ramaswamy, B.S., College of Engineering, Madras, 1944
Fred Edgar Rosell, Jr., B.S., United States Military Academy, 1942
Clayton Allen Rust, B.S., United States Military Academy, 1940
Frank Albert Swatta, B.S., State University of Iowa, 1938
Donald Calvin Tillman, B.S., California Institute of Technology, 1945
Joseph Ernest Veale, B.S., A.E., Georgia School of Technology, 1933; B.S., C.E., Georgia School of Technology, 1936
Clifford McBride Wimberly, B.S., New Mexico State College, 1942
Clyde Calhoun Zeigler, B.S., United States Military Academy, 1935

ELECTRICAL ENGINEERING

Charles Wesley Baugh, Jr., B.S., Purdue University, 1944
Floyd Kenneth Becker, B.S., University of Colorado, 1945
Robert Royce Bennett, B.A., Reed College, 1943
Arthur Trew Biehl, B.S., Illinois Institute of Technology, 1945
Jay Rolden Borden, B.S., California Institute of Technology, 1944
Earle Robert Bunker, Jr., B.S., California Institute of Technology, 1943
Paul Krishnama Charlu, B.E., College of Engineering, India, 1944
David Arthur Cooke, B.S., University of Colorado, 1944
Willard A. Dodge, Jr., B.S., California Institute of Technology, 1944
James Hughes Drake, B.S., California Institute of Technology, 1946
Norman Harry Enenstein, B.S., University of California at Los Angeles, 1946
Jerome Smyth Harrington, B.S., California Institute of Technology, 1945
Laurence Oliver Haupt, Jr., B.S., California Institute of Technology, 1946
William LeRoy Hayhurst, B.S., Queens University, 1946
Charles Robert Hill, B.S., University of Utah, 1941
Paul Trice Hutchison, B.S., Mississippi State College, 1944
William Glen Lall, B.S., Punjab College of Engineering and Technology, 1944
Vicente Hidalgo Lim, B.S., United States Military Academy
David Colvill Lincoln, B.S., California Institute of Technology, 1946
Richard Henri MacNeal, B.S., Harvard University, 1943
Andrew Wahlert McCourt, B.S., Washington University, 1943
Ruben Fred Mettler, B.S., California Institute of Technology, 1944
Lloyd Edward Ott, B.S., California Institute of Technology, 1945
Lowell Carr Parode, B.S., California Institute of Technology, 1945
Richard Wells Powell, B.S., California Institute of Technology, 1940
Robert George Rogers, B.S., University of Texas, 1945
Robert Kenneth Roney, B.S., University of Missouri, 1944
David Frederick Rutland, B.S., California Institute of Technology, 1944
Alfred Dale Scarbrough, B.S., California Institute of Technology, 1945
Jack Hamilton Slaton, B.S., Illinois Institute of Technology, 1945
Richard Allen Smith, B.S., California Institute of Technology, 1946

Carl Philip Spaulding, B.S., University of Colorado, 1943
John Albert Stallkamp, B.S., Columbia University, 1946
Frederick Stevens, Jr., A.B., Whitman College, 1944
Loren Frank Stringer, B.S., University of Texas, 1946
Stanley Grover Stroud, B.S., California Institute of Technology, 1941
Ernest Wade, B.S., California Institute of Technology, 1943
Orison Wade, B.S., California Institute of Technology, 1946
Dean Allen Watkins, B.S., Iowa State College, 1944
Barton Cook Wood, B.S., Purdue University, 1944
Gregory Odd Young, B.S., California Institute of Technology, 1944

MECHANICAL ENGINEERING

Spencer Roe Baen, B.S., Texas Agricultural and Mechanical College, 1943
Oliver Albrecht Baer, A.B., Stanford University, 1943
Richard Harding Ball, B.S., Purdue University, 1942
Robert Owen Barkdoll, B.S., Northwestern Technological Institute, 1945
Edward Rice Bartlett, Jr., B.S., California Institute of Technology, 1942
Earnest Hubert Clark, Jr., B.S., California Institute of Technology, 1946
David Arthur Elmer, B.S., California Institute of Technology, 1943
Edward William Garrison, B.S., Harvard University, 1943
Leon Green, Jr., B.S., California Institute of Technology, 1944
John Arnold Heinz, B.S., California Institute of Technology, 1945
Chi-nan Hsu, B.S., Chiao-Tung University, 1941
Herbert Arthur Lassen, B.S., California Institute of Technology, 1943
Theodore Gibson Lawrence, B.S., California Institute of Technology, 1943
David Lifton, B.S., Carnegie Institute of Technology, 1940
Michael Kevin Molloy, B.S., University of Toronto, 1945
Walter Mactavish Ogston, B.A., New College, Oxford, 1939; M.A., New College, Oxford, 1946
Douglas Chappell Reid, B.S., California Institute of Technology, 1943
William Treloar Russell, B.S., University of Washington, 1942
Glenn August Schurman, B.S., Washington State College, 1944
Richard Brigham Small, B.S., Massachusetts Institute of Technology, 1942
Richard Alvord Sutton, B.S., California Institute of Technology, 1943
Jack Dahlstrom Verschoor, B.S.E., University of Michigan, 1945

Bachelor of Science

SCIENCE

Reed Macomber Anderson
Rolland Sanford Asher
George Allen Austin
Hal Wayne Banbrook
John S. Billheimer
Arthur Frederick Blight, Jr.
Jonas Brachfeld
Harry Paul Brueggemann
David Orville Caldwell
Roderick Keener Clayton
Arthur J. Critchlow
John Joseph Deniston
David Lewis Douglas
George Gordon Gammans
Donald Irving Granicher
William Gordon Hammerle
George F. Hardy
Robert Hutchison Harris
John Wm. Harrison
Richard James Herndon
George Guldin Kelley
Robert Warner Kenney
William Robert King, Jr.
Harold William Kuhn
Harvey John Lawrence
Paul Audrey Linam
Bartholomew Locanthi
Raymond Ralph Lochhead
John Latimer Mason
John M. Mays
Charles Henry McDougall, Jr.
Dale Joseph Meier
Donald Dolton Mon
Elmo Moorehead
David Eugene Muller
Rollie John Myers, Jr.
Arnold Hastings Nevis
Walter Thomas Ogier
David Russell Opperman
Leon Shenfil

Eugene Merle Shoemaker
Peter Swerling
Warren Stanley Torgerson
Charoen Vadhanapanich
Jeptha Alan Wade, Jr.
Jerry Dalton Ward
Thomas Neal Wilson
Eric John Woodbury

Bachelor of Science in Engineering

Richard Stephen Barna
Robert Bearson
William Rochelle Bellew
Robert C. Belyea
Dudley Earl Bennett
Ellis Harley Beymer
Robert Louis Blink
Arthur S. Bolles
Francis Robert Bowerman
Robert King Breece
Latham Loomis Brundred, Jr.
James Ferguson Chalmers
Harold Comlossy, Jr.
Edwin J. Cowan
Cecil A. Crafts
Charles Burton Crumly
Rodney O. Darling
Chadwick Schuyler Dauwalter
Orin Jack Demuth
Wesley Moore Dynes
Manfred Eimer
Byrne Eggenberger
Richard LeRoy Felberg
Bernard Flam
Darwin LeGrande Freebairn, Jr.
Jack Edward Froehlich
William Francis Giacomazzi, Jr.
Wendall Max Boas Haas
Walter John Hamming
David Sheridan Hatcher
Harry Hoyt Hauger, Jr.
Robert Gray Hawthorne
Langdon Clyde Hedrick
Harold M. Hipsh
Merwyn Edgar Hodges
John Dwight Holmgren
Kenneth Fraser Holtby
Graham Allison Horine
Robert M. Kendall
Chresten Mills Knudsen
Henry George Kohler
Joel M. Kowan
James Fletcher Lane
Norman Ray Lee
Rodin Voltaire Lesovsky
Howard Kirk Lewis, Jr.
James Adams Lewis
LeVal Lund, Jr.
William Pearson Lundy
George Wilson Lyon
Ordway Talbot Manning
Lloyd Fuller Mauldin
Robert Stuart MacAlister, Jr.
Gordon McClure
Rob Roy McDonald
Stanley Harold Mendes
Charles Norman Miller
Edward Wilson Miller
Return Francis Moore
Stephen Faulkner Moran, III
Albert Herbert Joseph Mueller
Franklin Oliver Myers
Blaine R. Parkin
Lucien Arthur Pascoe
Arthur E. Platt
John Patrick Prendergast
Carl F. Rasmussen
Kamalesh Ray
Will Richeson, Jr.
John Cumming Riedel
Eugene S. Rose, Jr.
Joseph Rosener, Jr.
Herbert Nathan Royden
Willem Schaafsma
Henry William Schroeder
John Raymond Scull
George Donald Shipway
Carter Sinclair
Lyle Dean Six
James Stewart Smith
Donald Stewart, Jr.
Stanford Grant Stiles
Roger Dean Stuck
Clayton Robert Sturdevant
Francis Duane Sullivan
Richard Gordon Sweet
Raymond Bernard Tasker
John Phares Terry
Robert Harold Utschig
David Basil Van Deerlin
Arthur Francis Vieweg
Robert Lawrence Walker
Allen Dean Weeks
Jerard Ben Werner
James Stewart Wiggs
Edward Byron Winters, Jr.

GRADUATE STUDENTS

(For the Academic Year 1946-1947)

Name	Major Subject	Home Address
Adams, Raymond Voiles, Jr. B.S., Kansas State College, 1941	Ph	Manhattan, Kansas
Adams, Robert Train B.S., University of California, 1942	Ch	Berkeley
Adamson, Phil Allen B.A., University of Redlands, 1946	EE	San Marino
Aldrich, Jerry Frederick Louis A.B., University of California at Los Angeles, 1944	AE	Campbell
Alexander, David Murray B.S., St. Andrews University, 1938	My	St. Andrews, Scotland
Alford, Jack Leland B.S., California Institute, 1942 M.S., California Institute, 1946	ME	Altadena
Allen, Harry Berkley B.A., University of California at Los Angeles, 1939 M.A., University of California at Los Angeles, 1942	Ge	San Dimas
Allen, Thomas Lofton B.S., University of California, 1944	Ch	Cupertino
Alperin, Morton B.S., New York University, 1939	AE	Jackson Heights, New York
Altseimer, John Henry B.S., University of Wisconsin, 1941 M.S., California Institute, 1946	AE	Milwaukee, Wisconsin
Altshuler, Saul B.S., University of California at Los Angeles, 1943	Ph	Los Angeles
Amster, Warren Herbert B.S., California Institute, 1944	AE	Montclair, New Jersey
Anderson, Roy Gene, Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1940	AE	Neosho, Missouri
Andrew, Alan B.S., University of Nebraska, 1942 M.S., California Institute, 1944	Ph	St. Joseph, Missouri
Andrews, Clyde Cecil, Lt. Cdr., U.S.N. Kansas Junior College, 1939 M.S., California Institute, 1946	AE	Kansas City, Kansas
Anthon, Harold S. B.S., Illinois Institute, 1939	CE	Hermosa Beach
Appold, Norman Carl, Lt. Col., U.S.A. B.S., University of Michigan, 1940 M.S., University of Michigan, 1941	AE	Detroit, Michigan
Armour, Cecil Vining B.A., University of Toronto, 1926 M.S., University of Toronto, 1939	CE	Kingston, Ontario
Ashkenas, Harry Israel B.S., University of California, 1944 M.S., California Institute, 1946	AE	Los Angeles
Atencio, Adolfo Jose B.S., Buenos Aires University, 1944	AE	Buenos Aires, Argentina
Atkinson, Paul Gregory, Jr., Major, U.S.A. B.S., U.S. Military Academy, 1943	AE	Norristown, Pennsylvania

Name	Major Subject	Home Address
Auerbach, Charles Edwards B.S., University of California, 1942	ChE	San Francisco
Baen, Spencer Roe, Lt., U.S.A. B.S., Texas A & M College, 1943	ME	San Antonio, Texas
Baer, Oliver Albrecht A.B., Stanford University, 1943	ME	Sacramento
Ball, Richard Harding B.S., Purdue University, 1942	ME	Huntington, Indiana
Ballhaus, William Francis B.S., Stanford University, 1942	AE	San Francisco
Barden, Kenneth Perrin, Lt., U.S.N. University of Arkansas	AE	Pocahontas, Arkansas
Barkdoll, Robert Owen B.S., Northwestern Technological Institute, 1945	ME	Maywood, Illinois
Barnett, Kurt B.S., McGill University, 1946	EE	Westmount, Canada
Bartlett, Edward Rice, Jr. B.S., California Institute, 1942	ME	Bronxville, New York
Baugh, Charles Wesley, Jr. B.S., Purdue University, 1944	EE	Mentor, Ohio
Baum, William Alvin B.A., University of Rochester, 1943	Ph	Pasadena
Becker, Floyd Kenneth B.S., University of Colorado, 1945	EE	Denver, Colorado
Beddow, James Henderson, Lt. Col., U.S.A. B.S., West Virginia University, 1938	CE	Slagle, West Virginia
Begovich, Nicholas Anthony B.S., California Institute, 1943 M.S., California Institute, 1944	EE	San Francisco
Behroon, Khosrow M.S., Tehran University, 1938 M.S., California Institute, 1946	EE	Tehran, Iran
Bendat, Julius Samuel A.B., University of California, 1944	Ph	Los Angeles
Bennett, Edward Leigh B.A., Reed College, 1943	Ch	Hood River, Oregon
Bennett, John Wray, Lt., U.S.A. B.S., Florida University, 1942	AE	Miami, Florida
Bennett, Robert Royce B.S., California Institute, 1945	EE	Pomeroy, Washington
Benton, Robert Francis B.S., California Insitute, 1943	Ma	Santa Barbara
Bhattacharya, Probhat Kumar M.S., Calcutta University, 1942	Ge	Calcutta, India
Biehl, Arthur Trew B.S., Illinois Institute of Technology, 1945	EE	Richmond Hill, New York
Billman, Glenn Wagner B.S., California Institute, 1941 M.S., California Institute, 1942	ChE	Long Beach
Blake, Robert T., Capt., U.S.A. B.S., U.S. Military Academy, 1943	ME	Boise, Idaho
Blaker, Robert Hockman A.B., Berea College, 1942	Ch	Blue Sulpher Springs, W. Virginia
Blanchett, Leo Mose, Capt., U.S.A. B.S., U.S. Military Academy, 1943	ME	Seattle, Washington
Bleviss, Zegmund Oscar B.S., University of California, 1944	AE	Los Angeles

Name	Major Subject	Home Address
Boettcher, Richard Arns B.S., University of Wisconsin, 1938	CE	Milwaukee, Wisconsin
Bond, John Walter, Jr. B.S., University of Chicago, 1940	Ph	Altadena
Bond, Robert Elston B.A., Yale University, 1940	ID	Berkeley
Borden, Jay Rolden B.S., California Institute	EE	Los Angeles
Bowen, Dwain Burns B.S., California Institute, 1942 M.S., California Institute, 1946	Ph	Montrose
Bowen, John Thomas B.S., California Institute, 1942 M.S., California Institute, 1946	ME	Los Angeles
Bowie, James Monfort, Lt., U.S.N. Long Beach Junior College	AE	Chelan, Washington
Bradley, Harold Herbert, Jr. B.S., California Institute, 1943	ChE	Alhambra
Brinkman, Robert Philip B.S., Iowa State University, 1943	ID	Des Moines, Iowa
Brockman, John A., Jr. B.S., California Institute, 1942	Ch	Reno, Nevada
Brooks, Marvin Charles B.S., Yale University, 1942 M.S., New York University, 1944	Ch	Nutley, New Jersey
Brooks, Richard Fremont A.B., Brown University, 1941	Ge	Ithaca, New York
Brough, Harry Ward B.S., California Institute, 1945	Ch	Glendale
Brown, Alfred Bruce, Jr. B.S., Lehigh University, 1942	Ph	Essex Falls, New Jersey
Brown, David Henry B.S., California Institute, 1942	Ch	Altadena
Brown, Raymond Allen B.S., Wagner College, 1941	Ch	Staten Island, New York
Buchanan, John Mason B.S., University of Virginia, 1944	EE	Atlanta, Georgia
Buchholz, Werner B.S., University of Toronto, 1945	EE	Pasadena
Buff, Frank Paul B.S., University of California, 1944	Ch	San Francisco
Buffington, Edwin Conger B.A., Carleton College, 1941	Ge	Duluth, Minnesota
Buhler, James Logan B.S., University of California, 1942	Ch	Claekomas, Oregon
Buhler, Rolf D. B.A.E., University of Minnesota, 1943 M.S., California Institute, 1944	AE	Pasadena
Bull, Edward George, Lt. Cdr., U.S.N. B.S., University of Michigan, 1941	AE	Stockton
Bunker, Earle Robert, Jr. B.S., California Institute, 1943	EE	Alhambra
Burger, Glenn William, Lt. Cdr., U.S.N. Colorado University	AE	Rosemead
Burket, Stanley Campbell B.A., Linfield College, 1939 M.A., University of Kansas, 1943	Ch	Lawrence, Kansas
Carhart, Richard Raymond B.S., University of California at Los Angeles, 1940	Ph	Coronado

Name	Major Subject	Home Address
Carter, William Walton B.S., Carnegie Institute, 1943	Ph	Fort Worth, Texas
Cartwright, Kenneth Orlando B.S., Purdue University, 1941	EE	Anderson, Indiana
Chang, Chieh Chien B.A., National Northeastern University, China, 1932 M.S., California Institute, 1941	AE	Shantung, China
Chapman, Dean Roden B.S., California Institute, 1944	AE	Los Angeles
Charlu, Paul Krishnama B.E., College of Engineering, India, 1944	EE	Tiruvannamalai, South India
Chase, Patrick S. B.S., California Institute, 1943 M.S., California Institute, 1946	AE	Altadena
Chung, Ta San B.S., Tsing-Hwa University, 1938	My	Hunan, China
Clark, Earnest Hubert B.S., California Institute, 1946	ME	Burbank
Clarke, Donald Walter B.S., University of Alberta, 1941 M.S., University of Alberta, 1943	Ch	Alberta, Canada
Clarke, Fredric "B", Lt. Cdr., U.S.N B.S., U.S. Naval Academy, 1939	AE	Long Beach
Cleland, George Horace B.S., Occidental College, 1942	Ch	Los Angeles
Clements, Robert Emmett, Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1940	AE	Sanford, Florida
Clock, Raymond M., Lt. Col., U.S.A. B.S., U.S. Military Academy, 1940	CE	Rosedale, Long Island, New York
Cohen, E. Richard A.B., University of Pennsylvania, 1943 M.S., California Institute, 1946	Ph	Philadelphia, Pennsylvania
Cole, Charles W. B.A.E., University of Minnesota, 1940 M.S., California Institute, 1946 Ae.E., California Institute, 1946	AE	St. Paul, Minnesota
Collings, William Tatem B.S., California Institute, 1944	CE	Pasadena
Collins, Hugh "L" H., Lt., U.S.N. B.S., Spring Hill College, 1946	AE	Mobile, Alabama
Cooke, David Arthur B.S., University of Colorado, 1944	EE	Santa Barbara
Cooley, William Crockett B.S., Massachusetts Institute of Technology, 1944	AE	New London, Connecticut
Corcoran, William Harrison B.S., California Institute, 1941 M.S., California Institute, 1942	ChE	Pasadena
Corrsin, Stanley B.S., University of Pennsylvania	AE	Miami Beach, Florida
Cowan, Eugene Woodville B.S., University of Missouri, 1941 M.S., Massachusetts Institute of Technology, 1943	Ph	Columbia, Missouri
Cox, Carl Britton B.A., University of California at Los Angeles, 1936 M.A., University of California at Los Angeles, 1939	AE	Pomona
Cox, Charles Shipley B.S., California Institute, 1942	Ph	Honolulu, Hawaii
Craven, John Pinna B.S., Cornell University, 1946	CE	Brooklyn, New York

Name	Major Subject	Home Address
Cullen, James Albert B.S., California Institute, 1946	Ph	Los Angeles
Cutsforth, David Harrison B.S., Oregon State College, 1943	Ge	Portland, Oregon
Dacey, George Clement B.S., University of Illinois, 1942	Ph	Arcadia
Dagnall, Brian David B.S., University of London, 1942	My	Sidcup, Kent, England
Dailey, Charles Lee B.S., California Institute, 1941 M.S., California Institute, 1942	My	Los Angeles
Daniels, Jerry Forest, Jr., Lt. Cdr., U.S.N. University of Wichita	AE	Wichita, Kansas
Darling, Donald Allan A.B., University of California at Los Angeles, 1941	Ma	Pasadena
Das, Subodh Chandra B.S., Presidency College, 1937	AE	Calcutta, India
Davies, Richard William B.S., California Institute, 1946	Ma	Los Angeles
Davis, Leo B.S., California Institute, 1940 M.S., California Institute, 1942	Ph	Los Angeles
Davis, Richard Harding B.S., Purdue University, 1943	Ph	Sims, Indiana
Davis, Thomas V. B.S., California Institute, 1937	CE	Norfolk, Virginia
Davis, William Richard B.S., California Institute, 1944	Ph	Provo, Utah
Day, Robert Briggs A.B., Haverford College, 1943	Ph	Warren, Ohio
DeGroff, Harold Miller, Jr. B.S., Rensselaer Polytechnic Institute, 1946	AE	Troy, Ohio
Denby-Wilkes, John Edward B.A., University of Paris, 1940 B.A., Columbia University, 1942	Ma	San Marino
Denson, Mayette Elner, Jr. B.S., Montana State College, 1941	Ge	Selby, Montana
Deodati, Joseph Benjamin, Lt. Cdr., U.S.N. B.S., Texas A & M, 1939	AE	San Antonio, Texas
de Percin, Fernand Petrgille B.S., Rutgers University, 1943	My	New Brunswick, New Jersey
Dethier, Bernard Emile B.S., California Institute, 1946	My	Norwood, Massachusetts
De Witte, Leendert B.S., Goringen University	Ge	Thehaque, Holland
Dewald, Jacob F. B.S., Haverford College, 1943	Ch	New York, New York
Diack, James Alexander Gwilym B.S., University of Toronto, 1943	AE	Ottawa, Ontario
Dickey, Frank Host B.S., California Institute, 1941	Ch	Los Angeles
Ditch, William Earl, Lt., U.S.N. Independence Junior College	AE	Independence, Kansas
Dodge, Willard A. B.S., California Institute, 1944	EE	Fargo, North Dakota

Name	Major Subject	Home Address
Donohue, Jerry A.B., Dartmouth College, 1941 M.A., Dartmouth College, 1943	Ch	Sheboygan, Wisconsin
Dodson, Minot Boyd, Lt. Col., U.S.A. B.S., Arkansas State College, 1936 M.S., University of Arkansas, 1939	ME	Nettleton, Arkansas
Donahue, Gerald Michael, Lt. Col., U.S.A. B.S., Kansas University, 1932 M.S., Kansas University, 1933	ME	Ogden, Kansas
Dore, Frank John B.S., California Institute, 1945 M.S., California Institute, 1946	AE	Balboa Island
Dort, Wakefield, Jr. B.S., Harvard University, 1944	Ge	Spofford, New Hampshire
Dougherty, Charles Bullard B.S., Iowa State College, 1945 M.S., California Institute, 1946	Ph	Creston, Iowa
Doyle, George Joseph A.B., San Jose State College	Ch	Pasadena
Doyle, Worthie Lesier B.A., University of Washington, 1943	Ma	Port Orchard, Washington
Drake, James Hughes B.S., California Institute, 1946	EE	Los Angeles
Duke, Charles Marsden, Lt. Col., U.S.A. B.S., U.S. Military Academy, 1939	CE	Jacksonville, Texas
Duncan, Donal Baker B.S., California Institute, 1945	Ph	Claremont, California
Duncan, John Robert B.S., University of Southern California, 1945	EE	San Fernando
Durst, Lincoln Kearney B.A., University of California at Los Angeles, 1945 B.S., California Institute, 1946	Ma	Santa Monica
Durup, Paul C., Lt., U.S.N. Northeastern University	AE	Wallaston, Massachusetts
Edmundson, James William A.B., Stanford University, 1941	Ge	Laguna Beach
Edwards, Charles DeVires B.A., Carleton College, 1942	Ge	Excelsior, Minnesota
Edwards, Russell Keith B.S., Washington State College, 1940	ChE	Mansfield, Washington
Eisele, William Henry B.S., Rensselaer Polytechnic Institute, 1946	AE	Cleveland, Ohio
Ellis, Albert Tromly B.S., California Institute, 1943	Ph	Pasadena
Elmer, David Arthur B.S., California Institute, 1943	ME	South Pasadena
El-Sum, Hussein Mohammed Amin B.S., Fouad I University, 1941	Ph	Cairo, Egypt
Enenstein, Norman Harry B.S., University of California at Los Angeles, 1946	EE	Los Angeles
Engeloer, Paul Oscar B.S., California Institute, 1939 M.S., California Institute, 1940	Ge	Long Beach
Estabrook, Frank Behle A.B., Miami University, 1943	Ph	Nampa, Idaho
Eubank, Perry Huston, Lt. Col., U.S.A. B.S., U.S. Military Academy, 1937	ME	Madison, Missouri

Name	Major Subject	Home Address
Fairbanks, Auard Fox B.S.E., University of Michigan, 1941 M.S., University of Utah, 1942	EE	Ann Arbor, Michigan
Fairman, Francis Evarts, III B.S., Haverford, 1945	EE	San Marino
Farrington, Paul Stephen B.S., California Institute, 1941	ChE	Pasadena
Feigen, George Alexander A.B., University of California, 1938	Bi	Pasadena
Feigen, Morris B.S., University of California, 1940	AE	Los Angeles
Feldman, Arnold B.S., Pennsylvania State College, 1944	Ph	Los Angeles
Felt, Gaelen Lee A.B., Harvard University, 1943	Ph	Pasadena
Finkbeiner, Daniel Talbot, II A.B., Washington and Jefferson University, 1941 M.A., Washington and Jefferson University, 1943	Ma	Harrisburg, Pennsylvania
Flanders, Edward Aiken, Lt. Col., U.S.A. B.S., U.S. Military Academy, 1940	CE	Palo Alto
Fletcher, James Chipman A.B., Columbia University, 1940	Ph	Summit, New Jersey
Flores-Covarrubias, Luis C.E., National University of Mexico, 1937	Ge	Mexico City, Mexico
Follin, James W., Jr. B.S., Massachusetts Institute of Technology, 1940	Ph	San Marino
Ford, Harold H. B.S., California Institute, 1945	ID	Claremont
Fossier, Mike Walter B.S., Louisiana State University, 1945 M.S., California Institute, 1946	AE	New Orleans, Louisiana
Francis, Donald Lowell B.S., California Institute, 1945	AE	Auburn
Freire, Luis Eduardo B.S., California Institute, 1946	AE	Buenos Aires, Argentina
Fritz, John Edward, Major, U.S.A. C.E., University of Cincinnati, 1937	CE	Cincinnati, Ohio
Fung, Yuam-Cheng B.S., National Central University, 1941 M.S., National Central University, 1943	AE	Kiangsu, China
Fusfeld, Robert David B.S., Columbia, 1942	AE	Washington, D. C.
Garber, Max B.S., Washington University, 1942	EE	Kansas City, Missouri
Gardner, Arthur Henry B.S., California Institute, 1943	Ch	Pasadena
Garner, Harold Karl B.S., California Institute, 1943	Ch	Portland, Oregon
Garrison, Edward William B.S., Harvard University, 1943	ME	New Castle, Delaware
Garvin, Walter B.S., Massachusetts Institute of Technology, 1944 M.S., California Institute, 1945	Ph	New York, New York
Gebhart, Arthur Fletcher, Jr. B.S., University of Utah, 1943	ME	Salt Lake City, Utah
Geisberg, Ralph Lewis B.M.E., Clemson College, 1937 M.S., California Institute, 1944	AE	Los Angeles

Name	Major Subject	Home Address
Gerke, Richard Carl B.S., University of Colorado, 1946	CE	Sierra Madre
Giamboni, Louis Adams B.S., University of California at Los Angeles, 1941	Ph	Los Angeles
Gibbs, Jack Alban, Col., U.S.A. B.S., Oregon State College, 1936	AE	Roseburg, Oregon
Gilbert, Thomas Lewis B.S., California Institute, 1944	Ph	Pasadena
Gillam, Eric B.S., University of London, 1945	My	Surrey, England
Gilman, Richard Hall, III B.S., California Institute, 1944	CE	Los Angeles
Gilmore, Forrest Richard B.S., California Institute, 1944	Ph	Whittier
Glanville, James William B.S., Rice Institute of Technology, 1944	Ch	Dallas, Texas
Glaser, Donald Arthur B.S., Case School of Applied Science, 1946	Ph	Cleveland Heights, Ohio
Goff, Gordon Henry B.S., University of California, 1943	ChE	Walnut Creek
Golding, Bert Henry B.S., California Institute, 1944	Ch	Long Beach
Gompf, George Edward B.S., Virginia Polytechnic Institute, 1942	AE	Richmond, Virginia
Goodwin, Walter Hardenbroecke B.A., University of British Columbia, 1942 B.S., University of British Columbia, 1943	ME	Vancouver, B. C.
Goppert, Jean Glen, Capt., U.S.A. B.S., Texas A & M College, 1943	AE	Edna, Texas
Gould, Donnell H. B.A., Berea College, 1943	My	Juneau, Alaska
Graf, John A., Lt. Col., U.S.A. B.S., U.S. Military Academy, 1940	CE	New Albany, Indiana
Gray, Reed Alden B.S., University of Utah, 1944	Bi	Santa Clara, Utah
Graziano, William D. B.S., New York University, 1943	AE	Guttenberg, New Jersey
Green, Leon B.S., California Institute, 1944	EE	Chicago, Illinois
Griffing, Charles Wing, Lt. Cdr., U.S.N. B.S., University of Florida, 1940	AE	Miami, Florida
Grinstead, Robert Russell B.S., University of California, 1946	Ch	Sonoma
Griswold, Lee Martin B.S., Principia College, 1943	ID	Hollywood
Gruenberg, Harry B.A. of Sc., University of British Columbia, 1944	EE	Vancouver, B. C.
Gryder, John William B.S., California Institute, 1946	Ch	Los Angeles
Guyton, William Franklin B.S., University of Mississippi	CE	Pasadena
Hall, Albert Henry B.S., University of Alberta, 1942	AE	Ottawa, Canada
Hall, Elmer Ernest B.S., University of California, 1944	CE	McCloud
Hall, Robert Noel B.S., California Institute, 1942	Ph	Los Angeles

Name	Major Subject	Home Address
Hammock, Edward Woodrow A.B., Lynchburg College, 1937	Ch	Pasadena
Hannum, Richard W. M.E., Rensselaer Polytechnic Institute, 1935	Ph	Media, Pennsylvania
Harbottle, Garman B.S., California Institute, 1944	Ch	Dayton, Ohio
Harmon, Kent Midgley A.B., University of Redlands, 1942 M.S., University of California, 1944	Ch	Glendale
Harrington, Jerome B.S., California Institute, 1945	EE	Washington, D. C.
Harrington, Walter Delburt B.S., University of California, 1939	Ch	Carmel
Harris, Charles DeWitt B.S., Oklahoma A & M College, 1940	AE	Wagner, Oklahoma
Harris, Robert Blynn B.S., University of Colorado, 1940	CE	Horse Creek, Wyoming
Harter, Wendell William B.S., California Institute, 1942	AE	Riverside
Haupt, Laurence Oliver, Jr. B.S., California Institute, 1946	EE	Hanford
Hayhurst, William LeRoy B.S., Queens University, 1946	EE	Alberta, Canada
Hayward, Philip B.S., University of Arizona, 1941	Ch	Kewanee, Illinois
Head, Richard Moore B.S., California Institute, 1942	AE	Pasadena
Hedberg, Kenneth Wayne B.S., Oregon State College, 1943	Ch	Astoria, Oregon
Hedden, Albert Henry, Jr. B.S., Williams College, 1946	Ge	South Orange, New Jersey
Heidt, Herman B.S., Colorado University, 1944	ID	Ordway, Colorado
Heinz, John Arnold B.S., California Institute, 1945	ME	Anaheim
Helfand, Bernard Benjamin B.A., Toronto University, 1936 M.S., Massachusetts Institute of Technology, 1943	My	Monrovia
Heller, William Edwin B.S., California Institute, 1945	CE	Cashion, Oklahoma
Henke, Burton L. A.B., Miami University, 1944 M.S., California Institute, 1945	Ph	Madeira, Ohio
Heppe, Ralph Richard B.S., Stanford University, 1944 M.S., Stanford University, 1945	AE	San Mateo
Hermes, Richard Manning B.S., University of Santa Clara, 1934 M.A., Stanford University, 1938	ME	San Jose
Herold, Henry Lindsay A.B., University of California, 1945	Ge	Glendale
Hill, Armin J. B.S., Montana State College, 1932 M.S., Montana State College, 1938	Ph	Bozeman, Montana
Hill, Charles Robert B.S., University of Utah, 1941	EE	Evanston, Wyoming
Hindall, Lawrence D'Arle B.S., Carnegie Institute of Technology, 1942 M.S., California Institute, 1946	Ph	Muncie, Indiana

Name	Major Subject	Home Address
Hitchcock, Henry Selden B.S., Pomona College, 1943	Ge	Pasadena
Ho, Chung-Pen B.S., National Tsing-Hua University, 1932 M.S., California Institute, 1945	My	Liao-Nin, China
Hoff, Rodney Guy B.A., Washington State College, 1945	Ph	Metaline Falls, Washington
Holmes, Sterling Charles, Lt. Col., U.S.A. B.S., North Carolina State College, 1939	ME	Cambridge, New York
Holzman, George B.S., California Institute, 1943	Ch	Pasadena
Hopkins, Robert C. A.B., College of Emporia, 1935	EE	San Bernardino
Hornyak, William Frank B.E.E., College of New York, 1944 M.S., California Institute, 1945	Ph	New York, New York
Howes, Thomas Barron A.B., Knox College, 1943	Ge	Long Beach
Hoyer, Horst Walter B.S., City College of New York, 1942	Ch	Middle Village, New York
Hsu, Chi-nan B.S., Chiao-Tung University, 1941	ME	Chekiang, China
Hsueh, Chi-hsun B.S., National Central University, 1937	My	Chungking, China
Huang, Ea-Qua Technische Hochschule, Berlin	AE	Washington, D. C.
Hudson, Thomas Ernest B.S., California Institute, 1944 M.S., California Institute, 1946	ME	Monterey Park
Huestis, Gerald Stephen, Lt. U.S.N. University of California	AE	Lockeford
Hull, Herbert Mitchell University of California	Bi	San Francisco
Humphrey, George L. B.A., Marietta College, 1943	Ch	Belleville, West Virginia
Hutchison, Paul Trice B.S., Mississippi State College, 1944	EE	Tupelo, Mississippi
Ilfeld, Robert Max B.S., Massachusetts Institute of Technology, 1944	Ph	Taos, New Mexico
Imster, Harry Frederick B.S., University of Michigan, 1946	AE	Olin, Iowa
Inn, Edward Chang Yul B.S., University of Hawaii, 1939 M.S., University of Hawaii, 1942	Ph	Honolulu, T. H.
Inonu, Omer Technical University	ME	Ankara-Gaukaya, Turkey
Ismail, Hassan Mohammed B.S., Fouad I University, 1941	CE	Cairo, Egypt
Itano, Harvey Akio B.S., University of California, 1942 M.D., St. Louis University, 1945	Ch	Chicago, Illinois
Jenks, Leverett Norton, Lt., U.S.A. B.S., U.S. Military Academy, 1944	ME	Park Ridge, Illinois
Jensen, Arnold Axtell B.S., University of Minnesota, 1939	AE	Minneapolis, Minnesota
Johnson, Paul Bennett B.A., University of Washington, 1938 M.S., University of Washington, 1943	Ma	Missoula, Montana

Name	Major Subject	Home Address
Johnson, Philip O. B.S., California Institute, 1942 M.S., California Institute, 1943	AE	Sierra Madre
Johnston, Harold Sledge A.B., Emory University, 1941	Ch	Woodstock, Georgia
Jones, John Halsey B.S., Massachusetts Institute of Technology, 1942	ID	Portland, Oregon
Jones, Paul, Jr., Lt., U.S.A. B.S., U.S. Military Academy, 1944	AE	Greenville, South Carolina
Judd, David Lockhart A.B., Whitman College, 1943	Ph	Chehalis, Washington
Kahn, Herman B.A., University of California at Los Angeles, 1946	Ph	Los Angeles
Kalinski, Felix Andrew, Major, U.S.A. B.S., U.S. Military Academy, 1943	AE	Manchester, New Hampshire
Kamath, Mundkur Vasudev B.S., Madras University, 1938	ID	Nileswar, South India
Kaye, John B.S., California Institute, 1939	ME	San Marino
Keck, Henry Chapman B.A., Dartmouth College, 1943	ID	Manasquan, New Jersey
Keilin, Bertram B.A., New York University, 1942 M.S., California Institute, 1945	Ch	Bronx, New York
Kelly, John Andrew B.S., University of Colorado, 1946	AE	Pasadena
Kendrick, James Benjamin B.S., Massachusetts Institute of Technology, 1934 M.S., Massachusetts Institute of Technology, 1937	AE	Excelsior Springs, Missouri
Kenny, George Scott B.S., Seattle Pacific College, 1941	Ph	Monrovia
Keuffel, Jack Warren A.B., Princeton University, 1941	Ph	Essex Falls, New Jersey
Kilner, Scott Burgoyne B.S., University of California, 1941	Ch	Berkeley
King, Emmett Thomas B.S., University of California, 1933 M.S., University of California, 1936	ID	Long Beach
Kirkwood, Thomas Fredrick B.A., Stanford University, 1943 M.A., Stanford University, 1944	AE	Palo Alto
Klein, David J. B.S., California Institute, 1943	Ph	Los Angeles
Klein, Louis Edward B.S., Lehigh University, 1942	ChE	Easton, Pennsylvania
Knopoff, Leon B.S., California Institute, 1944 M.S., California Institute, 1946	Ph	Los Angeles
Koenig, Nathan Hart B.S., University of Chicago, 1937	Ch	Venice
Koerner, Warren Gottlieb B.S., Purdue University, 1942	AE	Pasadena
Krauss, Max B.A., University of California, 1938 B.A., University of California, 1940	Bi	Whittier
Kyropoulos, Peter Rudolf B.S., University of Gottingen, 1937 M.S., California Institute, 1938	ME	Pasadena
Lall, William Glen B.S., Punjab College of Engineering & Technology, 1944	EE	Lahore, India

Name	Major Subject	Home Address
Lampert, Seymour B.S., Georgia School of Technology, 1943	AE	Dumont, New Jersey
Lance, John Franklin B.A., Texas College of Mines, 1938 M.S., California Institute, 1946	Ge	El Paso, Texas
Land, LeRoy Cosby, Major, U.S.A. B.S., Utah State College, 1940	ME	Layton, Utah
Larson, Ray Forrest B.S., U.S. Naval Academy, 1945	ID	Huntington Park
Lass, Harry B.A., University of California at Los Angeles, 1938 M.A., University of California at Los Angeles, 1940	Ma	Los Angeles
Lassen, Herbert Arthur B.S., California Institute, 1943	ME	Beverly Hills
Latter, Richard B.S., California Institute, 1942	Ph	Pasadena
Laufer, John B.S., Louisiana State University, 1942 M.S., California Institute, 1943 AeE., California Institute, 1944	AE	Pasadena
Lawrence, Theodore Gibson B.S., California Institute, 1943	ME	Hermosa Beach
Leighton, Robert B. B.S., California Institute, 1941 M.S., California Institute, 1944	Ph	Pasadena
Lemaire, Henry B.S., Massachusetts Institute of Technology, 1942	Ch	New York, New York
Leo, Rannzo B.S., National Chio-Tung University, 1937	Ph	Sui-an, Chekiang, China
Lerman, Leonard Soloman B.S., Carnegie Institute of Technology, 1945	Ch	Pittsburgh, Pennsylvania
Lesko, James Steven B.S., Rensselaer Polytechnic Institute, 1943	AE	Bridgeport, Connecticut
Levitt, Bernard Barclay B.S., University of Colorado, 1941 M.S., California Institute, 1946	AE	Denver, Colorado
Lewis, Charles Hadley A.B., Whittier College, 1944	My	Whittier
Li, Ting Yi B.S., National Central University, 1940	AE	Nanking, China
Lifton, Hymen David B.S., Carnegie Institute of Technology, 1940	ME	Pittsburgh, Pennsylvania
Lim, Vicente Hedalgo, Jr. B.S., U.S. Military Academy, 1944	EE	Manila, Philippines
Lincoln, David C. B.S., California Institute, 1946	EE	Scottsdale, Arizona
Lind, David Arthur B.S., University of Washington, 1940 M.S., California Institute, 1943	Ph	Kirkland, Washington
Lindegren, Carl Robert B.S., University of California, 1943	Ch	Los Angeles
Linton, William Miles, Lt. Col., U.S.A. B.S., U.S. Naval Academy, 1941	CE	Takoma Park, Maryland
Long, Neville Stuart B.S., California Institute, 1944	CE	Los Angeles
Losch, Joseph Wesley B.S., U.S. Military Academy, 1940	ME	Los Angeles
Lowery, Byron Ordway A.B., Whitman College, 1938 M.S., California Institute, 1946	My	Walla Walla, Washington

Name	Major Subject	Home Address
Lurie, Harold B.S., University of South Africa, 1940	AE	Durban, South Africa
Lyon, John Ballachey, Jr. B.S., California Institute, 1945	Ph	San Juan, Puerto Rico
MacAllister, Robert A.B., Wartburg College, 1934	Ch	Clinton, Iowa
MacDonald, Norman Joseph B.S., California Institute, 1946	My	Bethesda, Maryland
MacNeal, Richard Henri B.S., Harvard University, 1943	EE	Los Angeles
MacNeill, Robert John B.A., Queens University, 1943	Ge	Ontario, Canada
Macomber, Mark Morris B.S., California Institute, 1945	CE	Pasadena
Maddox, Richard Irving B.S., U.S. Naval Academy, 1941	Ph	Portland, Oregon
Manoukian, John B.S., Imperial College of Science, 1942	My	London, England
Marble, Frank Earl B.S., Case School of Applied Science, 1940 M.S., Case School of Applied Science, 1942	AE	Pasadena
Marschner, Bernard Walter B.S., University of Minnesota, 1942	AE	Ontonagon, Michigan
Martin, Harold Clifford B.S., New York University, 1934 M.S., New York University, 1937	AE	Monrovia
Martin, Joseph Stewart B.S., California Institute, 1944	Ge	Monterey
Martin, Sidney Taylor, Lt. Col., U.S.A. B.S., U.S. Military Academy, 1939	CE	Gilmer, Texas
Martner, Samuel Theodore A.B., University of California, 1940 M.S., California Institute, 1946	Ge	Pasadena
Mason, David Malcolm B.S., California Institute, 1943	ChE	Los Angeles
Mastin, Robert Leavenworth, Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1939	AE	Madison, New Jersey
Maun, Eugene Kingery B.S., University of Illinois, 1945	Ch	Urbana, Illinois
Mayers, Donald B.A., Pomona College, 1943	Ma	Los Angeles
McClellan, Thomas Rufus, Lt., U.S.N. B.S., U.S. Naval Academy, 1942	AE	Waco, Texas
McClintock, Frank Ambrose B.S., Massachusetts Institute of Technology, 1943 M.S., Massachusetts Institute of Technology, 1943	ME	Minneapolis, Minnesota
McCourt, Andrew Wahlert B.S., Washington University, 1943	EE	St. Louis, Missouri
McDonald, Robert C., Jr., Lt. Col., U.S.A. B.S., U.S. Military Academy, 1935	ME	Washington, D. C.
McGoldrick, Francis Mark, Lt. Col., U.S.A. B.S., U.S. Military Academy, 1946	ME	Lee, Massachusetts
McLaughlin, Earl Wilson, Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1940	AE	Allegan, Michigan

Name	Major Subject	Home Address
McLaughlin, Jack Enloe B.S., University of Idaho, 1944	Ma	St. Maries, Idaho
McLean, Robert F. B.S., California Institute, 1943	ID	Pasadena
McRuer, Duane Torrance B.S., California Institute, 1945	EE	Los Angeles
Melrose, George Bert, Jr. B.S., Brown University, 1945	AE	Providence, Rhode Island
Menard, Henry William B.S., California Institute, 1942	Ge	Los Angeles
Mendenhall, Alfred Lewis B.A., Miami University, 1937	Ph	Dayton, Ohio
Merritt, Melvin B.S., California Institute, 1943	Ph	Portland, Oregon
Mettler, Ruben Fred B.S., California Institute, 1944	EE	Shafter
Michelson, Irving B.S., Georgia School of Technology, 1943	AE	Washington, D. C.
Miles, Richard Cutler, Capt., U.S.A. B.S., U.S. Military Academy, 1942	ME	Washington, D. C.
Miller, Curtis Edward B.S., University of Minnesota, 1943	AE	Redwood Falls, Minnesota
Miller, George Erikson B.S., Georgia School of Technology, 1942	ID	Atlanta, Georgia
Miller, Herman B.S., California Institute, 1943 M.S., California Institute, 1945	AE	Long Beach
Miller, James Cleveland, Jr., Capt., U.S.A. B.S., U.S. Military Academy, 1943	ME	Laurel, Mississippi
Miller, Julian Malcolm B.S., University of California, 1944	Ch	Pasadena
Miller, Wendell Smith B.A., Pomona College, 1944	Ch	Burbank
Mills, Mark Muir B.S., California Institute, 1940	Ph	Pasadena
Mills, Robert L. B.S., Carnegie Institute of Technology, 1943	Ch	Canton, Ohio
Mislow, Kurt Martin B.S., Tulane University, 1944	Ch	New York, New York
Mitchell, Fern Wood, Jr. A.B., University of Alabama, 1938 M.S., California Institute, 1946	Ch	South Pasadena
Molloy, Michael Kevin B.S., University of Toronto, 1945	ME	Victoria, B. C.
Monroe, Thomas Guy, Lt., U.S.A. B.S., North Carolina State College, 1943	AE	Hamlet, North Carolina
Monsanto, Edwin M. B.S., University of Nevada, 1943	EE	Victorville
Monteath, Edward Berlendis, Lt. Cdr., U.S.N. B.S., Washington University, 1940	AE	Pasadena
Montgomery, John Osmer B.A., University of Southern California, 1942	My	Los Angeles
Montgomery, Richard Alan B.A., University of British Columbia, 1940 M.S., California Institute, 1946	EE	Vancouver, B. C.
Mooney, Harold Morton B.S., Harvard University, 1943	Ge	South Hero, Vermont

Name	Major Subject	Home Address
Morgan, Antony J. A. B.S., California Institute, 1944	AE	Altadena
Morgan, Samuel Pope, Jr. B.S., California Institute, 1943 M.S., California Institute, 1944	Ph	Casa Grande, Arizona
Morikawa, George Kivoshi B.S., California Institute, 1939 M.S., California Institute, 1941	AE	Washington, D. C.
Morison, Rodney A.B., Kenyon College, 1940	Ph	Balboa
Morley, William Edward B.A. of Sc., University of Toronto, 1945	AE	Ottawa, Canada
Moyer, Ralph Earl, Jr., Lt., U.S.N. B.S., Maryville State Teachers College, 1941	AE	Maryville, Missouri
Mullane, Leo Wayne, Lt. Cdr., U.S.N. B.Ch.E., University of Minnesota, 1940	AE	Pasadena
Murphy, John Thomas, Jr. B.S., University of Oklahoma, 1944	Ge	Denver, Colorado
Murtaugh, Clyde Richard B.E.E., Ohio State University, 1943	AE	Orrville, Ohio
Nagamatsu, Henry Takeihi B.S., California Institute, 1939 M.S., California Institute, 1940	AE	Santa Ana
Naiditch, Sam B.A., University of California at Los Angeles, 1939	Ch	Altadena
Nelson, Conrad Nathaniel, Capt., U.S.A. B.S., Massachusetts Institute of Technology, 1941	AE	Dayton, Ohio
Nevenzel, Judd Cuthbert B.S., University of Arizona, 1941 M.S., University of Arizona, 1942	Ch	Tucson, Arizona
Newman, Stanley Fox B.S., California Institute, 1944	ChE	Kansas City, Missouri
Oberbeck, Thomas Edmond B.A., Washington University, 1938 A.M., University of Nebraska, 1940	Ma	Frankfort, Illinois
Odell, Francis Eugene B.S., California Institute, 1944	ME	Glendora
Ogston, Walter Mactavish B.A., New College, Oxford, 1939 M.A., New College, Oxford, 1946	ME	Dumfries, Scotland
Olds, Robert Horner B.S., California Institute, 1938 M.S., California Institute, 1939	Ph	Pasadena
O'Meara, Donald John, Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1939	AE	Pasadena
Opfell, John Burton B.S., University of Wisconsin, 1945	ChE	Iowa City, Iowa
Ordway, Fred D., Jr. B.S., Rensselaer Polytechnic Institute, 1942 M.S., Rensselaer Polytechnic Institute, 1943	Ch	Palm Beach, Florida
O'Reilly, Rev., James Donald B.S., St. Patrick's College, Eire, 1938 B.Theo., St. Patrick's College, 1940	Ph	Ballymote, Eire
Orr, John Lewis B.A.Sc., University of Toronto, 1939	AE	Ottawa, Ontario, Canada
Ott, Lloyd Edward B.S., California Institute, 1945	EE	Baldwin Park
Owen, Robert Pendleton B.S., University of Louisville, 1943	EE	Trenton, Kentucky

Name	Major Subject	Home Address
Page, Myron Ellsworth, Jr., Lt. Col., U.S.A. B.S., University of California, 1938	CE	Stockton
Paigen, Kenneth B.S., Johns Hopkins University, 1946	Bi	Bronx, New York
Palmer, George Marshall B.S., Purdue University, 1945 M.S., California Institute, 1946	AE	Bluefield, West Virginia
Palmer, Raymond Jefferson B.S., California Institute, 1944	ID	Long Beach
Panzer, Max Ludwig B.S., California Institute, 1944 M.S., California Institute, 1945	Bi	Beverly Hills
Pardee, Arthur Beck B.S., University of California, 1942 M.S., California Institute, 1943	Ch	Berkeley
Parker, Frederick Dent B.S., University of Oklahoma, 1944	ChE	Oklahoma City, Oklahoma
Parks, Jerome W. B.S., California Institute, 1945	ID	Balboa Island
Parode, Lowell Carr B.S., California Institute, 1945	EE	Los Angeles
Paul, Charles Craig B.S., Northeastern University, 1941	ID	East Braintree, Massachusetts
Pauw, Adrian B.S., University of Washington, 1937	CE	Seattle, Washington
Perlis, Alan Jay B.S., Carnegie Institute of Technology, 1942	Ch	Pittsburgh, Pennsylvania
Peterson, Norman Charles B.S., University of Michigan, 1943	AE	Sioux City, Iowa
Pettley, John B.A., London University, 1935	My	Faenborough, Hants, England
Petzold, Robert Frederick B.S., Massachusetts Institute of Technology, 1945	Ch	Lawrence, Massachusetts
Pfeiffer, Heinz Gerhard A.B., Drew University, 1941 M.A., Syracuse University, 1943	Ch	Newton, New Jersey
Phelps, Joseph Mansfield B.S., California Institute, 1944	CE	Long Beach
Pinckard, James H. B.A., Arizona State Teachers College, 1938 M.A., Arizona State Teachers College, 1939	CH	Tucson, Arizona
Pocock, Arthur Franklin A.B., College of Wooster	Ge	Cleveland Heights, Ohio
Pollock, Albert David, Jr., Lt. Cdr., U.S.N. B.S., Santa Barbara State College, 1938	AE	Santa Barbara
Ponsford, Henry Thomas A.B., Stanford University, 1944 M.S., California Institute, 1946	AE	El Paso, Texas
Pounder, Edwin B.S., California Institute, 1946	AE	Pasadena
Powell, Orville Samuel B.S., Purdue University, 1942	ID	Salem, New Jersey
Powell, Richard W. B.S., California Institute, 1940	EE	Glendale
Prasad, Kadaba Krishna B.S., University of Mysore, 1943 M.S., University of Mysore, 1944	EE	Mysore, India

Name	Major Subject	Home Address
Pray, Lloyd Charles B.A., Carleton College B.S., California Institute, 1943	Ge	Altadena
Pritchard, Ernest Ingersoll B.S., Antioch College, 1943	AE	Pasadena
Purdon, David, Lt. Cdr., U.S.N B.S., U.S. Naval Academy, 1940	AE	Hermosa Beach
Quinlan, Patrick Michael B.E., University College, 1941 B.Sc., University College, 1942 M.Sc., University College, 1943	CE	Kelfinane, Eire
Ramaswamy, Subramanyam G. B.S., College of Engineering, Madras, 1944	CE	Shencottah, South India
Rasmussen, Volney Kinne, Jr. B.S., California Institute, 1939	Ph	Eden, New York
Rasof, Bernard B.S., Illinois Institute of Technology, 1941	AE	West Los Angeles
Rattray, Maurice, Jr. B.S., California Institute, 1944	Ph	Seattle, Washington
Rau, R. Ronald B.S., College of Puget Sound, 1941 M.S., California Institute, 1943	Ph	Pasadena
Ray, Kamalesh M.S., Calcutta University, 1935	CE	Rangpur, Bengal, India
Rechtin, Eberhardt B.S., California Institute, 1946	EE	Palos Verdes
Reck, Floyd Francis, Lt., U.S.N. University of Minnesota	AE	Hector, Minnesota
Reed, Arthur Wayne, Major, U.S.A. B.S., U.S. Military Academy, 1939	ME	Wichita, Kansas
Reed, Irving Stoy B.S., California Institute, 1944	Ma	Fairbanks, Alaska
Regnery, David Cook A.B., Stanford University, 1941	Bi	Julian
Reid, Douglas, Chappell B.S., California Institute, 1943	ME	Bellflower
Reiserer, Russell Lawrence, Lt. Cdr., U.S.N. Stanford University	AE	Redwood City
Retherford, Kenneth Lynn A.B., University of Illinois, 1939 M.S., University of Washington, 1942	Bi	Lakebay, Washington
Rice, Harold Egbert, Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1941	AE	Emmaus, Pennsylvania
Richardson, Audre B.S., California Institute, 1943 M.S., California Institute, 1946	Ph	Hollywood
Richey, Eugene Porter B.S., University of Alaska, 1941	My	Westfir, Oregon
Roberts, Wayne Arthur B.S., California Institute, 1945	Ge	Los Angeles
Roberts, William B. E.M., Colorado School of Mines, 1943	Ge	San Marino
Robinson, Charles Franklin A.B., Missouri State Teachers College, 1935 B.A., Drury College, 1936 M.S., California Institute, 1938	Ph	Pasadena
Robinson, Leland P., Jr. B.S., University of New Hampshire, 1939 M.S., University of New Hampshire, 1940	Ph	Concord, New Hampshire

Name	Major Subject	Home Address
Roesch, William Carl B.A., Miami University, 1945	Ph	Dayton, Ohio
Rogers, Robert George B.S., University of Texas, 1945	EE	Austin, Texas
Rogell, Paul Sanford B.S., Iowa State College, 1944	EE	Kansas City, Missouri
Roney, Robert Kenneth B.S., Missouri University, 1944	EE	Morrisville, Missouri
Roop, Frederick Crouch A.B., Princeton, 1935 M.S., Harvard, 1936	My	Albany
Rosell, Fred E., Jr., Major, U.S.A. B.S., U.S. Military Academy, 1942	CE	Dayton, Ohio
Rosen, Milton William B.S., University of Pennsylvania	AE	Washington, D. C.
Roshko, Anatol B.S., University of Alberta, 1945	AE	Edmonton, Alberta, Canada
Rosicky, Fred George B.S., Creighton University, 1941	Ch	Omaha, Nebraska
Rostron, James T. B.S., University of California, 1941	CE	Pasadena
Rubin, Sylvan B.S., California Institute, 1939	Ph	Pasadena
Ruderman, Malvin Avram A.B., Columbia College, 1945	Ph	Brooklyn, New York
Rush, Charles Wesley, Jr., Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1941	AE	Dothan, Alabama
Russell, William Treloar, Major, U.S.A. B.S., University of Washington, 1942	ME	Tacoma, Washington
Rust, Clayton Allen, Lt. Col., U.S.A. B.S., U.S. Military Academy, 1940	CE	Brooklyn, New York
Rutland, David Frederick B.S., California Institute, 1944	EE	Pasadena
Sabersky, Rolf Heinrich B.S., California Institute, 1942 M.S., California Institute, 1943	ME	Los Angeles
Safonov, George Michael B.S., California Institute, 1943	Ph	Pasadena
Sanders, Gabriel Bermudez Agri.Eng., Escuela Nacional de Agricultura, 1943	CE	Mexico City, Mexico
Sanders, Lewis Ben, Lt. Cdr., U.S.N. B.A., Nebraska State Teachers College, 1941	AE	Merriman, Nebraska
Sandoval-Landazuri, Alberto Ch., University of Mexico, 1941	Ch	Mexico City, Mexico
Sappington, Merrill Homer, Lt., U.S.N. B.S., U.S. Naval Academy, 1942	AE	Barnesville, Georgia
Satterfield, Loys Malcolm, Lt. Cdr., U.S.N. B.S., Trinity College, 1940	AE	Waxachachie, Texas
Savit, Carl Hertz B.S., California Institute, 1943	Ma	Pasadena
Saxena, Ram Chandra B.S., Lucknow University, 1940 M.S., Lucknow University, 1941	Ph	Budaum, India
Scarbrough, Alfred Dale B.S., California Institute, 1945	EE	Yucaipa

Name	Major Subject	Home Address
Schamberg, Richard B.S., California Institute, 1943 M.S., California Institute, 1944	AE	Los Angeles
Schardt, Alois Wolfgang B.S., California Institute, 1944	Ph	Hollywood
Schlinger, Warren Gleason B.S., California Institute, 1944	ChE	Glendale
Schmidt, Louis Vincent B.S., California Institute, 1946	AE	Compton
Schneider, Arthur John R. B.S., California Institute, 1943 M.S., California Institute, 1943	ME	Alameda
Schocken, Victor B.A., New York University, 1942 M.S., Oregon State College, 1944	Bi	Yonkers, New York
Schuch, Adam F. B.S., Michigan State College, 1930 M.S., Michigan State College, 1931	Ch	Bowling Green, Ohio
Schurman, Glenn August B.S., Washington State College, 1944	ME	LaCenter, Washington
Schwartz, Hugo Escuela de Artes y Oficios	EE	Santiago, Chile
Scully, Charles Norman B.S., California Institute, 1941	Ch	Altadena
Schwennesen, Jarvis Larson B.S., Michigan College Mining and Technology, 1943	ChE	Orange
Seager, Donald Barstow B.S., University of California, 1942	AE	Filer, Idaho
Seagrave, John D. B.S., California Institute, 1946	Ph	Pasadena
Seriff, Aaron Jay B.S., University of Texas, 1944 M.S., University of Texas, 1946	Ph	San Antonio, Texas
Shackford, Robert Walton, Lt., U.S.N. B.S., Northeastern University, 1942	AE	Medford, Massachusetts
Shannon, Sidney R. B.S., North Dakota State College, 1936	ID	Monrovia
Shapiro, Haskell B.S., California Institute, 1942	EE	Pasadena
Shoemaker, David Powell B.A., Reed College, 1942	Ch	Boise, Idaho
Shor, George G. B.S., California Institute, 1944	Ge	New York, New York
Showell, John Sheldon B.S., California Institute, 1946	Ch	Pasadena
Singleton, Jesse R. A.B. & B.S., North West Missouri State Teachers College, 1938 M.A., University of Missouri, 1941	Bi	Burlington Junction, Missouri
Slaton, Jack Hamilton B.S., Illinois Institute of Technology, 1945	EE	Cincinnati, Ohio
Small, John Gilbert B.S., California Institute, 1941	AE	San Rafael
Small, Richard Brigham B.S., Massachusetts Institute of Technology, 1942	ME	Alhambra
Simmons, George Finlay B.S., California Institute, 1946	Ma	Chicago, Illinois
Smith, Josiah Edward B.S., California Institute, 1940	AE	South Pasadena

Name	Major Subject	Home Address
Smith, Raymond J. B.S., California Institute, 1945	Ge	Glendora
Smith, Richard Allen B.S., California Institute, 1946	EE	Laguna Beach
Smith, Robert Paul B.S., Carnegie Technology, 1944	Ch	Pittsburgh, Pennsylvania
Smith, Theodore Beaton A.B., Ohio State University M.S., Ph., California Institute, 1940 M.S., My., California Institute, 1942	My	Columbus, Ohio
Snyder, Conway Wilson A.B., University of Redlands, 1939 M.S., State University of Iowa, 1941	Ph	Pasadena
Soldate, Albert M. A.B., Stanford University, 1941 A.M., Stanford University, 1942	Ch	Alhambra
Soli, Orlan Alton, Lt. Cdr., U.S.N. B.S., River Falls State Teachers College, 1940	AE	River Falls, Wisconsin
Sorenson, Emil Leonard B.Ae.E., University of Minnesota	AE	Duluth, Minnesota
Spaulding, Carl Philip B.S., University of Colorado, 1943	EE	Watsonville
Spikes, John Daniel B.S., California Institute, 1941 M.S., California Institute, 1946	Bi	Redondo Beach
Springer, Richard Earl B.S., California Institute, 1945	EE	Los Angeles
Srinivasan, Natesan B.S., Madras University, 1938 M.S., California Institute, 1946	AE	Komal, India
Stallkamp, John Albert B.S., Columbia University, 1946	EE	South Pasadena
Standart, George Charles B.S., California Institute, 1946	ChE	Los Angeles
Steck, George Powell A.B., University of California, 1945		Oakland
Stegmann, Claudio Federico C.E., University of Buenos Aires, 1936	CE	Buenos Aires, Argentina
Stephenson, Thor Eyolfur B.A.Sc., University of Toronto, 1942	AE	Winnipeg, Canada
Stevens, Frederick, Jr. A.B., Whitman College, 1944	EE	Pasadena
Stevens, Jean Barrieu, Lt. Cdr., U.S.N. B.S., California Institute, 1940	AE	Long Beach
Stringer, Loren Frank B.S., University of Texas, 1946	EE	Los Angeles
Stroud, Stanley Grover B.S., California Institute, 1941	EE	Fillmore
Stumpf, Robert H., Lt. Col., U.S.A. B.S., U.S. Military Academy, 1937	ME	Washington, D. C.
Sullivan, John Henry B.A., University of California at Los Angeles, 1943	Ch	Hollywood
Sulzer, J. Friedrich	Ch	Zurich, Switzerland
Suman, Charles William B.S., University of Texas, 1945	ID	Bakersfield
Summers, James Leonard B.S., University of Washington, 1942	AE	Palo Alto
Sumrall, Calhoun Winfred B.S., Louisiana State University, 1945	AE	Little Rock, Arkansas

Name	Major Subject	Home Address
Sutton, Richard Alvord B.S., California Institute, 1943	ME	San Francisco
Swank, Robert Kessler B.A., Chicago University, 1943	Ph	Altadena
Swatta, Frank Albert, Lt. Col., U.S.A. B.S., Iowa University, 1938	CE	Chicago, Illinois
Swift, Jonathan Dean A.B., University of California, 1939	Ma	LaFayette
Tang, You-Chi B.S., National Ting-Chi University, 1942	Ch	Shanghai, China
Tang, Yu-Wei B.S., National Central University, 1940	Bi	Nantung, China
Tangren, Robert Fulton B.S., California Institute, 1940	AE	Pasadena
Tanyel, Besin O. B.S., University of Lyon, 1938	Ph	Istanbul, Turkey
Taylor, George Russell B.S., Carnegie Institute of Technology, 1944	Ch	Pittsburgh, Pennsylvania
Taylor, Jack Leslie, Major, U.S.A. B.S., University of California, 1939 M.S., Montana School of Mines, 1941	ME	Pasadena
Taylor, James Kirkbride B.S., Carnegie Institute of Technology, 1944	ME	Washington, D. C.
Teas, Howard Jones A.B., Louisiana State University, 1942 M.A., Stanford University, 1946	Bi	Freeport, New York
Tejada-Flores, Luis Hernan B.S., California Institute, 1938 M.S., California Institute, 1943	EE	LaPaz, Bolivia
Thiene, Paul George, Jr. B.S., California Institute, 1943	EE	Pasadena
Thomas, Dudley Watson A.B., University of California, 1942	Ch	Pasadena
Thomas, Robert G. B.S., California Institute, 1944	Ph	Pasadena
Thompson, Russell Albert, Jr. B.S., Massachusetts Institute of Technology, 1942 M.S., Massachusetts Institute of Technology, 1942	Ch	Baton Rouge, Louisiana
Thurlow, John Frank B.S., Bates College, 1943	Bi	Mechanic Falls, Maine
Tillman, Donald C. B.S., California Institute, 1945	CE	Los Angeles
Tollestrup, Alvin Virgil B.S., University of Utah, 1944	Ph	Salt Lake City, Utah
Trilling, Leon B.S., California Institute, 1944 M.S., California Institute, 1946	AE	Los Angeles
Trueblood, Kenneth Nyitray A.B., Harvard University, 1941	Ch	Dobbs Ferry, New York
Turnbow, James W. B.S., Texas Technological College, 1940	AE	Slaton, Texas
Tvedt, Joseph Arnold, Lt. Cdr., U.S.N. B.S., University of North Dakota, 1939	AE	Asheville, North Carolina
VandenHeuvel, George Renzo, Lt., U.S.A. B.S., Georgia School of Technology, 1939	AE	Staten Island, New York
Van Dyke, Milton Denman B.S., Harvard University, 1943	AE	Reno, Nevada

Name	Major Subject	Home Address
Vaughan, Philip Alfred B.A., Pomona College, 1943	Ch	Pasadena
Veale, Joseph Ernest, Lt. Col., U.S.A. B.S., A.E., Georgia School of Technology, 1933 B.S., C.E., Georgia School of Technology, 1936	CE	Atlanta, Georgia
Verschoor, Jack Dahlstrom B.S.E., University of Michigan, 1945	ME	Grand Rapids, Michigan
Vis, Vincent Almon B.S.Eng., University of Michigan, 1941 B.S.Ma., University of Michigan, 1941	Ch	Grand Rapids, Michigan
Voelker, William Henry B.S., Case School of Applied Science, 1944	Ph	Cleveland, Ohio
VonAbrams, Gordon J. B.S., University of California at Los Angeles, 1942	Bi	Los Angeles
Wade, Ernest B.S., California Institute, 1943	EE	Pasadena
Wade, Orison B.S., California Institute, 1946	EE	Pasadena
Walker, William Allan B.S., University of Alabama, 1940	AE	McLeod, Texas
Walters, James Willard, Jr., Major, U.S.A. B.S., U.S. Military Academy, 1940	ME	Cincinnati, Ohio
Wan, Pao-Kang B.S., National S.W. Associated University, 1938	My	Foochow, Fukien, China
Watkins, Dean Allen B.S., Iowa State College, 1944	EE	Omaha, Nebraska
Wayne, Lowell Grant B.S., University of California, 1937	Ch	Hynes
Webster, Paul W. B.S., California Institute, 1942 M.S., California Institute, 1943	ME	Jungo, Nevada
Weisenberg, Joseph Oscar, Lt., U.S.N. B.S., Rockhurst College, 1940	AE	Alhambra
Weldon, Thomas Franklin, Major, U.S.A. B.S., College of the Holy Cross, 1941 M.S., California Institute, 1946	AE	Pasadena
Wellman, Alonzo Holbrook, Jr., Lt. Cdr., U.S.N. B.S., U.S. Naval Academy, 1940	AE	Pikeville, Kentucky
Wendel, James Gutwillig B.A., Reed College, 1943	Ma	Pasadena
West, William Junius B.S., Massachusetts Institute of Technology, 1944	Ph	Pleasant Grove, Utah
Wheatley, John Paul, Lt. Cdr., U.S.N. B.S., University of Washington, 1938 M.S., Harvard University, 1939	AE	Seattle, Washington
Wheldon, Wilbert Gayton B.S., U.S. Naval Academy, 1941	AE	Hollydale
White, Harvey John B.S., University of Southern California, 1944	ID	Los Angeles
White, Robert Carleton A.B., Dartmouth College, 1942	Ge	Redlands
Whitmore, Quentin Robert, Lt., U.S.N. B.S., Nebraska State Teachers College, 1941	AE	Wayne, Nebraska
Whitney, James Earl B.S., Brown University, 1943	Ch	Attleboro, Massachusetts
Whittaker, Arthur Greenville B.S., Washington University, 1940	Ch	St. Louis, Missouri

Name	Major Subject	Home Address
Whittlesey, Curtis Cruver B.S., University of Southern California, 1944	ID	Pasadena
Wilburn, William Clarence, Lt. Cdr., U.S.N. A.B., Birmingham Southern College, 1941	AE	Moundville, Alabama
Williams, Max L. B.S., Carnegie Institute of Technology, 1942	AE	Pittsburgh, Pennsylvania
Wilson, Albert George B.S., Rice Institute, 1941 M.S., California Institute, 1942	Ma	Pasadena
Wilson, Martin B.A., Iowa State Teachers College, 1920	Ma	Glendale, Missouri
Wilson, M. Kent B.S., University of Utah, 1943	Ch	Salt Lake City, Utah
Wilts, Charles H. B.S., California Institute, 1940 M.S., California Institute, 1941	EE	Los Angeles
Wimberly, Clifford McBride B.S., New Mexico State College, 1942	CE	Capitan, New Mexico
Windsor, Emanuel B.S., California Institute, 1938	Bi	Los Angeles
Winniford, Robert Stanley B.S., Oregon State College, 1943	Ch	Lacomb, Oregon
Woerner, Norris Eugene B.S., Tri-State College, 1943	My	Wilmington, Ohio
Wood, Barton Cook B.S., Purdue University, 1944	EE	Grosse Pointe, Michigan
Wood, David Shotwell B.S., California Institute, 1941	ME	Sierra Madre
Wood, Fergus James B.S., University of California, 1938	Ge	Eugene, Oregon
Wooster, Warren Scriver Sc.B., Brown University, 1943	Ch	Newton, Massachusetts
Wright, Frederick Hamilton B.A., Haverford College, 1934	Ph	Los Angeles
Wright, Lauren Albert A.B., University of Southern California, 1940 M.A., University of Southern California, 1943	Ge	Los Angeles
Wyszpolski, Eugene Frank B.A.E., Rensselaer Polytechnic Institute, 1945	AE	Brooklyn, New York
Yanak, Joseph Dennis B.S., Lafayette College, 1939 M.S., Brooklyn Polytechnic Institute, 1942	ChE	Jersey City, New Jersey
Yankauskas, Paul Charles, Jr. B.S., Rhode Island State College, 1943	ID	Worcester, Massachusetts
Ying, Lai-Chao Institute of My. Chungking, China	My	Chungking, China
Young, Gregory Odd B.S., California Institute, 1944	EE	San Gabriel
Young, Richard Davidson B.A., Princeton University, 1945	Ph	Pasadena
Yu, Sien-Chine B.S., National Wu-Han University	Bi	Hupeh, China
Ziegler, Clyde Calhoun, Col., U.S.A. B.S., U.S. Military Academy, 1935	CE	St. Matthews, South Carolina
Zieman, Clayton Melvin B.A., University of Wisconsin, 1927 M.S., University of Hawaii, 1939	Ph	Randolph, Wisconsin

UNDERGRADUATE STUDENTS

(For the Academic Year 1946-1947)

SENIOR CLASS

Name	Course	Home Address
Anderson, Reed Macomber	APh	Pasadena
Attias, John Joshua	ME	New York, New York
Austin, George Allen	Ph	Birmingham, Michigan
Banbrook, Hal Wayne	Ph	Los Angeles
Barna, Richard Stephen	ME	Pasadena
Bauer, J. R.	Ph	Millbrae
Bearson, Robert	EE	Los Angeles
Bellew, William R.	ME	Los Angeles
Belyea, Robert Combs	CE	Palm Springs
Bennett, Dudley Earl	CE	Arlington
Beymer, Ellis Harley	EE	Santa Ana
Bezdecheck, William Dionecious	ME	Long Beach
Billheimer, John S.	ACh	Pasadena
Blight, Arthur Frederick, Jr.	APh	South Pasadena
Blink, Robert Louis	EE	Burlingame
Bolles, Arthur Stanard	ME	La Habra
Bowerman, Francis Robert	CE	San Gabriel
Brachfeld, Jonas	Ch	Mexico City, Mexico
Breece, Robert K.	CE	Pasadena
Brueggemann, Harry Paul	APh	Pasadena
Brundred, Latham L.	CE	Watertown, Connecticut
Caldwell, David Orville	Ph	Los Angeles
Caprio, Joseph Michael	Aer	New Brunswick, New Jersey
Chaffee, Glenn Albert	ME	Alhambra
Chalmers, James Ferguson	CE	La Jolla
Clayton, Roderick Keener	Ph	Pasadena
Comlossy, Harold, Jr.	ME	Los Angeles
Conrath, Philip Russell	ME	Webster Groves, Missouri
Cowan, Edwin Jack	ME	Los Angeles
Crafts, Cecil Annand	EE	Pasadena
Critchlow, Arthur J.	APh	Pasadena
Crumly, Charles Burton	EE	Los Angeles
Darling, Rodney Oswald	ME	Victoria, British Columbia
Dauwalter, Chadwick S.	ME	Pasadena
Demuth, Orin Jack	ME	Portland, Oregon
Deniston, John Joseph	APh	Pasadena
Douglas, David Lewis	Ch	Kilmarnock, Virginia
Dynes, Wesley Moore	ME	Hollywood
Eggenberger, Byrne	CE	Altadena
Eimer, Manfred	ME	Los Angeles
Felberg, Richard LeRoy	EE	Monrovia
Flam, Bernard	ME	Sherman Oaks
Freebairn, Darwin L.	EE	Glendale
Froehlich, Jack Edward	ME	Burbank
Gammans, George Gordon	ACh	North Hollywood
Giacomazzi, William Francis	ME	San Jose
Granicher, Donald I.	ACh	San Francisco
Grimm, Lewis Leroy	EE	Placentia

Name	Course	Home Address
Haas, Wendall M. B.	ME	Hollywood
Hammerle, William G.	Ph	Hamilton, Ohio
Hamming, Walter John	ME	Arcadia
Hardy, George F.	Ch	Pass-A-Grille, Florida
Harris, Robert H.	Ch	Dayton, Ohio
Harrison, John William	Ch	Pasadena
Hatcher, David Sheridan	CE	South Pasadena
Hauger, Harry Hoyt, Jr.	ME	Los Angeles
Hawthorne, Robert Gray	ME	Los Angeles
Hedrick, Langdon C.	EE	Seattle, Washington
Herndon, Richard James	Ch	Los Angeles
Hipsh, Harold Marvin	ME	Lakewood, Ohio
Hodges, Merwyn E.	EE	Los Angeles
Holmgren, John Dwight	EE	Pasadena
Holtby, Kenneth Fraser	ME	El Monte
Horine, Graham Allison	ME	Whittier
Johnson, C. Dean, Jr.	ME	Portland, Oregon
Kelley, George Guldin	Ph	Bozman, Maryland
Kendall, Robert Murray	CE	Alhambra
Kenney, Robert Warner	Ph	Portland, Oregon
King, William Robert, Jr.	Ch	Los Angeles
Knudsen, Chresten M.	CE	Redlands
Kohler, Henry George	ME	Mexico City, Mexico
Kowan, Joel M.	EE	Los Angeles
Kuhn, Harold William	Ma	Pasadena
Lane, James Fletcher	ME	Pasadena
Lawrence, Harvey John	ACh	Los Angeles
Lee, Norman Ray	EE	Baton Rouge, Louisiana
Lesovsky, Rodin	ME	Los Angeles
Lewis, Howard Kirk, Jr.	ME	Honolulu, T. H.
Lewis, James Adams	Ge	Redding
Linam, Paul Audrey	ACh	Los Angeles
Lipow, Myron	Ma	Altadena
Locanthi, Bart N.	Ph	White Plains, New York
Lund, LeVal, Jr.	CE	Los Angeles
Lundy, William P.	CE	Glendale
Lyon, George Wilson	ME	Kosse, Texas
MacAlister, Robert Stuart	ME	Los Angeles
MacLean, Douglas James	ME	Los Angeles
Manning, Ordway Talbot	EE	Los Altos
Marshall, Warren Monroe	ME	Atlanta, Georgia
Mason, John L.	ACh	Los Angeles
Mauldin, Lloyd Fuller	ME	Hollywood
Mays, John M.	Ch	Hollywood
McClure, Gordon	EE	Phoenix, Arizona
McDonald, Rob Roy	ME	Ketchum, Idaho
McDougall, Charles Henry	Ma	Evanston, Illinois
Meier, Dale Joseph	Ch	Los Angeles
Mendenhall, Richard Mason	Ch	Dayton, Ohio
Mendes, Stanley Harold	CE	Los Angeles
Miller, Charles Norman	EE	San Diego
Miller, Edward Wilson	ME	Los Angeles
Mon, Donald Dolton	ACh	Long Beach
Moore, Return F.	CE	Long Beach
Moorehead, Basil E. A.	ACh	Oakland
Moran, Stephen Faulkner	ME	Pacific Grove
Mueller, Albert Herbert J.	EE	Van Nuys
Muller, David Eugene	Ph	Pasadena

Name	Course	Home Address
Myers, Franklin Oliver	ME	Eugene, Oregon
Myers, Rollie John	Ch	South Pasadena
Nevis, Arnold Hastings	Ph	Glendale
Ogier, Walter Thomas	Ph	Pasadena
Opperman, David Russell	Aer	Piper City, Illinois
Parkin, Blaine R.	ME	Visalia
Pascoe, Lucien Arthur	EE	Oceanside
Platt, Arthur E.	CE	Pasadena
Pond, Marshall Clarke	ME	Pasadena
Prendergast, John Patrick	CE	Redlands
Rasmussen, Carl F.	EE	Los Angeles
Richeson, Will, Jr.	CE	Glendale
Riedel, John Cumming	EE	Altadena
Rose, Eugene S., Jr.	ME	Vicksburg, Mississippi
Rosener, Joseph	ME	San Francisco
Royden, Herbert N.	EE	Los Angeles
Schaafsma, Willem	ME	Pasadena
Schroeder, Henry William	EE	Stockton
Scull, John Ray	ME	Arcadia
Shauer, Kenneth Melville	EE	Pelham, New York
Shaw, Charles B., Jr.	Ph	Dallas, Texas
Shenfil, Leon	APh	San Francisco
Shipway, George Donald	ME	Sierra Madre
Shoemaker, Eugene M.	Ge	Los Angeles
Sinclair, Carter	ME	Pasadena
Six, Lyle Dean	ME	Pasadena
Smith, James Stewart	ME	San Diego
Stewart, Donald, Jr.	EE	Van Nuys
Stewart, Robert M.	Ph	Arlington, Virginia
Stiles, Stanford G.	ME	Whittier
Stuck, Roger Dean	EE	Santa Paula
Sturdevant, Clayton Robert	ME	Pasadena
Sullivan, Francis Duane	ME	Pomona
Sweet, Richard Gordon	EE	Los Angeles
Swerling, Peter	Ma	Beverly Hills
Tasker, Raymond B.	EE	Van Nuys
Terminel, Ramon Salido	ACh	Sonora, Mexico
Terry, John P.	EE	Los Angeles
Utschig, Robert Harold	ME	La Jolla
Vadhanapanich, Charoen	Ph	Siam
Van Deerlin, David Basil	ME	La Canada
Vieweg, Arthur Francis	EE	Wilmington
Wade, Jeptha A., Jr.	ACh	San Mateo
Walker, Robert Lawrence	ME	San Pedro
Ward, Jerry Dalton	Ph	Beaumont, Texas
Weeks, Allen Dean	EE	Alhambra
Werner, Jerard Ben	ME	Los Angeles
Wiggs, James S.	ME	Pasadena
Wilson, Thomas Neal	APh	Pasadena
Winters, Edward Byron	EE	San Bernardino
Woodbury, Eric John	Ph	Pasadena

JUNIOR CLASS

Name	Course	Home Address
Alexander, Richard Clarke	EE	Glendale
Allen, James Stewart	ME	Ogden, Utah
Allingham, John Wing	Ge	Los Angeles
Alpert, Adelbert I.	ME	San Gabriel

Name	Course	Home Address
Anderson, Robert Graham	ME	Hollywood
Anderson, Roger Alan	ME	Bishop
Au, Yin Ching	ME	Hong Kong, China
Bagley, Allan Stevenson	ME	Twentynine Palms
Banks, David C.	Ch	Altadena
Barker, William Alfred	Ph	Arcadia
Barlow, Griffith Chaffin	Bi	Los Angeles
Baron, David	ME	Compton
Baraclough, Robert Paul	EE	Los Angeles
Basham, William Lassiter	Ge	New London, Texas
Bass, Manuel Nathan	Ch	Los Angeles
Baugh, Harold Wilfred	Ph	Wahiawa, Oahu, T. H.
Bayley, Rupert Morris	EE	Los Angeles
Bear, John Christian	EE	San Diego
Beder, Earl	ME	Los Angeles
Blair, John Marvin	CE	Hollywood
Bloom, Justin Lee	ACh	Los Angeles
Botts, Emmett M.	CE	Carmel
Boutelle, George William	ME	Berkeley
Brown, Robert James	Ph	Lawndale
Bruun, Erik George	APh	San Diego
Burkholder, Joseph F.	ME	San Diego
Burrows, Julian Sage	ME	Houston, Texas
Burt, Frederick Bedell	Bi	Pasadena
Butler, Stuart Markle	CE	St. Louis, Missouri
Carroll, William Jerome	CE	Escondido
Chambers, Guy Roger	EE	Kelso, Washington
Chinn, Elroy Kui Chon	EE	Honolulu, Hawaii
Christopherson, Warren Allen	EE	Martinez
Clark, Paul Torkelson	ACh	Los Angeles
Collins, Burgess Franklin	Ch	Long Beach
Conner, William Michael	EE	Los Angeles
Cotton, Mitchell L.	EE	Washington, D. C.
Cox, Arthur Nelson	APh	Van Nuys
Dahm, Lawrence Philip	ME	Brawley
Dalton, Robert D., Jr.	CE	Oakland
Davis, James Robert	CE	Shady Cove, Oregon
Davis, Russell L.	CE	Monterey Park
Davis, Wayne Kenneth	EE	Burbank
Deutsch, Daniel Harold	Ch	Los Angeles
Dixon, William Joseph	EE	Milwaukee, Wisconsin
Drew, William Atwood	Ma	Chula Vista
Eatherly, Walter Pasold	Ph	Decatur, Illinois
Eldridge, Seba, Jr.	ME	Lawrence, Kansas
Elia, Lewis George	ME	Pasadena
Eller, Arthur Lloyd	EE	Los Angeles
Elms, James Cornelius	Ph	Phoenix, Arizona
Emerson, Frank Morton	EE	Los Angeles
Fahy, Thomas Robert	CE	San Diego
Fay, Alfred Paul	ME	Ventura
Feferman, Solomon	Ma	Los Angeles
Felbeck, George T., Jr.	Ch	New York, New York
Ferrell, Richard Allan	Ph	San Francisco
Flam, Frederick H.	EE	Los Angeles
Fletcher, Taylor Crosby	EE	Temple City
Foster, Robert J.	Ch	San Bernardino
Francis, John Prescott	EE	Los Angeles
Fullerton, Paul William	Ch	Denver, Colorado
Gaskell, Robert Christopher	CE	Los Angeles

Name	Course	Home Address
Gavril, Bruce David	ME	Sand Springs, Oklahoma
Glover, Patrick Norman	Ge	Los Angeles
Green, Howard Wendell	Ch	Ft. Dodge, Iowa
Green, Joseph Matthew	Ph	Los Angeles
Gunther, Fred Carl	ME	Escondido
Hamilton, Thomas Humphries	ACh	Goleta
Hammermeister, Orval Eugene	ACh	Los Angeles
Harder, James Albert	ME	Long Beach
Harris, John Nathaniel	Ph	Hinton, West Virginia
Harrison, Stanley Richard	ME	Tyler, Texas
Harrison, Warren D.	CE	Los Angeles
Hausmann, Delbert A.	CE	Glendale
Hedenberg, John W.	Ph	Pasadena
Henderson, Keith W.	EE	Los Angeles
Henigson, Robert	ACh	Los Angeles
Heppe, Robert John	EE	New York, New York
Herzog, Leonard Frederick, II	Ge	Hollywood
Hickey, Yates	ME	Seattle, Washington
Holditch, George Stanley	ACh	Placentia
Holditch, James Ellyson	ME	Placentia
Holm, Harvey K.	ME	Sacramento
Holser, Alexander Fraser	Ph	Blythe
Honnold, Vincent Richard	Ph	Los Angeles
Howard, Paul John	ME	Whittier
Hybertsen, Horace Martin	CE	South Pasadena
Jarmie, Wilbur Nelson	Ph	Los Angeles
Johnston, Hugh F.	Ph	Chevy Chase, Maryland
Jones, Bruce Chandler	ME	Monrovia
Kaplan, Abner	ME	New York, New York
Kaplun, Saul	ME	New York, New York
King, Robert Fra	ME	Los Angeles
Koch, Arthur Louis	Ch	Pasadena
Krasin, Fred Elvin	EE	Phoenix, Arizona
Krueger, Robert Edward	ME	Los Angeles
Lambert, Peter Charles	CE	Willows
Lamson, Phil	ME	San Bernardino
Lang, Thomas Glenn	ME	Redlands
Leavenworth, Cameron Douglas	ME	Oak Park, Illinois
Levin, Alfred	ME	Pasadena
Levy, Robert Carl	EE	Los Angeles
Lewis, Howard B.	ME	Los Angeles
Lilienthal, Donald Murphy	EE	Spokane, Washington
Lochhead, Raymond Ralph	ACh	University City, Missouri
Lovelace, Donald Eugene	ME	San Diego
Macmillan, Robert Smith	Ph	La Canada
Markowitz, Irwin Louis	ME	Los Angeles
Martin, James Eugene	CE	Whittier
Martinek, George A.	EE	Berwyn, Illinois
Mason, Herman Allen	Ph	Pasadena
Matzdorff, Roger Edward	ME	Pasadena
Maurus, Ray A.	ME	Los Angeles
McCarthy, John	Ma	Pasadena
McClellan, Robert	ME	Grand Rapids, Michigan
McEuen, Albert Harry	Ph	Los Angeles
Mehl, Ross Martin	ME	Stockton
Metzler, David Everett	Ch	Fresno
Mitchell, Edward Eugene	Ph	Honolulu, Hawaii
Mittenthal, Lothrop	APh	Los Angeles
Mones, Jack A.	ME	Phoenix, Arizona

Name	Course	Home Address
Moody, Charles Colburn Bills	ME	Santa Monica
Moore, Boude C.	EE	Redlands
Moore, Harry J.	CE	Long Beach
Morrison, Donald Robert	ACh	Los Angeles
Morrison, Ralph	Ph	Los Angeles
Morrison, Stephen C.	APh	Palo Alto
Muehlberger, William Rudolf	Ge	Hollywood
Mullen, John Kingsley	EE	Los Angeles
Murphy, Charles Gordon	EE	La Jolla
Navarro, Carlos Beeck	ME	Lima, Peru
Nicolai, Fred Henry	Ge	Redwood City
Nobles, Laurence Hewit	Ge	Spokane, Washington
Noon, William Lawrence	ACh	Bellingham, Washington
Oberman, Carl Raymond	Ph	Los Angeles
Olson, Norman Eric	ME	Fallbrook
Otto, Donald Waldo	ME	Fresno
Payne, Paul Gardner	ME	El Monte
Pedraglia, Robert Martin	ME	Saticoy
Peeler, Robert L., Jr.	Ch	Santa Monica
Peterson, Philip Erik	ACh	Oklahoma City, Oklahoma
Phillips, Robert Edward	Ch	Glendale
Platzek, Richard Carl	EE	Pasadena
Podell, Herbert Lawrence	ME	Pasadena
Poindexter, Robert Warner	ME	Carlsbad
Puder, Allen Thrasher	ME	Riverside
Quirmbach, Charles Frederick	ME	Alhambra
Rasmussen, John Oscar, Jr.	Ch	Pasadena
Reese, David Edward	ME	Los Angeles
Rennie, Bruce Bolton	EE	Los Angeles
Rigsby, George Pierce	Ge	Albuquerque, New Mexico
Roach, John Elliott, Jr.	EE	Texarkana, Texas
Roberson, Harvey Lee	ME	Rooky, Oklahoma
Robinson, Martin S.	EE	Los Angeles
Rock, Frank Charles	ACh	Salem, Oregon
Roe, George Winton, Jr.	CE	Oakland
Roehm, Richard Monroe	Ph	Long Beach
Roskowski, Edward F.	ME	San Gabriel
Ruddick, Ronald Bryan	ACh	Los Angeles
Rypinski, Chandos Arthur, Jr.	EE	Los Angeles
Scheck, Frank F.	ME	Los Angeles
Schetne, Hector Anthony	EE	Costa Mesa
Schuyler, Arent Henry, Jr.	ACh	La Jolla
Scott, George R.	ME	Sacramento
Scott, Robert	Ph	Los Angeles
Sefton, Wayne E.	EE	Phoenix, Arizona
Seiden, William	ME	North Hollywood
Sheriffs, Leigh	Ph	Los Angeles
Shiells, James Francis, Jr.	ME	Fillmore
Shippee, William Henry	ACh	Orange
Shore, Bernard	Ch	Los Angeles
Silliker, Donal Logan	ME	Alhambra
Simmons, Robert Wilson	ME	Pasadena
Sinclair, Rolf Malcolm	Ph	Atlanta, Georgia
Smyth, William Edwards	EE	Mt. Vernon, New York
Spalding, Donald Parker, Jr.	EE	Los Angeles
Spellmann, Richard Arthur	ACh	Chico
Spooner, Mike Edward	ME	Grants Pass, Oregon
Stix, Thomas Howard	Ph	St. Louis, Missouri
Stokely, Robert Gregg	Ph	Palo Alto

Name	Course	Home Address
Stone, Robert S.	Ph	Evanston, Illinois
Strain, Douglas C.	EE	Alhambra
Stubbins, Robert Lacey	ME	Crisfield, Maryland
Suhrer, Ferdinand Charles	ACh	Los Angeles
Sulmeyer, Irving Ira	CE	Los Angeles
Susskind, Charles	EE	Altadena
Swain, John Sabin	EE	Pasadena
Talmadge, Richard Bennett	Ma	Los Angeles
Tang, Kenneth Kai-nan	ME	Berkeley
Thomas, John Hunter	Bi	Chuquicamata, Chile
Thorpe, James R.	ME	Santa Fe, New Mexico
Tracy, Thomas William	Ph	Berkeley
Vail, Thomas Edward	EE	Los Angeles
Valle-Riestra, Joseph Frank	ACh	Beverly Hills
Vrabec, Arundale	Ph	Ventura
Vrebalovich, Thomas	ME	Los Angeles
Wanlass, Sylvan Dean	APh	El Monte
Waters, Alfred Earnest	CE	Pasadena
Wechsler, Joseph Wolff	ME	New York, New York
Wenick, Robert Leonard	EE	Los Angeles
Wheeler, Henry Orson, Jr.	Bi	Los Angeles
Whittlesey, John	Ph	Los Angeles
Wilford, David B.	ACh	Los Angeles
Wilkinson, Donald Pahl	ME	Los Angeles
Williams, Joe Keith	CE	Lubbock, Texas
Williamson, William Jeffris	ME	University City, Missouri
Winchester, Robert LeFever	EE	St. Louis, Missouri
Wolf, Frank J.	ME	Beverly Hills
Wong, Albert Koon Biu	CE	Honolulu, Hawaii
Woodson, William Logan	EE	Berkeley
Worcester, Bruce Alan	ME	Oak Park, Illinois
Wright, Harvey Weston, Jr.	ME	Los Angeles
Youtz, Byron LeRoy	Ph	Santa Maria
Zablow, Leonard	Ma	New York, New York
Zacharias, Robert	EE	Altadena
Zwick, Eugene Balfour	Ph	Pasadena

SOPHOMORE CLASS

Adams, Claude Harris	Ph	Merced
Albee, Philip Harper	ME	Hingham, Massachusetts
Alexander, Edward Lawrence	ME	Los Angeles
Allinder, Forest Sturdevant	ACh	Balboa Island
Anderson, Oscar J., Jr.	EE	Roscoe
Andres, John Milton	Ph	Anaheim
Archer, William Earl	ME	Long Beach
Armstrong, David Ligon	ACh	Ontario
Bailey, William Howard	ACh	South Pasadena
Baird, James Kilpatrick	ME	Delair, New Jersey
Barnes, Stanley Manton	ME	Palo Alto
Barnes, Wallace A., Jr.	EE	South Pasadena
Barnett, John Edward	EE	Pasadena
Barr, John George	Ge	Milwaukee, Wisconsin
Baumann, Lawrence Irving	EE	Long Beach
Beardsley, Frank Howard	EE	Altadena
Bennett, Charles Richard	EE	Cristobal, Canal Zone
Benton, Arthur Robert	ME	Pasadena
Bergstrom, George Willard	EE	Pasadena
Bible, Robert Edward	Ph	Abilene, Texas

Name	Course	Home Address
Bickford, Edward Frank	ME	Vallejo
Blair, Ernest William, Jr.	EE	Fallon, Nevada
Blanton, William Edgar	EE	Santa Paula
Bond, Charles Richard	EE	Burbank
Bowen, George Hamilton, Jr.	Ch	Tulsa, Oklahoma
Brady, Franklyn Harold	ME	Los Angeles
Bratnober, Elwood Holt	Ph	Altadena
Brayford, Elton Robert	EE	Salt Lake City, Utah
Breiman, Leo	Ph	Los Angeles
Brochmann, Michael John	ME	Altadena
Brown, Douglas Ray	Ge	North Hollywood
Brown, Erle, Jr.	ME	Ventura
Brown, George James	ME	Los Angeles
Browne, Davenport, Jr.	ME	Escondido
Bryan Wharton Whitworth	APh	Denton, Maryland
Bulkley, Edward O.	EE	Alhambra
Cantwell, Joseph R.	ME	Downey
Carnachan, Robert Shaw	ME	Los Angeles
Carter, Hugh C.	ME	Omaha, Nebraska
Carus, Milton Blouke	EE	La Salle, Illinois
Chapin, Seymour Leon	EE	Long Beach
Cohan, Howard	Ch	Denver, Colorado
Coit, John Henry	Ma	Pasadena
Conover, Joseph M.	ME	Pasadena
Cook, Eugene Mercer	Ph	San Luis Obispo
Cootes, William Rudolph	EE	San Pedro
Cornelius, Richard C.	Ph	National City
Cuff, Leland Jerome	Ch	Glendale
Curray, Joseph Ross	Ge	Cedar Rapids, Iowa
Curtis, Frank Joseph	ME	Westfield, Massachusetts
Danielson, Warren Evald	Ph	Santa Ana
Dannan, John Henry	ME	North Hollywood
Darms, Fred John, Jr.	ME	Arcadia
Darrow, Robert Allen	ACh	Playa Del Rey
Denny, Joseph M.	Ph	Kent, Washington
Dobrowolski, Joseph Adolph	CE	Tacoma, Washington
Dodson, Denny Denslow	ACh	Burbank
Dolan, Edwin John	EE	Portland, Oregon
Drapes, Alex George	EE	Great Falls, Montana
Drew, Daniel Laughlin	Ma	Redwood City
DuFort, Edward Charles	EE	Los Angeles
Dunbar, Elton Earl	EE	Seattle, Washington
Earle, Gardner Wade, Jr.	EE	La Crescenta
Eilau, William Eugene	ME	Irvington, New Jersey
Elder, John Kendall	Ma	San Diego
Englar, Clayton	Ch	San Mateo
Evans, Don LeRoy	EE	Hollywood
Evans, Frank	Ph	Palo Alto
Famularo, Kendall Ferris	Ph	La Canada
Fasola, Henry, Jr.	ME	Glendale
Ferguson, Robert Conrad	ME	Santa Barbara
Ferguson, Robert Howard	ME	Los Angeles
Fisher, Robert Lloyd	ACh	San Gabriel
Fisk, Edward Penn	Ge	Los Angeles
Fletcher, Aaron Nathaniel	ACh	Los Angeles
Fong, Samuel	ME	Santa Barbara
Forester, Charles Francis	ME	Riverside
Funk, Robert B.	ACh	South Gate

Name	Course	Home Address
Gardiner, Kenneth Wayne	Ph	Topeka, Kansas
Gibbins, Sidney Gove	Ch	Tarzana
Gift, Myven Frank	EE	Glendale
Goodman, Franklin Ralph	EE	La Crescenta
Grey, Geoffrey Hamline	ME	Sidney, Australia
Gould, Roy Walter	EE	Colton
Graham, Fred Brown	Ph	Alhambra
Greene, Ronald Crundon	ACh	South Gate
Greer, Paul Hayden	EE	Cape Girardeau, Missouri
Hann, John Philip	ME	Los Angeles
Hall, Wilbur Lee	ACh	Ashland, Oregon
Harris, Andrew VanVleet	ME	Fresno
Harris, Paul Bernard	CE	El Monte
Harris, William Nelson	ME	San Francisco
Hartman, Dirck TenBroeck	ME	San Fernando
Haufe, Robert C.	Ph	Los Angeles
Hayward, David Kirkland	ME	Pasadena
Heath, John, Jr.	ME	Los Olivos
Heggland, Radoy W.	Ge	Altadena
Heiman, Jarvin R.	Ph	Los Angeles
Herzig, Wayne M.	ME	Santa Ana
Heyneman, Robert G.	Ma	San Diego
Hibbard, Don Ernest	Ge	South Pasadena
Hickey, Malcolm VanCleve	ACh	Seattle, Washington
Hirschberg, Walter Joseph	EE	Los Angeles
Hockaday, Robert Carroll	ME	Santa Ana
Hogness, David Swenson	Ch	Chicago, Illinois
Holcomb, Wade Gladstone	EE	Pasadena
Hook, Albert Schiller	Ph	Culver City
Houghton, William John	Ph	Honolulu, Hawaii
Hrebec, George Martin	ME	Houston, Texas
Hummel, James Alexander	Ph	Los Angeles
Hurley, Neal L.	Ge	Los Angeles
Hylton, Frank George	ME	Pasadena
Johnson, Gaylen Morris	Bi	Salt Lake City, Utah
Johnson, James Edgar	ME	Coronado
Johnson, Roger Christie	Ch	Belmond, Iowa
Jonston, William Jerome	ME	Carlyle, Illinois
Johrde, Raymond Arnold	ME	Pasadena
Kachadoorian, Reuben	ACh	Fresno
Kahn, Robert Lee	Ch	Los Angeles
Kariotis, John Chris	CE	San Diego
Karzas, Byron Constantine	ACh	Chicago, Illinois
Karzas, William James	Ph	Chicago, Illinois
Katz, Eli	EE	Los Angeles
Keese, Oliver John	ME	Los Angeles
Keinonen, Frank W.	ME	Baltimore, Maryland
Kenney, James T., Jr.	ME	Lompoc
Kermeen, Robert Wendel	Ph	Los Angeles
Kidder, Paul Howard	EE	Altadena
Kincaid, Donald Preston	ME	Bellingham, Washington
King, Daniel Warner	EE	Burlingame
King, Richard Galpin	EE	Orange
Kinkel, John Franklin	EE	Wichita, Kansas
Knight, Charles Henry, Jr.	CE	Compton
Kofahl, Robert Eugene	Ch	Glendale
Kohnen, Keith Douglas	ME	Pacific Grove
Kono, Edward Hiroshi	Ph	Thermal

Name	Course	Home Address
Kostelac, John Francis	EE	Steelton, Pennsylvania
Krumholz, Irving Leon	Ph	Pasadena
Kvammen, Kenneth Royce	Bi	Los Angeles
Lane, Claude Allen	ME	Cut Bank, Montana
Lanz, William Thomas	ACh	Mandan, North Dakota
Leggett, Elmer Neal, Jr.	EE	Pasadena
Lehr, Chester Kenneth	ME	Glendale
Levonian, Edward Puzant	EE	Los Angeles
Liberman, David Arthur	Ph	Los Angeles
Linderman, Harold Jay	CE	Garland, Utah
Loggins, Reuben Henry	EE	Merced
Long, Dennis Vernon	CE	Los Angeles
Long, Henry Allan	ME	San Diego
Love, John Richard	EE	Montebello
Lucas, Campbell Macgregor	ME	Long Beach
Lym, Vernon William	EE	Los Angeles
MacGinitie, Walter Harold	Ph	Corona Del Mar
Machetanz, Frederick Allen	Ma	Exeter
Madden, Dave W.	ME	San Pedro
Malone, James Donald	Ph	Beaver Dam, Wisconsin
Marshall, John Cotton	ME	Grosse Pointe, Michigan
Martel, Hardy Cross	APh	Pasadena
Matthews, Jerry Orchard	Ch	San Gabriel
McPhate, John Archie	EE	Los Angeles
Miller, Thomas W.	Ch	Coronado
Mitchell, Orson Lorenzo	ACh	Pasadena
Montemezzi, Marco Antonio	Ph	Beverly Hills
Moore, Thomas Warner	Ph	San Diego
Mooring, Eugene C., Jr.	Ch	Temple City
Morgan, George Richard	ME	El Monte
Morrison, Donald R.	ACh	Los Angeles
Mudgett, Walter L.	EE	Los Angeles
Muehlberger, Roy Phillip	Bi	Los Angeles
Myers, Ridley	EE	Los Angeles
Myers, William Marshall	Ph	Nilford, Ohio
Nelson, Kenneth Laverne	EE	Pasadena
Orr, Chester Bruce	ME	Los Angeles
Ottestad, Jack Benton	EE	Los Angeles
Paine, William Overton, Jr.	Ma	Pasadena
Palmer, William Eaton	ME	Sioux City, Iowa
Parkhurst, Kenneth Leroy	CE	Berkeley
Parten, Kenneth Marion	Ge	Sweeney, Texas
Patterson, Richard LaBarre	CE	South Pasadena
Perry, Byrne	CE	Glendale
Perry, Richard Holden	ME	Los Angeles
Peterson, Donald William	Ph	Sacramento
Petrulas, Thomas George	ACh	San Francisco
Petzar, George Michael	ME	Pottstown, Pennsylvania
Pickrell, Don H., Jr.	Ph	Tulsa, Oklahoma
Pilling, Robert Rea	APh	Compton
Pollak, Richard Jack	ME	Los Angeles
Powell, David Owen	ME	Downey
Prevost, Walter Glen	EE	Los Angeles
Price, Carl Arthur	Bi	Long Beach
Pyle, William Dalliba	EE	Santa Barbara
Ramsey, William James	Ch	Los Angeles
Richartz, John Dalton	CE	Los Angeles
Rinehart, Marion Colburn	Ph	Leonia, New Jersey

Name	Course	Home Address
Rose, Theodore Walford	ME	Pasadena
Ross, Cecil John, Jr.	ME	Portland, Oregon
Rudin, Bernard David	Ph	Los Angeles
Rudin, Marvin Bernard	EE	Glendale
Rumer, William Isaac	EE	Van Nuys
Rutkin, Burton Benjamin	EE	Los Angeles
Ryder, Dale Delbert	EE	Los Angeles
Saltman, Paul David	Ch	Los Angeles
Satre, Leland Harley	ME	Lisbon, North Dakota
Saunders, Allan MacPherson	ME	Claremont
Savant, Clement Joseph, Jr.	EE	Los Angeles
Schneider, Fred Carl	EE	Chicago, Illinois
Schneider, Louis James	ACh	Santa Monica
Schoen, Richard Isaac	Ph	New Rochelle, New York
Seitz, Clyde R.	ME	South Pasadena
Selleck, Frederic Thompson	ACh	Los Angeles
Shaller, Charles H.	CE	El Centro
Shelton, Frank Harvey	Ph	Boulder City, Nevada
Simons, William Herbert	ME	San Marino
Sinker, Robert Allen	EE	Los Angeles
Six, Don E.	Ge	Pasadena
Six, Gene David	CE	Pasadena
Smith, Vernon Lomax	Ph	Wichita, Kansas
Spaulding, Arthur Ogilvy	Ch	Goleta
Spear, Kellogg Emerson	ME	Pasadena
Sprecher, Melvin	Ch	Bronx, New York
Stappler, Robert F.	ME	Far Rockaway, New York
Stein, Robert Saul	CE	Phoenix, Arizona
Stewart, Robert Malcolm, Jr.	ACh	Burlingame
Stiles, Keith Leonard	EE	South Pasadena
Stoddart, Hugh Franklin	Ph	Portland, Oregon
Stonerod, David Carter	Ch	Glendale
Sundsmo, Albert	CE	Bonners Ferry, Idaho
Sylvies, William Ainsworth	ME	Honolulu, Hawaii
Taylor, William Charles	CE	Altadena
Terriere, Robert T.	Ge	Fallbrook
Terwilliger, Kent M.	Ph	Santa Monica
Turner, Thomas Albert	CE	Bishop
Vickrey, William T.	CE	Sacramento
Vogel, Milton C.	ME	San Gabriel
Vreeland, Thad, Jr.	ME	San Marino
Wakeman, Thomas Herbert	EE	San Pedro
Walance, Charles George	APh	Chicago, Illinois
Walquist, Robert Louis	EE	Long Beach
Ward, Elmer Francis	ME	Pasadena
Waters, Robert Reid	EE	San Diego
Waters, Warren Palmer	Ph	El Centro
Webster, Wilton W.	ME	Altadena
Weir, Kenneth Owen	EE	Los Angeles
Weisbrod, Steven	Ph	San Diego
West, Estal Dale	Ch	Pasadena
Westervelt, Donald Ramsey	Ph	Darien, Connecticut
White, Jack L.	ACh	Glendale
Whitehouse, Gilbert Abraham	ACh	Mexico City, Mexico
Whiting, Gordon Joseph	Ph	Culver City
Wikholm, Wilbur Andrew	Ph	Los Angeles
Willson, George Potter	CE	Palm Beach, Florida
Wiren, Jean Folke	EE	Pasadena

Name	Course	Home Address
Woodbury, Henry Hugh	Ph	Altadena
Woods, William Charles Alua	Ch	San Bernardino
Woodward, George Walter	ACh	Glendale
Young, James Dean	ACh	Tucson, Arizona

FRESHMAN CLASS

Name	Home Address
Abell, Jared	Santa Monica
Allen, Alexander MacMillan	Carmel
Amster, Harvey Jerome	Shaker Heights, Ohio
Anderson, Carl Albin, Jr.	Oildale
Arcand, George Myron	Seattle, Washington
Arvidson, Rodney Fisher	Scituate, Massachusetts
Asquith, Donald O.	La Canada
Baker, Donald R.	La Mesa
Barrie, Donald Shaw	West Palm Beach, Florida
Bear, Herbert Stanley	San Diego
Benton, Bramley Hart	Sacramento
Bergreen, Weldon Oscar	Salt Lake City, Utah
Blom, Christian James	San Marino
Boblett, Emil Vincent	Indianapolis, Indiana
Bochanski, Felix Caldwell	Mt. Ephraim, New Jersey
Bogart, Louis	Redwood City
Boicourt, Stanley Clyde	San Diego
Booth, Galt Buhler	Los Angeles
Bowen, Theodore Munson	Long Beach
Bradley, Wilson	Duluth, Minnesota
Bratton, Donald Warren	Hollywood
Brow, Raymond E.	Los Angeles
Buck, Richard Pierson	San Marino
Burriss, William Louis	San Leandro
Butler, Eliot Andrew	Snowflake, Arizona
Calhoun, William Denman	Glendale
Carson, Odell Edwards	Tustin
Check, Andrew John	Erie, Pennsylvania
Clark, Howard Ellsworth, Jr.	Van Nuys
Convis, William Douglas	Roseville
Cook, Samuel Pinckney	Los Angeles
Coons, Thomas Paul	South Pasadena
Cooper, Duane Herbert	Bloomington, Illinois
Corbato, Fernando Jose	Los Angeles
Couch, Billy Lloyd	Azle, Texas
Coulter, Harold Keith	Antioch
Cox, William Parker	Topeka, Kansas
Crichton, Edward Bailey	Harrisburg, Pennsylvania
Culbertson, William Craven	Glendale
Davenport, George Lyman	Los Angeles
Davison, Walter Francis	Fox River Grove, Illinois
Dayman, Bain, Jr.	Hollywood
Dean, William Daniel	Glendale
Dibbern, Hans H.	Long Beach
Dickson, Robert John, Jr.	Atherton
Durham, David Leon	Whittier
Edwards, Vern Allan	Danville
Erickson, Ralf Austin	South Pasadena
Eschner, Albert, Jr.	Santa Monica

Name	Home Address
Fairall, Richard Snowden	Fresno
Fehrenbach, James Joseph	Marshfield, Wisconsin
Forester, Robert Donald	Los Angeles
Forrester, Herbert Amasa	Pasadena
Fox, Carl Edward	Alstead, New Hampshire
Freed, William August	North Hollywood
Furth, Donald Herbert	Los Angeles
Gage, Boyd MacIntosh	Fountain City, Tennessee
Gentile, Maury Daniel	Burlingame
George, Abram Nute	South Pasadena
Gerhart, James Basil	Pasadena
Ghaffari, Parviz	Tehran, Iran
Gonzalez, Sergio Tornero	Santiago, Chile
Goodenow, Elden L.	Van Nuys
Goodwin, Lester Kepner	Long Beach
Gram, Nils Lysholm	Oslo, Norway
Greene, John M.	Englewood, Colorado
Haefliger, William White	Dixon, Illinois
Hale, Clinton Darle	Fullerton
Hall, Michael Alexander	San Diego
Hammond, Kenneth James	Great Bend, Kansas
Hedrick, Bruce Burgess	Seattle, Washington
Henley, William Harris	Reseda
Higgins, William Bernard	Schuyler, Nebraska
Holly, Donald Howard	San Diego
Honda, Shigeru Irwin	Pasadena
Honer, Richard C.	Santa Ana
Houser, Bradford Carr	Washington, D. C.
Housman, Howard Burton, Jr.	San Antonio, Texas
Howard, Charles Stetson, Jr.	Hemet
Howell, Peter A.	Pasadena
Hughes, John David	Akron, Ohio
Humphrey, Floyd Bernard	Pasadena
Inman, John Keith	Clayton, Missouri
Jennings, Donald Bruce	San Gabriel
John, Walter, Jr.	Oklahoma City, Oklahoma
Juleen, Stanley Lawrence	Pasadena
Jung, Moe You	Los Angeles
Kennedy, Pete Ralph	Moscow, Idaho
Khaw, Kon-Hock	Bassein, Burma
Knight, Wilbur Lawrence	San Gabriel
Kohl, James Lorenz	Arcadia
Kreml, Warren Jay	Rosemead
Kreston, Max Stewart	Arlington
Krum, Warren Eugene	Artesia
Larsh, Almon Elsdon	El Monte
Lehman, John Robert	Pasadena
Lord, Robert Joseph	Los Angeles
Lovberg, Ralph Harvey	Missoula, Montana
Lutwack, Ralph	Los Angeles
Mackenzie, David Brindley	Victoria, British Columbia
Markoff, Daniel	North Hollywood
Marks, Craig	Los Angeles
Marks, Monte Lee	Beverly Hills
Mathews, Max Vernon	Peru, Nebraska
McGrane, John Forsyth	Long Beach
McIntyre, Richard Moore	Los Angeles
McKenna, Gerald Wayne	Tucson, Arizona

Name	Home Address
McKinnon, Richard Alexander	Seattle, Washington
McLellan, Albert Edward	Yreka
McLellan, William Howard	Yreka
Merrifield, Donald Paul	Inglewood
Moffat, John Paul, Jr.	Medford, Oregon
Montgomery, Jay Allen	Los Angeles
Moore, Donald William	El Monte
Norman, Charles A.	San Diego
Oakley, David Charles	Hammonton
Odgers, Irving Lee	Altadena
Parker, Alan Breck	Ann Arbor, Michigan
Parker, Robert Eames	San Marino
Picciotto, Roger Alexander	Shanghai, China
Pollard, David Onan III	Santa Monica
Poole, Grant Calvin	Manhattan, Kansas
Potts, Roswell Harry	South Gate
Proud, William Howard	Lompoc
Quandt, Ronald Lewis	Santa Monica
Ragon, Rex Bernard	Silverton, Oregon
Reber, John Jacob	Steelton, Pennsylvania
Reeves, Douglas Wendell	Pasadena
Reha-Masara, Hasan	Ankara, Turkey
Reinecke, Howard Edwin	Glendale
Revay, Edward Albert	Arcadia
Rider, John Leslie	Los Angeles
Riesenfeld, Werner Boris	Los Angeles
Robinson, Bruce, Jr.	Long Beach
Rolph, Donald B.	Los Banos
Romero, Marco Antonio	Santurce, Puerto Rico
Root, William Howard, Jr.	Whittier
Ross, Lee Wallace	Lomita
Rosser, Willis Andrew	Pasadena
Royce, Donald Frazer	Balboa Island
St. Helen, Roger	Pasadena
Sawyer, George Marshall	Mojave
Scantlin, Jack R.	Los Angeles
Schiff, Gunter Hans	Hollywood
Schroeder, Dwight Clare	Santa Ana
Schultz, Leonard Gene	Los Angeles
Schuster, Danver	San Bernardino
Sellen, John Michael, Jr.	Lubbock, Texas
Shakespeare, Gene C.	Los Angeles
Shapiro, Henry	Pasadena
Shaw, Charles McEwen	Pasadena
Shurig, Arthur John	Jasper, Indiana
Sichel, Gerhard	Montevideo, Uruguay
Sims, Virgil Jones, Jr.	Arcadia
Singer, Irvin M.	Philadelphia, Pennsylvania
Smathers, Donald Lee	San Diego
Smith, Frederick Anthony	Madison, Connecticut
Smith, Jack Wendell	Los Angeles
Smoot, Roland Nesbit	Arlington, Virginia
Spencer, Eugene Godfrey	Perry, Georgia
Stauffer, Tom Hamilton	Glendale
Steiner, Fred Alvin	Chula Vista
Stert, Robert Leavens	San Diego
Stevens, Robert Tarrant	Buffalo, New York
Stillman, Donald Wayne	Hollywood

Name	Home Address
Stockton, Stanley Fouts	Riverside
Stone, Ralph Jay	Pasadena
Streaker, Harold Alwin	Los Angeles
Stutesman, Jack Bard	Whittier
Sulmeyer, Joseph	Los Angeles
Sutter, Cletus Carl, Jr.	El Monte
Tarbel, Brook Dawson	Los Angeles
Thomas, Lloyd Allen	Bisbee, Arizona
Van Lint, Victor Anton Jacobus	Raton, New Mexico
Vetter, George Robert	San Diego
Viglierchio, David Richard	Madera
Vrolyk, John Junior	Blue Jay
Walt, Martin	La Crescenta
Warren, David	San Francisco
Watson, Harold Thomas	East Liverpool, Ohio
Weagant, Frank Earl	Oceanside
Weeks, Leroy William	El Monte
Welte, Robert Stephen	Alhambra
Whist, Harald Magne	Kr. Sand-S, Norway
Whiting, Warren Grant	St. Johns, Arizona
Widenor, James Kenneth	Glendale
Wilcox, James Rutledge	Ventura
Willis, Jack K.	San Francisco
Worrell, Edsel Augustus	Bakersfield
Wright, Richard Bruce	Akron, Ohio
Zwick, Stanley Alan	Hollywood

GENERAL INDEX

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PASADENA, CALIFORNIA

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PUBLICATIONS
OF
THE STAFF

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PUBLICATIONS
OF
THE STAFF

OCTOBER 1, 1946, TO FEBRUARY 29, 1948

PASADENA, CALIFORNIA, JUNE, 1948

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INTRODUCTION

As has been the custom for many years, the California Institute of Technology presents herewith the annual list of publications of the members of its staff. This list has naturally grown longer as the research work at the Institute has expanded over the last 25 years. It is now evident that this record of publications constitutes more than simply a list of titles, but is a condensed report of progress on a vast amount of research now under way at the Institute.

To bring out this "report of progress" feature more clearly, the listings have been rearranged in this edition and an introductory summary by the chairman of each division has been prepared. These summaries, it is hoped, will be a general guide to those interested in an over-all picture of the research activities now in progress at the California Institute.

Though it would be misleading to judge the research activity of any division by the number of published papers, it is nevertheless impressive to note the large volume of work represented by the publications of the Divisions of Biology and of Chemistry and Chemical Engineering. It is particularly important to note how much of the work of these two divisions is so closely related, to such an extent that it can be said that a large share of the effort of the two divisions is now being devoted to the combined field of "Chemical-Biology" or "Molecular Biology." This field is without a doubt one of the most exciting in all of modern science and the dynamic groups working so intimately together at the California Institute have assumed a place of national leadership in exploring this field. The excellence of the work of these groups has commanded generous financial support, particularly from such foundations as the Rockefeller Foundation, the National Foundation for Infantile Paralysis, the American Cancer Society and many others. The generous support of these foundations has in turn greatly accelerated, improved and extended the research program.

The research activity in the field of Aeronautics, including the work of the Guggenheim Aeronautics Laboratory, the Southern California Cooperative Wind Tunnel and the Jet Propulsion Laboratory, has also expanded greatly in recent years and continues on the high plane of excellence on which it started when the Guggenheim Laboratory was organized 20 years ago. It would be hard to exaggerate the influence which this basic research in an important field has had on the development of the aircraft industry in the United States and particularly in Southern California. Radical new developments in both military and commercial aircraft are now taking place and important studies in supersonic speeds and with jet propulsion now going on at the Institute will, as they have in the past, play a basic role in forwarding this development.

The activities in Civil and Mechanical Engineering are represented by a smaller list of publications but they are of basic importance in these critical fields. The developments in these fields are of such great importance and the demand for trained men so great that it is urgently necessary that the Institute expand its facilities and personnel in these areas as soon as practicable.

The fact that the Southwest is a region of intense geological interest is reflected in the activities of the Division of Geological Sciences. Problems of earthquakes, of mineral and oil deposits, make these studies of great practical importance. At the same time the important palentological deposits of the area have provided rich material for the study of the early evolution of certain mammals.

A long list of important publications in the fields of Physics, Astronomy, Mathematics and Electrical Engineering reflects the continued strength of these fields at the Institute which began with the arrival of Dr. R. A. Millikan in 1921. The California Institute has always, since that time, held a leading place in the country in its research in nuclear physics and cosmic rays. The important work in Astrophysics and Cosmology which has gone forward in the past will be greatly expanded as the 200-inch Hale Telescope and the 48-inch Schmidt Telescope of the Palomar Observatory come into operation during the coming year. The cooperative plan of operation between Palomar and Mount Wilson essentially adds the entire scientific staff of Mount Wilson to the California Institute research staff and future publications in this field will be under the joint auspices of the Institute and of Mount Wilson.

Taken as a whole, this compilation of scholarly work completed constitutes an impressive record in which the Institute can take pride. But it is also a stimulating challenge to continue and expand its work in many critical areas.

L. A. DuBridge, *President.*

July 7, 1948

PUBLICATIONS OF THE STAFF

OCTOBER 1, 1946, TO FEBRUARY 29, 1948

Note: Books or articles of multiple authorship are listed under the name of the first author. A name-index of all authors, pages 44 to 46, can be consulted for the publications of individuals.

Requests for reprints should be addressed to the division, department, laboratory or section under which the publication is listed. Where a division or laboratory serially numbers the contributions of its staff members, these numbers appear in parentheses immediately after the title, and may be used for brevity in requesting reprints.

DIVISION OF BIOLOGY

William G. Kerckhoff Laboratories of the Biological Sciences

PUBLICATIONS of the staff members of the Division of Biology for the year 1947-1948 cover a wide range of subject matter. Among them are reports of work in the fields of plant and animal biochemistry, bioorganic chemistry, plant and animal physiology, genetics, chemical genetics, embryology, cytology, neurophysiology, psychobiology, immunogenetics, marine biology and others.

Three examples will serve to illustrate how basic work in biological fields often has far-reaching implications.

The work of Emerson and Zalokar on sulfonamide-requiring strains of the red bread mold Neurospora has contributed in a significant way to our understanding of the biological action of these widely used drugs. All too often in medical practice such knowledge is lacking.

The demonstration by Mitchell, Nyc, and collaborators, that the amino acid tryptophane is converted to the vitamin niacin through kynurenine and 3-hydroxyanthranilic acid as intermediates clarifies several heretofore puzzling relations in the dietary deficiency disease pellagra. This is another of an increasing list of instances in which it is evident that protoplasmic metabolism is very much alike wherever it is found—whether in bread mold or in man.

In making clear the conditions under which liver homogenates synthesize hippuric acid, Borsook and Dubnoff have made an important contribution to an understanding of peptide linkage formation. The manner in which this type of union between amino acid components of proteins is brought about is a part of the large and key biological problem of the mechanism of protein synthesis.

Additions to our knowledge of living systems usually come in small increments. It is the hope of the authors of the papers listed below that each of them represents a step in the forward direction.

G. W. BEADLE, *Chairman.*

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On the Role of the Oxidation in the Methylation of Guanidoacetic Acid, *J. Biol. Chem.*, 171, 1, 363-375 (1947).
Ornithine-catalyzed Urea Formation in Liver Homogenate, *J. Biol. Chem.*, 169, 2, 461-462 (1947).
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Plant Growth under controlled Conditions. VIII. Growth and Fruiting of the Chili pepper (Capsicum Annuum), *Am. J. Bot.*, 34, 8, 393-401 (1947).

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The Enzymatic Conversion of Tryptophan to Auxin by Spinach Leaves, *Arch. Biochem.*, 13, 1, 131-144 (1947).
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The Effects of Asphyxiation and Narcosis on Peripheral Nerve Polarization and Conduction, *Am. J. Physiol.*, 148, 1, 174-184 (1947).
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The p-Aminobenzoic Acid Requirement of the "Sulfonamide-requiring" Mutant Strain of Neurospora, *Proc. Nat. Acad. Sci.*, 34, 32-36 (1948).

DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

Gates and Crellin Laboratories of Chemistry

PUBLICATIONS of the staff of the Division of Chemistry and Chemical Engineering for this period report progress in a wide variety of investigations in the fields of physical chemistry, inorganic chemistry, organic chemistry, and chemical engineering.

New results in the fields of protein chemistry and immunochemistry are presented by Pauling, Niemann, Campbell, and their collaborators. Recent advances in the techniques of chromatography and in their applications to the study of natural products are described by Zechmeister. Contributions to the chemistry of antimalarials are reported by Koepfli and his coworkers.

Structural studies of molecules and of organic and inorganic crystals by the techniques of electron and x-ray diffraction are reported by Schomaker, Sturdivant, and other workers in the field of structural chemistry. Pauling describes a new theory of the metallic bond which promises to clarify many obscure points in the structure of metals. Badger and coworkers describe the molecular properties of nitrocellulose and discuss new optical techniques of general importance in high polymer chemistry.

Sage and Lacey report new results and describe new techniques in their studies of phase equilibria in hydrocarbon systems. Preliminary studies on heat transfer in turbulent gas streams are also presented.

J. G. KIRKWOOD, *Acting Chairman.*

BENNETT, EDWARD L., CLARK W. GOULD, JR., ERNEST H. SWIFT, AND CARL NIEMANN.
Systematic Qualitative Tests for Certain Acidic Elements in Organic Compounds, (1117), *Analyt. Chem.*, 19, 1035-1039 (1947).

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Molecular Properties of Nitrocellulose. II. Studies of Molecular Heterogeneity, (1077), *J. Phys. & Coll. Chem.*, 51, 574-579 (1947).

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DIVISION OF CIVIL AND MECHANICAL ENGINEERING AND AERONAUTICS

PUBLICATIONS of members of the Division of Civil and Mechanical Engineering and Aeronautics for the period covered by this bulletin reflect the continued strong interest of the Division in the broad subjects of fluid mechanics, structures, and materials. These publications also focus attention on the growing interest in problems of fluid dynamics, such as the studies in the shock phenomena of transonic flow, hydrodynamics of water entry, and structural vibrations of aerodynamic bodies.

The aerodynamic studies reported here range in scope from fine details of boundary layer phenomena to thermodynamic problems of large-scale atmospheric circulation. The hydrodynamic investigations cover problems of steady flow, as well as those of dynamic flow. Basic to all of these studies has been the instrumentation, which has been the subject of several of the publications listed.

Investigations in static and dynamic properties of materials are reported here, as well as applications to structures. Porous metals in particular are of interest because of the indicated application to new cooling techniques. The dynamic properties of materials which are reported are part of an extended study in this subject and have led to reports which indicate continuing interest in these problems, particularly those of elastic and plastic strain propagation. Closely associated with the dynamic behavior of structures is the analysis of strong motion earthquakes, a study of considerable interest to structural engineers and which is a continuing one at the Institute.

Some of the papers listed represent wartime publications reported in this listing for the first time as the result of the removal of security classification.

F. C. LINDVALL, *Chairman.*

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INDUSTRIAL DESIGN SECTION

DURING the war years and immediately thereafter, a major part of the Industrial Design Section's efforts were devoted to a reorganization of the information needed to enable product design to reflect more accurately the then available materials and processes. To this end, the Section's war-time research and publications show design adjusted to the use of refractory earths and other non-critical basic materials.

The post-war readjustment period in Industrial Design is characterized by re-evaluation of the basic elements in the light of current technological advances and economic conditions. The designer of mass-produced items today must be trained in engineering, sales management, and finance, as well as in the arts traditionally associated with design. The approach used by Mr. Welch in his articles is representative of the type of industrial design which today finds the greatest acceptance in industry—that is, planning for the future by the use of product and market research, and designing in terms of engineering materials and processes unknown to the past generation.

J. P. YOUTZ, *Administrative Assistant in Charge.*

WELCH, DAVID F.
Ceramic Street Lamp Reflector,† *Eng. & Sci. Mo.,* 7, 19, 20 (1944).
Designing for Improved Appearance, *Machine Design,* 19, 101, 106 (1947).
Design Trends,* *Machine Design,* 19, 109-113, 190 (1947).
Industrial Design at the California Institute, *Eng. & Sci. Mo.,* 10, 2-10 (1947).

* Not available for distribution.
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DIVISION OF THE GEOLOGICAL SCIENCES

Balch Graduate School of the Geological Sciences; Charles Arms and Seeley W. Mudd Laboratories of the Geological Sciences; Seismological Laboratory

Among the research contributions by staff members and students in the Division of the Geological Sciences are investigations of earthquake phenomena, propagation of elastic waves in the earth's crust, studies in geomorphology and paleontology, river floods and mineral deposits of economic value.

It has been found by C. Y. Fu that the usual way of treating energy propagation through the earth by means of the ray picture may lead to incorrect results. This has led to a new theory more in conformity with the facts.

Study has been made by B. Gutenberg of the records obtained from the atomic bomb test, and not only have travel times been obtained of elastic waves through the earth from New Mexico to California, but information is also available regarding the propagation of sound waves through the atmosphere. The travel times calculated from earthquake records are confirmed. Gutenberg has likewise summarized the method employed to locate hurricanes by the use of microseismic records that were obtained from the experimental stations of the U. S. Navy Department.

The waves through the earth which resulted from the Bikini test and were recorded on a number of Pacific Coast Benioff vertical seismographs were used by Gutenberg and C. F. Richter to check the travel times of elastic waves through the earth, calculated from earthquakes, and the agreement between the two was found to be close. These two authors have also published a summary of research conducted at the Seismological Laboratory during 1946.

Richter published the results of a microseismic study of an earthquake known to have occurred along a fault previously studied in detail in the field by J. P. Buwalda.

R. P. Sharp of the Division staff, lately appointed associate editor of the Journal of Geology, reports in this journal on a new interpretation as to the origin of a certain formation found in the Big Horn Mountains, Wyoming, regarded for the past forty years as representing a glacial deposit.

R. H. Jahns is responsible for the most exhaustive study of pegmatite deposits yet published. It represents the first of a series to be published by the U. S. Geological Survey. The contribution demonstrates a systematic distribution of commercially desirable minerals in pegmatites. In a paper published by the U.S.G.S., Division of Water Resources, Jahns attempts to determine the periodicity of extraordinary floods in the Connecticut Valley by study of flood sedimentation and the recording of the detailed Quaternary history of the Connecticut River.

CHESTER STOCK, *Chairman.*

BENIOFF, HUGO.

Seismological Instruments Developed at CIT, *Eng. & Sci. Mo.*, 11, 24-25 (1948).

BUWALDA, J. P.

Geologic Faulting in Southern California, *Eng. & Sci. Mo.*, 11, 15-18 (1948).

Unusual Opportunities for Training in Geophysics at CIT, *Eng. & Sci. Mo.*, 11, 10 (1948).

CAMPBELL, IAN.

Petrology at the California Institute, *Eng. & Sci. Mo.*, 11, 21-23 (1948).

DAVID, LORE R.

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DURHAM, J. W.

Upper Aptian Nautiloids from Colombia, *J. Paleo.*, 20, 428-434 (1946).

Corals from the Gulf of California and North Pacific Coast of America, *Geol. Soc. Amer. Memoir* 20, 68 pp. (1947).

FU, C. Y.

On Seismic Rays and Waves, *Bull. Seismo. Soc. Amer.*, 37, 331-346 (1947).

GUTENBERG, B.

A Geophysicist X-Rays Mother Earth, *Eng. & Sci. Mo.*, 11, 19-20 (1948).

Interpretation of Records Obtained from the New Mexico Atomic Bomb Test, July 16, 1945, *Bull. Seismo. Soc. Amer.*, 36, 327-330 (1946).

Microseisms and Weather Forecasting. *J. Meteor.*, 4, 21-28 (1947).

__________, AND C. F. RICHTER.

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Remarks on Multiple Reflections, *Geophysics*, 13, 45-48 (1948).

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HOWELL, B. F., JR.
Some Effects of Geologic Structure on Radio Reception, *Geophysics*, 8, 165-176 (1943)

JAHNS, RICHARD H.
The Gem Deposits of Southern California, *Eng. & Sci. Mo.*, 11, 6-9 (1948).
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Mica Deposits of the Petaca District, Rio Arriba County, New Mexico, *New Mexico Bureau of Mines Bull.* 25, 294 pp. (1946).
Review of *Notes on Optical Mineralogy,** by George Tunell, *Amer. Min.*, 32, 697-698 (1947).

____________, AND J. L. GILLSON.
Basic Research in the Field of Industrial Minerals and Rocks, *Econ. Geol.*, 42, 737-746 (1947).

NIGRA, JOHN O., AND JOHN F. LANCE.
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RICHTER, C. F.
International Recovery in Seismology, *Sci. Mo.*, 46, 67-70 (1948).
The Manix, California, Earthquake of April 10, 1947, *Bull. Seismo. Soc. Amer.*, 37, 171-179 (1947).
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Geomorphology—The Science of Today's Geology, *Eng. & Sci. Mo.*, 11, 26-28 (1948).

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SMITH, ALEXANDER.
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STOCK, CHESTER.
The Dawn Horse or Eohippus, *Eng. & Sci. Mo.*, 10, 4-5 (1947).
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A Peculiar New Carnivore from the Cuyama Miocene, California, *Bull. So. Cal. Acad. Sci.*, 46, 84-89 (1947).
Uncovering the Ancient Life of Mexico, *Eng. & Sci. Mo.*, 11, 29-31 (1948).

WILLOUGHBY, D. P.
Dwarf Horses of the Southwest,*† *West. Horseman*, 10, 10-11, 38, 40 (1945).
The Origin of Dwarf Horses, *West. Horseman*, 11, 17, 36-37 (1946).
The Zebra is a Dark Horse, *Fauna*, 8, 66-70 (1946).

WOOD, HARRY O.
Earthquakes in Southern California with Geologic Relations, Parts I and II, *Bull. Seismo. Soc. Amer.*, 37, 107-258 (1947).
A Possible Layer for the Transmission of Fast P Waves from Surface Disturbances, *Bull. Seismo. Soc. Amer.*, 38, 33-39 (1948).

DIVISION OF THE HUMANITIES

THE publications listed below reflect some of the varied interests and activities of the members of the Division. Professor Gilbert's articles present some of the results of work carried on during the war, when he was on loan, part- or full-time, to the War Production Board and the Army Air Forces. As is the case with many other members of the Faculty, some of his work must still remain unreported because of security restrictions.

Professor Paul's book on the first twenty-five years of gold-mining in California was fortunately published in time for the centennial of the discovery of gold in the state. It is the first part of an extensive investigation of the growth and development of California as a part of the Union during the second half of the nineteenth century.

Dr. Stern's articles indicate that he is primarily a philosopher, though his appointment at the Institute is as Lecturer in French and German.

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* Not available for distribution.
† Not previously reported.

Of particular interest at present is his critical analysis of Existentialism, a theory which is currently attracting a good deal of attention.

Professor Stanton's article is an appreciation of the late Professor Laing's service to the Institute during the years 1921-1946.

The work of the Industrial Relations Section, since it represents a closely unified program of activity, is listed separately below.

C. K. JUDY, *Chairman.*

GILBERT, H. N.

Air Offensive Against Germany,† *Eng. & Sci. Mo.*, 9, 5, 10-13 (1946).

The Emergency in Aircraft Manufacture,† *Harvard Bus. Rev.*, 518-519 (Summer, 1941).

The Expansion of Shipbuilding,† *Harvard Bus. Rev.*, 20, 2, 156-170 (Winter, 1942).

From Industrial Mobilization to War Production,† *Harvard Bus. Rev.*, 21, 1, 124-136 (Autumn, 1942).

Planes Planes Planes Planes Planes,†* *The Christian Science Monitor*, 3, 14 (1942).

PAUL, R. W.

California Gold. The Beginning of Mining in the Far West, xvi + 341 pp., Harvard University Press, Cambridge, (1947).

STANTON, R.

Graham Allan Laing,* *Eng. & Sci. Mo.*, 10, 1, 11-12 (1947).

STERLING, J. E. W.

Who Is Clio? Where Is She? *Pac. Spectator*, 1, 3, 272-284 (Summer, 1947).

STERN, A.

Husserl y el nuevo absolutismo filosófico, *Cuadernos Americanos*, Año 5, 5, 100-119, Mexico, D. F. (1946).

Mythologie et Positivisme dans la Conception de l'Etat, pp. 85-110 of *Les Doctrines Politiques Modernes*, ed. by B. Mirkine-Guetzévitch, Brentano's, New York, 1947.

Sartre and French Existentialism, *Personalist*, 29, 1, 17-31 (1948).

TANHAM, G. K.

British Press Reaction to the Belgian Surrender in 1940*, *Historian*, 10, 1, 3-13 (Autumn, 1947).

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* Not available for distribution.

† Not previously reported.

The Industrial Relations Section has issued a variety of publications designed for two purposes: (1) to interpret to as large a group as possible some of the problems and some of the solutions of problems of industrial relations, and (2) to present the results of original research.

Since the problems of industrial relations affect all industries including manufacturing, service, and even government itself, the Section has felt a responsibility to explain the problems of industrial relations and some of the proposed solutions to as many groups as possible. Some of the many addresses by the director were published for still wider distribution among such diverse groups as the alumni of the California Institute, the producers of butadiene, and employers in the apparel industry.

The Section recognizes the need for developing and training the staffs of the personnel and industrial relations departments. As part of this activity the Section has started a series of publications outlining some of the "Current Problems of Personnel Management" and providing selected reading lists to aid in further study of these problems by individuals.

The Section has not confined its activities to personnel departments alone. It has realized that every supervisor has to perform a great variety of personnel functions. The Section has made available a carefully annotated list of thirty-two books for supervisors and has compiled for the same books a composite index in tabular form. This new technique makes it relatively easy for supervisors to find solutions for specific problems and for training directors to develop appropriate courses within individual companies.

One of the most pressing problems of management in the post-war period has been the problem of maintaining discipline. The Section encouraged the preparation of a study of the experience of General Motors Corporation by H. W. Anderson, Vice President in Charge, Personnel Staff of General Motors. Mr. Anderson's analysis was presented at a special dinner and his paper was published by the Section. As a supplement to this analysis of the experience of one company, Francis Odell prepared an analysis of "Disciplinary Clauses in Union Contracts."

In the area of research the Section inaugurated a survey of personnel practices among industries in Los Angeles County. The first study, which was published early in 1948, pioneered in the use of new techniques in the preparation and analysis of questionnaires. The response to the improved questionnaire was so satisfactory that for the first time in any community it has been possible to analyze personnel practices in terms of specific industries as well as in terms of the community as a whole. The Section plans to amplify such material and keep it up to date, and by so doing, make available a great deal of information needed in the formulation of sound policies either by companies or through collective bargaining.

ROBERT D. GRAY, *Director.*

Note: Of the publications listed below, Bulletin No. 14 is for sale at $2.50 per copy. Single copies of Circulars No. 10, 11, 12, 13, 14, 15 are available for free distribution; quantity prices will be quoted on request.

ANDERSON, H. W.
Management's Responsibility for Discipline, 7 pp., Circ. No. 12, Industrial Relations Section, Feb., 1947.

CARPENTER, C. U.
The Working of a Labor Department in Industrial Establishments, 6 pp., Circ. No. 15, Industrial Relations Section, Jan., 1948; reprinted from *Eng. Mag.*, 25, 1-9 (1903).

GRAY, ROBERT D.
Are Workers and Bosses People?* *Western Apparel Industry*, 2, 11; 1819, 21 (June, 1947); also under title, "Management Can Get Better Results," *Apparel Manufacturer*, 63-64, 79 (June, 1947).
A Challenge to Management,* *Proc. 24th Ann. Conv. Nat. Ass. Foremen*, 18 (Sept., 1947).
How Can We Improve Industrial Relations?* *Eng. & Sci. Mo.*, 9; 10-11, 19 (Oct., 1946).
[Industrial Relations],* pp. 45-52, *Minutes of Meeting of Operations Com. on Prod. of Butadiene from Petroleum, Los Angeles, Nov.* 4-6, 1946.
Research in Wage Problems,* *Training and Research in Industrial Relations: II*, pp. 71-75, Bull. 4, Industrial Relations Center, Univ. of Minnesota, Apr., 1947.

INDUSTRIAL RELATIONS SECTION STAFF.
Annual Report, 4 pp., Circ. No. 14, Industrial Relations Section, Oct., 1947.
Catalog of Publications on Industrial Relations, 3 pp., Circ. No. 11, Industrial Relations Section, Nov., 1946.
Selected Reading List on Industrial Relations for Supervisors, 8 pp., Circ. No. 10, Industrial Relations Section, October, 1946.

ODELL, FRANCIS.
Disciplinary Clauses in Union Contracts, 7 pp., Circ. No. 13, Industrial Relations Section, May, 1947.

SENSOR, RICHARD O., AND MARY FAITH MARTIN, COMPILERS.
Survey of Personnel Practices in Los Angeles County, 45 pp., Bull. No. 14, Industrial Relations Section, Jan., 1948.

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* Not available for distribution.

DIVISION OF PHYSICS, ASTRONOMY, MATHEMATICS AND ELECTRICAL ENGINEERING

ASTRONOMY *and Physics.* While the members of the Physics Staff at the Institute have for the most part resumed their prewar activities, this is not yet fully evident from their publications. Nevertheless the following list does indicate in a general way, in spite of serious gaps, the range of investigations underway in physics and astrophysics.

Thus important cosmic-ray and mesotron studies, fundamental work on the energy levels in the nuclei of the light elements, and the systematic search of the sky with the Schmidt telescopes on Palomar Mountain have been resumed. Moreover, the gamma-ray spectrometer described in one of the papers listed below has been put to use and promises to provide an important new precision tool for the attack on nuclear disintegration processes.

As indicated also in the list of publications that follows, intensive work on many different types of theoretical problems is being carried on and somewhat scattered investigations of various problems of the solid state and low-temperature physics are under way, as well as experiments on the production of artificial meteors from shaped charges.

Other important investigations actually in progress, but not yet published, include experimental work in electronics, in spectroscopy, on the separation of isotopes and a new precision determination of e/m, and theoretical work on the absorption of sound in fogs, on cosmic-ray showers, and on astronomical applications of physics.

Mathematics. In the past the main lines of mathematical research and publication at the Institute have been algebra and the theory of numbers, abstract spaces and general analysis, and the special functions of mathematical physics. That these lines are still being intensively followed is indicated in the following list of publications but not that new work is also underway in modern analysis, theory of differential equations, mathematical statistics, lattice theory, etc., as is actually the case.

Electrical Engineering. As indicated in part only in the list of publications that follows, the Electrical Engineering staff and students at the Institute are engaged in research work in the following fields: high voltage dielectric studies (particularly dielectric recovery), instrumentation for rockets, airplanes and missiles, television techniques, the use of electronic circuits in cosmic-ray work, noise sources in radio (including solar noises), frequency modulation phenomena (particularly multipath distortion), the physics of microwaves as related to dielectric constants, conductivity and permeability, microwave propagation and its contribution to meteorology, phase conversion of electric currents, basic studies of missile control systems, airplane stability and landing shock, building vibration analyses, and temperature distribution and heat flow in liquids.

E. C. WATSON, *Chairman.*

ASTRONOMY AND PHYSICS

ANDERSON, C. D.

Review of *Elementary Nuclear Theory,* by H. A. Bethe, *Air Univ. Quart. Rev.,* Maxwellfield, Alabama, 1, 3, 101-103 (1947).

————, RAYMOND V. ADAMS, PAUL E. LLOYD, AND R. RONALD RAU.

On the Mass and the Distintegration Products of the Mesotron, *Phys. Rev.,* 72, 724-727 (1947).

————, PAUL E. LLOYD, R. RONALD RAU, AND RAM C. SAXENA.

Cosmic Rays at 30,000 Feet, *Rev. Mod. Phys.,* 20, 334-339 (1948).

BATEMAN, HARRY.

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————, AND D. S. WEBBER.

Note on a Variation with Frequency of the Torsional Modulus of German Silver Wire and Its Relation to Gyromagnetic Measurements, *Phys. Rev.,* 71, 896-902 (1947).

BIEHL, A. T., R. A. MONTGOMERY, H. V. NEHER, W. H. PICKERING, AND W. C. ROESCH.

New Cosmic-Ray Telescope for High Altitudes, *Rev. Mod. Phys.,* 20, 353-359 (1948).

Recent Studies of the Cosmic-Ray Latitude Effect at High Altitudes, *Rev. Mod. Phys.,* 20, 360-366 (1948).

CHRISTY, R. F., AND R. LATTER.

Proton Widths of Light Nuclei, *Rev. Mod. Phys.,* 20, 185-190 (1948).

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The Conservation of Momentum in the Disintegration of Li^8, *Phys. Rev.,* 72, 698-711 (1947).

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Contribution to the Mathematical Theory of the Electrotonus, *Studies for Rockefeller Inst. for Med. Res.*, 141, 442-496 (1947).

DUMOND, JESSE W. M.
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Solid-State Interpretation of the Structure Near the Limit of the Continuous X-Ray Spectrum, *Phys. Rev.*, 72, 276-283 (1947).
X-Rays, Nature of, *Encycl. Brit.*, 23, 838D-847 (1947).

———————, AND E. RICHARD COHEN.
Our Knowledge of the Atomic Constants F, N, m, and h in 1947, and of other Constants Derivable from Them, *Rev. Mod. Phys.*, 20, 82-108 (1947).

———————, DAVID A. LIND, AND E. RICHARD COHEN.
Precision Method of Generating Circular Cylindrical Surfaces of Large Radius of Curvature for Use in the Curved-Crystal Spectrometer, *Rev. Sci. Instru.*, 18, 617-625 (1947).

EPSTEIN, PAUL S.
On the Elastic Properties of Lattices, *Phys. Rev.*, 70, 915-922 (1946).
Radio-Wave Propagation and Electromagnetic Surface Waves, *Proc. Nat. Acad. Sci.*, 33, 195-199 (1947).
Robert Andrews Millikan as Physicist and Teacher, *Rev. Mod. Phys.*, 20, 10-25 (1948).

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Electrostatic Analyzer for 1.5-Mev Protons, *Rev. Sci. Instru.*, 18, 818-820 (1947).
Gamma-Radiation from Excited States of Light Nuclei, *Rev. Mod. Phys.*, 20, 236-277 (1948).
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Materials, Techniques, and Testing Methods for the Sanitation (Bacterial Decontamination) of Small-Scale Water Supplies in the Field Used in Germany during and after the War,* *Fiat Final Report* 1312, Joint Intelligence Objectives Agency, Washington, D.C. (1947).

——————— E. L. ARMI, M. G. FOSTER, AND A. B. C. ANDERSON.
Metallic Film Formation at Low Temperatures, *Chem. Rev.*, 39, 418-495 (1946).

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————————, AND EDWARD C. Y. INN.

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Vibrational Spectrum and Specific Heat of a Face-Centered Cubic Crystal, *Rev. Mod. Phys.*, 20, 165-175 (1948).

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Electrons (+ and —), Protons, Photons, Neutrons, Mesotrons, and Cosmic Rays, vii + 642 pages, University of Chicago Press, Chicago, Illinois, 1947.

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The Double Current Sheet in Diffraction, *Phys. Rev.*, 72, 1066-1070 (1947).

Narrow Gaps in Microwave Problems, *Rev. Mod. Phys.*, 20, 175-179 (1948).

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A Survey of the Sciences, *Science*, 106, 135-140 (1947); also published in *Brown University Papers*, No. XX, and Calif. Inst. Forum, No. 3, 1947.

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On the Irreversible Production of Entropy, *Rev. Mod. Phys.*, 20, 51-77 (1948).

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28. The First Hydrogen Balloon, *Am. J. Phys.*, 14, 439-444 (1946).
29. Steam Locomotion as an Art Subject, *Am. J. Phys.*, 15, 82-84 (1947).
30. Egyptian and Assyrian Pictorial Representations of the "Mechanical Powers," *Am. J. Phys.*, 15, 187-189 (1947).
31. The Scientific Paintings of Joseph Wright, *Am. J. Phys.*, 15, 277-278 (1947).
32. Physical Science in the Paintings, Murals, Prints, Busts, Statues, and other Pictorial Records at Versailles, *Am. J. Phys.*, 15, 353-355 (1947).
33. *Quasi Cursores Vitai Lampada Tradunt*, *Am. J. Phys.*, 15, 422-425 (1947).
34. A Pictorial Summary of Magnetic Knowledge in the 17th Century, *Am. J. Phys.*, 15, 509-511 (1947).
35. Frontispiece to the 1550 Edition of Tartaglia's *La Nova Scientia*, *Am. J. Phys.*, 16, 55 (1948).
36. Raphael's "School of Athens," *Am. J. Phys.*, 16, 115-117 (1948).

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JET PROPULSION LABORATORY OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY

THE prime function of the Jet Propulsion Laboratory is the evaluation of propulsion systems for the armed services rather than the development and fabrication of specified jet propulsion equipment. For this reason publications of the staff members cover a very wide range of subject matter related to the field of jet propulsion.

During the year 1947-48 a total of 127 reports were published and distributed to various Government agencies, educational institutions, and industrial organizations. The distribution of these reports is generally made according to the Army-Navy distribution lists, and approximately 195 copies of each report are so distributed.

The following representative list indicates the type of problems with which the Laboratory is concerned and on which reports have been published:

1. Thermodynamics and kinetics of combustion.
2. Physical and chemical properties of liquid and solid propellants.
3. Theoretical and experimental studies of the performance of both liquid and solid propellants.
4. Development of porous metals for use in the cooling of rocket-motor chambers and the study of flow of gases through porous media.
5. The investigation of ceramic materials for rocket motors.
6. Fluid mechanics and chemistry of air-fuel combustion.
7. Basic as well as applied studies on heat transfer with surface boiling, and sweat cooling with porous metals.
8. Supersonic aerodynamics as applied to guided missiles.
9. The effect of rocket motor geometry on performance.

A fairly large portion of the work at the Jet Propulsion Laboratory is still of a classified nature; only the unclassified reports are listed below.

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