

CALIFORNIA INSTITUTE  
OF TECHNOLOGY

CATALOGUE  
1948-1949

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INSTITUTE OF TECHNOLOGY  
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CALIFORNIA INSTITUTE OF TECHNOLOGY

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

CATALOGUE

1948 - 1949

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Pasadena, California

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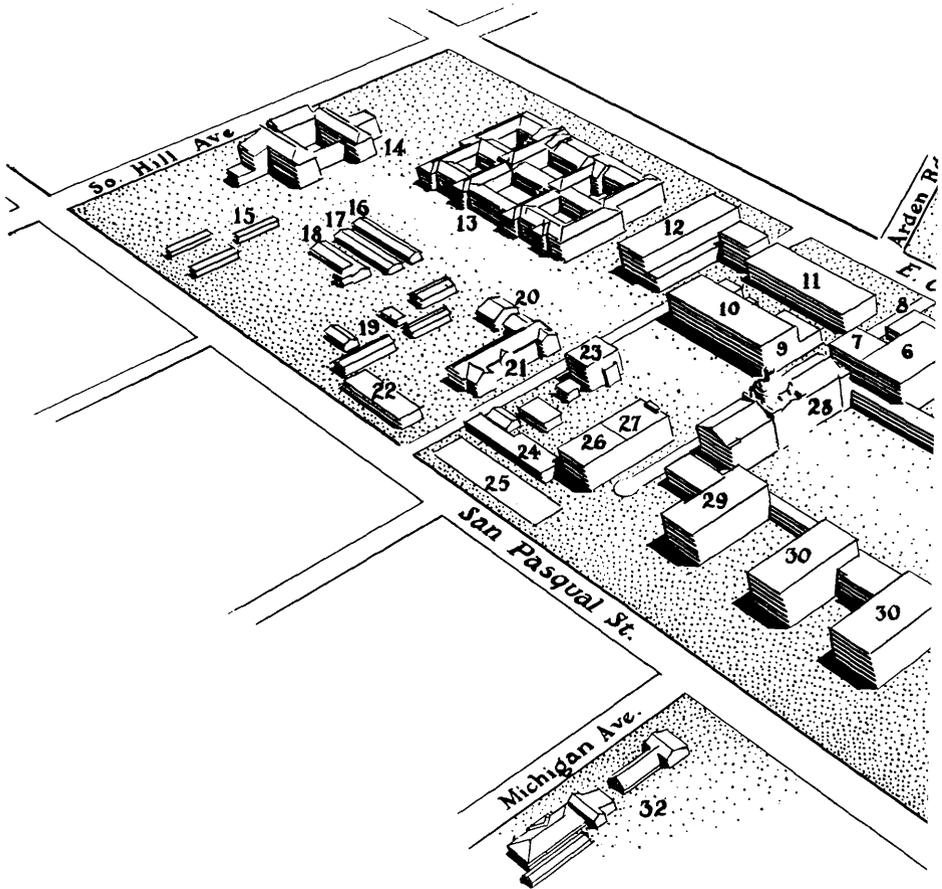
## THE CAMPUS OF THE CALIFORNIA INSTITUTE

The following two pages present a schematic view of the campus of the California Institute. The campus is in a residential section of Pasadena, about a mile from the central business district. The area bounded by East California Street, South Hill Avenue, San Pasqual Street, and South Wilson Avenue is the original campus of about thirty acres, acquired in 1909 when the Institute moved from downtown Pasadena to its present location. In this area have been constructed, since 1909, nearly all of the principal facilities of the Institute—laboratories, lecture and class rooms, offices, undergraduate residence halls, and a club for faculty, graduate students, and the staffs of the Mount Wilson Observatory and the Huntington Library.

Tournament Park, the area lying south of East California Street, was originally the property of the City of Pasadena. In March, 1947, the citizens of the city voted to authorize the sale of Tournament Park to the Institute, and the formalities involved in the transfer of title are now (October, 1948) nearly completed. Tournament Park adds about twenty acres to the campus and provides additional space and facilities for present and future needs of student life.

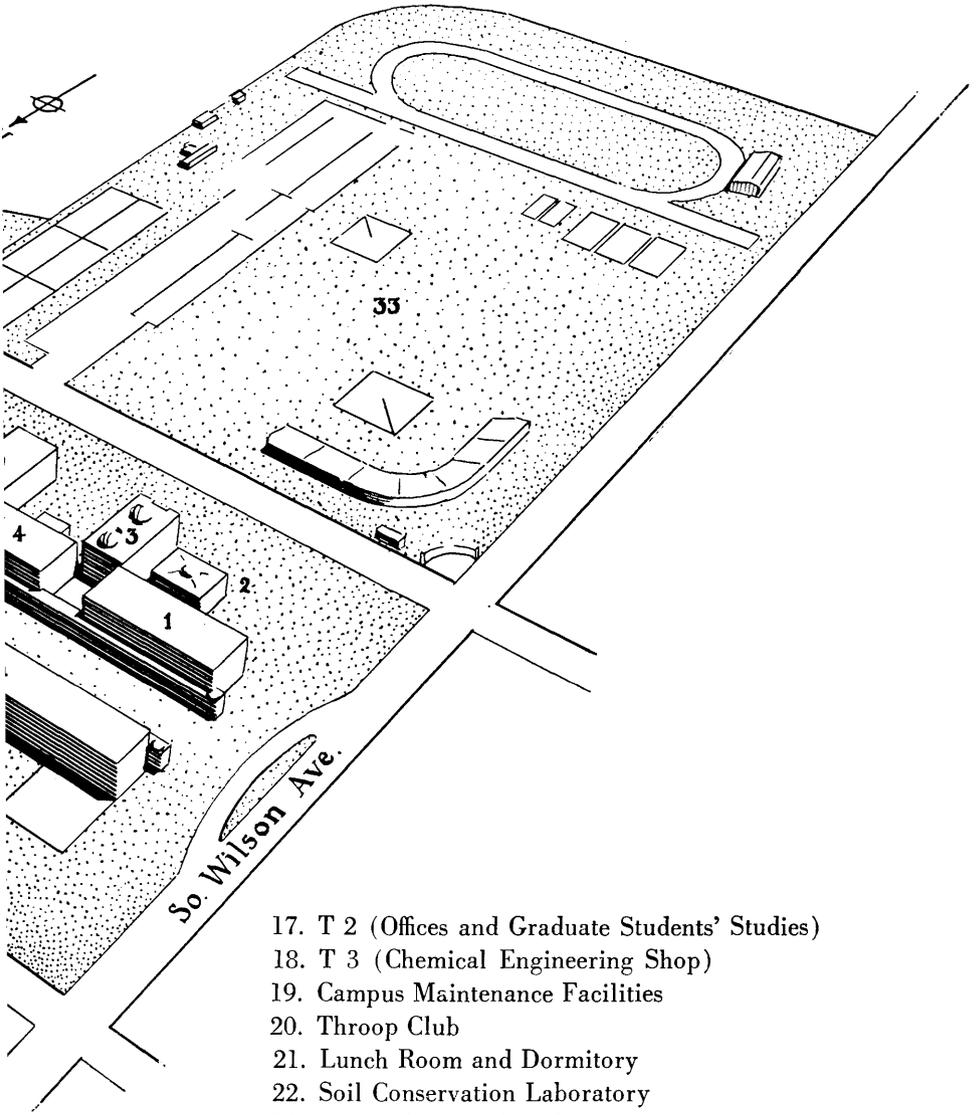
Besides supplying much-needed parking space for students and staff, Tournament Park has the following facilities for athletics and recreation: tennis and badminton courts; three outdoor basketball and three volley ball courts; a football practice field; a quarter-mile track with a 220-yard straightaway; two baseball diamonds, one with a grandstand seating 5000; and training quarters with locker and shower rooms.

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



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

# MAP



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

# CALENDAR

## 1948

SEPTEMBER							OCTOBER							NOVEMBER							DECEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
			1	2	3	4						1	2		1	2	3	4	5	6				1	2	3	4
5	6	7	8	9	10	11	3	4	5	6	7	8	9	7	8	9	10	11	12	13	5	6	7	8	9	10	11
12	13	14	15	16	17	18	10	11	12	13	14	15	16	14	15	16	17	18	19	20	12	13	14	15	16	17	18
19	20	21	22	23	24	25	17	18	19	20	21	22	23	21	22	23	24	25	26	27	19	20	21	22	23	24	25
26	27	28	29	30			24	25	26	27	28	29	30	28	29	30					26	27	28	29	30	31	
							31																				

## 1949

JANUARY							FEBRUARY							MARCH							APRIL						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
						1			1	2	3	4	5			1	2	3	4	5						1	2
2	3	4	5	6	7	8	6	7	8	9	10	11	12	6	7	8	9	10	11	12	3	4	5	6	7	8	9
9	10	11	12	13	14	15	13	14	15	16	17	18	19	13	14	15	16	17	18	19	10	11	12	13	14	15	16
16	17	18	19	20	21	22	20	21	22	23	24	25	26	20	21	22	23	24	25	26	17	18	19	20	21	22	23
23	24	25	26	27	28	29	27	28						27	28	29	30	31			24	25	26	27	28	29	30
30	31																										

MAY							JUNE							JULY							AUGUST							
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	
						1				1	2	3	4						1	2			1	2	3	4	5	6
8	9	10	11	12	13	14	5	6	7	8	9	10	11	3	4	5	6	7	8	9	7	8	9	10	11	12	13	
15	16	17	18	19	20	21	12	13	14	15	16	17	18	10	11	12	13	14	15	16	14	15	16	17	18	19	20	
22	23	24	25	26	27	28	19	20	21	22	23	24	25	17	18	19	20	21	22	23	21	22	23	24	25	26	27	
29	30	31					26	27	28	29	30			24	25	26	27	28	29	30	28	29	30	31				
														31														

SEPTEMBER							OCTOBER							NOVEMBER							DECEMBER						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
				1	2	3						1			1	2	3	4	5					1	2	3	
4	5	6	7	8	9	10	2	3	4	5	6	7	8	6	7	8	9	10	11	12	4	5	6	7	8	9	10
11	12	13	14	15	16	17	9	10	11	12	13	14	15	13	14	15	16	17	18	19	11	12	13	14	15	16	17
18	19	20	21	22	23	24	16	17	18	19	20	21	22	20	21	22	23	24	25	26	18	19	20	21	22	23	24
25	26	27	28	29	30		23	24	25	26	27	28	29	27	28	29	30				25	26	27	28	29	30	31
							30	31																			

# ACADEMIC CALENDAR, 1948-1949

## FIRST TERM

1948

September 23	Registration of entering freshmen—9:00 A.M. to 3:30 P.M.
September 23	Registration of students transferring from other colleges—8:30 A.M.
September 27	General registration—8:30 A.M. to 3:30 P.M.
September 28	Beginning of instruction—8:00 A.M.
October 15	Last day for adding courses.
October 16	Examinations for the removal of conditions and incompletes.
November 1-6	Mid-term week.
November 6	MID-TERM.
November 12	Last day for dropping courses.
November 19	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
November 22- December 11	Pre-Registration for 2nd term 1948-49.
November 25-28	Thanksgiving Recess.
December 13-18	Final examinations—1st term 1948-49.
December 18	Last day for filing application for candidacy for the degree of Doctor of Philosophy in June, 1949.
December 18	End of 1st term 1948-49—12 M.
December 19- January 2	Christmas Vacation.
December 27	Meeting of Freshman Registration Committee.
December 28	Meeting of Upperclass Registration Committee.

## SECOND TERM

1949

January 3	General registration—8:30 A.M. to 3:30 P.M.
January 4	Beginning of instruction—8:00 A.M.
January 21	Last day for adding courses.
January 22	Examinations for the removal of conditions and incompletes.
January 31- February 5	Mid-term week.
February 11	MID-TERM.
February 18	Last day for dropping courses.
February 21- March 12	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
February 21- March 12	Pre-Registration for 3rd Term 1948-49.
March 5 & 12	Examinations for admission to the freshman class, September, 1949.
March 14-19	Final examinations—2nd Term 1948-49.
March 19	End of 2nd Term 1948-49—12 M.
March 25	Meeting of Freshman Registration Committee.
March 26	Meeting of Upperclass Registration Committee.

## THIRD TERM

1949

March 28	General registration—8:30 A.M. to 3:30 P.M.
March 29	Beginning of instruction—8:00 A.M.
April 15	Last day for adding courses.
April 16	Examinations for the removal of conditions and incompletes.
April 25-30	Mid-term week.
April 30	MID-TERM.
May 6	Last day for dropping courses.
May 13	French and German examinations for admission to candidacy for the degree of Doctor of Philosophy.
May 16-June 4	Pre-Registration of 1st term of 1949-50.
May 28	Last day for final oral examinations and presenting of theses for the degree of Doctor of Philosophy.
May 30	Memorial Day Holiday.
May 31-June 4	Final examinations for senior and graduate students—3rd term 1948-49.
June 3-4	Examinations for admission to upper classes, September, 1949.
June 6-11	Final examinations for undergraduate students—3rd term 1948-49.
June 8	Meetings of Committees on Course in Science and Engineering—10:00 A.M.
June 8	Faculty meeting—2:00 P.M.
June 9	Class Day.
June 10	Commencement.
June 11	End of 3rd term 1948-49—12 M.
June 17	Meeting of Freshman Registration Committee.
June 18	Meeting of Upperclass Registration Committee.

## FIRST TERM, 1949-50

September 22	Registration of entering freshmen—9:00 A.M.
September 22	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 27	Beginning of instruction—8:00 A.M.

## PART ONE

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- Student Life (page 99)

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ASSOCIATE DEAN FOR FRESHMEN.....	FOSTER STRONG

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SUPERINTENDENT OF THE GUGGENHEIM AERONAUTICAL LABORATORY.....	WILLIAM H. BOWEN

# FACULTY OFFICERS AND COMMITTEES

1948-49

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SECRETARY—R. R. MARTEL

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FACULTY BOARD—*Watson*, Beadle, Eagleson, Eaton, Jones, Judy, Kirkwood, Lacey, C. C. Lauritsen, Lindvall, Martel, Michael, C. B. Millikan, Pauling, Robertson, Sechler, Smythe, Sorensen, Stock, Strong, Swift, Thomas.

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STUDENT BODY FINANCE—*Thomas*, Pickering, Sorensen, Untereiner, Youtz.

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UPPER CLASS ADMISSION AND REGISTRATION—*Jones*, Bates, Converse, Eaton, Goldsworthy, Martel, Maxstadt, Smythe, Strong, Swift, Thomas, Wear.

# STAFF OF INSTRUCTION AND RESEARCH SUMMARY

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### PROFESSORS

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GEORGE W. BEADLE, PH.D., D.Sc.....	Biology
JAMES F. BONNER, PH.D.....	Biology
HENRY BORSOOK, PH.D., M.D.....	Biochemistry
MAX DELBRUCK, PH.D.....	Biology
STERLING EMERSON, PH.D.....	Genetics
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
FRIITS W. WENT, PH.D.....	Plant Physiology
CORNELIUS A. G. WIERSMA, PH.D.....	Biology

### RESEARCH ASSOCIATES

GORDON A. ALLES, PH.D.....	Biology
CHARLES E. BRADLEY, D.Sc.....	Biology
HENRY O. EVERSOLE, M.D.....	Plant Physiology
ALBERT E. LONGLEY, PH.D.....	Biology
LILIAN V. (MRS. T. H.) MORGAN, M.A.....	Biology
ESTHER BOGEN TIETZ, PH.D., M.D.....	Biology

### ASSOCIATE PROFESSORS

NORMAN H. HOROWITZ, PH.D.....	Biology
GEORGE E. MACGINITIE, M.A.....	Biology
RAY D. OWEN, PH.D.....	Biology
ALBERT TYLER, PH.D.....	Embryology

### ASSISTANT PROFESSOR

EDWARD B. LEWIS, PH.D.....	Genetics
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### SENIOR FELLOWS IN RESEARCH

CLARA LOUIS DEASY, PH.D.....	Biology
JACOB W. DUBNOFF, PH.D.....	Biology
ARTHUR W. GALSTON, PH.D.....	Biology
ALFRED D. HERSHEY, PH.D.....	Biology
GEOFFREY L. KEIGHLEY, PH.D.....	Biology
HERSCHEL K. MITCHELL, PH.D.....	Biology
EDWARD NOVITSKI, PH.D.....	Biology
J. A. WHIELDON, M.D.....	Physiology
SAM G. WILDMAN, PH.D.....	Biology

## GOSNEY FELLOWS

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JOHN R. LAUCHNAN, PH.D.....	Biology

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GEORGE H. MICKEY**, PH.D.	MARKO ZALOKAR, D.Sc.
JOSEPH NYC, PH.D.	BRONISLAW ZAWADZKI, PH.D.

## RESEARCH ASSISTANTS

1947-48

ELIZABETH ANN BARTRON, B.A.	MARTHA KENT, A.B.
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MARGERY E. HAND, A.B.	YU-WEI TANG, PH.D.
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IRENE YOUNG

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1947-48

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MARTYNAS F. YCAS

\*Merck Fellow

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Director of the Gates and Crellin Laboratories

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STUART J. BATES, PH.D.....	Physical Chemistry
JOHN G. KIRKWOOD†, PH.D.....	Chemistry
WILLIAM N. LACEY, PH.D.....	Chemical Engineering
HOWARD J. LUCAS, M.A.....	Organic Chemistry
CARL G. NIEMANN, PH.D.....	Organic Chemistry
LINUS PAULING, PH.D., SC.D.....	Chemistry
BRUCE H. SAGE, PH.D.....	Chemical Engineering
J. HOLMES STURDIVANT, PH.D.....	Chemistry
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EDWARD W. HUGHES, PH.D.....	Physical Chemistry
JOSEPH B. KOEPLI, D.PHIL.....	Chemistry
SEELEY MUDD, M.D.....	Medical Chemistry
OLIVER R. WULF, PH.D.....	Physical Chemistry

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

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JERRY DONOHUE*, PH.D.....	Chemistry
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ELDRED W. HOUGH, PH.D.....	Chemical Engineering
WALTER A. SCHROEDER, PH.D.....	Chemistry
DAVID P. SHOEMAKER, PH.D.....	Chemistry
STANLEY M. SWINGLE, PH.D.....	Physical Chemistry

### INSTRUCTOR

NORMAN DAVIDSON, PH.D.....	Chemistry
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†Arthur A. Noyes Professor.

\*Arthur A. Noyes Senior Research Fellow.

\*\*On leave of absence, first term, 1948-49.

## RESEARCH FELLOWS

A. B. Biswas <sup>1</sup> , Ph.D.	TZU-CHING HUANG, Ph.D.
HERMAN R. BRANSON <sup>2</sup> , Ph.D.	MIYOSHI IKAWA, Ph.D.
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N. HOFMAN-BANC <sup>6</sup> , M.S.	PETER WECER, M.D.
HSING-TSUNG HUANG, Ph.D.	IBERT C. WELLS <sup>9</sup> , Ph.D.

J. NORTON WILSON, Ph.D.

## RESEARCH ASSISTANTS

1947-48

ANNE T. BLAKER, B.S.	RENE S. MILLS, B.S.
ELIZABETH F. CANNEY, B.S.	H. HOLLIS REAMER, M.S.
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1947-48

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WILLIAM W. WOOD, B.S.

1/Watumull Foundation Fellow.  
 2/American Cancer Society Fellow.  
 3/Belgian-American Foundation Fellow.  
 4/Arthur A. Noyes Fellow.  
 5/Merck Fellow.  
 6/Danish Government Fellow.  
 7/Swiss Foundation Fellow.  
 8/U.S. Public Health Service Fellow.  
 9/National Research Fellow.

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ROBERT L. DAUGHERTY, M.E.....	Mechanical and Hydraulic Engineering
THEODORE VON KÁRMÁN*, PH.D., DR.ING., SC.D., LL.D., ENG.D.....	Aeronautics
FREDERICK C. LINDVALL, PH.D.....	Electrical and Mechanical Engineering
R. R. MARTEL, S.B.....	Structural Engineering
CLARK B. MILLIKAN, PH.D.....	Aeronautics
ERNEST E. SECHLER, PH.D.....	Aeronautics
FRANKLIN THOMAS, C.E.....	Civil Engineering

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DONALD S. CLARK, PH.D.....	Mechanical Engineering
LOUIS G. DUNN, PH.D.....	Aeronautics
POL DUWEZ, D.Sc.....	Mechanical Engineering
ALADAR HOLLANDER, M.E.....	Mechanical Engineering
ARTHUR L. KLEIN, PH.D.....	Aeronautics
ROBERT T. KNAPP, PH.D.....	Hydraulic Engineering
HANS W. LIEPMANN, PH.D.....	Aeronautics
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MILTON S. PLESSET, PH.D.....	Applied Mechanics
HOMER J. STEWART, PH.D.....	Aeronautics

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W. J. BOBISCH, M.S.....	Civil Engineering
CHARLES R. DEPRIMA, PH.D.....	Applied Mechanics
GEORGE W. HOUSNER, PH.D.....	Applied Mechanics
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PETER R. KYROPOULOS, PH.D.....	Mechanical Engineering
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VITO A. VANONI, PH.D.....	Hydraulics
WILBUR R. VARNEY, M.S.....	Mechanical Engineering
WARREN O. WACNER†, PH.D.....	Hydraulics
CHARLES H. WILTS, PH.D.....	Applied Mechanics

\*Emeritus

\*\*Leave of absence

†Acting

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DAVID ALTMAN, PH.D.....	Jet Propulsion
RICHARD W. BELL, A.E.....	Aeronautics
FREDERICK FELBERG, M.S.....	Aeronautics
JOSEPH LEVY, M.S.....	Hydrodynamics
HAROLD LURIE, M.S.....	Aeronautics
DINO MORELLI, PH.D.....	Mechanical Engineering
HENRY NAGAMATSU, M.S.....	Aeronautics
ALLEN E. PUCKETT, M.S.....	Aeronautics
HOWARD SEIFERT, PH.D.....	Jet Propulsion
ROBERT F. TANGREN, A.E.....	Jet Propulsion
MAX L. WILLIAMS, A.E.E.....	Aeronautics
J. PAUL YOUTZ, M.S.....	Industrial Design

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HARRY R. GREENE, M.A.....	Industrial Design
SALVATORE MERENDINO, M.A.....	Industrial Design

## RESEARCH FELLOWS

FELIX BUCKENS, D.A.Sc.....	Applied Mechanics
YUAN-CHENG FUNG, PH.D.....	Aeronautics
JOHN LAUFER, PH.D.....	Aeronautics
LEON TRILLING, PH.D.....	Aeronautics

## INSTRUCTORS

JOHN S. CAMPBELL, M.S.....	Engineering Drafting
FRANK A. MARBLE, PH.D.....	Aeronautics
FRANK A. McCLINTOCK, PH.D.....	Mechanical Engineering
ALBERT A. MERRILL.....	Aeronautics
BEVERLY W. MORANT.....	Industrial Design
PATRICK M. QUINLAN, M.S.....	Applied Mechanics
BERNARD RASOF, M.S.....	Aeronautics
DAVID F. WELCH, I.D.....	Industrial Design & Engineering Drafting
NATHANIEL W. WILCOX, A.B.....	Engineering Drafting

## RESEARCH ASSISTANTS

1947-48

ROBERT M. JAMES, B.S.

J. PAT O'NEILL, B.S.

JOSEPH LEVY, M.S.

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1947-48

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 YUANG-CHENG FUNG, B.S.  
 RICHARD H. GILMAN, III, M.S.  
 MALCOLM S. HARNED, M.S.  
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 ANTONY J. A. MORGAN, M.S.  
 GEORGE K. MORIKAWA, M.S.  
 GEOFFREY V. PARKINSON, B.S.  
 ADRIAN PAUW, B.S.  
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 HENRY T. PONSFORD, A.E.E.  
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 ALLEN E. PUCKETT, M.S.  
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 WILLIAM T. RUSSELL, B.S.  
 ROLF H. SABERSKY, M.S.  
 LOUIS V. SCHMIDT, B.S.  
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 GLENN A. SCHURMAN, M.S.  
 DONALD B. SEACER, M.S.  
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 LYLE D. SIX, B.S.  
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 WILBUR M. SWANSON, B.S.  
 LEON TRILLING, A.E.E.  
 FRED M. WELLS, B.S.  
 MAX L. WILLIAMS, JR., M.S.  
 DAVID S. WOOD, M.S.  
 WILLIAM S. WUNCH, M.S.

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IAN CAMPBELL, PH.D.....	Petrology
BENO GUTENBERG, PH.D.....	Geophysics
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ROBERT P. SHARP, PH.D.....	Geomorphology
CHESTER STOCK, PH.D.....	Paleontology

## VISITING PROFESSORS

R. DANA RUSSELL, PH.D.....	Sedimentation
CLINTON R. STAUFFER, PH.D.....	Invertebrate Paleontology

## RESEARCH ASSOCIATES

DONNEL F. HEWETT, PH.D.....	Geology
HARRY O. WOOD, A.M.....	Seismology

## VISITING RESEARCH ASSOCIATE

W. HEISKANEN, PH.D.....	Geodesy
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HUGO BENIOFF, PH.D.....	Seismology
CHARLES HEWITT DIX, PH.D.....	Geophysics
RICHARD H. JAHNS, PH.D.....	Geology
CHARLES W. MERRIAM, PH.D.....	Invertebrate Paleontology
GENNADY W. POTAPENKO†, PH.D.....	Geophysics
CHARLES F. RICHTER, PH.D.....	Seismology

## ASSISTANT PROFESSOR

ALBERT E. J. ENGEL.....	Mineralogy
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## RESEARCH FELLOW

WILLIS P. POPENOE, PH.D.....	Invertebrate Paleontology
------------------------------	---------------------------

## VISITING RESEARCH FELLOWS

ENVER ALTINLI, D.Sc.....	Geology
S. K. CHAKRABARTY, D.Sc.....	Seismology
ANTONIO DUEROJO, S.J.....	Seismology
RICHARD E. INGRAM, S.J., PH.D.....	Seismology
SAUL MEIBOOM, M.A.....	Geophysics

---

†Member of the Division of Physics, Astronomy, Mathematics, and Electrical Engineering.

## RESEARCH ASSISTANTS

1947-48

TOSHIO ASAEDA  
RUDOLF VON HUENE, E.M.

WILLIAM J. P. OTTO  
DAVID P. WILLOUGHBY

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1947-48

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HAROLD M. MOONEY, B.S.  
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M. DARWIN QUIGLEY, M.S.  
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ROBERT C. WHITE, M.S.

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WILLIAM HUSE, M.A.....	English
CLINTON K. JUDY, M.A.....	English
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GEORGE R. MACMINN, A.B.....	English
HUNTER MEAD, PH.D.....	Philosophy and Psychology
WILLIAM B. MUNRO*, PH.D., LL.D., LITT.D.....	History and Government
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J. E. WALLACE STERLING, PH.D.....	History

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ROGER STANTON, PH.D.....	English

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JOHN A. SCHUTZ, PH.D.....	History

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MELVIN BROCKIE, PH.D.....	Economics
JACOB CHAITKIN, LL.B.....	Russian
J. KENT CLARK, A.B.....	English
GEORGE K. TANHAM, M.A.....	History
CALDER T. WILLIAMS, B.A.....	English

\*Emeritus

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H. VICTOR NEHER, PH.D.....	Physics
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WILLIAM R. SMYTHE, PH.D.....	Physics
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H. C. VAN BUSKIRK**, PH.B.....	Mathematics
MORGAN WARD, PH.D.....	Mathematics
ERNEST C. WATSON, PH.B.....	Physics
FRITZ ZWICKY, PH.D.....	Astrophysics

RESEARCH ASSOCIATES

WALTER S. ADAMS, Sc.D., LL.D.....	Astronomy and Astrophysics
SAMUEL J. BARNETT, PH.D.....	Physics
IRA S. BOWEN, PH.D., Sc.D.....	Astronomy
A. ERDÉLYI, D.Sc.....	Mathematics
JOSEF J. JOHNSON, PH.D.....	Astronomy
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MAX MASON, PH.D., LL.D., Sc.D.....	Astronomy
FRITZ OBERHETTINGER, DR. PHIL.....	Mathematics
SIMON RAMO, PH.D.....	Electrical Engineering
F. TRICOMI, DR. MATH.....	Mathematics
DEAN E. WOOLDRIDGE, PH.D.....	Electrical Engineering

VISITING LECTURER

W. D. CAIRNS, PH.D.....	Mathematics
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\*On leave of absence

\*\*Emeritus

## ASSOCIATE PROFESSORS

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JESSE L. GREENSTEIN, PH.D.....	Astrophysics
ROBERT B. KING, PH.D.....	Physics
FRANCIS W. MAXSTADT, PH.D.....	Electrical Engineering
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LUTHER E. WEAR, PH.D.....	Mathematics

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LEVERETT DAVIS, JR., PH.D.....	Physics
E. C. GOLDSWORTHY, PH.D.....	Mathematics
THOMAS LAURITSEN, PH.D.....	Physics
FOSTER STRONG, M.S.....	Physics

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ROBERT V. LANGMUIR, PH.D.....	Physics
ROBERT J. FINKELSTEIN, PH.D.....	Theoretical Physics

## INSTRUCTOR

SAMUEL KARLIN, PH.D.....	Mathematics
--------------------------	-------------

## RESEARCH FELLOWS

RAYMOND V. ADAMS, PH.D.....	Physics
EUGENE W. COWAN, PH.D.....	Physics
H. KURT FORSTER, PH.D.....	Physics
ALBERT RAYMOND HARVEY, PH.D.....	Mathematics
SPIRO KYROPOULOS, PH.D.....	Physics
ROBERT B. LEIGHTON, PH.D.....	Physics
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B.S., College of the City of New York, 1940; M.A., University of Texas, 1947; Ph.D., 1948. California Institute, 1947-

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Mount Wilson Observatory, 1920-; California Institute, 1948-

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A.B., Stanford University, 1911 ; Ch.E., 1912 ; M.S., University of California, 1913 ; Ph.D., 1915.  
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1919-31 ; Professor, 1931-  
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Fil. Kand., University of Stockholm, 1935 ; Fil. Lic., 1939 ; Ph.D., Princeton University, 1942. Re-  
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791 North Oak Street, Temple City

**HOWARD JOHNSON LUCAS, M.A.***Professor of Organic Chemistry*

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B.S., University of South Africa, 1940; M.S., 1946. California Institute, 1948-

**W. LÜSCHER, PH.D.***Research Fellow in Chemistry*

Ph.D., University of Bern, 1946. California Institute, 1948-

**JOHN ROBERTSON MACARTHUR, PH.D.***Professor of Languages, Emeritus*

B.A., University of Manitoba, 1892; Ph.D., University of Chicago, 1903. Associate Professor, California Institute, 1920-23; Professor of Languages, 1923-; Dean of Freshmen, 1923-37.

304 Ellis Street, Elsinore

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A.B., Fresno State College, 1925; M.A., Stanford University, 1928. Assistant Professor, California Institute, 1932-46; Associate Professor, 1946-

Corona Del Mar

**SAMUEL STUART MACKEOWN\*, PH.D.***Professor of Electrical Engineering*

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**WILHELM MAGNUS, DR. PHIL. NAT.***Research Associate in Mathematics*

Dr. Phil. Nat., University of Frankfurt, 1931. California Institute 1948-

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B.S., Texas Agricultural and Mechanical College, 1934; M.S., California Institute, 1935 and 1936; Ph.D., 1940. Research Fellow, 1940-42; Assistant Professor, 1942-

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California Institute, 1918-30 ; 1940-  
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A.B., Oberlin College, 1891; A.M., 1893; Ph.D., Columbia University, 1895. 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-

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B.S., George Washington University, 1930; M.S., 1933; Ph.D., California Institute, 1936. Curator in Invertebrate Paleontology, California Institute, 1929-45; Research Fellow, 1945-

1736 Vistillas Road, Altadena

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C.Sc., University of Moscow, 1917; M.A., Ph.D., (Habilitation), 1920. California Institute, 1930-

1718 Oakdale Street

**E. T. PREISLER, B.A.***Coach*

B.A., San Diego State College, 1941. California Institute, 1947-

937 East Hyde Park, Boulevard, Inglewood

**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

**PATRICK MICHAEL QUINLAN, M.Sc.***Instructor in Applied Mechanics*

B.E., University College, London, 1941; B.Sc., 1942; M.Sc., 1943. California Institute, 1948-

24 South San Marino Avenue

**SIMON RAMO, Ph.D.***Research Associate in Electrical Engineering*

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2751 Midvale Avenue, Los Angeles

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**ROBERT S. RICHARDSON, Ph.D.***Research Associate in Astronomy*

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1244 North Holliston Avenue

**CHARLES FRANCIS RICHTER, Ph.D.***Associate Professor of Seismology*

A.B., Stanford University, 1920; Ph.D., California Institute, 1928. Assistant Professor, California Institute, 1937-47; Associate Professor, 1947-

1820 Kenneth Way

**HEINRICH RINDERKNECHT, Ph.D.***Research Fellow in Chemistry*

Matriculation, Gymnasium, Zurich, 1932; Diploma in Science, Federal Institute of Technology, 1936; Ph.D., University of London, 1936. California Institute, 1947-48.

**H. P. ROBERTSON, Ph.D.***Professor of Mathematical Physics*

B.S., University of Washington, 1922; M.S., 1923; Ph.D., California Institute, 1925. California Institute, 1947-

590 Auburn Avenue, Sierra Madre

**SYLVAN RUBIN, Ph.D.***Research Fellow in Physics*

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265 South Holliston Avenue

**R. DANA RUSSELL, Ph.D.***(Visiting) Professor of Sedimentation*

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553 Gravilla Place, La Jolla

**BRUCE HORNBOOK SAGE, PH.D.***Professor of Chemical Engineering*

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

3216 Mount Curve Avenue, Altadena

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1521 East Mountain Street

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**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

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B.Sc., University of Nebraska, 1939; M.A., 1940; Ph.D., California Institute, 1943. 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*

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**ERNEST EDWIN SECHLER, PH.D.***Professor of Aeronautics*

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

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382 South Grand Oaks Avenue

**ROBERT PHILLIP SHARP, PH.D.***Professor of Geomorphology*

B.S., California Institute, 1934; M.S., 1935; A.M., Harvard University, 1936; Ph.D., 1938. California Institute, 1947-

1941 Milan Avenue, South Pasadena

**DAVID P. SHOEMAKER, PH.D.***Senior Research Fellow in Chemistry*

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**SEYMOUR JONATHAN SINGER, PH.D.***Research Fellow in Chemistry*

A.B., Columbia University, 1943; A.M., 1945; Ph.D., Polytechnic Institute of Brooklyn, 1947. California Institute, 1947-

415 Mariposa Avenue, Sierra Madre

**WILLIAM RALPH SMYTHE, PH.D.***Professor of Physics*

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674 Manzanita Avenue, Sierra Madre

**ROYAL WASSON SORESENSEN, E.E., D.Sc.***Professor of Electrical Engineering**Chairman of the Division of Physical Education*

B.S., University of Colorado, 1905; E.E., 1928. California Institute, 1911-

384 South Holliston Avenue

**ROGER FELLOWS STANTON, PH.D.***Associate Professor of English**Acting Director of Institute Libraries*

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

551 South Hill Avenue

**CLINTON R. STAUFFER, PH.D.***(Visiting) Professor of Invertebrate Paleontology*

B.S., Ohio State University, 1903; A.M., 1906; Ph.D., University of Chicago, 1909. California Institute, 1947-

2247 Loma Vista Avenue

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620 Madison Avenue

**J. E. WALLACE STERLING, PH.D.***Associate in History*

B.A., University of Toronto, 1927; M.A., University of Alberta, 1930; Ph.D., Stanford University, 1938. Assistant Professor of History, California Institute, 1937-40; Associate Professor, 1940-42; Professor, 1942-48; Associate, 1948-

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551 South Hill Avenue

**ALFRED HENRY STURTEVANT, PH.D., D.Sc.***Professor of Genetics*

A.B., Columbia University, 1912; Ph.D., 1914. California Institute, 1928-

1244 Arden Road

**ERNEST HAYWOOD SWIFT, PH.D.\****Professor of Analytical Chemistry*

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

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**LUIS H. TEJADA-FLORES, PH.D.***Research Fellow in Electrical Engineering*

B.S., California Institute, 1938; M.S., 1943; Ph.D., 1948. California Institute, 1948-

**FRANKLIN THOMAS, C.E.***Professor of Civil Engineering**Dean of Students*

B.E., University of Iowa, 1908; C.E., 1913. Associate Professor of Civil Engineering, California Institute, 1913-15; Professor, 1915-

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**LEON TRILLING, PH.D.***Research Fellow in Aeronautics*

B.S., California Institute, 1944; M.S., 1946; Ph.D., 1948. Research Fellow, 1948-

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**KENNETH N. TRUEBLOOD, PH.D.***Research Fellow in Chemistry*A.B., Harvard College, 1941 ; Ph.D., California Institute, 1947. California Institute, 1947-  
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Assistant Professor, 1938-45 ; Associate Professor, 1946-  
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505 South Wilson Avenue**RAY EDWARD UNTEREINER, PH.D.***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. California Institute, 1925-  
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35 ; Professor, 1915-  
390 South Holliston Avenue**VITO AUGUST VANONI, PH.D.***Assistant Professor of Hydraulics*B.S., California Institute, 1926 ; M.S., 1932 ; Ph.D., 1940. California Institute, 1942-  
386 South Meridith Avenue**WILBUR R. VARNEY, M.S.***Assistant Professor of Mechanical Engineering*B.S., Northeastern University, 1936 ; Ch.E., 1937 ; M.S., Rensselaer Polytechnic Institute, 1938.  
California Institute, 1948-**CARROLL E. WAGNER, B.S.***Research Fellow in Biology*B.S., Loyola College, 1940. California Institute, 1947-48.  
Dormitory**ROBERT PHILIP WAGNER, PH.D.***Research Fellow in Biology*

B.S., City College of New York, 1940 ; Ph.D., University of Texas, 1943. California Institute, 1946-48.

**WARREN ORVAL WAGNER, PH.D.***(Acting) Assistant Professor of Hydraulics*B.S., Washington State College, 1934 ; M.S., University of Michigan, 1936 ; Ph.D., California Insti-  
tute, 1945. California Institute, 1945-  
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Assistant Professor, 1929-35 ; Associate Professor, 1935-40 ; Professor, 1940-  
265 South Holliston Avenue**EARNST CHARLES WATSON, PH.B.***Professor of Physics**Dean of the Faculty**Chairman of the Division of Physics, Astronomy, Mathematics and Electrical Engineering*  
Ph.B., Lafayette College, 1914. Assistant Professor, California Institute, 1919-20 ; Associate Pro-  
fessor, 1920-30 ; Professor, 1930-  
551 South Hill Avenue

**LUTHER EWING WEAR, PH.D.***Associate Professor of Mathematics*

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**PETER WEGER, M.D.***Research Fellow in Chemistry*

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641 South Lake Avenue

**IBERT C. WELLS, PH.D.***Research Fellow in Chemistry*

A.B., Central College, 1942; Ph.D., Saint Louis University, 1948. California Institute, 1948-

**FRITS WARMOLT WENT, PH.D.***Professor of Plant Physiology*

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B.S., Pacific Union College, 1941; M.D., College of Medical Evangelists, 1942. California Institute, 1947-

3314 Tonia Street

**EOIN LAIRD WHITNEY, B.Sc.***Research Fellow in Mathematics*

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533 South Hudson Avenue

**CORNELIS A. G. WIERSMA, PH.D.***Professor of Biology*

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290 South Michigan Avenue

**CALDER T. WILLIAMS, B.A.***Instructor in English*

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**MAX L. WILLIAMS, A.E.E.***Lecturer in Aeronautics*

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**ALBERT G. WILSON, PH.D.***Research Fellow in Astronomy*

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**J. NORTON WILSON, PH.D.***Research Fellow in Chemistry*

B.A., University of British Columbia, 1934 ; M.A., 1936 ; Ph.D., California Institute, 1939. California Institute, 1948-

**OLIN C. WILSON, PH.D.***Research Associate in Astronomy*

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B.A., Carleton College, Northfield, Minnesota, 1906 ; Ph.D., University of Virginia, 1910. California Institute, 1948-

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**CHARLES H. WILTS, PH.D.***Assistant Professor of Applied Mechanics*

B.S., California Institute, 1940 ; M.S., 1941 ; Ph.D., 1948. Assistant Professor, 1947-2887 Wagner Court, Altadena

**ELIE WOLLMAN***Research Fellow in Biology*

California Institute, 1948-

**HARRY O. WOOD, A.M.***Research Associate in Seismology*

A.B., Harvard University, 1902 ; A.M., 1904. California Institute, 1925-551 South Hill Avenue

**ALVALYN E. WOODWARD, PH.D.***Research Fellow in Biology*

Ph.B., University of Rochester, 1905 ; M.S., 1911 ; Ph.D., University of Michigan, 1918. California Institute, 1947-

**DEAN E. WOOLDRIDGE, PH.D.***Research Associate in Electrical Engineering*

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B.S., Worcester Polytechnic Institute, 1920 ; M.S., American University, 1922 ; Ph.D., California Institute, 1926. California Institute, 1945-

81 El Nido Avenue

**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*

California Institute, 1939-

3 Rosemary Lane, Santa Barbara

**J. PAUL YOUTZ, M.S.***Lecturer in Industrial Design  
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B.S. (TCT), California Institute, 1917 ; M.S., Union College, 1919. California Institute, 1932-

1477 North Holliston Avenue

**MARKO ZALOKAR, D.Sc.***Research Fellow in Biology*

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

173 South Meridith Avenue

**BRONISLAW ZAWADZKI, Ph.D.***Research Fellow in Biology*

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**LÁSZLÓ ZECHMEISTER, DR.ING.***Professor of Organic Chemistry*

Diploma of Chemist, 1911; Dr. Ing., 1913; Eidgenossische Technische Hochschule, Zurich, Switzerland. California Institute, 1940-

551 South Hill Avenue

**FRITZ ZWICKY, Ph.D.***Professor of Astrophysics*

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212 West California Street

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1947-1948

- ROBERT TRAIN ADAMS.....Graduate Assistant, Chemistry  
B.S., University of California, 1942.
- JACK LELAND ALFORD.....Graduate Assistant, Mechanical Engineering  
B.S., California Institute, 1942; M.S., 1946.
- THOMAS LOFTON ALLEN.....Shell Fellow, Chemistry  
B.S., University of California, 1944.
- MORTON ALPERIN.....Graduate Assistant, Aeronautics  
B. of AeE., New York University, 1939; M.S., California Institute, 1947.
- WARREN HEBERT AMSTER.....Graduate Assistant, Aeronautics  
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- ALAN H. ANDREW.....Drake Scholar, Physics  
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- HAROLD SEVERIN ANTHON.....Graduate Assistant, Civil Engineering  
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- CHARLES HAMMOND ARRINGTON JR.....  
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- TOSHIO ASAEDA ..... Research Assistant, Geology
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B.S., University of California, 1944; M.S., California Institute, 1946.
- CHARLES EDWARD AUERBACH.....  
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B.S., University of California, 1942; M.S., California Institute, 1947.
- JOHN WILLIAM BACON, JR.....Graduate Assistant, Aeronautics  
B.S., California Institute, 1943.
- OLIVER ALBRECHT BEAR .....Graduate Assistant, Mechanical Engineering  
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- KURT BARNETT ..... Graduate Assistant, Roeser Scholar, Electrical Engineering  
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- JULIUS SAMUEL BENDAT ..... Graduate Assistant, Applied Mechanics  
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- ROBERT FRANCIS BENTON.....Graduate Assistant, Mathematics  
B.A., Reed College, January, 1943.
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- ROBERT ROYCE BENNETT .....Graduate Assistant, Electrical Engineering  
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- JOHN THOMAS BOWEN..... Cole Fellow, Mechanical Engineering
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- ROLF DIETRICH BUHLER..... Graduate Assistant Applied Mechanics  
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- NORMAN BULMAN..... Graduate Assistant, Murray Scholar, Chemistry  
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- STANLEY CAMPBELL BURKET ..... Graduate Assistant, Chemistry  
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- WILLIAM JEROME CARRÖLL, JR..... Assistant, Physical Education
- WILLIAM WALTON CARTER ..... Graduate Assistant, Physics  
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- WILLIAM HARRISON CORCORAN.....  
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 B.S., California Institute, 1941; M.S., 1944.

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- HAROLD MILLER DEGROFF, JR.....Graduate Assistant, Aeronautics  
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- JOHN EDWARD DENBY-WILKES.....Graduate Assistant, Mathematics  
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- MAYETTE ELNER DENSON, JR.....Graduate Assistant, Geology  
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- FRANK HOST DICKEY.....Graduate Assistant, Dobbins Scholar, Chemistry  
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- CHARLES BULLARD DOUGHERTY.....Graduate Assistant, Physics  
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- WORTHIE LEFLER DOYLE.....Graduate Assistant, Mathematics  
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 ALFRED LEE LOOMIS  
 MRS. JAMES B. LUCKIE  
 LEONARD S. LYON  
 MRS. JAMES E. MACMURRAY  
 JOHN R. MAGE  
 FRED S. MARKHAM  
 TOM MAY  
 MRS. ALONZO C. MATHER  
 EDWIN A. MESERVE  
 BEN R. MEYER  
 MRS. BEN R. MEYER  
 ROBERT A. MILLIKAN  
 MRS. ROBERT A. MILLIKAN  
 BRUCE H. MILLS  
 ROBERT L. MINCKLER  
 LOUIS T. MONSON  
 ROBERT T. MOORE  
 ALAN E. MORPHY  
 LINDLEY C. MORTON  
 R. H. MOULTON  
 HARVEY S. MUDD  
 SEELEY G. MUDD  
 WILLIAM C. MULLENDORE  
 WILLIAM B. MUNRO  
 MRS. WILLIAM B. MUNRO  
 MRS. ANNA BISSELL McCAY  
 WILLIAM S. McCAY  
 JOHN A. McCONE  
 WILLIAM C. McDUFFIE  
 J WALLACE MCKENZIE  
 MALCOLM McNAGHTEN  
 MRS. JAMES G. NEWCOMB  
 MRS. ARTHUR NOBLE  
 K. T. NORRIS  
 MRS. HENRY W. O'MELVENY  
 JOHN O'MELVENY  
 STUART O'MELVENY  
 MRS. CHARLES W. PADDOCK  
 MRS. BENJAMIN E. PAGE  
 JAMES R. PAGE  
 MRS. JAMES R. PAGE

I. GRAHAM PATTINSON  
 MRS. JUNE BRAUN PIKE  
 CLARENCE B. PIPER  
 MRS. WILLIAM M. PRINDLE  
 MRS. CHARLES H. PRISK  
 W. F. PRISK  
 MRS. LOUIS D. RICKETTS  
 ALDEN G. ROACH  
 MRS. HARRY W. ROBINSON  
 FREDERICK ROESER  
 ALBERT B. RUDDOCK  
 MRS. ALBERT B. RUDDOCK  
 HOWARD J. SCHODER  
 MRS. RICHARD J. SCHWEPPE  
 FRANK R. SEAVER  
 KEITH SPALDING  
 MRS. KEITH SPALDING  
 SILSBY M. SPALDING  
 CHARLES F. STERN  
 DILLON STEVENS  
 W. L. STEWART, JR.  
 LEONARD G. STRATER  
 REESE H. TAYLOR  
 CHARLES H. THORNE  
 MRS. JOSEPH E. TILT  
 MRS. JOHN TREANOR  
 MRS. JOHN K. URMSTON  
 EDWARD R. VALENTINE  
 MRS. W. L. VALENTINE  
 WILLIAM W. VALENTINE  
 J. BENTON VAN NUYS  
 CHARLES B. VOORHIS  
 VICTOR VON BOROSINI  
 RICHARD R. VON HAGEN  
 MRS. THOMAS W. WARNER  
 MRS. GURDON W. WATTLES  
 A. L. WEIL  
 R. J. WIG  
 P. G. WINNETT  
 THOMAS WOLFE  
 MRS. CASEY A. WOOD  
 ARCHIBALD B. YOUNG  
 GERALD C. YOUNG

## HISTORICAL SKETCH

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

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

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

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

physics at the University of Chicago, arranged to spend a part of each year at Throop, where as Director of Physical Research, he was to develop a program of graduate work in physics.

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

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

In the same year, 1921, financial stability was assured by Mr. Arthur H. Fleming's agreement to give the California Institute his personal fortune as permanent endowment. In November of that year, the Board of Trustees formulated in the "Educational Policies of the Institute" an explicit statement of the principles which were to govern the present conduct of the Institute and its future development. Recognition by the Southern California community of the value of these aims has resulted in a steady growth of the physical facilities and has made possible the addition of work in geology, paleontology, geophysics, biology, biophysics, biochemistry, aeronautics, astrophysics, meteorology and industrial relations. In 1923 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 geophysics, with a minimum of two years; and the degree of Doctor of Philosophy. In all the graduate work, research is strongly emphasized, not only because of its importance in contributing to the advancement of science and thus to the intellectual and material welfare of mankind, but also because research activities add vitality to the educational work of the Institute. Graduate students constitute a comparatively large proportion (about forty per cent) of the total student body. Engaged themselves on research problems of varying degrees of complexity, and taught by faculty members who are also actively engaged in research, they contribute materially to the general atmosphere of intellectual curiosity and creative activity which is engendered on the Institute campus.

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

## BUILDINGS AND FACILITIES

**THROOP HALL, 1910.**

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

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

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

**CULBERTSON HALL, 1922.**

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

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

The gift of the late Dr. Norman Bridge.

**HIGH-POTENTIAL RESEARCH LABORATORY, 1923.**

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

**CHEMICAL ENGINEERING LABORATORY AND HEATING PLANT, 1926.**

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

**DABNEY HALL OF THE HUMANITIES, 1928.**

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

**SEISMOLOGICAL RESEARCH LABORATORY (of the Division of the Geological Sciences), 1928.****DANIEL GUGGENHEIM AERONAUTICAL LABORATORY, 1929.**

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

**WILLIAM G. KERCKHOFF LABORATORIES OF THE BIOLOGICAL SCIENCES:**

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

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

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

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

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

ATHENAEUM, 1930.

The gift of the late Mr. and Mrs. Allan C. Balch, of Los Angeles.

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

STUDENT HOUSES, 1931.

Blacker House.

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

Dabney House.

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

Fleming House.

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

Ricketts House.

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

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.

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

#### LIBRARIES

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

# STUDY AND RESEARCH AT THE CALIFORNIA INSTITUTE

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## 1. THE SCIENCES

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### ASTRONOMY

The Rockefeller Boards provided in 1928 for the construction by the Institute of an astronomical observatory on Palomar Mountain, equipped with a 200-inch reflecting telescope, 48-inch and 18-inch Schmidt wide-angle telescopes and other auxiliary instruments, together with an astrophysical laboratory, an optical shop and a machine shop on the Institute campus. The purpose of this observatory is to supplement, not to duplicate, the facilities of the Mount Wilson Observatory of the Carnegie Institution of Washington, which, while not a part of the California Institute, is located even closer to Pasadena than is Palomar Mountain. The increased light-collecting power of the 200-inch telescope will permit further studies of the size, structure and motion of the galactic system; of the distance, motion, radiation and evolution of the stars; of the spectra of the brighter stars under very high dispersion; of the distance, motion and nature of remote nebulae; and of many phenomena bearing directly on the constitution of matter. The 48-inch Schmidt will make possible a systematic survey of the sky as well as an attack upon such problems as the structure of clusters of nebulae, the luminosity function of nebulae and absolutely faint stellar systems, intergalactic matter, nebulae as gravitational lenses, supernovae, and the stellar content of the milky way. These two unique instruments will supplement each other as well as the telescopes on Mount Wilson; the one will reach still further into space in a given direction, while the other will photograph upon a single plate an entire cluster of nebulae in its full geometrical and large scale material content.

The Mount Wilson and Palomar Observatories constitute a unique and unprecedented concentration of scientific facilities in astronomy. Outstanding scientific talent is present both in the field of astronomy and in the neighboring fields of physics, mathematics, and chemistry. Hence extraordinary opportunities for accomplishment exist. For some time the California Institute of Technology and the Carnegie Institution of Washington have recognized the advantages implicit in the creation of a great astronomical center in which a unitary scientific program would be pursued under highly favorable circumstances, that would attract distinguished investigators to collaborate with the staff of the observatories in scientific matters, and that would draw young men of great ability to graduate studies where they might enjoy the inspiration of leading minds, and familiarize themselves with powerful tools of exploration. For this purpose a plan for the unified operation of the two observatories, in which they will function as a single scientific organization under the direc-

tion of Dr. I. S. Bowen, has been approved by the Trustees of the two institutions. Under this plan all the equipment and facilities of both observatories are made available for the astronomical investigations of the staff members of the combined observatories and the unified research program is paralleled by undergraduate and graduate training in astronomy and astrophysics in which members of the Staff of the Mount Wilson Observatory will join with the Institute Faculty.

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

### BIOLOGICAL SCIENCES

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

ories 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 the late Mr. and Mrs. E. W. Crellin.

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

With the Gates and Crellin Laboratories is associated the Chemical Engi-

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

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

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

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

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

The supervision of the research work of graduate students is distributed among the members of the staff of the Division of Chemistry and Chemical Engineering. Some of the many fields in which researches are being actively prosecuted are listed on page 195-196.

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 meas-

urement 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 five members, devoting themselves to different phases of the subject. Instruction is given in seismic, gravity, electrical, magnetic and other methods of prospecting. The design and construction of geophysical instruments in the shop of the 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 161 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 in-

dependent 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. 134-136; additional requirements for mathematics are found on p. 137. 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. 237-238. A candidacy course requirement may be passed by examination if the student is sufficiently prepared.

As stated on p. 139, the student must submit his thesis before May first of the year in which his degree is to be granted. In addition, he must be prepared to present the work of his thesis in person to the staff in one of the research seminars before April 16 of the same year.

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

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

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

## PHYSICS

### UNDERGRADUATE WORK

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

Since the best education is that which comes from the contact of youth with creative and resourceful minds, the members of the staff of the Norman Bridge Laboratory of Physics have been from the beginning productive physicists rather than merely teachers. The instruction is done by the small group method, twenty to a section, save for one rather elaborate demonstration lecture each week throughout the freshman and sophomore years. All the mem-

bers 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 137.) 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.

## 2. ENGINEERING

### UNDERGRADUATE WORK

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

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

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

### GRADUATE STUDY AND RESEARCH IN ENGINEERING

Graduate study and research opportunities in Engineering are available in the fields of aeronautical, civil, mechanical, electrical, and chemical engineer-

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

## 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.  
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 tun-

nels 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 atmospheric pressure and is used for studying the aerodynamic problems of modern aircraft and guided missiles.

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

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

The graduate courses may be taken either by students who have completed a four-year course at the Institute, or by students from other colleges who have had substantially the same preparation. The field of aeronautics is so many-sided that a student who has completed the undergraduate course either in engineering or in 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. 84-85)

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## 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 work; the location, design, construction and operation of railroads and highways; the study of properties and economical utilization of construction materials; and the study of soil mechanics as related to foundations, earth dams, stability of slopes, and other earthwork problems.

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

*The High Voltage Building* and the million-volt power frequency transformer were provided by the Southern California Edison Company. The million-volt transformer, which was designed by Professor R. W. Sorensen, has a normal rating of 1,000 kilovolt amperes but is capable of supplying several times the rated load at the above potential, with one end of the winding grounded. A 2,000,000 volt surge generator which can be conveniently used as two 1,000,000 volt surge generators and a high current surge generator supplemented by cathode-ray oscillographs and other apparatus used in the study of electric surges (artificial lightning) and its effect upon electrical apparatus provides ample facility for the study of high voltage transients. 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 Professor G. D. McCann.

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

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 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 re-

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

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

In advanced work the Mechanical Engineering Department provides facilities in four general areas: (1) hydrodynamics, (2) design, mechanics, and dynamics, (3) physical metallurgy and mechanics of materials, and (4) thermodynamics and heat power. In hydrodynamics extensive facilities are available as described under a separate section of the catalogue. A Dynamics Laboratory is provided for the study of problems in vibration, transient phenomena in mechanical systems, and experimental stress analysis by means of special mechanical and electronic equipment. Instruction and research in physical metallurgy is made possible by a well equipped metallography lab-

oratory 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 94.) This laboratory is built around an analog computer which merges the various interests in applied mechanics, applied mathematics, and electrical engineering in the solution of problems. The computer is valuable not only for solution of specific research problems but also as a field of research in itself in the development of new elements to extend the usefulness of the computer to more general mathematical analysis.

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

### 3. THE HUMANITIES

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

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

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

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

#### THE INDUSTRIAL RELATIONS SECTION

The Industrial Relations Section, which was established in 1939, is supported by special contributions from a substantial number of individuals, companies, and labor unions.

The program of the Industrial Relations Section includes four types of activities: (1) it provides an introductory course in industrial relations for seniors and graduate students and specialized courses without academic credit for representatives of companies and unions; (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) for the use of students and representatives of companies and unions, it maintains a comprehensive reference library in its quarters in Culbertson Hall on the campus. As a result of these varied activities, the Section publishes a series of bulletins and circulars.

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

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

*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 Christian Fellowship Group, Christian Science Group, Episcopal Group, and the Newman Club are organized on the basis of religious interests. The Walrus Club comprises a group interested in the discussion of questions of current national and international importance.

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

All students are eligible to apply for membership in the Student Workshop organization. These applications are acted upon by a governing committee of students, and this committee is charged with the responsibility of admitting

only those who can demonstrate their competence in the operation of the machines in the shop. Yearly dues are collected to provide for maintenance and replacement.

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

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

## PART TWO

### DETAILED INFORMATION FOR PRESENT AND PROSPECTIVE UNDERGRADUATE AND GRADUATE STUDENTS

- Admission to the Freshman Class (page 105)
- Admission to Upper Classes by Transfer (page 108)
- Special Admission Arrangements for Veterans (page 110)
- Registration Regulations (page 112)
- Scholastic Grading and Requirements (page 113)
- Student Health and Physical Education (page 117)
- Expenses (page 119)
- Scholarships (page 122)
- Student Aid (page 124)
- Prizes (page 126)
- General Regulations for Graduate Students (page 127)
- Regulations for the Degree of Master of Science (page 129)
- Regulations for the Engineer's Degree (page 131)
- Regulations for the Degree of Doctor of Philosophy (page 132)
- Graduate Scholarships, Fellowships, and Assistantships (page 145)

## 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, chemistry 1 unit. All entrance deficiencies must be made up before registration for the second year.

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

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

*ENTRANCE EXAMINATIONS.* In addition to the above credentials, all applicants for admission to the freshman class are required to take 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 23, 1949, entrance examinations will be held at the Institute on March 5. (English and chemistry) and March 12 (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 1949.

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.

The Institute maintains examination centers in Boston, Chicago, New York, Pasadena, Philadelphia, San Diego and San Francisco. Applicants living in or near one of these cities are expected to take the examinations at the appropriate center. Those who live at a distance from any of these points may, upon request, be allowed to take the entrance examinations under the super-

vision 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, 1949.

Applicants living outside the continental limits of the United States must submit their credentials by November 1, 1948.

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 108. 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 117. 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 105-107 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 105-107.) 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 115.

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 152-164) or make up their deficiencies as soon as possible after admission (see Special Arrangements for Veterans, page 110). In case there is a question regarding either the quality or the extent of the previous work, examinations in the subjects concerned may be arranged.

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

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

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

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

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

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

The schedule for the three-hour examinations for admission to upper classes September 22, 1949, is as follows:

Mathematics	.....9:00 a.m.....	June 3, 1949
English	.....1:00 p.m.....	June 3, 1949
Physics	.....9:00 a.m.....	June 4, 1949
Chemistry	.....1:00 p.m.....	June 4, 1949

No other examinations for admission to upper classes in 1949 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 113-116. 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 115.

Physical examinations and vaccination are required as in the case of students entering the freshman class. See page 117. 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 108.) 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 prerequisite

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.)

## REGISTRATION REGULATIONS

<i>Registration Dates</i>	<i>Fees Payable</i>	<i>Instruction Begins</i>
Freshmen and Transfer Students.....	Sept. 22, 1949	Sept. 27, 1949
Upperclassmen and Graduate Students....	Sept. 26, 1949	Sept. 27, 1949

### *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 four dollars is assessed for failure to register on the scheduled date, and a similar fee is assessed for failure to pay fees within the specified dates.

### *Change of Registration*

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

### *General Regulations*

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

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

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

### *Auditing of Courses*

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

# SCHOLASTIC GRADING AND REQUIREMENTS

## SCHOLASTIC GRADING

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

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

In 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.

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

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

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

*Ineligibility for registration.* Any undergraduate student or Master's candidate 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, except that after a student has completed at least three full terms of residence at the Institute and has been registered for his senior or Master's 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 senior year is subject to this requirement during his 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 described below.)

(c) An undergraduate student is ineligible to register for any term if he

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

\*\*Students who take less than 45 units in any term or less than 135 units in an academic year must make at least 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.

fails during the preceding term to remove a deficiency in physical education from an earlier term.

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

*Deficiency.* Any freshman, sophomore, or new transfer student who fails to receive at least 72 credits during any one term will be required to report to the Dean before registering and may be requested to withdraw from all 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.† (See note at head of each option in schedules of undergraduate courses, for special departmental applications of this rule.) 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.

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

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

*Honor standing.* At the close of each academic year the Committee on

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\*The curriculum of the Institute is organized under six divisions, as follows:

Division of Physics, Astronomy, 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.

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

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

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

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

*Excess or 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.* Leave of absence involving non-registration for one or more terms must be sought by written petition to the Registration Committee, and the student must indicate the length of time, and the reasons, for which absence is requested. In case of brief absences from any given exercise, arrangements must be made with the instructor in charge.

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

#### CANDIDACY FOR THE BACHELOR'S DEGREE

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

# STUDENT HEALTH AND PHYSICAL EDUCATION

## PHYSICAL EDUCATION

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

During 1948-49, men over 24 years of age by the opening date of the academic year, and Juniors and Seniors who have had a year of active service in any branch of the Armed Forces, (exclusive of the time spent in educational programs) may be excused from the requirement of physical education by action of the Physical Education Committee. It is the responsibility of students who wish to be excused and who are eligible under 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 applicant's own choosing. Payment for this service is the applicant's responsibility. Vaccination against smallpox is required at the time of the examination. Applicants who refuse to be vaccinated will be denied admission.

### B. HEALTH FEE

Each undergraduate and graduate student will pay a health fee of (\$10.00) ten dollars per academic year, \$4.00 of which is paid toward the Emergency Hospitalization Fund.

### C. SERVICES OF THE INSTITUTE PHYSICIAN

The services of a physician are available on the campus at all times for any needed medical service. Under the supervision of the Director of Student Health essential medical attendance may be secured at any time. Regular office hours are kept by a physician and by registered nurses. The Health Center on the campus is conducted for the benefit primarily of the students; a limited amount of medical service is available also for the faculty, the families of students, the employees of the Institute and their families.

### 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 infirmity 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. It is equipped with medical facilities and will provide many services which will reduce the number of cases requiring outside hospitalization.

## NOTICE

*Commencing in September, 1949, the tuition charge for all students who enroll for the normal number of units will be \$600 for the academic year of three terms. The schedule of expenses on pages 119-120 is for the academic year of 1948-1949; hence, for the year 1949-1950, all totals involving tuition should be increased by \$100.*

*Tuition fees for programs involving less than the normal number of units, as given on page 120, will be increased in 1949-1950 by 20 per cent.*

*Tuition for the Jet Propulsion option, offered in the graduate school of aeronautics, will be \$600 plus the special fee of \$100, or a total of \$700.*

## EXPENSES

The following is a list of student expenses at the California Institute of Technology for the academic year 1948-49, 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 \$65 should be allowed for books and supplies for the full year.

<i>Date Due</i>	<i>Fee</i>	<i>Amount</i>	
Upon notification of admission .....	Registration Fee .....	\$ 10.00 <sup>1</sup>	
At time contract for Student House reservation is signed, or at time of registration for off-campus students...	General Deposit .....	25.00 <sup>2</sup>	
Sept. 23, 1948: Freshman and transfer students .....	Tuition, 1st term .....	168.00	
Sept. 27, 1948: All others .....			1st installment of Board and Room
			21 meals per week .....
	15 meals per week .....	104.10 <sup>3</sup>	
<i>First Term Incidental Fees for undergraduates:</i>			
	Associated Student Body Dues .....	3.75 <sup>4</sup>	
	Subscription to California Tech for 1948-9 .....	1.25	
	Health and Hospitalization Fee .....	10.00 <sup>5</sup>	
	Total .....	15.00	
	Locker Rent, 1st Term .....	1.00 <sup>6</sup>	
	Parking Fee, 1st Term .....	1.50 <sup>6</sup>	
	Student House Dues, 1st Term .....	4.00	
<i>First Term Incidental Fees for graduates:</i>			
	Health and Hospitalization Fee .....	10.00 <sup>5</sup>	
November 8, 1948 .....	2nd installment of Board and Room		
	21 meals per week .....	102.76 <sup>3</sup>	
	15 meals per week .....	99.40 <sup>3</sup>	
January 3, 1949 .....	Tuition, 2nd Term .....	166.00	
	3rd installment of Board and Room		
	21 meals per week .....	89.88 <sup>3</sup>	
	15 meals per week .....	86.75 <sup>3</sup>	
<i>Second Term Incidental Fees for undergraduates:</i>			
	Associated Student Body dues .....	5.00 <sup>4</sup>	
	Locker Rent, 2nd Term .....	1.00 <sup>6</sup>	
	Parking Fee, 2nd Term .....	1.50	
	Student House Dues, 2nd Term .....	4.00	

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

(2) \$15 required from veterans inasmuch as laboratory breakage is reimbursed under Public Laws 16 and 346.

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

(4) If applicable, \$0.20 federal tax on admissions is added to Student Body dues per term. Not chargeable under Public Laws 16 and 346, but collectible from all students, veteran or non-veteran.

(5) Required of all students (veteran and non-veteran).

(6) Optional.

February 7, 1949	4th installment of Board and Room		
	21 meals per week	.....	110.04 <sup>3</sup>
	15 meals per week	.....	104.10 <sup>3</sup>
March 28, 1949	Tuition, 3rd Term	.....	166.00
	5th installment of Board and Room		
	21 meals per week	.....	89.88 <sup>3</sup>
	15 meals per week	.....	86.75 <sup>3</sup>
	<i>Third Term Incidental Fees for undergraduates:</i>		
	Associated Student Body Dues	.....	5.00 <sup>4</sup>
	Locker Rent, 3rd Term	.....	1.00 <sup>6</sup>
	Parking Fee, 3rd Term	.....	1.50 <sup>6</sup>
	Student House Dues, 3rd Term	.....	4.00
May 2, 1949	6th installment of Board and Room		
	21 meals per week	.....	110.04
	15 meals per week	.....	104.10

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

A. Without Board and Room		Tuition	.....	500.00	
		Health Fee	.....	10.00	
		Student Body Dues	....	15.00	525.00
B. With Board and Room					
21-meal plan		As under (A)	.....	525.00	
		Board and Room	.....	610.82	
		Student House Dues	....	12.00	1,148.42
15-meal plan		As under (A)	.....	525.00	
		Board and Room	.....	585.20	
		Student House Dues	....	12.00	1,122.80

Tuition Fees for fewer than normal number of units:

Over 32 units	.....	Full Tuition <sup>7</sup>
32 to 25 units	.....	\$125 per term
24 to 10 units	.....	\$5 per unit per term
Minimum per term	.....	\$50.00

**WITHDRAWALS:** Students withdrawing from the Institute during the first three weeks of a term, for reasons deemed satisfactory to the Institute, are entitled to a refund of tuition fees paid, less a reduction of 20% and a pro rata charge for time in attendance.<sup>8</sup>

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

(2) \$15 required from veterans inasmuch as laboratory breakage is reimbursed under Public Laws 16 and 346.

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

(4) If applicable, \$0.20 federal tax on admissions is added to Student Body dues per term. This tax is not chargeable under Public Laws 16 and 346, but collectible from all students, veteran or non-veteran.

(5) Required of all students (veteran and non-veteran).

(6) Optional.

(7) Although the Institute charges full tuition for over 32 units, the Veterans Administration requires a minimum of 36 units for full subsistence allotments.

(8) Pro rata refunds are allowed students who are drafted (not volunteers) at any time in the term provided the period in attendance is insufficient to entitle student to receive final grades.

**EMERGENCY HOSPITALIZATION FEE**

The emergency hospitalization fee, payable by each student at the beginning of each year, provides a certain amount of hospitalization and medical and surgical care in accordance with regulations prescribed by the Board of Trustees and administered by the Institute Physician and the Faculty Committee on Student Health (see pages 117-118).

**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.

**TELEPHONE FEE**

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

**GENERAL DEPOSIT**

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

**STUDENT HOUSES**

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

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

**SPECIAL FEES**

Students in the jet-propulsion option of Aeronautical Engineering pay \$100 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 112) 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, STUDENT AID, AND PRIZES\*

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### SCHOLARSHIPS

**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 Committee on Honors and Awards from the candidates who have stood sufficiently high on the entrance examinations and have otherwise satisfied the entrance requirements of the Institute.

The scholarships are awarded to the extent of available funds where financial need is demonstrated. Awards are made on the basis of all the information available in regard to the applicants—the results of their examinations, their high school records and recommendations, the statements submitted as to their student activities and outside interests, and the result of personal interviews where these are possible. Applications for scholarships should be made on a form which may be obtained by writing to the Registrar or calling at the office. Scholarship forms should be submitted at the same time as is the entrance application.\*\* Funds for these scholarships are provided in large part by the income from the various scholarship funds described below and by other gifts for scholarships.

Recipients of these scholarships are expected to maintain a reasonably good standing in their academic work during the year for which the scholarship is granted. If the recipient fails to maintain such an academic standing, or if, in the opinion of the Committee, the recipient in any other way has failed to justify the confidence placed in him, the Committee on Honors and Awards may cancel the scholarship for the balance of the academic year.

**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.

**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 and who demonstrate need for financial assistance. Application is made on a form ob-

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\*For further information on Graduate Scholarships and Fellowships see page 145.

tainable in the Registrar's Office and must be submitted during the first week of the fall term.\*\*

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

The second, the Walter Humphry Scholarship, is to be awarded preferably to a well-qualified candidate from the state of Iowa. If there is no such candidate, the Institute may award the scholarship elsewhere.

**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 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.

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\*\*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.

**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.

**Thomas Hunt Morgan Scholarship:** The Thomas Hunt Morgan Scholarship is named in honor of the famous geneticist and Nobel Laureate who established the Division of Biology at the California Institute of Technology. It is a full-tuition scholarship, that may be awarded to an entering freshman who indicates an interest in Biology by writing on the Biology option of the entrance examinations. The recipient is under no obligation to elect the Biology option during his student career at the Institute.

**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.

## STUDENT AID

### LOAN FUNDS

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

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

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

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

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

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

The Roy W. Gray Fund.

The James R. Page Loan Fund.

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

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

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

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

#### STUDENT EMPLOYMENT

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

#### PLACEMENT SERVICE

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

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

## PRIZES

### THE CONGER PEACE PRIZE

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

### THE FREDERIC W. HINRICHS, JR., MEMORIAL AWARD

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

### THE MARY A. EARL MCKINNEY PRIZE IN ENGLISH

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

The contest for this prize is designed to cultivate proficiency in English. Eligibility is limited to the junior class. Each year the department of English announces the subject for an essay to be based on certain prescribed books. The several students submitting the best essays engage in a final discussion before a group of judges, who award a first and second prize, each consisting of a trophy and a sum of money. The awards are announced at Commencement.

# INFORMATION AND REGULATIONS FOR THE GUIDANCE OF GRADUATE STUDENTS

## A. GENERAL REGULATIONS

### I. REQUIREMENTS FOR ADMISSION TO GRADUATE STANDING

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

2. To be admitted to graduate standing an applicant must in general have received a bachelor's degree representing the completion of an undergraduate course in science or engineering substantially equivalent to one of 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 page 145). For requirements in regard to physical examination, see page 117.

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

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

### II. GRADUATE RESIDENCE

One term of residence shall consist of one term's work of not 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. See pages 130, 131, 134 for special requirements for residence.

Graduate students are encouraged to continue their research during the whole or a part of the summer, but in order that such work may count in fulfillment 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 121 for special fees in jet propulsion) 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 \$10.00 per academic year to assist in defraying expenses for medical care and emergency hospitalization. (See page 117.) 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 145-147 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 165-175) as well as in the schedule of the four-year course in science or in engineering, except that, in the case of students transferring from other institutions, equivalents will be accepted in subjects in which the student shows by examination or otherwise that he is proficient, and except in so far as substitutions may be approved by special vote of the committee in charge.

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

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

A student before entering upon work for the degree of Master of Science should, after consultation with the department concerned, submit a plan of study (together with his previous record if he 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 112 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 an engineer's degree, and holding a position as graduate assistant, the actual number of hours per week required by his teaching or research services shall be deducted from the total number of units for which he might otherwise register. This number of units shall be determined by his Department.

### 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. A student will not, in general, be admitted to graduate standing until he has completed work equivalent to that required for the bachelor's degree.

2. Scholastic requirements for undergraduate students (see page 114) also apply to students working toward the master's degree. In meeting the graduation requirements as stated on page 115, the following rule will apply for master's degree candidates: Only those courses shown on the candidacy blank and approved by the department representative shall be counted in figuring the grade-point average. Changes on the candidacy blank which are not initialed by the proper authority are not to be recognized. No course which appears on the candidacy blank and for which the candidate is registered may be removed after the last date for dropping courses as listed in the catalogue.

3. Candidates for the degree of Master of Science who have completed the senior year at the Institute are subject to the same regulations as are seniors, as listed on page 114.

4. Candidates for the degree of Master of Science who have completed their undergraduate work at other institutions are subject to the scholastic regulations applying to new transfer students as listed on page 114.

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

### IV. THESIS

In the case of a required thesis two final copies must be filed with the Division concerned ten days before the degree is to be conferred. In the Department of Mathematics, a complete first draft of a thesis presented in partial fulfillment of the requirements for the degree of Master of Science must be submitted to the supervising instructor not later than six weeks before the date on which the degree is to be conferred. Instructions for the preparation of theses may be obtained from the office of the Dean of Graduate Studies.

### C. REGULATIONS CONCERNING WORK FOR THE ENGINEER'S DEGREE

1. The work for an engineer's degree must consist of advanced studies and research in the field appropriate to the degree desired. It must conform to the special requirements established for the degree desired and should be planned in consultation with the members of the faculty concerned. Advanced studies are defined on page 134. Regulations governing registration will be found on page 133.

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 an engineer's degree. Of these, at least the last three terms must be at the California Institute. It must be understood that these are minimum requirements, and students must often count on spending a somewhat longer time in graduate work.

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

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, each student is required to submit to the Dean of Graduate Studies two copies of a satisfactory individual thesis describing his research, including a one-page digest or summary of the main results obtained. In form, the thesis must satisfy the requirements for theses for the degree of Doctor of Philosophy. (See page 136).

The use of "classified" research as thesis material for any degree will not

be permitted. Exceptions to this rule can be made only under special circumstances, and then only when approval is given by the Dean of Graduate Studies before the research is undertaken.

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 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 45 units and in most cases at least 70 units of this work shall be for research and thesis, the exact number of units to be left to the discretion of the Supervising Committee appointed by the Dean of Graduate Studies. The courses shall be closely related to Mechanical Engineering, and the specific courses to be taken and passed with a grade of "C" or better by each candidate shall be determined by the Supervising Committee, but must include:

ME 125 abc	Engineering Laboratory
and one of the following:	
EE 226 abc	Engineering Mathematical Physics
Ph 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 174.

### *Special Requirements for the Degree of Electrical Engineer*

See page 137 and page 138.

## 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 ex-

pressing himself clearly and forcefully both orally and in written language, and he must have a good reading knowledge of French and German\*.

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

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

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

With the approval of the Committee on Graduate Study, students are admitted to graduate standing by the department in which they choose their major work toward the doctor's degree. In some cases, applicants for the doctor's degree may be required to register for the master's degree first. The master's degree, however, is not a general prerequisite for the doctor's degree. Students who have received the master's degree and wish to pursue further studies leading towards the doctor's degree must file a new application for admission to graduate standing to work 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. At the first meeting of each class he should furnish the instructor with a regular assignment card for the course, obtained on registration. *The student himself is charged with the responsibility of making certain that all grades to which he is entitled have been recorded.*

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

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

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

6. Graduate students studying for the doctor's degree who are devoting their whole time to their studies will be allowed to register for not more than 60 units in any one term. When admitted for work leading to the doctor's degree, Graduate Assistants with duties in either teaching or research will be allowed to register for not more than 45 units.

#### IV. GRADES IN GRADUATE COURSES

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

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

3. The following system of grades is used to indicate class standing in graduate courses: "A" excellent, "B" good, "C" satisfactory, "D" poor, "E" conditioned, "F" failed. In addition to these grades, which are to be interpreted as having the same significance as for undergraduate courses, (See page 113) the grade "P", which denotes passed, may be used at the discretion of the instructor, in the case of seminar, research, or other work which does not lend itself to more specific grading.

#### V. GENERAL REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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

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

Advanced studies include courses with numbers of 90 or over. However, no graduate residence credit is given for such courses when they are required in the undergraduate option corresponding to the student's major field. No residence credit is given for courses with numbers under 90 when they constitute prerequisites to the student's minor subject courses. Credit in amount to be determined by the Committee on Graduate Study may be allowed for other courses with numbers under 90 when they are outside the student's major field.

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 fulfillment 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 fulfillment of residence requirements. The number of units to be credited for such work shall be determined by the Dean of Graduate Studies in consultation with the Chairman of the Division in which the student is carrying his major work; and a recommendation as to the proportion of the full tuition to be paid for such work shall be made by the Dean to the Business Manager.

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

3. *Admission to Candidacy:* Any student admitted to work for the doctor's degree who has been in residence one term\* or more, who has satisfied the several departments concerned by written or oral examination or otherwise that he has a comprehensive grasp of his major and minor subjects as well as of subjects fundamental to them, who has satisfied the department of modern languages that he can read with reasonable facility scientific literature in German and one other approved language (see page 132), who has shown ability in carrying on research and whose research subject has been approved by the Chairman of the Division concerned, and whose program of study has been approved by both his major and minor departments may, on recommendation of the Chairman of the Division in which he is working, be admitted by the Committee on Graduate Study to candidacy for the degree of Doctor of Philosophy. Members of the permanent Institute staff of rank higher than that of Assistant Professor are not admitted to candidacy for a higher degree. For special departmental regulations concerning admission to candidacy, see Section VI.

A regular form, to be obtained from the Dean of Graduate Studies, is provided for making application for admission to candidacy. Such admission to candidacy must be obtained before the close of the first term of the year in 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 three times in the year, these times to be announced by the Registrar's Office. In place of these examinations, students may take the advanced undergraduate examinations offered at the end of each term. Students who have credit for courses

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

in languages taken at the Institute and who have a grade above average may be exempted from further requirements after consultation with the language department.

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

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

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

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. For regulations regarding use of "classified" material, see page 131.

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

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

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

VI. SPECIAL REQUIREMENTS FOR THE DOCTOR'S DEGREE

In agreement with the general requirements for the doctor's degree adopted by the Committee on Graduate Study, as set forth in Section V (page 134), the various divisions and departments of the Institute have adopted the following supplementary regulations.

A. DIVISION OF PHYSICS, ASTRONOMY, 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 C or better:

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

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

Ay 101 abc	Astrophysics I
and/or	
Ay 102 abc	Astrophysics II
with the balance from:	
Ph 100 abc	Methods of Mathematical Physics
Ph 103 abc	Analytical Mechanics
Ph 105 ab	Optics
Ph 107	Spectroscopy
Ph 109 abc	Nuclear Physics
Ph 113 ab	Principles of Quantum Mechanics

1c. *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 ab	Modern Algebra
Ma 114 ab	Mathematical Analysis
Ma 256 ab	Modern Differential Geometry
Ma 102 ab	Introduction to Higher Geometry

and one of the following subjects:

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

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

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

EE 226 abc	Engineering Mathematical Physics
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To be recommended for candidacy the applicant must pass the following subject with a grade C or better:

Ph 101 abc Electricity and Magnetism

and one of the following subjects:

Ph 103 abc Analytical Mechanics

AM 1 abcd Applied Mechanics

and one of the following subjects:

Ph 6 abc Introduction to Mathematical Physics and  
Differential Equations

AM 115 abc Engineering Mathematics

Ma 8 abc Methods of Advanced Calculus

and one of the following subjects:

EE 120 abc Advanced Electric Power System Analysis

EE 121 abc Alternating Current Laboratory

EE 158 abc Circuit Analysis.

To be recommended for the degree of Electrical Engineer the applicant must pass with a grade of C or better (with the exception of Ph 101) the same subject requirements as listed above for the doctor's 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 fulfillment 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

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

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

To be recommended for candidacy for the doctor's degree in chemistry the applicant must give satisfactory evidence of his proficiency, at a graduate level, in that field of chemistry elected as his primary field of interest and approved by the Division of Chemistry and Chemical Engineering. In general the applicant will be required to pass an oral examination and to present evidence of his industry and ability in research, and of his power to present his results in clear, concise language and with discrimination as to what is essential in scientific reports.

A student admitted to work for the Ph.D. degree who fails to be admitted to candidacy by the end of his fifth term of residence at the Institute will not

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\*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.

be allowed to register in a subsequent academic year except by special permission of the Division of Chemistry and Chemical Engineering.

1b. *Chemical Engineering.* The requirements in chemical engineering are the same as those in chemistry except that the placement examinations will be required in the fields of physical chemistry, either inorganic or organic chemistry, engineering thermodynamics of one-component systems, and the unit operations of chemical engineering.

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

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

4. 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 related to his minor subject.

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

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:

AE 257 abc	Engineering Mathematical Principles
or	
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. A student cannot become eligible for admission to candidacy for the doctorate in the Division of the Geological Sciences until after completion at the Institute of 3 terms of graduate residence. The applicant may or may not be given either a qualifying oral examination or a written one or both at the discretion of the Division.

2. Doctorate research may not be undertaken until admission to candidacy for the doctorate has been approved by the Division.

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

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

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

4. Although the requirements for the degree of Doctor of Philosophy may in exceptional cases be fulfilled in three years of graduate work, a total of four years will normally be needed. Students transferring to this Division from other institutions are eligible for admission to candidacy after one year of graduate work and must pursue graduate study in residence at least one year after admission to candidacy.

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

6. The candidate must prepare a paper for publication embodying the results of his major or minor thesis work in whole or in part. Approval of the Division on the choice of subject (particularly as between major and

minor) and on the scope of the paper must be obtained prior to preparation. This paper must either be accepted by an agency of publication or be in form such that the examining committee believes that it will be published. This paper, the major thesis, and the minor thesis must be completed and in final form for submission to the Division Secretary by April 20.

#### E. DIVISION OF BIOLOGY

1. *Admission.* 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 post-war 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) Bioorganic 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 his 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 3) 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 required 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. Three copies of the candidate's thesis, one of which will be

retained by the Division, must be submitted at least two weeks before the date of the final examination. The Examining Committee will consist of the instructors in charge of the major and minor work and such other individuals as may be designated by the chairman of the division.

## F. OPPORTUNITIES FOR GRADUATE AND SCIENTIFIC WORK AT THE INSTITUTE

### I. GRADUATE FELLOWSHIPS, SCHOLARSHIPS, AND ASSISTANTSHIPS

The Institute offers in each of its divisions a number of fellowships, scholarships, and graduate assistantships. In general, scholarships carry tuition grants; assistantships, cash stipends; and fellowships often provide both tuition and cash grants or stipends.

Provision is made so that appointees may secure for themselves board in the Athenaeum (see page 80), 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 satisfactory (see page 127) are eligible to apply for graduate assistantships, scholarships, and fellowships. In the award of such appointments preferred consideration will be given to students who have been accepted as candidates for the degree of Doctor of Philosophy.

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

#### (A). Graduate Assistantships

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

#### (B). Graduate Scholarships and Fellowships

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

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

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

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

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

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

7. Meriden Hunt Bennett Fellowships: These fellowships for graduate students are granted from the Meriden Hunt Bennett Fund as stated on page 123.

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.

#### (C). Special Fellowship and Research Funds

1. A considerable group of governmental units, industrial organizations, and private individuals have contributed funds for the support of Fellows and Assistants engaged in fundamental researches related to their interests and activities. These include Abbot Laboratories, Allied Chemical and Dye Corporation, American Cancer Society, American Petroleum Institute, California Ship Building Corporation, Carbide and Carbon Chemicals Corporation, Childs Frick Corporation, Cole Electric Company, Consolidated Vultee Aircraft Corporation, Corn Industries Research Foundation, Douglas Aircraft Company, Inc., E. I. du Pont de Nemours and Company, Eastman Kodak Company, John G. Ellis, Essick Manufacturing Company, Ethyl Corporation, Frasch Foundation, Dr. Harriet Allen Heath, Kelman Electric and Manufacturing Company, Lane Publishing, Eli Lilly and Company, Loomis Institute for Scientific Research, Inc., Lummus Company, Mr. and Mrs. F. S. Markham, John and Mary L. Markle Foundation, Merck and Company, Charles E. Merrill, National Advisory Committee for Aeronautics, Nutrition Foundation,

Inc., Pioneer Hi-Bred Corn Company, Polymerization Process Corporation, Proctor and Gamble Company, Purdue University Corn Research Fund, Research Corporation, Shell Fellowship Committee, Socony-Vacuum Oil Company, Southern California Edison Company, Standard Oil Company of California, Stanolind Oil and Gas Company, State of California, Sugar Research Foundation, 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 Rubber Company, Westinghouse Educational Foundation.

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

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

## II. 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."

### 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.

## PART THREE

### COURSE SCHEDULES AND SUBJECTS OF INSTRUCTION

#### SCHEDULES OF THE UNDERGRADUATE COURSES

- First Year, All Options (page 152)
- Astronomy Option (page 153)
- Biology Option (page 154)
- Chemistry or Applied Chemistry Option (page 155)
- Civil Engineering Option (page 157)
- Electrical Engineering Option (page 158)
- Geological Sciences Option (page 159)
- Mathematics Option (page 161)
- Mechanical Engineering Option (page 162)
- Physics, Applied Physics, or Astronomy Option (page 163)

#### SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

- Aeronautics and Jet Propulsion (page 165)
- Astronomy (page 167)
- Biology (page 167)
- Chemistry (page 167)
- Chemical Engineering (page 168)
- Civil Engineering (page 169)
- Electrical Engineering (page 170)
- Geological Sciences (page 171)
- Mathematics (page 172)
- Mechanical Engineering (page 173)
- Physics (page 175)

#### SUBJECTS OF INSTRUCTION

- Aeronautics (page 176)
- Applied Mechanics (page 180)
- Astronomy (page 182)
- Biology (page 184)
- Chemistry and Chemical Engineering (page 188)
- Civil Engineering (page 197)
- Economics (page 201)
- Electrical Engineering (page 203)
- Engineering Drafting (page 208)
- English (page 209)
- Geological Sciences (page 211)
- History and Government (page 219)
- Hydraulics (page 221)
- Mathematics (page 223)
- Mechanical Engineering (page 229)
- Modern Languages—French, German, Russian (page 234)
- Philosophy, Psychology, and Sociology (page 235)
- Physics (page 236)

## 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	Electrical Engineering .....	EE
Applied Chemistry.....	ACh	English .....	En
Applied Mechanics .....	AM	Geology .....	Ge
Applied Physics.....	APh	History and Government .....	H
Assembly .....	As	Hydraulics .....	Hy
Astronomy .....	Ay	Languages .....	L
Biology .....	Bi	Mathematics .....	Ma
Chemistry .....	Ch	Mechanical Engineering .....	ME
Civil Engineering .....	CE	Philosophy .....	Pl
Drafting and Drawing .....	D	Physical Education .....	PE
Economics .....	Ec	Physics .....	Ph
		Thesis .....	Th

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

\*\*See page 117 for rule regarding excuse from physical education.

## FIRST YEAR, ALL OPTIONS

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

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

## ASTRONOMY OPTION

(For First Year See Page 152)

(For Second and Third Years see Physics Option, page 163)

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 115.

## 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 (3-0-7) .....	....	10	....
Ay 2 abc	General Astronomy (2-3-4) .....	9	9	9
Ph 12 abc	Introduction to Atomic & Nuclear Physics (3-0-6) .....	9	9	9
Ph 107	Spectroscopy (3-0-6) .....	....	....	9
Ph 108	Spectroscopy Laboratory (0-3-0) .....	....	....	3
Ma 12	Elementary Statistics (3-0-6) .....	9	....	....
L 32 abc	Elementary German (4-0-6) ** .....	10	10	10
		48	49	51

\*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	H 4	The British Empire
Pl 4	Ethics	H 7	Modern and Contemporary Germany
Pl 5	Sociology		
Pl 6	Psychology	H 8	The History of Russia
En 8	Contemporary English and European Literature	H 15	The World Since 1914
En 9	American Literature	H 16	American Foreign Relations Since 1789
En 10	Modern Drama	H 17	The Far West and the Great Plains
En 11	Literature of the Bible		
En 17	Technical Report Writing	H 18	The South: A Study in Persistence
L 5	French Literature	H 19	Modern America
L 40	German Literature	H 20	Modern France
Ec 48	Introduction to Industrial Relations		

\*\*Students who plan no Ph.D. work may substitute Ph 100 abc Methods of Mathematical Physics, or Ph 105 ab Optics, Ph 106 ab Optics Laboratory, Ch 30 Photochemistry, for L 32 abc.

## BIOLOGY OPTION

(For First Year See Page 152)

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 115.

## 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 (4-2-3) .....	9	....	....
Bi 1	Elementary Biology (3-3-3) .....	....	9	....
Bi 2	Genetics (2-4-3) .....	....	....	9
Bi 3	Plant Biology (2-6-2) .....	....	....	10
		49	49	49

## THIRD YEAR

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	Physical Chemistry (4-0-6) .....	10	10	10
Bi 5 abc	Advanced Plant Biology (3-8-2; 3-8-2; 2-4-1) .....	13	13	7
		49	49	49

## FOURTH YEAR

		9	9	9
H 5 ab	Humanities Electives (3-0-6)** .....	9	9	9
H 10	Current History (1-0-1) .....	2	2	....
Bi 14	The Constitution of the United States (1-0-1) .....	....	....	2
Bi 7 ab	Immunology (2-4-4) .....	....	....	10
Ec 2	Biochemistry (3-4-5) .....	....	12	12
Bi 11	General Economics and Economic Principles (3-0-7) .....	10	....	....
Bi 12	Histological Technique (1-3-1) .....	5	....	....
Bi 13	Histology (1-3-2) .....	....	6	....
Bi 16 abc	Mammalian Anatomy (1-3-1) .....	5	....	....
Bi 6	Animal Physiology (2-3-3) .....	8	8	8
Bi 8	Embryology (2-6-4) .....	....	12	....
	Advanced Genetics (1-6-2) .....	9	....	....
	Biology Electives† .....	....	....	9
		48	49	50

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

\*\*For the list of Humanities electives, see footnote, page 153.

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

Bio-organic Chemistry Laboratory  
Entomology (1948-49)  
Biophysics

Invertebrate and Experimental Embryology  
Marine Ecology  
Paleontology (Ge 1 b)

## CHEMISTRY OR APPLIED CHEMISTRY OPTIONS

(For First Year see page 152)

Any student of the Chemistry or Applied Chemistry Option whose grade point average (credits divided by units) in the required chemistry subjects of any year is less 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 (4-2-3) .....	9	.....	.....
Bi 1	Elementary Biology (3-3-3) .....	.....	9	.....
Bi 2	Genetics (2-4-3) .....	.....	.....	9
or				
Ay 1	Introduction to Astronomy (3-1-5) .....	.....	.....	9
		49	49	49

## THIRD YEAR

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

## CHEMISTRY OPTION

## FOURTH YEAR

		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	Surface and Colloid Chemistry (3-0-5) .....	.....	.....	8
Ch 16	Instrumental Analysis (0-6-2) .....	8	.....	.....
Ch 26 ab	Physical Chemistry Laboratory (0-6-2) .....	.....	8	8
L 35	Scientific German (4-0-6) .....	10	.....	.....
	Elective Subjects** .....	13	17	21
		48	48	48

\*For the list of Humanities electives, see footnote, page 153.

\*\*Professional elective subjects include the following: Chemical Research Ch 80-86, Inorganic Chemistry Ch 13 c, 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 and Differential Equations Ph 6 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	Surface and Colloid 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

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\*For the list of Humanities electives, see footnote, page 153.

## CIVIL ENGINEERING OPTION

(For First Year see page 152)

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 115.

## 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	9	....
ME 3	Materials and Processes (3-3-3) .....	9 or 9	9	....
Ge 1 a	Physical Geology (4-2-3) .....	9	....	....
AM 1 a	Applied Mechanics (Statics) (3-3-6) * .....	....	....	12
D 2	Descriptive Geometry (0-6-0) .....	....	....	6
ME 1 ab	Empirical Design (0-3-0; 0-6-0) .....	....	3	6
		48	48	48

## THIRD YEAR

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
CE 2	Advanced Surveying (2-7-3) .....	12	....	....
EE 1 abc	Basic Electrical Engineering (2-0-4) .....	6	6	6
EE 2 ab	Basic Electrical Engineering Laboratory (0-3-0) .....	3	3	....
Ec 2	General Economics and Economic Problems (3-0-7) .....	....	10	....
Hy 2 ab	Hydraulics (3-0-6) .....	9	9	....
CE 7	Curves and Earthwork (2-0-4) .....	....	....	6
CE 6	Transportation Engineering (2-0-4) .....	....	....	6
GE 110	Engineering Geology (2-3-4) .....	....	....	9
		50	48	47

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

## 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 18	Industrial Organization (3-0-6) .....	....	9	....
CE 4	Highways & Airports (2-4-4) .....	....	10	....
CE 8	Route Surveying (0-7-0) .....	7	....	....
CE 10 abc	Theory of Structures (3-3-6; 3-0-6) .....	12	12	9
CE 12	Reinforced Concrete (3-3-6) .....	....	....	12
AM 3	Testing Materials Laboratory (1-6-1) .....	....	....	8
Ec 25	Business Law (3-0-3) .....	....	....	6
AM 5	Soil Mechanics (2-0-4) .....	6	....	....
Hy 11	Hydraulic Laboratory (0-6-0) .....	....	6	....
ME 20	Heat Engineering (3-0-6) .....	9	....	....
CE 14 abc	Engineering Conference (1-0-1; 1-0-0; 1-0-1) .....	2	1	2
		47	49	48

\*For the list of Humanities electives, see footnote, page 153.

## ELECTRICAL ENGINEERING OPTION

(For First Year see page 152)

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 115.

## SECOND YEAR

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 (4-2-3) .....	9	....	....
AM 1 a	Applied Mechanics (Statics) (3-3-6) * .....	....	....	12
D 2	Descriptive Geometry (0-6-0) .....	....	6	....
ME 1 ab	Empirical Design (0-3-0; 0-6-0) .....	....	3	6
		—	—	—
		48	48	48

## THIRD YEAR

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 b	Basic Electrical Engineering Laboratory (0-3-0) .....	3	3	3
AM 15 abc	Engineering Mathematics (3-0-6)** .....	9	9	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-3-5) .....	11	11	11
		—	—	—
		49	49	49

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

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

## FOURTH YEAR

		Units per Term		
		1st	2nd	3rd
H 5 ab	Humanities Electives (3-0-6) * .....	9	9	9
H 10	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 6 ab	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 7 abc	Electricity and Magnetism (2-0-4) ** .....	6	6	6
EE 16	Electrical Measurements (0-3-3) .....	....	6	....
EE 70 ab	Engineering Conference (1-0-1) .....	2	2	....
AM 3	Testing Materials Laboratory (1-6-1) .....	8	....	....
EE 62 ab	Electron Tubes (2-3-5) .....	....	10	10
		—	—	—
		49	50	49

\*For the list of Humanities electives, see footnote, page 153.

\*\*Electrical engineering students who have completed Ph 5 abc will, as an alternate for Ph 7 abc, take the following:

Ph 8	Electricity and Magnetism (3-0-6) .....	9	....	....
EE 15 ab	High Frequency Circuits (2-0-4; 0-3-3) .....	....	6	6
		—	—	—
		52	50	49

## GEOLOGICAL SCIENCES OPTION

(For First Year see page 152)

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 12 a	Analytical Chemistry (2-6-2) .....	10	....	....
H 2 abc	History of the United States (2-0-4) .....	6	6	6
CE 1	Surveying (2-4-3) .....	....	....	9
Ge 1 a	Physical Geology (4-2-3) .....	9	....	....
Bi 1	Elementary Biology (3-3-3) .....	....	9	....
Ge 3 ab	Mineralogy (3-3-2; 3-6-1) .....	....	8	10
<i>Geology Option</i>				
Ge 1 b	Elementary Paleontology (4-1-4) .....	....	....	9
		49	47	46
<i>Geophysics Option</i>				
Ma 2 c	Solid Analytic Geometry, Vector Analysis, Differential and Integral Calculus (4-0-8) .....	....	....	12
		49	47	49

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

## GEOLOGICAL SCIENCES OPTION

## THIRD YEAR\*

		Units per Term		
		1st	2nd	3rd
En 7 abc	Introduction to Literature (3-0-5) .....	8	8	8
Ec 2	General Economics and Economic Problems (3-0-7) .....	....	....	10
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 9	Structural Geology (4-0-6) .....	10	....	....
Ge 14	Geologic Illustration (0-3-2) .....	....	....	5
Ge 21 abc	Introduction to Field Geology (2-5-1; 2-7-1; 0-8-4) .....	8	10	12
Ge 176	Elementary Seismology (3-0-3) .....	....	....	6
Ge 102	Oral Presentation (1-0-0) .....	....	1 or 1	....
<i>Geology Option</i>				
Ch 24 ab	Physical Chemistry (4-0-6) .....	10	10	....
D 5	Descriptive Geometry (0-6-0) .....	....	....	6
		50	48	48
			or 49	or 49
<i>Geophysics Option</i>				
EE 1 abc	Basic Electrical Engineering (2-0-4) .....	6	6	6
EE 2 ac	Basic Electrical Engineering Laboratory (0-3-0) .....	3	3	....
		49	47	48
			or 48	or 49

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

## GEOLOGICAL SCIENCES OPTION

## FOURTH YEAR\*

		Units per Term		
		1st	2nd	3rd
	Humanities 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 .....	10	10	10
Ge 100	Geology Club (1-0-0) .....	1	1	1
Ge 128	Introduction to Economic Geology (4-0-3) .....	....	....	7
Ge 175	Introduction to Applied Geophysics (3-0-3) .....	6	....	....
<i>Geology Option</i>				
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 (1-8-0; 0-7-4) .....	....	9	11
		—	—	—
		48	51	50

*Geophysics Option*

Ph 6 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10) .....	15	15	15
EE 16	Electrical Measurements (0-3-3) .....	....	6	....
Ma 12	Elementary Statistics (3-0-6) .....	9	....	....
D 5	Descriptive Geometry (0-6-0) .....	....	....	6
Ge 165	Introduction to General Geophysics I (2-0-4) .....	....	6	....
or				
Ge 166	Introduction to General Geophysics II (2-0-4) .....	....	6	....
		—	—	—
		52	49	50

\*Spring Field Trip, Ge 122, 1 unit, required in third and fourth years.

\*\*For the list of Humanities electives, see footnote, page 153.

## MATHEMATICS OPTION

(For First Year see page 152)

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 115.

## 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 (4-2-3) .....	9	.....	.....
Bi 1	Elementary Biology (3-3-3) .....	.....	9	.....
Ay 1	Introduction to Astronomy (3-1-5) .....	.....	.....	9
Ma 3	Theory of Equations (4-0-6) .....	10	.....	.....
Ma 16	Matrices and Quadratic Forms (4-0-6) .....	.....	10	.....
	<i>Schedule A</i> (1948-49, and alternate years thereafter)			
Ma 10	Differential Equations (4-0-6) .....	.....	.....	10
	<i>Schedule B</i> (1949-50, and alternate years thereafter)			
Ma 4	Geometry (4-0-6) .....	.....	.....	10
		49	49	49

## THIRD YEAR

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 abc	Introduction to Mathematical Physics and Differential Equations (5-0-10) .....	15	15	15
L 32 abc	Elementary German (4-0-6) .....	10	10	10
Ma 8 abc	Advanced Calculus (4-0-5) .....	9	9	9
	<i>Schedule A</i> (1949-50, and alternate years thereafter)			
Ma 4	Geometry (4-0-6) .....	.....	.....	10
	<i>Schedule B</i> (1948-49, and alternate years thereafter)			
Ma 10	Differential Equations (4-0-6) .....	.....	.....	10
		48	48	52

## 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 153.

## MECHANICAL ENGINEERING OPTION

(For First Year see page 152)

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 115.

## 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 (4-2-3) .....	9	....	....
AM 1 a	Applied Mechanics (Statics) (3-3-6)* .....	....	....	12
D 2	Descriptive Geometry (0-6-0) .....	....	6	....
ME 1 ab	Empirical Design (0-3-0; 0-6-0) .....	....	3	6
		<hr/>	<hr/>	<hr/>
		48	48	48

## THIRD YEAR

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 abc	Engineering Mathematics (3-0-6)** .....	9	9	9
ME 15 abc	Thermodynamics and Fluid Mechanics (3-3-5) .....	11	11	11
		<hr/>	<hr/>	<hr/>
		49	49	49

## FOURTH YEAR

	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	Business Law (3-0-3) .....	....	....	6
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
		<hr/>	<hr/>	<hr/>
		50	49	49

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

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

†For the list of Humanities electives, see footnote, page 153.

## PHYSICS, APPLIED PHYSICS, OR ASTRONOMY OPTION

(For First Year see page 152)

Attention is called to the fact that any student whose grade-point average is less than 1.9 in the subjects listed under his division may, at the discretion of his department, be refused permission to continue work of that option. A fuller statement of this regulation will be found on page 115.

## 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 (4-2-3) .....	9	....	....
Bi 1	Elementary Biology (3-3-3) .....	....	9	....
Ay 1	Introduction to Astronomy (3-1-5) .....	....	....	9
ME 3	Materials and Processes (3-3-3) .....	9	....	....
Ch 43	Organic Chemistry (2-6-2) .....	....	....	10
Ch 11	Quantitative Chemical Analysis (2-6-2) .....	....	10	....
		48	49	49

## THIRD YEAR

En 7 abc	Introduction to Literature (3-0-5) .....	8	8	8
Ch 21 abc	Physical Chemistry (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 ab	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

		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 12 abc	Introduction to Atomic and Nuclear Physics (3-0-6) .....	9	9	9
Ph 101 abc	Electricity and Magnetism (3-0-6) .....	9	9	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	....	....
	Approved Elective .....	....	....	9
		50	51	47

\*For the list of Humanities electives, see footnote, page 153.

## APPLIED PHYSICS 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 (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 12 ab	Introduction to Atomic and Nuclear Physics (3-0-6) .....	9	9	....
		49	46	50

## ASTRONOMY OPTION

(First three years same as Physics Option.)

For Fourth Year see page 153.)

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\*For the list of Humanities electives, see footnote, page 153.

# SCHEDULES OF FIFTH- AND SIXTH-YEAR COURSES

## AERONAUTICS

### FIFTH YEAR

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

		Units per Term		
		1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6) * .....	9 or 10	9 or 10	9 or 10
AE 251 abc	Aerodynamics (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	50	50
		or	or	or
		51	51	51

### JET PROPULSION†

#### FIFTH YEAR

		Units per Term		
		1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6) * .....	9 or 10	9 or 10	9 or 10
AE 251 abc	Aerodynamics of the Airplane (3-0-6) .....	9	9	9
AE 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	52	52
		or	or	or
		53	53	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 121 for extra fee for this option.

## AERONAUTICS

## SIXTH YEAR

(Leading to the 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 Term		
		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 272 abc	Precision Measurements (1-0-2) .....	3	3	3
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
		—	—	—
		52	52	52

\*See page 121 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

### FIFTH YEAR

As nearly all Astronomy and Astrophysics majors work for the doctor's degree with the ultimate goal of research and teaching, no specific graduate curricula have been outlined. All are required to obtain the working knowledge of mathematics and physics necessary for an understanding of modern astrophysics. Each student's program will be arranged in consultation with the members of his Division. Fifth year students are encouraged to fulfill as large a part as possible of the candidacy requirements (page 137) so that they may begin their own research early.

## BIOLOGY

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

## CHEMISTRY

### FIFTH YEAR

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

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 165. Candidates who have not had courses substantially equivalent to Inorganic Chemistry Ch 113ab, Thermodynamic Chemistry Ch 122ab, 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 Chemical Engineer)

		Units per Term		
		1st	2nd	3rd
		9 or 10	9 or 10	9 or 10
	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	50	50
		or	or	or
		51	51	51

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

## SIXTH YEAR

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

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.

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\*For list of Humanities electives, see footnote, page 165.

## 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	Soil Mechanics (1-3-2) .....	....	6	....
Hy 100	Hydraulics Problems (2-0-4) * .....	6	....	....
CE 130 abc	Engineering Seminar (1-0-1) .....	2	2	2
	Approved Elective .....	....	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

## SIXTH YEAR

(Leading to the degree of Civil Engineer)

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

\*For students who have credit for AM 5.

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

ELECTRICAL ENGINEERING

FIFTH YEAR

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

		Units per Term		
		1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6) * .....	9 or 10	9 or 10	9 or 10
EE 120 abc	Advanced Electric Power System Analysis (4-0-8) ....	12	12	12
EE 121 abc	Alternating Current Laboratory (0-6-0) .....	6	6	6
EE 158 abc	Circuit Analysis (3-0-6) .....	9	9	9
		—	—	—
		36	36	36
		or	or	or
		37	37	37
	Electives .....	12	12	12

SIXTH YEAR

(Leading to the degree of Electrical Engineer)

EE 226 abc	Engineering Mathematical Physics (3-0-12) ** .....	15	15	15
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The balance of the programs are selected from a comprehensive list of available subjects and are arranged by the student in consultation with members of the Division.

\*For list of Humanities electives, see footnote, page 165.

\*\*This course is also required for the doctor's degree in electrical engineering.

**GEOLOGICAL SCIENCES  
FIFTH YEAR**

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

		Units per Term		
		1st	2nd	3rd
		9 or 10	9 or 10	9 or 10
	Humanities Electives (3-0-6; 4-0-6) * .....			
Ge 100	Geology Club .....	1	1	1
Ge 102	Oral Presentation .....	1	or 1	or 1
Ge 295	Master's Thesis Research (units and subjects 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 99	Structural Geology .....	6	....	....
Ge 105	Optical Mineralogy .....	10	....	....
Ge 106 ab	Petrography .....	....	10	10
Ge 107	Stratigraphy .....	....	....	12
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 .....	....	9	11
Ge 122	Spring Field Trip .....	....	....	1
Ge 123	Summer Field Geology .....	....	....	20
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	Ore Deposits .....	....	10	....
Ge 209	Sedimentary Petrology** .....	....	10	....
Ge 210	Metamorphic Petrology† .....	....	10	....
Ge 212	Nonmetalliferous Deposits .....	....	....	10
Ge 213	Mineralogy (Seminar) .....	5	....	....
Ge 214	Petrology (Seminar) .....	....	5	....
Ge 215	Ore Deposits (Seminar) .....	....	....	5
Ge 220	History of the Geological Sciences (Summer reading) .....	....	....	5
Ge 226	Advanced Geomorphology** .....	....	10	....
Ge 228	Geomorphology or Arid Regions** .....	....	10	....
Ge 229	Glacial Geology† .....	....	10	....
Ge 230	Geomorphology (Seminar) .....	....	....	5
Ge 232	Petroleum Geology .....	10	....	....
Ge 233	Petroleum Geology Practices .....	....	10	....
Ge 235	Petroleum Geology (Seminar) .....	....	....	5
Ge 237	Tectonics .....	....	....	10
Ge 238	Structural Geology (Seminar) .....	5	....	....
Ge 245 ab	Vertebrate Paleontology (Seminar) .....	....	5	5

\*For list of Humanities electives, see footnote, page 165.

\*\*1949-50  
†1948-49

		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	6	6
Ge 166	Introduction to General Geophysics II*	6	6	6
Ge 174	Well Logging	5	5	5
Ge 175	Introduction to Applied Geophysics	6	6	6
Ge 176	Elementary Seismology	6	6	6
Ge 261	Theoretical Seismology**	6	6	6
Ge 262	Interpretations of Seismograms of Teleseisms**	4	4	4
Ge 263	Field Work in Earthquakes and Interpretation of Seismograms of Local Earthquakes**	4	4	4
Ge 270	Geophysical Instruments**	7	7	7
Ge 273 ab	Applied Geophysics I*	5	5	5
Ge 274 abc	Applied Geophysics II*	5	5	5
Ge 275 abc	Applied Geophysics III**	6	6	6
Ge 282 abc	Geophysics (Seminar)	1	1	1
Ge 297	Advanced Study (units and subject by arrangement)	6	6	6
Ge 299	Research (units and subject by arrangement)	6	6	6
CE 2	Advanced Surveying	12	12	12
CE 122	Earthquake Effects Upon Structures (units by arrangement)	6	6	6
EE 1 abc	Basic Electrical Engineering	6	6	6
EE 2 abc	Basic Electrical Engineering Laboratory	3	3	3
EE 16	Electrical Measurements	6	6	6
EE 62 ab	Electron Tubes	10	10	10
EE 156	Electrical Communication	6	6	6
Ma 60	Mathematical Probability and Statistics	9	9	9
Ma 98 abc	Advanced Calculus	6	6	6
Ph 92 abc	Introduction to Mathematical Physics	10	10	10
Ph 101 abc	Electricity and Magnetism	9	9	9

\*1948-49

\*\*1949-50

## MATHEMATICS

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

MECHANICAL ENGINEERING

FIFTH YEAR

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

		Units per Term		
		1st	2nd	3rd
	Humanities Electives (3-0-6; 4-0-6) * .....	9 or 10	9 or 10	9 or 10
ME 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	48	48
		or	or	or
		48	49	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

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
- Ph 92 abc Introduction to Mathematical Physics and Differential Equations

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\*For list of Humanities electives, see footnote, page 165.

## MECHANICAL ENGINEERING

## SIXTH YEAR

(Leading to the degree of Mechanical Engineer)

Specific requirements for the degree of Mechanical Engineer are given on page 132. 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

## PHYSICS

## FIFTH YEAR

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

		Units per Term		
		1st	2nd	3rd
Ph 103 abc	Humanities Electives (3-0-6; 4-0-6) * .....	9 or 10	9 or 10	9 or 10
	Analytical Mechanics (4-0-8) .....	12	12	12
	Electives as below .....	27	27	27
		—	—	—
		48	48	48
		or	or	or
		49	49	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	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 list of Humanities electives, see footnote, page 165.

\*\*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. Students who have received credit for Ph 101 abc as undergraduates may use these credits towards a master of science degree provided they replace them with undergraduate credits in L 32 abc (4-0-6) earned during the fifth year.

‡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 airplane including control and flap systems, landing gears, power plants, electrical, radio, and instrument installations, heating and ventilating problems, hydraulic systems and acoustics.

Instructor: Klein, assisted by engineers from aircraft companies.

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

Prerequisites: AE 252, AE 253.

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

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.

Text: *Wind Tunnel Testing*, Pope.

Instructor: Bowen.

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

Prerequisite: AE 251 abc.

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

Instructor: Williams.

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

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.

Instructors: DePrima, Marble, Plesset

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

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

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

Instructor: Liepmann.

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

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

**AE 261 abc. Hydrodynamics of Compressible Fluids. 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: Millikan.

**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 and 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, monoplane, biplane, interference, propellers, theory of airfoils in non-uniform motion, hydrodynamics of viscous fluids, laminar motion in pipes and channels, turbulence and Reynolds' criterion, similarity laws, theory of drag, discontinuous flow, and vortex streets, theory of skin-friction, boundary layer, general theory of turbulence.

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

Instructor: Stewart.

**AE 267. 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 connection with statistical concepts.

Instructor: Lagerstrom.

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

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

Instructor: Liepmann.

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

Prerequisites: Applied Mechanics, 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 and Assistants.

**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.

Text: *Mathematical Methods in Engineering*, Kármán and Biot.

Instructor: Hudson.

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

Prerequisites: AE 251, AE 265, AE 270, AE 271.

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

Instructor: Fung.

**AE 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.**

Prerequisite: AM 15.

Fundamentals of rockets, solid propellant rocket design, liquid propellant rocket design. Underwater 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 5. Soil Mechanics. 6 units (2-0-4); first term.**

Prerequisite: AM 1 abcd.

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

Texts: *Soil Mechanics*, Krynine; *Procedures for Soil Testing*, A.S.T.M.

Instructors: Converse, Bobisch.

**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 95. Soil Mechanics. 5 units (2-0-4); first term.**

Prerequisite: AM 1 abcd.

This course is the same as AM 5, but with reduced credit for graduate students.

**AM 105. Soil Mechanics. 6 units (1-3-2); second term.**

Prerequisite: AM 5 or AM 95.

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

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.**

Prerequisite: 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.**

Prerequisite: 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, AM 110 a.

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

Instructor: Housner.

**AM 115 abc. Engineering Mathematics. 9 units (3-0-6); first, second, third terms.**

Prerequisites: Ma 1 abc, Ma 2 abc.

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.

**AM 200. Special Problems in Advanced Mechanics.**

Dynamics of solid and deformable bodies, fluids, and gases. Mathematical and Applied Elasticity. By arrangement with members of the staff, properly qualified graduate students are directed in independent studies. Hours and units by arrangement.

**AM 201. Theory of Cavitating Flow. Units in accordance with work done.**

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

Instructor: Plesset.

**AM 250 abc. Research in Applied Mechanics.**

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

## ASTRONOMY

### UNDERGRADUATE SUBJECTS

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

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

Text: *Astronomy*, Baker.

Instructor: Johnson.

**Ay 2 abc. General Astronomy. 9 units (2-3-4); first, second and third terms.**

Prerequisites: Ay 1, Ph 1 abc, 2 abc, 6a; Ma 2 abc.

Coordinate and gravitational astronomy, instruments and methods, introduction to astronomical spectroscopy, galactic structure, and the nebulae.

Texts: *Spherical Astronomy*, Smart; *Astronomy*, Vol. II, Russell, Dugan and Stewart.

Instructor: Wilson.

### ADVANCED SUBJECTS

**Ay 92 abc. General Astronomy. 6 units; first, second and third terms.**

This subject is the same as Ay 2, but with reduced credit for graduate students.

Instructor: Wilson.

**Ay 101 abc. Astrophysics I. 9 units (3-0-6); first, second and third terms.**

Prerequisites: Ay 2 abc, Ph 12, abc, Ma 10, or their equivalents.

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

Instructor: Greenstein.

**Ay 102 abc. Astrophysics II. 9 units (3-0-6); first, second, and third terms.  
Offered in alternate years with Ay 101.**

Prerequisites: Ay 2 abc, Ph 12, abc, Ma 10, or their equivalents.

Stellar interiors; nuclear energy sources and the internal constitution of the stars. Diffuse nebulae and interstellar space. Galactic structure. Extragalactic nebulae.

Instructor: Greenstein.

**Ay 103 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.

Principles of stellar dynamics; star streaming, galactic rotation. Stellar encounters. Cluster motion. Stability of clusters. Dynamics of the interstellar gas. Dynamics of galactic systems.

**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, assistants, faculty members, and visiting research personnel are admitted to the seminar who have the time, inclination and ability to engage in active, constructive work on problems which will be formulated in this seminar.

Meetings throughout the year according to agreement.

Instructor: Zwicky.

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

Meets twice a month at the Mount Wilson Observatory, in Pasadena, Wednesday 11 A.M. for discussion of work in progress. Students will also meet subsequently for discussion and reports on these and other problems.

**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. Interstellar Matter
- Ay 211. Structure of the Galaxy
- Ay 212. Extragalactic Nebulae
- Ay 213. Observational Cosmology
- Ay 214. Theoretical Cosmology

## BIOLOGY

## UNDERGRADUATE SUBJECTS

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

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

Instructors: Delbrück, Beadle.

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

Prerequisite: Bi 1.

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

Instructor: Owen.

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

Prerequisite: Bi 1.

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

Instructor: Went.

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

Prerequisite: Bi 1.

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

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

Instructor: MacGinitie.

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

Prerequisite: Bi 3.

A general survey of growth and the chemical processes taking place in the living plant, followed by a survey of the plant kingdom.

Instructors: Bonner, Galston, Wildman.

**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); first term.**

Prerequisite: Bi 2.

A course dealing especially with *Neurospora* genetics.

Instructors: Horowitz, Beadle.

**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); third term.**

Prerequisites: Bi 2, Ch 41 abc.

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

Instructors: Emerson, Owen.

**Bi 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.

**Bi 30. Entomology. 9 units (2-5-2); third term.**

A general survey of the insects.

Instructor: Sturtevant.

## 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); first term.**

Prerequisite: Bi 2.

A course dealing especially with neurospora genetics.

Instructors: Horowitz, Beadle.

**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); third term.**

Prerequisites: Bi 2, Ch 41 abc.

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

Instructors: Emerson, Owen.

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

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

A survey of comparative and mammalian physiology.

Instructors: Wiersma, van Harreveld.

B. Subjects that may be counted toward either a major or a minor for the degree of Doctor of Philosophy:

**Bi 130. Entomology. 9 units (2-5-2); third term.**

A general survey of the insects.

Instructor: Sturtevant.

**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 ab. Graduate Genetics. 6 units (2-0-4); second and third terms.**

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

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

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

Reading and discussion of the problems of plant physiology.

Instructors: Went, Bonner, Wildman, Galston.

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

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

Instructor: Bonner.

**Bi 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.

**Text:** *General Chemistry*, Pauling.

**Instructors:** Pauling, Davidson and Assistants.

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

**Prerequisite:** Ch 1 c.

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

**Text:** *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. Analysis of selected alloys, minerals, and other materials will be made. Students may be assigned individual problems for investigation. The class exercises are devoted to a discussion and review of the general principles of analytical and inorganic chemistry. The examination in this subject covers the chemistry work of the whole sophomore year.

**Instructor:** Swift.

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

**Prerequisites:** Ch 12 b, 21 ab.

The chemical and physical properties of the elements are discussed with reference to the periodic system and from the view-points of atomic structure and radiation effects. Such topics as coordination compounds, the liquid ammonia system, the compounds of nitrogen, the halides, and selected groups of metals are taken up in some detail. The class work is supplemented by problems which require a study of current literature.

**Instructor:** Yost.

**Ch 16. Instrumental Analysis. 8 units (0-6-2); first term.**

**Prerequisite:** Ch 12 c.

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

**Instructor:** Sturdivant.

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

Prerequisites: Ch 12 ab or Ch 11; Ph 2 abc; Ma 2 abc.

Conferences and recitations dealing with the general principles of chemistry from an exact, quantitative standpoint, and including studies on the pressure-volume relations of gases; on thermodynamics, on vapor-pressure, boiling point, freezing point, and osmotic pressure of solutions; on the molecular and ionic theories; on electrical transference and conduction; on chemical and phase equilibria; on thermochemistry, and the elements of thermodynamic chemistry and electro-chemistry. A large number of problems are assigned to be solved by the student.

Text: *Chemical Principles*, Noyes and Sherrill.

Instructors: Bates, Badger.

**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 electro-chemistry 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.

Instructor: Hughes.

**Ch 26 ab. Physical Chemistry Laboratory. 8 units (0-6-2), second term; and 8 units (0-6-2) or 4 units (0-3-1), third term.**

Prerequisites: Ch 12 ab, Ch 21 a.

Text: Mimeographed Notes.

Instructor: Badger.

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

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

Instructors: Yost, Davidson.

**Ch 29. Surface and Colloid 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.

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); third term.**

Prerequisite: Ch 1.

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

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

Prerequisite: Ch 12.

Laboratory exercises to accompany Ch 41 abc. The preparation and purification of carbon compounds and the study of their characteristic properties. Qualified students may pursue research work.

Text: 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 (84) 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 physicochemical view-points; thus with reference to their physical properties, their thermodynamic constants (their heat-contents, free-energies, and entropies), their rates of conversion into one another (including effects of catalysis and energy radiations), and their molecular structure and valence relations.

Instructor: Yost.

**Ch 122 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. Surface and Colloid 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.**

This course is the same as Ch 30.

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 or ME 15.

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

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

Prerequisites: Ch 61, Ch 63 ab.

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

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

Instructor: Lacey.

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

Prerequisites: Ch 21, Ch 61, Ch 63.

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

Instructors: Sage, 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, Schomaker.

**Ch 223 abc. Statistical Mechanics. 9 units (3-0-6); first, second, third terms.**

After a survey of the principles of classical and quantum mechanics and of the theory of probability, the equilibrium theory of statistical mechanics is developed and used to interpret the laws of thermodynamics from the molecular standpoint. A detailed study of the relationships between the thermodynamic functions of gases, liquids, and solids and their structure on the molecular scale follows. The interpretation of phase transitions as cooperative phenomena in aggregates of molecules is presented. In the third term the statistical mechanics of systems departing from equilibrium is developed, and the transport process, diffusion, heat transfer, and viscous fluid flow are analyzed in the light of current theories.

Given every other year. Offered in 1947-48.

Instructor: Kirkwood.

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

Prerequisite: Ch 21 or the equivalent.

Basic concepts and the laws of thermodynamics are reviewed. The theories of heterogeneous equilibrium and chemical equilibrium are developed according to the methods of Willard Gibbs. Methods of calculation of the thermodynamic functions of pure chemical substances and of components of real gas mixtures and liquid solutions are treated in a systematic manner. Heterogeneous equilibrium is interpreted analytically by means of the differential equations of the equilibrium lines and surfaces in phase diagram space. Chemical equilibrium in homogeneous real gas reactions, and in reactions in liquid solutions, is treated in detail. Attention is given to the important applications of thermodynamics to electrochemical systems, surface phases, and to systems under the influence of external gravitational, electric, and magnetic fields. Problems.

Given in alternate years. Offered in 1948-49.

Instructor: Kirkwood.

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

A review of Lagrangian and Hamiltonian mechanics and of the old quantum theory is first given, followed by the discussion of the development and significance of the new quantum mechanics and the thorough treatment of the Schrödinger wave equations, including its solution for many simple systems such as the rotator, the harmonic oscillator, the hydrogen atom, etc. During the second and third terms various approximate methods of solution (perturbation theory, the variation method, etc.) are discussed and applied in the consideration of the resonance phenomenon, the structure of many-electron atoms and of simple molecules, the nature of the covalent chemical bond, the structure of aromatic molecules, and other recent chemical applications.

Given every third year. Offered in 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 gases, liquids, glasses, and crystals.

Given every third year. Offered in 1948-49.

Instructors: Schomaker, Hughes, Sturdivant.

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

The physical, electrical, and magnetic as well as the structural, chemical, and thermodynamic properties of metals and alloys considered from modern viewpoints.

Instructor: Yost.

**Ch 234. Introduction to the Spectra of Molecules. 6 units; first term.**

The theory of the structure of the spectra of both the diatomic and the simpler polyatomic molecules is presented, and the transition rules and their relation to the symmetry elements of molecules are discussed. Emphasis is laid on the methods of interpreting and analyzing molecular spectra, and it is shown how from an analysis one obtains information regarding the structure and other properties of a molecule of interest to the chemist. Problems are given in the interpretation of actual data.

Given every third year. Offered in 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 1947-48.

Instructor: Niemann.

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

Prerequisite: Ch 41, Ch 46.

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

Given every third year. Offered in 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 System. 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 by diffraction of X-rays and electrons.

The application of quantum mechanics to chemical problems.

The study of molecular structure and of chemical problems by spectroscopic methods.

The diamagnetic anisotropy of crystals.

The nature of the metallic bond and the structure of metals and intermetallic compounds.

Studies of radioactivity.

Studies of the transuranic elements.

The application of physical methods to the study of proteins and other high molecular weight substances.

*(Inorganic 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); first 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); third 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. 6 units (2-0-4); third term.**

Prerequisite: CE 1.

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

Text: *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 application of this type of construction to various engineering structures.

Text: *Reinforced Concrete*, Caughy.

Instructor: Martel.

**CE 14 abc. Engineering Conference. 2 units (1-0-1) first term; 1 unit (1-0-0) second term; 2 units (1-0-1) third term.**

Conferences participated in by faculty and seniors of the Civil Engineering department. The discussions cover current developments and advancements within the field of civil engineering and related sciences.

The technique of effective oral presentation of reports is emphasized through criticisms of the reports from the standpoint of public speaking by a member of the department of English. In the third term 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 the modern practice of the collection, storage, purification and distribution of water for municipal, domestic and irrigation uses; design, construction and operation of systems; consideration of the conditions adapted to irrigation developments, dams, reservoirs, canals; laws pertaining to irrigation; the economic aspects of projects.

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 ab. Advanced Study in Sewerage and Sewage Treatment. Units to be based upon work done; any term.**

Prerequisite: CE 127.

A study of the mechanisms of sewage treatment processes with particular reference to the effects of pollution on the receiving water course or other body of water.

Instructor: Banta.

**CE 131 c. Sewage Treatment Plant Design. Units to be based upon work done; any term.**

A design of treatment works for a selected community and site involving special conditions of location, volume, and requirements for disposal. Includes selection of type of treatment, arrangement of tanks and equipment, and general design of structures.

Instructor: 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 ab. Advanced Study in Water Supply and Treatment. Units to be based upon work done; any term.**

Prerequisite: CE 125.

A more detailed study of methods of hydrology, water supply, treatment, and control of water quality.

Instructor: Banta.

**CE 133 c. Water Treatment Plant Design. Units to be based upon work done; any term.**

Preparation of a layout and design of the general features of a plant to effect the purification and softening of water as may be required in specific circumstances. Includes design of typical structural features of the plant.

Instructor: Banta.

**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.**

Prerequisites: AM 5 or AM 95, AM 105.

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.

## ECONOMICS

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

**Ec 2. 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, Gray.

**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.

Instructor: Untereiner.

**Ec 48. Introduction to Industrial Relations\* 9 units (3-0-6).**

Senior Elective.

This course stresses the personnel and industrial relations functions and responsibilities of supervisors and executives. The history, organization, and activities of unions and the provisions of current labor legislation are included. The relationships of a supervisor or executive with his employees, his associates, and his superiors are analyzed, and the services which he may receive from the personnel department are examined. The course also discusses the use of basic tools of supervision.

Instructor: Gray.

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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.

## 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 courses are: 1) business organization, 2) industrial promotion and finance, 3) factory management, 4) industrial sales, and 5) business economic topics, especially the business cycle. This treatment provides a description of the industrial economy about us and of the latest management techniques. The points of most frequent difficulty are given special study. The case method of instruction is used extensively in the course.

Instructor: Gilbert.

**Ec 106 abc. Business Economics (Seminar). Units by arrangement; first, second, third terms.**

Open to graduate students.

This seminar is intended to assist the occasional graduate student who wishes to do special work in some part of the field of business economics or industrial relations. Special permission to register for this course must be secured from the instructors.

Instructors: Gilbert, Gray.

**Ec 110. Industrial Relations. 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 problems of setting wage rates.

Instructors: Gray, Arthur H. Young.

## 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 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; and EE 12.

Windings, special characteristics, graphical methods, commutation, machine reactances, and short circuit currents. System stability; short transmission lines.

Instructor: Sorensen.

**EE 7. Electrical Engineering Laboratory. 7 units (0-6-1); third term.**

Prerequisites: EE 1 abc; EE 2 abc; and enrollment in EE 6.

A continuation of EE 2 abc. Efficiency tests of alternating current machinery. Graphic analysis of alternator performance; operation of 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 and Assistants.

**EE 12. Electric Circuits. 12 units (4-0-8); first term.**

Prerequisites: EE 1 abc; EE 2 abc.

A course of study relating to the calculation of voltage, current, and power in electrical power and electronic circuits, including an introductory study of filter circuits. In all of these studies free use is made of the symbolic or complex method of solving problems using Kirchoff's laws, Thevenin's theorem and other special methods of calculation.

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 or Ph 8; EE 62 to be taken concurrently.

Maxwell's equations, electromagnetic fields, generation and propagation of microwaves. Laboratory experiments illustrating microwave phenomena.

Instructors: Mackeown and Pickering.

**EE 16. Electrical Measurements. 6 units (0-3-3); second term.**

Prerequisites: Ph 2 abc; EE 1 abc; EE 12.

Advanced course in precision electrical measurements, measurements of impedance, voltage, current, etc.

Text: *Advanced Electrical Measurements*, Michels.

Instructors: Pickering and Graduate Assistants.

**EE 60 abc. Electronics and Circuits. 9 units (3-0-6; 2-3-4; 2-3-4); first, second, third terms.**

Prerequisite: EE 1 abc.

Basic physics of vacuum tubes, electron ballistics, thermionic 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 70 ab. Engineering Conference. 2 units (1-0-1); first, second terms.**

Prerequisites: EE 1 abc; EE 2 abc.

Presentation and discussion of new developments in the industry. Review of current literature.

Instructors: 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.

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.

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 communication problems.

Instructors: Pickering and Assistants.

**EE 158 abc. Circuit Analysis. 9 units (3-0-6); first, second, third terms.**

Prerequisites: EE 12, EE 62 ab.

Transient analysis of linear networks; Laplace transform methods; 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 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, Ph 7 or Ph 8, EE 15.

Applications of Maxwell's equations to the generation and radiation of microwaves. Includes antenna problems, wave guides, cavity resonators, etc.

Instructor: 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, Electrical Transients, and High Voltage Engineering Problems, under the direction of Professors R. W. Sorensen, F. C. Lindvall, and G. D. McCann; Electrical Engineering Problems relating to 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 abc. Electric Strength and Dielectrics. Units by arrangement; first, second, third terms. Not given every year.**

A study of the effect of high potentials applied to dielectrics.

Instructor: Sorensen.

**EE 224 abc. Vacuum Tube and Radio Frequency Circuits. Units to be based on work 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 abc. Conduction of Electricity in Gases and Solids. Units to be arranged; first, second, third terms. Not given every year.**

Fundamental physical processes underlying electrical conduction, with examples from flow, arc, and spark discharges, rectifiers (gaseous and solid), conductors, insulators, and semi-conductors.

Instructor: Wooldridge.

**EE 230. Microwave Electronics. 9 units (3-0-6); third term.**

The behavior of vacuum tubes at ultra-high frequencies, electron transit time effects, microwave oscillators.

Instructor: Pickering.

**EE 232 abc. Advanced Problems in Modern Radio Engineering. 8 units (2-0-6); first, second, third terms. Given in alternate years.**

Prerequisites: EE 15 ab, EE 62 ab, Ph 7, Ph 8; or Ph 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.

**EE 234 abc. Radio Engineering. 9 units (3-0-6); first, second, third terms.**

Prerequisites: EE 15 ab, EE 60 abc, EE 62 abc, or EE 190.

An advanced lecture and problem course covering most important aspects of modern radio engineering for students who have completed a first course.

Instructor: Ramo.

## ENGINEERING DRAFTING

### **D 1 a. Freehand Drawing. 3 units (0-3-0); first term.**

The study of geometrical forms and their representation by means of freehand orthographic and perspective. 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 1 b. 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 1 c. Engineering Drafting. 3 units (0-3-0); third term.**

Prerequisite: D 1 b.

A continuation of D 1 b. 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.**

Prerequisite: D 1 abc.

This course is planned primarily for geology students and is designed to cover the fundamentals of descriptive geometry as given in the first part of D 2. Emphasis is placed, throughout the course, on practical problems in mining and earth structures.

Text: *Geometry of Engineering Drawing*, Hood.

Instructors: Tyson, Welch.

### **D 7. Advanced 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.

## 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.

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 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, 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: Bowerman, 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. Units to be determined for the individual by the department. Maximum 8 units. Elective.**

Reading in literature, history, philosophy, and other fields during summer vacation, books to be selected from a recommended reading list, or in consultation with a member of the staff. A brief written report will be required.

## FIFTH-YEAR AND ADVANCED SUBJECTS

**En 100 abc. Seminar in Literature. 9 units (2-0-7).**

A study of some selected group of writers chosen to illustrate trends in literary and social history. Further definition will be announced.

Instructor:

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

## FRENCH

(See under Modern Languages)

## GEOLOGICAL SCIENCES

## UNDERGRADUATE SUBJECTS

**Ge 1 a. Physical Geology. 9 units (4-2-3); first term.**

Prerequisites: Ch 1 abc, Ph 1 abc.

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: *Manual of Mineralogy*, Dana-Hurlbut.

Instructor: Engel.

**Ge 4 a. Petrology. 6 units (2-3-1); first term.**

Prerequisites: Ge 1 a, Ge 3 ab.

A study of the origin and occurrence; with training in the megascopic identification, description, and interpretation of these rocks and their constituent minerals.

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: Engel.

**Ge 9. Structural Geology. 10 units (4-0-6); first term.**

Prerequisite: Ge 1 a.

A consideration of the structural features of the Earth's crust: folds, faults, joints, foliation.

Text: *Structural Geology*, Billings.

Instructor: Buwalda.

**Ge 14. Geologic Illustration. 5 units (0-3-2); third term.**

Classroom training in the drawing of block diagrams. Problems in perspective, projection, and the rendering of topographical features and stratigraphy. Exercises, using various mediums, in freehand and mechanical drawing as applied to geologic illustration. Freehand sketching of landscape forms and visible geologic structures in the field.

Text: *Block Diagrams*, Lobeck.

Instructor: Willoughby.

**Ge 21 abc. Introduction to Field Geology. 8 units (2-5-1) first term; 10 units (2-7-1) second term; 12 units (0-3-4) third term.**

Prerequisites: Ge 1 ab, Ge 3 ab.

An introduction to the interpretation of geologic features in the field, and to the fundamental principles and techniques of geologic mapping. Classroom and field studies include the interpretation of geologic maps, megascopic investigation of rock types, the solution of simple field problems in structure and stratigraphy, geologic computations, and an introduction to the use of aerial photographs and of the plane table for field mapping. To these ends, small areas are mapped in great detail and reports are prepared in professional form.

Text: *Field Geology*, Lahee.

Instructor: Jahns.

## UNDERGRADUATE OR GRADUATE SUBJECTS

**Ge 99. Structural Geology. 6 units; first term.**

This subject is the same as Ge 9 but with reduced credit for graduate students.

Text: *Structural Geology*, Billings.

Instructor: Buwalda.

**Ge 100. Geology Club. 1 unit (1-0-0); all terms.**

Presentation of papers on research in geological science by the students and staff of the Division of the Geological Sciences, and by guest speakers.

Required of all senior and graduate students in the Division; optional for sophomores and juniors.

**Ge 102. Oral Presentation. 1 unit (1-0-0); first, second or third term.**

Training in the technique of oral presentation. Practice in the effective organization and delivery of reports before groups.

Successful completion of this course is required of all candidates for the bachelor's, master's, and doctor's degrees in the Division. The number of terms taken will be determined by the proficiency shown in the first term's work.

Instructor: Jones.

**Ge 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.

Texts: *Optical Crystallography*, Wahlstrom, and *Notes on Optical Mineralogy*, Tunell.

Instructor: Jahns.

**Ge 106 ab. Petrography. 10 units (2-6-2); second and third terms.**

Prerequisites: Ge 105, Ch 24 ab.

A systematic study of rocks; identification of their constituents by means of the polarizing microscope; interpretation of textures; problems of genesis; qualitative and quantitative classifications.

Text: *Petrography and Petrology*, Grout.

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.

Instructor: Merriam.

**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: *Geology and Engineering*, Legget.

Instructor: Buwalda.

**Ge 111 ab. Invertebrate Paleontology. 10 units (2-6-2); first, second terms.**

Prerequisite: Ge 1 ab.

Morphology and geologic history of the common groups of fossil invertebrates, with emphasis on 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.

Instructors: Stauffer (111 a), Merriam (111 b).

**Ge 112 ab. Vertebrate Paleontology. 10 units (2-6-2); second, third terms.**

Prerequisite: Ge 1 b.

Osteology, affinities, and history of the principal groups of fossil mammals and reptiles. History of vertebrate life with special reference to the region of western North America.

Instructor: Stock.

**Ge 115. Micropaleontology. 8 units (1-3-4); second term.**

Prerequisite: Ge 111 ab.

Introduction to the morphology and classification of the foraminifera. 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. 9 units (1-8-0), second term; 11 units (0-7-4), 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.

Text: *Principles of Field and Mining Geology*, Forrester.

Instructors: Engel, 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 such regions as Owens and Death Valleys where excellent Paleozoic sections are exposed, and Basin Range structure and morphology may be observed; to the Salton Basin and Lower California where the San Andreas fault and the Peninsular Range may be studied; to the San Joaquin Valley and the mountains to the west where important Tertiary formations are exposed and typical Coast range structure may be seen; and to the Grand Canyon of the Colorado River where a fascinating record of Archean, Algonkian and Paleozoic geologic history may be investigated.

Required of junior, senior, and graduate students in the Division of the Geological Sciences.

Instructors: Buwalda, Jahns, Sharp.

**Ge 123. Summer Field Geology. 20 units (0-17-3).**

Prerequisites: Ge 3 ab, Ge 21 ab.

Intensive field mapping of a selected area from a centrally located field camp. Determination of the rock types, fossil content, stratigraphy, structure and geologic history of this area. Preparation of a map, structure sections, and a report in professional form. Both field and office work are done under close supervision.

The area chosen will probably lie in the Great Basin or other parts of the southwestern states, inasmuch as the regular school-year courses, Ge 21 and Ge 121, provide training in the geology of the California Coast Ranges. As an occasional alternative an expedition will be conducted to localities important in western geology. The interpretations of classical localities afforded in the literature will be studied in the field.

The course begins immediately after Commencement (about June 12), and lasts for approximately 6 weeks. Required at the end of the junior year for the Bachelor's degree, and required also of candidates for the Master of Science degree in the Division of the Geological Sciences.

**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, Hewett, Jahns, Noble, Sharp.

**Ge 126. Geomorphology. 10 units (4-0-6); first term.**

Prerequisites: Ge 9, Ge 121 ab.

Origin and evolution of land features produced by weathering, mass movements, wind, running water, glaciers, shore processes, vulcanism, and diastrophism.

Text: *Geomorphology*, 4th edition, revised. Cotton.

Instructor: Sharp.

**Ge 128. Introduction to Economic Geology. 7 units (4-0-3); third term.**

A survey course of geology applied to coal, oil and gas, industrial minerals, metalliferous deposits, water resources, and engineering.

Text: *Economic Mineral Deposits*, Bateman.

Instructors: Noble and other members of Geology staff.

**Ge 165. Introduction to General Geophysics, I. 6 units (2-0-4); second term, 1949-50.**

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); first 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 174. Well Logging. 5 units (3-0-2); second term.**

Physical principles of various methods of well logging and their applications. Electrical, radioactive, chemical, fluoroscopic and mechanical methods will be studied.

Instructor: Potapenko.

**Ge 175. Introduction to Applied Geophysics. 6 units (3-0-3); first term.**

A survey of pure and applied geophysics designed mainly for geological, engineering, and other students who do not expect to enroll in specialized subjects in this field.

Text: *Geophysical Prospecting for Oil*, Nettleton.

Instructor: Potapenko.

**Ge 176. Elementary Seismology. 6 units (3-0-3); third term.**

Prerequisites: Ge 1 a, Ma 2 ab.

A survey of the geology and physics of earthquakes.

Instructor: Richter.

## GRADUATE SUBJECTS

Courses given in alternate years are so indicated. Courses in which the enrollment is less than five may, at the discretion of the instructor, not be offered.

## GEOLOGY

**Ge 200. Mineragraphy. 10 units (1-9-0); first term.**

Prerequisites: Ge 106 ab, Ge 128.

Techniques of the study of the minerals of ore deposits in polished and in thin sections.

Texts: *Microscopic Determination of Ore Minerals*, M. N. Short; U.S.G.S. Bull. 914.

Instructor: Noble.

**Ge 202. Ore Deposits. 10 units (2-6-2); second term.**

Prerequisites: Ge 106 ab, Ge 128, Ge 200.

A study of the mode of occurrence and theory of origin of the main types of ore deposits of the world. The laboratory work will use the technique of Ge 200 and the materials of the Frederick Leslie Ransome memorial collection. Reading will be assigned in the literature of ore deposits; there will be no required textbook.

Instructor: Noble.

**Ge 209. Sedimentary Petrology. 10 units (2-4-4); second term, 1949-50.**

Prerequisite: Ge 106 ab.

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: *Manual of Sedimentary Petrology*, Krumbein and Pettijohn.

Instructor: Russell.

**Ge 210. Metamorphic Petrology. 10 units (2-4-4); second term, 1948-49.**

Prerequisite: Ge 106 ab.

A study of metamorphic processes.

Text: *Metamorphism*, Harker.

Instructor: Campbell.

**Ge 212. Nonmetalliferous Deposits. 10 units (2-3-5); third term.**

Prerequisite: Ge 106 ab.

A study of the industrial minerals; their occurrence, exploitation, beneficiation. In the laboratory the petrographic microscope is applied not only to problems of identification and paragenesis of the minerals, but also to problems involving processed and fabricated materials. Occasional field trips.

Text: *Economic Geology*, Ries.

Instructor: Campbell.

**Ge 213. Mineralogy (Seminar). 5 units; first term.**

Discussion of special problems and current literature related to the general province of mineralogy. Topics in such broad fields as the geology of mineral deposits, crystallography, geochemistry, techniques of mineral identification, and optical mineralogy are selected for attention during the term, largely on the basis of trends of interest among members of the group.

In charge: Jahns.

**Ge 214. Petrology (Seminar). 5 units; second term.**

Discussion of classic and current literature with consideration of recent advances in the field of petrology. Occasional conferences on research problems are included.

In charge: Campbell.

**Ge 215. Ore Deposits (Seminar). 5 units; third term.**

Discussion of problems and current literature concerning ore deposits.  
In charge: Noble.

**Ge 220. History of the Geological Sciences. 5 units, summer reading course.**

Development of basic concepts and specialized fields by great geologists of the past. Intended to provide historical background and understanding of growth of the science.

Assigned reading during summer, examination second week of fall term.

Instructor: Stock.

**Ge 226. Advanced Geomorphology. 10 units (3-0-7); second term, 1949-50.**

Prerequisites: Ge 9, Ge 121 ab, Ge 126.

Detailed analysis of geological processes acting on the earth's crust, and of the land forms they produce, with emphasis on humid regions. Lectures, assigned reading, field trips to the San Gabriel Mountains, the Coast Ranges, and the coast of California.

Instructor: Sharp.

**Ge 228. Geomorphology of Arid Regions. 10 units (3-0-7); second term 1949-50.**

Prerequisite: Ge 126.

A study of the geological processes of arid regions and their products. Origin of pediments and evolution of other land forms. Reading, discussion, and field trips to the Mojave Desert.

Text: *Climatic Accidents*, Cotton.

Instructor: Sharp.

**Ge 229. Glacial Geology. 10 units (3-0-7); second term 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 (2-0-8); first term.**

Prerequisites: Ge 9, Ge 21 ab.

Studies of individual oil fields; of theories of origin, movement and accumulation of oil and gas; and of types of structures and reservoir rocks. Occasional field trips.

Text: *Geologic Formations and Economic Developments of the Oil and Gas Fields of California*, California State Division of Mines, Bull. 118.

**Ge 233. Petroleum Geology Practices. 10 units (2-4-4); second term.**

Prerequisites: Ge 9, Ge 21 ab.

Methods of discovering and exploiting traps; methods of surface and subsurface mapping; logging methods; oriented cores; estimates of reservoir capacity. Occasional field trips.

Text: *Geologic Formations and Economic Developments of the Oil and Gas Fields of California*, California State Division of Mines, Bull. 118.

**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 9, or equivalent, and Ge 121 ab, or equivalent.

Advanced structural and tectonic geology. Structure of some of the great mountain ranges; theories of origin of mountains, mechanics of crustal deformation; isostasy, continental drift.

Instructor: Buwalda.

**Ge 238. Structural Geology (Seminar). 5 units; first term.**

Critical review of literature dealing with some part of the field of structural geology.  
In charge: Buwalda.

*GRADUATE SUBJECTS—PALEONTOLOGY***Ge 245 ab. Vertebrate Paleontology (Seminar). 5 units; second and third terms.**

Discussion of progress and results of research in vertebrate paleontology.  
Critical review of current literature.  
In charge: Stock.

**Ge 248. Fossils of the California Tertiary. 5 units; second term.**

Study of some of the more important invertebrate fossils of the California Tertiary with especial emphasis on their use as horizon markers in field geology.

**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.

*GRADUATE SUBJECTS—GEOPHYSICS***Ge 261. Theoretical Seismology. 6 units (2-0-4); first term 1949-50.**

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, 1949-50.**

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 1949-50.**

Prerequisite: Ge 261.  
Instructor: Richter.

**Ge 270. Geophysical Instruments. 7 units (3-2-2); third term 1949-50.**

Prerequisite: Ph 92 abc or equivalent.  
Discussion of instruments used in seismology and geophysical exploration.  
Instructor: Dix.

**Ge 273 ab. Applied Geophysics, I. 5 units (2-0-3); first and second terms 1948-49.**

Prerequisite: Ph 92 abc or equivalent.  
Methods of seismology applied to geological problems and prospecting. Theory and practice.  
Instructor: Dix.

**Ge 274 abc. Applied Geophysics, II. 5 units (2-0-3), first and second terms; 7 units (0-4-3), third term; 1948-49.**

Prerequisite: Ph 92 abc or equivalent.  
Theory of electrical methods of prospecting, laboratory and field work.  
Text: *Geophysical Exploration*, Heiland.  
Instructor: Potapenko.

**Ge 275 abc. Applied Geophysics, III. 6 units (3-0-3), first term; 8 units (3-2-3), second term; 4 units (1-2-1), third term; 1949-50.**

Prerequisite: Ph 92 abc or equivalent.

Theory of potential useful in making interpretations of gravity and magnetic field data. Brief discussion of gravity and magnetic fields of the earth. Interpretation of field data. Practice in making field observations.

Instructor: Dix.

**Ge 282 abc. Geophysics (Seminar). 1 unit; first, second, third terms.**

Prerequisite: At least two subjects in geophysics.

Discussion of papers in both general and applied geophysics.

In charge: Gutenberg, Buwalda, Dix, Potapenko.

#### GRADUATE SUBJECTS—GENERAL

**Ge 295. Master's Thesis Research. Units to be assigned. Listed as to field according to the letter system under Ge 299.**

**Ge 297. Advanced Study.**

Students may register for 8 units or less of advanced study in fields listed under Ge 299. Occasional conferences; final examination.

**Ge 299. Research.**

Original investigation, designed to give training in methods of research, to serve as theses for higher degrees, and to yield contribution to scientific knowledge. These may be carried on in the following fields.

- |                               |                                |
|-------------------------------|--------------------------------|
| (e) engineering geology,      | (q) geomorphology,             |
| (f) petroleum geology,        | (r) petrology,                 |
| (g) ground water geology,     | (s) vertebrate paleontology,   |
| (h) metalliferous geology,    | (t) invertebrate paleontology, |
| (i) nonmetalliferous geology, | (u) seismology,                |
| (j) geochemistry,             | (w) general geophysics,        |
| (m) mineralogy,               | (x) applied geophysics,        |
| (n) areal geology,            | (y) geophysical instruments,   |
| (o) stratigraphic geology,    | (z) glacial geology.           |
| (p) structural geology        |                                |

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

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

#### GERMAN

(See under Modern Languages)

## HISTORY AND GOVERNMENT

## UNDERGRADUATE SUBJECTS

**H 1 abc. History of European Civilization. 5 units (2-0-3); first, second, third terms.**

Lectures 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 industrialization, 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.

Instructor: McCreery.

**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 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 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.

**H 20. Modern France.\* 9 units (3-0-6).**

Senior elective.

France from 1789 to 1940. Emphasis will be on the revolutionary tradition and its influence both within France and in the broader European community.

Instructor: Davies.

**H 40. Reading in History. Units to be determined for the individual by the department.**

Elective, in any term. Approval of the Registration Committee is required where excess units are involved.

Reading in history and related subjects, done either in connection with the regular courses or independently of any course, but under the direction of members of the department. A brief written report will usually be required.

**H 41. Summer Reading. Units to be determined for the individual by the department. Maximum, 8 units.**

Elective.

Reading in history and related subjects during summer vacation. Topics and books to be selected in consultation with members of the department. A brief written report will usually be required.

## FIFTH-YEAR AND ADVANCED SUBJECTS

**H 100 abc. Seminar in History and Government. 9 units (2-0-7).**

A study of recent developments in national and international history. First and second terms: English and American foreign policy considered in its political, social and economic aspects; third term, to be announced.

Instructors: Davies, Sterling.

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

## HYDRAULICS

## UNDERGRADUATE SUBJECTS

**Hy 1. Hydraulics. 9 units (3-0-6); first term.**

Prerequisites: AM 1 abcd, ME 15 abc.

Application of basic principles of fluid mechanics to engineering problems in laminar and turbulent flow, flow in closed conduits, flow in open channels, flow around immersed bodies, 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.

Instructor: Kyropoulos.

## ADVANCED SUBJECTS

**Hy 100. Hydraulics Problems. Units to be based upon work done, any term.**

Special problems or courses arranged to meet the needs of fifth year students or qualified undergraduate students.

**Hy 101 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.

**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.

**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 in AE, CE, and ME.

**Hy 200. Advanced Work in Hydrodynamics or Hydraulic Engineering. Units to be based upon work done; and term.**

Special courses on problems to meet the needs of students beyond the fifth year.

**Hy 201 abc. Hydraulic Machinery. 6 units (2-0-4); first, second, third terms.**

A study of such rotating machinery as turbines, pumps, and blowers, and their design to meet specific operating conditions. This course will be given in seminar form led by members of the Hydrodynamic and Mechanical Engineering staffs.

**Hy 202 ab. Hydraulics of Free Surface Phenomena. 6 units (2-0-4).**

A study of the hydrodynamics of a fluid having a free surface with special reference to gravity wave phenomena. Fields studied will include low and high velocity in open channels and wave phenomena in enclosed bodies of fluid.

**Hy 203. Cavitation Phenomena. 6 units (2-0-4).**

Study of the experimental and analytical aspects of cavitation and allied phenomena. Problems will be considered from the field of hydraulic machinery and also for bodies moving in a stationary fluid.

Instructors: Knapp, Plesset.

**Hy 210 ab. Hydrodynamics of Sediment Transportation. 6 units (2-0-4).**

A study of the mechanics of the entrainment, transportation, and deposition of solid particles by flowing fluids. This will include problems of water and wind erosion, and density currents.

Instructor: Vanoni.

**Hy 300. Thesis.**

## 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: *Unified Calculus*, Smith, Salkover and Justice.

Professor in charge: Goldsworthy.

**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*, Kae and Randolph; *Vector Analysis*, Phillips.

Professor in charge: Ward.

**Ma 3. Theory of Equations. 10 units (4-0-6); first term.**

Includes topics of algebra of interest primarily to prospective mathematicians.

Topics Treated: the fundamental algebraic operations, the field concept, properties of number fields and polynomials, symmetric functions, elimination and results.

Text: *Introduction to Theory of Equations*, Weiner.

Instructor: Cairns.

**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: *Functions of a Complex Variable*, Goursat-Hedrick.

Instructors: Bohnenblust, Comba, Karlin.

**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 58. Introduction to Lebesgue Integration. 9 units (3-0-6); second term.**

Prerequisite: Ma 8 abc or its equivalent.

This course will include the elementary theory of measure, the Lebesgue-Stieltjes integral with applications to Fourier series.

Instructor: Dilworth.

**Ma 60. Mathematical Probability and Statistics. 9 units (3-0-6).**

Prerequisite: 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 103. Fourier Analysis. 9 units (3-0-6); third term.**

Prerequisites: Ma 8 abc and Ma 58 or their equivalent. A working knowledge of Lebesgue and Stieltjes integration will be assumed.

This course is intended for pure mathematicians and those applied mathematicians, physicists and engineers who must use Fourier Series and Integrals extensively. The topics treated will include complete orthonormal systems, Fourier Integral theorem, Plancherel theorem, Fourier-Stieltjes transforms and other unitary transforms, Fejer-Lebesgue kernels with application to various fields of analysis and number theory.

Instructor: DePrima.

**Ma 106 abc. Introduction to Theory of Functions of Real Variables. 9 units; three terms.**

Prerequisite: Ma 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 geometrics. 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: *Application of the Absolute Differential Calculus*, McConnell; *Riemannian Geometry*, Eisenhart; collateral reading.

Instructor: Michal.

**Ma 114 abc. Mathematical Analysis. 12 units; three terms.**

Prerequisites: Ma 8 abc; Ma 10 or its equivalent.

Theory of convergence, integration and residues, expansions of functions in infinite series. asymptotic and divergent series. Fourier series. Differential equations and function theory, integral equations, the gamma function and the zeta function, the hyper-geometric function and related functions of mathematical physics, elliptic functions, ellipsoidal harmonics.

Text: *Functions of a Complex Variable*, Copson.

Instructors: Bohnenblust, 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, Bernoulli numbers, quadratic residues, quadratic forms and other topics in elementary number theory.

Instructor: Ward.

**Ma 137 abc. Real Variables. 9 units; three terms.**

Prerequisite: 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.**

Prerequisite: 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 abc 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 201 ab. Introduction to the Calculus of Variations. 9 units; first and second terms.**

Prerequisites: Ma 8, Ma 114 or their equivalents.

Topics treated in 201 a will include:

Variational problems of physics and engineering. Euler equation. Natural boundary conditions. Classical necessary and sufficient conditions. Extremal Fields. Hamilton-Jacobi Theory. Iso-perimetric Problems. Lagrange Multipliers.

Topics treated in 201 b will include:

Modern direct methods. Dirichlet's principle. Approximate methods of Rayleigh, Ritz, Trefftz, Synge, etc. Finite difference and random-walk methods. Applications to boundary-value and eigen-value problems of physics and engineering, to conformal mapping minimal surfaces, geometry.

Instructor: DePrima.

**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 203 abc. Spectral Theory. 9 units; three terms.**

Prerequisite: Graduate standing.

Geometry of Hilbert space, operator theory of Hilbert space. General representation of maximal symmetric, Hermitian operators and normal Hermitian operators by their spectra. Applications to integral and differential operators.

Instructor: Karlin. To be given 1948-49 only.

**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 abc. Seminar in Algebra and Theory of Numbers. 6 units (2-0-4).**

Prerequisite: Graduate standing.

Topics selected to suit the class.

In charge: 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 hyper-complex 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 Elliptic Type—Green's Function. Vibration and Quantum Mechanical Problems—equations of Sturm-Liouville 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 273 abc. Seminar in Structure of Abstract Algebras. 6 units; three terms.**

Prerequisite: Graduate standing.

This seminar is a continuation of Ma 253 with emphasis upon the structure theorems of groups, rings, and fields.

In charge: Dilworth.

## MECHANICAL ENGINEERING

## UNDERGRADUATE SUBJECTS

**ME 1 a. Empirical Design. 3 units (0-3-0); second term.**

Prerequisite: D 1 abc.

This course is designed to supplement 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.

Instructors: Clark, Varney.

**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.

Instructors: Clark, Varney.

**ME 15 abc. Thermodynamics and Fluid Mechanics. 11 units (3-3-5); first, second, third terms.**

Prerequisites: Ph 2 abc, Ma 2 abc.

A study of the first and second laws of thermodynamics and their application to flow and non-flow processes both with and without friction. Emphasis will be placed on single component systems. Fluid motion treated from the point of view of thermodynamics and of mechanics for flow with and without friction. Steady flow versus non-steady flow. Introduction to the detailed mechanics of fluid motion and its relation to energy dissipation.

Application of the basic principles to the main types of fluid motions encountered in engineering problems and to the main classes of industrial heat engines, thermodynamic processes, and hydraulic machinery.

Laboratory demonstrations of thermodynamic and fluid mechanic principles. Tests of industrial heat engines and hydraulic machinery.

Instructors: Daugherty, Kyropoulos.

**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.

Instructors: Rannie, Kyropoulos.

**ME 20. Heat Engineering. 9 units (3-0-6); first term.**

An abridgement of ME 15 and 16 for students in Civil Engineering.

Text: *Fundamentals of Thermodynamics*, Adams and Hilding

Instructor: Kyropoulos.

**ME 25. Mechanical Laboratory. 9 units (0-6-3); third term.**

Prerequisite: ME 15 abc.

Tests of steam engine, steam turbine, blower and gas engine, etc., for efficiency and economy.

Instructor: Kyropoulos.

**ME 50 ab. Engineering Conferences. 2 units (1-0-1); first, third terms.**

A course in public speaking for engineers, on engineering topics.

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 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 transformations in steel, hardenability of steel, the function of alloying elements in steel, grain size and grain growth, and precipitation hardening.

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: Rannie.

**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).**

Prerequisite: One of the following courses; ME 105, AE 257 abc, AE 271 abc, Ph 92 ab.

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.**

Prerequisite: ME 110.

Atomic structure of metals, free atoms, assembly of atoms, physics of X-rays, elementary crystal structure. Methods of analysis by X-ray diffraction applied to metals and alloys. Structure of alloys, solid solutions, intermetallic compounds, electron compounds, electrical and magnetic properties. Plastic deformation, internal friction, age hardening, grain growth, recrystallization, and diffusion. During the latter part of the course, topics are assigned from the literature.

Text: *Atomic Theory for Students of Metallurgy*, Hume, Rothery; *Structure of Metals*, C. S. Barrett; *X-ray Metallography*, Taylor.

Instructor: Duwez.

**ME 211 abc. Metallography Laboratory. 8 units (1-6-1); first, second, third terms.**

Prerequisite: Me 110.

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 212 ab. X-ray Metallography. 6 units (0-6-0); second and third terms.**

Prerequisites: Me 210 a, ME 211 a.

Experimental methods of obtaining diffraction patterns of metals. The interpretation and identification of diffraction patterns of metals and alloys. Study of phase diagrams, plastic deformation and grain orientation, recrystallization texture, precipitation and age hardening, determination of grain size, and stress measurement by X-ray diffraction methods.

Text: *An Introduction to X-ray Metallography*, Taylor.

Instructor: Duwez.

**ME 215. Internal Combustion Engines. 9 units (3-0-6); one term.**

Prerequisites: ME 15 abc, ME 16.

Advanced study of: engine cycles with real fuel-air mixtures, combustion processes, fuels, detonation, octane and cetane rating, engine performance, and design.

Instructor: Daugherty.

**ME 216 ab. Refrigeration and Air Conditioning. 9 units (2-3-4); two terms.**

Prerequisites: Heat Power (class and laboratory)

Principles of vapor and absorption refrigeration; composite cycles. Deep freezing and liquifaction of gases. Reversed cycles.

Principles of air conditioning: properties of air-water vapor mixtures, air conditioning cycles. Comfort air conditioning (residence, trains, airplanes), industrial air conditioning (food, photographic, textile, paper industries).

Instructor: Kyropoulos.

**ME 217 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.**

Prerequisite: ME 215, or to be taken concurrently.

Survey of combustion research in spark and ignition engines. Flame front observation. High speed indicators, detonation indicators. Study of experimental methods of fuel injection problems and droplet formation. Carburetion and direct injection in spark ignition engines. Hydrocarbon thermodynamics. Reaction kinetics. Measurement of ignition quality of spark and compression ignition fuels. Standard methods (ASTM-CFR). Power measurement at sea level and altitude. Preparation of power charts and cruising charts. Measurement of exhaust composition and temperature. Measurement of cooling requirements and performance.

Texts: *Science of Petroleum* (Oxford Press), *I. C. Engines*, Pye (Oxford Press), *The Chemical Background of Engine Research* (Interscience Publishers).

Instructor: Kyropoulos.

**ME 220. Lubrication. 6 units (2-0-4); one term.**

Prerequisites: Internal combustion engines, machine design, hydrodynamics.

Hydrodynamic theory of lubrication. Application to actual bearings. Boundary lubrication. Interaction between bearing surface and lubricant. Extreme pressure lubricants, detergent oils. Lubricant performance in the engine.

Flow of viscous fluids (Reynolds, Sommerfeld) viscosity and friction. Pressure distribution and load carrying capacity of theoretical and actual bearing. Dimensional analysis of the problem. Partial bearings, thrust bearings. Temperature rise and heat dissipation. Bearings for high speed. Clearances. Gear tooth lubrication.

Boundary lubrication, problem, theory 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.**

## MODERN LANGUAGES

The subjects in modern languages are arranged primarily to meet the needs of science students who find it necessary to read books, treatises, and articles in French, German and Russian. In the study of these languages correct pronunciation and the elements of grammar are taught, but the emphasis is laid upon the ability to translate from them into English.

### UNDERGRADUATE SUBJECTS

#### **L 1 ab. Elementary French. 10 units (4-0-6); second, third terms.**

A subject in grammar, pronunciation, and reading that will provide the student with a vocabulary and with a knowledge of grammatical structure sufficient to enable him to read at sight French scientific prose of average difficulty. Accuracy and facility will be insisted upon in the final tests of proficiency in this subject. Students who have had French in the secondary school should not register for these subjects without consulting the department of modern languages.

Instructors: Bowerman, Stern.

#### **L 5 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.

## PALEONTOLOGY

(See under Geological Sciences)

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

## PHILOSOPHY, PSYCHOLOGY, AND SOCIOLOGY

## UNDERGRADUATE SUBJECTS

**PI 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.

**PI 4. Ethics.\* 9 units (3-0-6); third term.**

Prerequisite: PI 1.

Senior elective.

The principal concepts and conflicts of man's ethical thought, studied in terms of the major ethical systems. The problems of the good life, the nature of obligation, and the sources of moral authority are considered at length, particularly in relation to modern life and its ethical tensions.

Instructor: Mead.

**PI 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 1948-49.)

**PI 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

**PI 100 abc. Seminar in Philosophy. 9 units (2-0-7); 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, causality 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.

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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.

## 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 6 abc. Introduction to Mathematical Physics and Differential Equations. 15 units (5-0-10); first, second, third terms.**

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

An introduction to the application of mathematics, including vector analysis and differential equations, to physics; and practice in the solution of problems.

Text: *Principles of Mathematical Physics*, Houston.

Instructors: Anderson, Leighton.

**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 ab. Electrical Measurements. 3 units (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 11. Optical Design. 9 units (3-0-6); third term.**

Prerequisite: Ph 2.

A practical course in the design of optical instruments, including a study of the properties of optical materials, the manufacture of optical parts, and the techniques of lens design. Various instruments such as cameras, telescopes, microscopes, and spectrographs will be treated in detail. During the latter part of the course, each student will have an opportunity to select an individual design problem of interest to him. The text will be supplemented by material from outside sources and by visits to local instrument shops.

Text: *The Principles of Optics*, Hardy and Perrin.

Instructor: Baum.

**Ph 12 abc. Introduction to Atomic and Nuclear Physics. 9 units (3-0-6); first, second, third terms.**

Prerequisites: Ph 6 abc, Ph 7 abc or equivalent.

An introductory problem and lecture course in the experimental and theoretical foundation of modern atomic and nuclear physics. Subjects include electromagnetic waves, radiation laws, specific heats, photo-electricity, thermionics, atomic structure and the quantum theory, X-rays, radioactivity, and artificial transmutations.

Text: *Introduction to Modern Physics*, Richtmeyer and Kennard.

Instructor: C. C. Lauritsen.

#### 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. 9 units (3-0-6); first, second, third 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. Application of the tensor calculus to mechanical problems.

Text: *Dynamics*, Webster; and collateral reading.

Instructor: Davis.

**Ph 105 ab. Optics. 9 units (3-0-6); first, second terms.**

Prerequisite: 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: King.

**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: King.

**Ph 107. Spectroscopy. 9 units (3-0-6); third term.**

Prerequisite: 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. Nuclear Physics. 9 units (3-0-6); first, second, third terms.**

Prerequisite: Ph 12 abc or equivalent.

A problem and lecture course in nuclear physics. Subjects include fundamental properties and structure of nuclei, nuclear forces, nuclear reactions, and the behavior of high energy particles and radiation including cosmic rays.

Text: *Elementary Nuclear Theory*, Beth, and outside references.

Instructors: Fowler and Christy.

**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 on the constitution of matter as well as practical applications are discussed (such as thermodynamics of low temperature phenomena, liquifaction of gases, phase relations, specific heats, crystallization, plasticity.)

Instructor: Goetz.

**Ph 113 ab. Principles of Quantum Mechanics. 9 units (3-0-6); (b) first term, 1948-49; (ab) first and second terms, 1949-50.**

Prerequisites: 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 ideas 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 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 ab. Applications of Maxwell's Equations. 12 units (3-0-9); first, third terms.**

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 equation, propagation of waves, absorption and reflection, approximate and rigorous treatment of diffraction, theory of dispersion, electro- and magneto-optics.

Instructor: Epstein.

**Ph 224. Physical Optics. 12 units (4-0-8).**

Prerequisite: Ph 105.

Metal optics, theory of dispersion, Zeeman effect, Stark effect, optical activity, and other problems of electro- and magneto-optics.

Instructor: Epstein.

**Ph 225. Theory of Electrons. 12 units (4-0-8); third term.**

Prerequisites: Ph 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 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.

Schroedinger'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 234. Topics in Theoretical Physics. 9 units (3-0-6); one term.**

The content of this course will vary from year to year. Typical Topics: Non-relativistic Quantum Theory; Relativistic Quantum Theory.

Instructor: Christy.

**Ph 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 physics of the solid states. 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.

## PSYCHOLOGY

(See under Philosophy)

## RUSSIAN

(See under Modern Languages)

## SOCIOLOGY

(See under Philosophy)

## PART FOUR

### DEGREES, HONORS, AND AWARDS, 1947-1948

#### DEGREES CONFERRED JUNE 11, 1948

Doctor of Philosophy (page 245)

Engineer's Degree (page 246)

Master of Science (page 248)

Bachelor of Science (page 252)

#### HONORS AND AWARDS (PAGE 254)

## DEGREES CONFERRED JUNE 11, 1948

### DOCTOR OF PHILOSOPHY

- RAYMOND VOILES ADAMS, JR. (*Physics and Mathematics*), B.S., Kansas State College of Agriculture and Applied Science, 1941.
- NICHOLAS ANTHONY BEGOVICH (*Electrical Engineering and Physics*), B.S., California Institute of Technology, 1943; M.S., 1944.
- GLENN WAGNER BILLMAN (*Chemical Engineering and Mechanical Engineering*), B.S., California Institute of Technology, 1941; M.S., 1942.
- JOHN A. BROCKMAN, JR. (*Chemistry and Animal Physiology*), B.S., California Institute of Technology, 1942.
- DAVID HENRY BROWN (*Chemistry and Plant Physiology*), B.S., California Institute of Technology, 1942.
- DEAN RODEN CHAPMAN (*Aeronautics and Mathematics*), B.S., California Institute of Technology, February, 1944; M.S., June, 1944.
- WILLIAM HARRISON CORCORAN (*Chemical Engineering and Mechanical Engineering*), B.S., California Institute of Technology, 1941; M.S., 1942.
- EUGENE WOODVILLE COWAN, JR. (*Physics and Electrical Engineering*), B.S., University of Missouri, 1941; M.S., Massachusetts Institute of Technology, 1943.
- GEORGE ALEXANDER FEIGEN (*Immunology and Animal Physiology*), A.B., University of California, 1938.
- JAMES CHIPMAN FLETCHER (*Physics and Mathematics*), A.B., Columbia University, 1940.
- YUAN-CHENG FUNG (*Aeronautics and Mathematics*), B.S., National Central University, China, 1941; M.S., 1943.
- WALTER WILLIAM GARVIN (*Physics and Mathematics*), B.S., Massachusetts Institute of Technology, 1944; M.S., California Institute of Technology, 1945.
- REED ALDEN GRAY (*Biochemistry and Plant Physiology*), B.S., University of Utah, 1943; M.S., 1944.
- ROBERT NOEL HALL (*Physics and Mathematics*), B.S., California Institute of Technology, 1942.
- KENNETH WAYNE HEDBERG (*Chemistry and Physics*), B.S., Oregon State College, 1943.
- CHUNG-PEN HO (*Meteorology and Physics*), B.S., National Tsing-Hua University, China, 1932; M.S., California Institute of Technology, 1945; Meteorologist, 1946.
- GEORGE HOLZMAN (*Chemistry and Plant Physiology*), B.S., California Institute of Technology, 1942.
- HAROLD SLEDGE JOHNSTON (*Chemistry and Physics*), A.B., Emory University, 1941.
- JACK WARREN KEUFFEL (*Physics and Mathematics*), A.B., Princeton, 1941.
- PETER RUDOLF KYROPOULOS (*Mechanical Engineering and Civil Engineering*), University of Göttingen, 1937; M.S., California Institute of Technology, 1938.
- HARRY LASS (*Mathematics and Physics*), A.B., University of California at Los Angeles, 1938; M.A., 1940.
- JOHN LAUFOR (*Aeronautics and Physics*), B.S. Louisiana State University, 1942; M.S., California Institute of Technology, 1943; A.E.E., 1944.
- DAVID ARTHUR LIND (*Physics and Mathematics*), B.S., University of Washington, 1940; M.S., California Institute of Technology, 1943.
- FRANK EARL MARBLE (*Aeronautics and Mathematics*), B.S., Case School of Applied Science; M.S., 1942; A.E.E., California Institute of Technology, 1947.
- MARK MUIR MILLS (*Physics and Mathematics*), B.S., California Institute of Technology, 1940.
- FERN WOOD MITCHELL, JR., (*Chemistry and Plant Physiology*), A.B., University of Alabama, 1938; M.S., California Institute of Technology, 1946.
- RICHARD ALAN MONTGOMERY (*Electrical Engineering and Physics*), B.A., University of British Columbia, 1940; M.S., California Institute of Technology, 1946.
- THOMAS EDMOND OBERBECK (*Mathematics and Physics*), B.A., Washington University, 1938; A.M., University of Nebraska, 1940.
- MAX LUDWIG PANZER (*Biochemistry and Plant Physiology*), B.S., California Institute of Technology, 1944; M.S., 1945.

- RALPH RONALD RAU (*Physics and Mathematics*), B.S., College of Puget Sound, 1941; M.S., California Institute of Technology, 1943.
- FREDERICK CROUCH ROOP (*Meteorology and Applied Mechanics*), A.B., Princeton University, 1935; M.S., Harvard University, 1936.
- VICTOR SCHOCKEN (*Plant Physiology and Immunochemistry*), B.A., New York University, 1942; M.S., Oregon State College, 1944.
- JESSE ROBERTSON SINGLETON (*Genetics and Embryology*), A.B. & B.S., North West Missouri State Teachers College, 1938; A.M., University of Missouri, 1941.
- CONWAY WILSON SNYDER (*Physics and Mathematics*), A.B., University of Redlands, 1939; M.S., State University of Iowa, 1941.
- JOHN DANIEL SPIKES (*Embryology and Plant Physiology*), B.S., California Institute of Technology, 1941; M.S., 1946.
- YU-WEI TANG (*Plant Physiology and Biochemistry*), B.S., National Central University, China, 1940.
- LUIS HERNAN TEJADA-FLORES (*Electrical Engineering and Mathematics*), B.S., California Institute of Technology, 1938; M.S., 1943.
- JOHN FRANK THURLOW (*Biochemistry, Bio-organic Chemistry and Plant Physiology*), B.S., Bates College, 1943.
- LEON TRILLING (*Aeronautics and Physics*), B.S., California Institute of Technology, 1944; M.S., 1946; A.E.E., California Institute of Technology, 1947.
- JAMES GUTWILLIG WENDEL (*Mathematics and Physics*), B.A., Reed College, 1943.
- ARTHUR GREENVILLE WHITTAKER (*Chemistry and Physics*), B.S., Washington University, 1940.
- CHARLES HAROLD WILTS (*Electrical Engineering, Physics and Mathematics*), B.S., California Institute of Technology, 1940; M.S., 1941.
- FREDERICK HAMILTON WRIGHT (*Physics and Mathematics*), A.B., Haverford College, 1934.

#### AERONAUTICAL ENGINEER

- JOHN H. ALTSEIMER, B.S. (M.E.), University of Wisconsin, 1941; M.S., California Institute of Technology, 1946.
- WARREN AMSTER, B.S., California Institute of Technology, 1944; M.S., 1947.
- ROLF DIETRICH BUHLER, B.A.E., University of Minnesota, 1943; M.S., California Institute of Technology, 1944.
- RAYMOND LU-PO CHUAN, B.A., Pomona College, 1944; M.S., California Institute of Technology, 1945.
- THOMAS V DAVIS, B.S., California Institute of Technology, 1938; M.S., 1947.
- HAROLD M. DEGROFF, JR., B.AERO.E., Rensselaer Polytechnic Institute, 1946; M.S., California Institute of Technology, 1947.
- WELKO ELTON GASICH, A.B., Stanford University, 1943.
- HARRY FREDERICK IMSTER, B.S.S., University of Michigan, 1946; M.S., California Institute of Technology, 1947.
- ARNOLD AXTELL JENSEN, B.PHYS., University of Minnesota, 1939; M.S., California Institute of Technology, 1947.
- CHINTAKINDI VENKATA JOCARAO, B.S., Benares Hindu University, India, 1944; M.S., Stanford University, 1947.
- WARREN GOTTLIEB KOERNER, B.S., Purdue University, 1942; M.S., California Institute of Technology, 1947.
- SEYMOUR LAMPERT, B.S. IN A.E., Georgia School of Technology, 1943, M.S., California Institute of Technology, 1947.
- JAMES STEVEN LESKO, B.AERO.E., Rensselaer Polytechnic Institute, 1943; M.S., California Institute of Technology, 1947.
- RICHARD JEFFREY MAGNUS, B.AERO.E., University of Minnesota, 1944; M.S., 1947.
- BERNARD WALTER MARSCHNER, B.AERO.E., University of Minnesota, 1942; M.S., California Institute of Technology, 1947.
- HERMAN MILLER, B.S., California Institute of Technology, 1943; M.S., 1945.
- WALTER PATRICK MURPHY, JR., LT. COMDR., U.S.N., B.S., United States Naval Academy, 1941.
- CONRAD NATHANIEL NELSON, CAPT., U.S.A.F., S.B., Massachusetts Institute of Technology, 1941; M.S., California Institute of Technology, 1947.
- ERNEST I. PRITCHARD, B.S., Antioch College, 1943; M.S., California Institute of Technology, 1947.
- DONALD BARSTOW SEAGER, B.S., University of California, 1942; M.S., California Institute of Technology, 1947.

- WILLIAM EDWARD SIMS, LT. COMDR., U.S.N., B.S., United States Naval Academy, 1941.  
 MERVIN OTIS SLATER, LT. COMDR., U.S.N., B.S., United States Naval Academy, 1941.  
 JOSIAH E. SMITH, B.S., California Institute of Technology, 1939; M.S., 1940.  
 NATESAN SRINIVASAN, B.S., Madras University, India, 1938; M.S., California Institute of Technology, 1946.  
 WILBERT GAYTON WHELDON, B.S., United States Naval Academy, 1941; M.S., California Institute of Technology, 1947.  
 RICHARD STREET WHITE, III, LIEUT., U.S.N., B.S., United States Naval Academy, 1942.  
 MAX L. WILLIAMS, JR., B.S., Carnegie Institute of Technology, 1942; M.S., California Institute of Technology, 1947.  
 WILLIAM STUART WUNCH, B.S.(A.E.), University of Michigan, 1945; B.S.(MA.), 1945.

## CIVIL ENGINEER

- PHILLIP EISENBERG, B.S., Wayne University, 1941.  
 GURUVAYUR SUBRAMANYAM RAMASWAMY, B.S., Madras University, India, 1944; M.S., California Institute of Technology, 1947.

## ELECTRICAL ENGINEER

- PAUL SANFORD ROCELL, B.S., Iowa State College, 1944.

## INDUSTRIAL DESIGNER

- ROBERT ELSTON BOND, B.A., Yale University, 1940.  
 ROBERT PHILIP BRINKMAN, B.S., Iowa State College, 1943.  
 HAROLD HARRISON FORD, B.S., California Institute of Technology, 1945.  
 ROBERT FRANCIS McLEAN, B.S., California Institute of Technology, 1943.  
 RAYMOND JEFFERSON PALMER, B.S., California Institute of Technology, 1944.  
 JEROME WESLEY PARKS, B.S., California Institute of Technology, 1945.  
 CHARLES CRAIG PAUL, B.S., Northeastern University, 1941.  
 SIDNEY R. SHANNON, JR., B.S., North Dakota Agricultural College, 1936.  
 HARVEY JOHN WHITE, B.E., University of Southern California, 1944.  
 CURTIS CRUVER WHITTLESEY, B.E., University of Southern California, 1944.

## MECHANICAL ENGINEER

- OLIVER A. BAER, A.B., Stanford University, 1943; M.S., California Institute of Technology, 1947.  
 DAVID ARTHUR ELMER, B.S., California Institute of Technology, 1943; M.S., 1947.  
 CHI-NAN HSU, B.S., Chiao-Tung University, Chungking, China, 1941.  
 OMER ISMET INONU, Istanbul Technical University, Turkey.  
 LEROY COSBY LAND, MAJOR, U.S.A., B.S., Utah State Agricultural College, 1940.  
 WALTER CHARLES SWAN, B.M.E., Rensselaer Polytechnic Institute, 1942; M.S., Northwestern University, 1947.

## CHEMICAL ENGINEER

- CHARLES EDWARD AUERBACH, B.S., University of California, 1942; M.S., California Institute of Technology, 1947.  
 PAUL STEPHEN FARRINGTON, B.S., California Institute of Technology, 1941; M.S., 1947.  
 JAMES WILLIAM GLANVILLE, B.S., Rice Institute, 1944; M.S., California Institute of Technology, 1946.  
 JOSEPH DENNIS YANAK, B.S., Lafayette College, 1939; M.Ch.E., Polytechnic Institute of Brooklyn, 1942.

## METEOROLOGIST

- ROBERT FRANKLIN STRICKLER, B.S., California Institute of Technology, M.S., 1942.

## MASTER OF SCIENCE IN SCIENCE

*Biology*

EMANUEL WINDSOR, B.S., California Institute of Technology, 1938.

*Chemistry*

CHARLES IDOL BROWNE, B.A., Drew University, 1941; M.A., University of Texas, 1944.  
 GEORGE JOSEPH DOYLE, A.B., San Jose State College, 1940.  
 HORST WALTER HOYER, B.S., College of the City of New York, 1942.  
 GEORGE LOUIS HUMPHREY, B.A., Marietta College, 1943.  
 CARL ROBERT LINDEGREN, A.B., University of California, 1943.  
 DALE JOSEPH MEIER, B.S., California Institute of Technology, 1947.  
 ROBERT LEROY MILLS, B.S., Washington and Jefferson College, 1943.  
 ROLLIE JOHN MYERS, JR., B.S., California Institute of Technology, 1947.  
 JAMES EARL WHITNEY, Sc.B., Brown University, 1943.  
 ROBERT STANLEY WINNIFRED, B.S., Oregon State College, 1943.

*Chemical Engineering*

JOHN S. BILLHEIMER, B.S., California Institute of Technology, 1947.  
 JAMES LOGAN BUHLER, B.S., University of California, 1942.  
 GORDON HENRY GOFF, B.S., University of California, 1943.  
 BERT HENRY GOLDING, B.S., California Institute of Technology, 1944.  
 DONALD IRVING GRANICHER, B.S., California Institute of Technology, 1947.  
 JOHN LATIMER MASON, S.B. in Meteorology, University of Chicago, 1944; B.S., California Institute of Technology, 1947.  
 FREDERICK DENT PARKER, B.S., University of Oklahoma, 1944.  
 LEWIS ALVIN ROBINSON, B.S., Lehigh University, 1946.  
 DAVID BRITAIN WILLNER, B.S.E., Princeton University, 1947.

*Geological Sciences*

HADDON WILSON AGNEW, B.A., University of British Columbia, 1934.  
 MAYETTE ELMER DENSON, JR., B.S., Montana State College, 1941.  
 WAKEFIELD DORT, JR., S.B., Harvard University, 1944.  
 CHARLES DeVRIES EDWARDS, B.A., Carleton College, 1942.  
 ALBERT HENRY HEDDEN, JR., B.A., Williams College, 1946.  
 HENRY LINDSAY HAROLD, A.B., University of California, 1945.  
 HENRY SELDEN HITCHCOCK, B.A., Pomona College, 1943.  
 ROBERT JOHN MACNEILL, B.A., Queens College, 1943.  
 HAROLD MORTON MOONEY, S.B., Harvard University, 1943.  
 RETURN FRANCIS MOORE, B.S., California Institute of Technology, 1947.  
 WAYNE ARTHUR ROBERTS, B.S., California Institute of Technology, 1945.  
 EUGENE MERLE SHOEMAKER, B.S., California Institute of Technology, 1947.  
 GEORGE G. SHOR, JR., B.S., California Institute of Technology, 1944.  
 RAYMOND JAMES SMITH, B.S., California Institute of Technology, 1945.

*Meteorology*

HAROLD OSCAR BERGMAN, CAPT., U.S.A.F., B.S., University of Colorado, 1938.  
 JAMES ARTHUR BUNCE, CAPT., U.S.A.F., B.S., Georgia Teachers College, 1942.  
 HENRY ROY CHOPE, JR., B.E.E., Ohio State University, March 1948.  
 ALBERT RAYMOND CLARK, LT., U.S.A.F., B.S., Western Michigan College of Education, 1942.  
 WILLIAM DONHAM CRAWFORD, B.S., United States Naval Academy, 1947.  
 EDWIN BASCOM DICKSON, LT., U.S.A.F., B.S. IN E.E., Georgia School of Technology, 1942;  
 B.S. IN MATH., University of Tampa, 1943.  
 LUTHER FITZGERALD FISHER, B.A., Southern Methodist University, 1947.  
 LEWIS OCTAVE GRANT, B.S., University of Tulsa, 1947.  
 CARL ROBERT HAMILTON, MAJOR, U.S.A.F., B.S., Colorado State College, 1934.  
 GEORGE JAMES HEBEL, B.S., University of Illinois, 1940.  
 LYNN THORNTON IRISH, MAJOR, U.S.A.F., B.S., Iowa State College, 1938.  
 CHARLES OTTO JENISTA, JR., B.S., Ohio State College, March 1948.  
 GEORGE ARTHUR JENSEN, B.A., College of the Pacific, 1947.

GEORGE JOSEPH NEWGARDEN, III, CAPT., U.S.A.F., B.S., University of Maryland, 1943.  
 EDWARD DIONYSIUS OLIVER, JR., B.S., Sulross University, 1947.  
 RALPH MCGEE ROTT, B.S., State University of Iowa, 1947.  
 WILLIAM HAROLD SHIVAR, LT., U.S.A.F., B.S., Presbyterian College, 1947.  
 JOHN THOMAS SLUSHER, B.A., Austin College.  
 DAVID S. STOLLER, A.B., University of California at Los Angeles, 1947.  
 MILTON ARTHUR STRAUSS, B.S., California Institute of Technology, 1946.  
 EDWARD ALEXANDER TAYLOR, B.S., University of Nebraska.  
 RAYMOND NICHOLAS TOMLIN, B.S., University of Colorado, 1947.  
 CHAROEN VADHANAPANICH, B.S., California Institute of Technology, 1947.  
 JOE KEITH WILLIAMS, California Institute of Technology.  
 MARION C. WOODS, B.S., Colorado State College, 1947.

### *Physics*

WILLIAM ALFRED BARKER, II, B.A., Yale University, 1941.  
 JULIUS SAMUEL BENDAT, A.B., University of California, 1944.  
 JAMES ROY BROWN, B.S., Allegheny College, 1944.  
 WILLIAM WALTON CARTER, B.S., Carnegie Institute of Technology, 1943.  
 ARNOLD FELDMAN, B.S., Pennsylvania State College, 1944.  
 HARVEY JUNIOR FLETCHER, B.S., Massachusetts Institute of Technology, 1944.  
 DONALD THEODORE GREENWOOD, B.S., California Institute of Technology, 1944.  
 CHIEN HSIAO, B.S., National Southwest Associated University, Peiping, China, 1944.  
 CHIA LIN HSIEH, B.S., Yenching University, Changtu, China, 1943.  
 ERDAL INONU, University of Ankara, Turkey, 1947.  
 PAUL BEATTIE MACCREADY, JR., B.S., Yale University, 1947.  
 RICHARD IRVING MADDOX, B.S., United States Naval Academy, 1941.  
 GEORGE MICHAEL SAFONOV, B.S., California Institute of Technology, 1943.  
 JOHN DORRINGTON SEACRAVE, B.S., California Institute of Technology, 1946.  
 LEON SHENFEL, B.S., California Institute of Technology, 1947.  
 GEORGE FOSTER SMITH, B.S., California Institute of Technology, 1944.  
 GEORGE POWELL STECK, A.B., University of California, 1945.  
 ROBERT KESSLER SWANK, B.A., Miami University, 1943.  
 RONALD WALTER URE, JR., B.S.E., University of Michigan, 1947.  
 WILLIAM HENRY VOELKER, B.S., Case School of Applied Science, 1944.  
 WILLIAM ALFRED WENZEL, B.A., Williams College, 1944.

## MASTER OF SCIENCE IN ENGINEERING

### *Aeronautics*

CLIFTON LEON ADCOCK, B.S., Agricultural and Mechanical College of Texas, 1946.  
 JOHN WILLIAM BACON, JR., B.S., California Institute of Technology, 1943.  
 WILLIAM CYRUS BARKER, B.S., University of California, 1942.  
 ROBERT ERNEST BENEFIELD, CAPT., U.S.A.F., B. AERO. E., Rensselaer Polytechnic Institute, 1942.  
 JOSEPH NISSIM BENEZRA, B.S., University of Washington, 1944.  
 PHILIP G. BLENKUSH, B. AERO. E., University of Detroit, 1941.  
 JAMES DONAHUE BURKE, B.S., California Institute of Technology, 1945.  
 FENG-KAN CHUANG, B.S., Chiao Tung University, Shanghai, 1946.  
 DONALD COLES, B.S., University of Minnesota, 1947.  
 CARL BRITTON COX, A.B., University of California at Los Angeles, 1936; M.A., 1939.  
 JAMES ROY DALE, JR., MAJOR, U.S.A.F., B.S., Virginia Military Institute, 1941.  
 ORIN JACK DEMUTH, B.S., California Institute of Technology, 1947.  
 JAMES EDWARD DENSMORE, B.S., California Institute of Technology, 1946.  
 JAMES FREDERICK DRAKE, B.S., California Institute of Technology, 1946.  
 LORNE CAMPBELL DUNSWORTH, B.ENG., McGill University, 1944.  
 MANFRED EIMER, B.S., California Institute of Technology, 1947.  
 HAMED KAMAL EL DIN, B.ENG., Fouad I University, Cairo, Egypt, 1945.  
 HOWARD LEONARD ENCEL, B.S., Carnegie Institute of Technology, 1944.  
 PERRY HUSTON EUBANK, LT. COL., A.G.F., B.S., United States Military Academy, 1937.  
 DONALD LOWELL FRANCIS, B.S., California Institute of Technology, 1945.  
 JACK EDWARD FROELICH, B.S., California Institute of Technology, 1947.  
 EDGAR WILLIS GREGORY, II, CAPT., U.S.A.F., B.S., United States Military Academy, 1944.

- EDWARD NATHANIEL HALL, MAJOR, U.S.A.F., B.S. IN ENC., College of the City of New York, 1935; B.S. IN CHEM. ENG., 1936.
- JAMES NEWTON HALL, MAJOR, U.S.A.F., B.S., Purdue University, 1940.
- MALCOLM STUART HARNED, B.S., University of Kansas, 1943.
- THOMAS P. HIGGINS, JR., B.S., University of Oklahoma, 1943.
- HAROLD M. HIPSH, B.S., California Institute of Technology, 1947.
- WILLIAM SUMPTER JOHNSON, JR., B.AERO.E., North Carolina State College of Agriculture and Engineering, 1942.
- FRANKLIN H. KNEMEYER, B.S., California Institute of Technology, 1944.
- HARVEY H. LATSON, JR., MAJOR, U.S.A.F., B.S., United States Military Academy, 1943.
- BENOIT B. MANDELBROT, B.S., Université de Clermont-Ferrand, 1942; Ingénieur de L'École Polytechnique, 1947; Licencié es Sciences Mathématiques, Université de Paris, 1947.
- ROBERT WAYNE MCJONES, B.S., University of Kansas, 1947.
- JOHN DILL MCKENNEY, B.S., California Institute of Technology, 1945.
- GILBERT GUNTER MOREHOUSE, CAPT., U.S.A.F., B.S., University of Nevada, 1942.
- HARVEY ORIN NAY, B.S., University of Colorado, 1947.
- DOUGLAS CLARK OGILVIE, B.S., University of California, 1947.
- BLAINE R. PARKIN, B.S., California Institute of Technology, 1947.
- GEOFFREY VERNON PARKINSON, B.A.Sc., University of British Columbia, 1946.
- EDWIN POUNDER, B.S., California Institute of Technology, 1946.
- ARTHUR WAYNE REED, MAJOR, A.G.F., B.S., United States Military Academy, 1939.
- WAYNE E. RHYNARD, LT. COL., U.S.A.F., B.S., United States Military Academy, 1941.
- EUGENE S. ROSE, JR., LT., U.S.A.F., B.S., California Institute of Technology, 1947.
- GERALD DOWD RYAN, B.S., Worcester Polytechnic Institute, 1947.
- LOUIS VINCENT SCHMIDT, B.S., California Institute of Technology, 1946.
- HARRIS MCINTOSH SCHURMEIER, B.S., California Institute of Technology, 1945.
- DAVID EDWIN SHONERD, B.S., California Institute of Technology, 1943.
- ROBERT RICHARD SOLVERSON, S.B., Harvard University, 1944.
- BASIL STAROS, B.S., Massachusetts Institute of Technology, 1941.
- ROBERT STANLEY STEWART, B.AERO.E., University of Minnesota, 1943.
- TORSTEIN STRAND, B.S., Massachusetts Institute of Technology, 1947.
- JAY WILLIAM STUART, JR., B.S., California Institute of Technology, 1946.
- CONSTANTINE SVIMONOFF, LT., U.S.A.F., AAF Institute, Tech. Wright Field, 1947.
- JAMES KIRKBRIDE TAYLOR, MAJOR, A.G.F., B.S., United States Military Academy, 1940.
- JOHN WILLIAM THOMAS, B.S., United States Naval Academy, 1935.
- FRANK WESLEY VON TUNGELN, B.S., Oklahoma Agricultural and Mechanical College, 1942.
- JAMES WILLARD WALTERS, JR., MAJOR, A.G.F., B.S., United States Military Academy, 1940.
- THORNTON ARNOLD WILSON, B.S., Iowa State College, 1943.
- JOHN KENNETH WIMPRESS, B.S., Georgia School of Technology, 1946.
- ROBERT M. WRAY, LT. COL., U.S.A.F., B.S., United States Military Academy, 1939.

#### *Civil Engineering*

- MIHRAN S. AGHABABIAN, B.A. IN PHYSICS, American University of Beirut, Lebanon, 1944; B.S. IN C.E., 1947.
- MATTHEW JOHN ALTENHOFEN, LT. COL., U.S.A., B.S., United States Military Academy, 1938.
- ADAM JACK BEINSCHROTH, B.C.E., Rensselaer Polytechnic Institute, 1947.
- ANDREW THOMSON BINGHAM, B.C.E., University of Saskatchewan, 1947.
- DOUGLAS KING BLUE, MAJOR, U.S.A., B.S., Union College, 1939; B.S., United States Military Academy, 1943.
- FRANCIS ROBERT BOWERMAN, B.S., California Institute of Technology, 1947.
- ROBERT KING BREECE, B.S., California Institute of Technology, 1947.
- CURTIS WHEATON CHAPMAN, JR., LT. COL., U.S.A., B.S., United States Military Academy, 1941.
- ROBERT LEWIS COLLINS, B.S., University of Texas, 1947.
- EDWARD GAYLORD COOK, LT. COL., U.S.A., B.S., United States Military Academy, 1940.
- HARVEY REED FRASER, LT. COL., U.S.A., B.S., United States Military Academy, 1939.
- FRANK AUSTIN GERIG, JR., MAJOR, U.S.A., B.S., United States Military Academy, 1941.
- JOHN DEAN HOLM, LT. COL., U.S.A., B.S., University of Minnesota, 1937.
- ROY SKILES KELLEY, LT. COL., U.S.A., B.S., Western Kentucky State Teachers College, 1939; B.S., United States Military Academy, 1941.
- ELMORE GRENVILLE LAWTON, LT. COL., U.S.A., B.S., Clemson Agricultural College, 1933.
- NEVILLE STUART LONG, B.S., California Institute of Technology, 1944.
- WILLIAM PEARSON LUNDY, B.S., California Institute of Technology, 1947.

ALBERT EDGAR MCCOLLAM, LT. COL., U.S.A., B.S., United States Military Academy, 1939.  
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 ANDREW P. ROLLINS, JR., LT. COL., U.S.A., B.S., Agricultural & Mechanical College of Texas, 1939.  
 JAMES THOMAS ROSTRON, B.S., University of California, 1941.  
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 ROBERT MARSHALL WHITENTON, MAJOR, U.S.A., B.S., Oklahoma A. & M. College, 1942.  
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*Electrical Engineering*

FRED PETER ADLER, B.S., University of California, 1945.  
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 CARL WILLIAM BERGMAN, JR., B.S., Worcester Polytechnic Institute, 1945.  
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 CHARLES EDWARD BURDG, B.S., California Institute of Technology, 1946.  
 JOHN JUNIOR BURKE, B.S., California Institute of Technology, 1946.  
 JOHN PAUL DAVIS, B.S., University of Colorado, 1946.  
 DOUGLAS GEORGE DETHLEFSEN, B.S., California Institute of Technology, 1945.  
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 GEORGE WALTER EPPRECHT, Diplom, Electro-Ingenieur, Swiss Federal Institute of Technology, 1946.  
 FRANCIS EVARTS FAIRMAN, III, B.S., Haverford College, 1945.  
 RAYMOND WILLIAM FERGUSON, B.S., Agricultural and Mechanical College of Texas, 1947.  
 GEORGE JAY GLEGHORN, JR., B.S., University of Colorado, 1947.  
 JAMES WARD HAGER, B.S., University of Wisconsin, 1946.  
 DONALD JAMES HASS, B.S., California Institute of Technology, 1946.  
 JAMES WARREN HILL, B.S., California Institute of Technology, 1933.  
 ROBERT CLARKE HOPKINS, A.B., College of Emporia, 1935.  
 WILLIAM FRANKLIN HORTON, B.S., California Institute of Technology, 1946.  
 SOL MATT, B.S., Ohio University, 1944.  
 WILLIAM CARL McDONELL, B.S., California Institute of Technology, 1945.  
 DUANE TORRANCE McRUER, B.S., California Institute of Technology, 1945.  
 EDWARD VAUGHAN PHILLIPS, B.S., University of Illinois, 1945.  
 JOHN CUMMING RIEDEL, B.S., California Institute of Technology, 1947.  
 KENNETH WALTER ROBINSON, B.S., California Institute of Technology, 1946.  
 PAUL SANFORD ROGELL, B.S., Iowa State College, 1944.  
 HAROLD ALVIN ROSEN, B.E., Tulane University, 1947.  
 GEORGE ROBERT SCHULL, B.S., Rose Polytechnic Institute, 1941.  
 HASKELL SHAPIRO, B.S., California Institute of Technology, 1942.  
 BERNARD OWEN STEENSON, B.S., Illinois Institute of Technology, 1944.  
 MALCOLM HARWOOD STEWARD, A.B., University of California at Los Angeles, 1942.  
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 RAYMOND BERNARD TASKER, B.S., California Institute of Technology, 1947.  
 VINCENT ALMON VIS, B.S.E. (CHEM.ENG.), University of Michigan, 1941; B.S.E. (MATH.), 1941.  
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*Mechanical Engineering*

JAMES EDWARD ASH, B.S.M.E., Illinois Institute of Technology, 1947.  
 NIELS JOHANNES BECK, B.S., University of Colorado, 1947.  
 JOHN ALBERT BURTON, B.A.Sc. (M.E.), University of British Columbia, 1944; B.A. (MATH.), 1947.  
 TAO HUNG CHU, Diploma in M.E., Henry Lester Institute of Technical Education, Shanghai, 1943.  
 DONALD GUY FURST, B.S., California Institute of Technology, 1946.  
 JOHN HENRY GERPHEIDE, B.S., California Institute of Technology, 1945.  
 GEORGE ELMER HLAVKA, B.S., University of Wisconsin, 1946.  
 RICHARD FREDERICK JOHNSON, B.S., Agricultural & Mechanical College of Texas, 1947.  
 JOHN KAYE, B.S., California Institute of Technology, 1939.

LEROY COSBY LAND, B.S., Utah State Agricultural College, 1940.  
 RICHARD FRANK LEMON, B.S., University of Oklahoma, 1945.  
 LLOYD GERALD LUDWIG, B.M.E., Ohio State University, 1943.  
 RICHARD LEE ROBINSON, S.B., Massachusetts Institute of Technology, 1947.  
 LYLE DEAN SIX, B.S., California Institute of Technology, 1947.  
 RICHARD JOSEPH SOIKE, B.S., California Institute of Technology, 1944.  
 PAUL GUSTAV STEIN, B.S.M.E., University of Rochester, 1947.  
 WILBUR MILTON SWANSON, B.S., California Institute of Technology, 1944.  
 FRED MILTON WELLS, B.S., University of Kentucky, 1947.

## BACHELOR OF SCIENCE

### *Science*

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 ROBERT WARNER POINDEXTER  
 MARSHALL CLARKE POND  
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 WILLIAM EDWARD SMITH\*  
 DONALD PARKER SPALDING, JR.  
 MIKE EDWARD SPOONER, JR.  
 DOUGLAS C. STRAIN  
 IRVING IRA SULMEYER  
 CHARLES SUSSKIND  
 JOHN SABIN SWAIN  
 KENNETH KAI-HAN TANG  
 JAMES RUGGLES THORPE, JR.  
 THOMAS VREBALOVICH  
 ALFRED EARNEST WATERS  
 JOSEPH WOLFF WECHSLER  
 ROBERT LEONARD WENICK  
 DONALD PAHL WILKINSON\*  
 JOE KEITH WILLIAMS  
 WILLIAM JEFFRIES WILLIAMSON  
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 FRANK J. WOLF†  
 ALBERT KOON-BIU WONG  
 WILLIAM LOGAN WOODSON  
 BRUCE A. WORCESTER†  
 JACOB FRANCIS WOZNIAC, JR.†  
 HARVEY WESTON WRIGHT, JR.  
 ROBERT ZACHARIAS

\*Graduated with honor in accordance with a vote of the Faculty.

†Awarded the Honor Key by the Associated Students CIT, for participation in student activities.

## HONORS AND AWARDS

## HONOR STANDING

The undergraduate students listed below have been awarded honor standing for the current year, on the basis of the excellence of their academic records for the year 1947-1948:

*Class of 1949*

F. S. ALLINDER  
J. M. ANDRES  
F. H. BRADY  
J. R. CANTWELL  
W. E. DANIELSON  
R. W. GOULD  
W. J. HIRSCHBERG

R. L. KAHN  
W. J. KARZAS  
R. E. KOFAHL  
D. A. LIBERMAN  
H. C. MARTEL  
B. B. RUTKIN  
W. M. MYERS

C. J. SAVANT  
K. M. TERWILLIGER  
R. L. WALQUIST  
R. R. WATERS  
E. D. WEST  
J. L. WHITE  
G. W. WOODWARD

*Class of 1950*

J. R. ALLDER  
H. J. AMSTER  
G. B. BOOTH  
F. J. CORBATO  
D. H. COOPER  
R. J. DICKSON  
B. GAGE

J. B. GERHART  
L. K. GOODWIN  
W. JOHN, JR.  
J. L. KOHL  
M. V. MATHEWS  
R. S. PIERCE  
W. B. RISENFELD

L. W. ROSS  
V. A. J. VAN LINT  
M. WALT  
R. S. WELTE  
E. A. WORRELL  
R. B. WRIGHT

*Class of 1951*

H. A. BEGG  
K-Y. CHONG  
E. F. DAVIS  
F. H. EISEN  
H. FORRESTER  
P. F. HELFREY  
J. A. IBERS

J. B. JOHNSTON  
R. J. KURLAND  
T. W. LAYTON  
PETER V. MASON  
J. H. MCQUISTON  
G. MERKEL  
U. MERTEN

J. J. W. ROGERS  
K. SATO  
R. B. TAYLOR  
G. TRILLING  
A. E. WENNSTROM  
W. M. WHITNEY

## AWARDS

## CONGER PEACE PRIZE ORATION

*First Prize:* ROBERT J. HEPPE

*Second Prize:* JOHN HEATH, JR.

## MARY A. EARL MCKINNEY PRIZE IN ENGLISH

*First Prize:* JAMES D. YOUNG

*Second Prize:* CARL A. PRICE

## FREDERIC W. HINRICHS, JR., MEMORIAL AWARD

WILLIAM R. MUEHLBERGER

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