

# Information for Undergraduate Students

20



The undergraduate program leads to a four-year Bachelor of Science degree. Admitted students matriculate in the fall term only. Caltech does not have a summer session or part-time program, and cannot consider you if you already have a bachelor's degree from another college, university, or the equivalent. If you have matriculated at any college, university, or the equivalent in a program leading to any degree, you will probably be required to apply as a transfer student, and should read the requirements in the section titled "Transfer Admissions."

## ADMISSION TO THE FRESHMAN CLASS

Students are admitted to the freshman class on the basis of strong academic performance in a rigorous course of college preparatory study, especially in the areas of math and science; results of the SAT I or ACT, and two SAT II subject exams; teacher and counselor evaluations; personal characteristics; a demonstrated interest in math, science, or engineering; and information provided on the application.

### *Applying*

An application for admission may be obtained by writing or calling the Office of Undergraduate Admissions, California Institute of Technology, Mail Code 1-94, Pasadena, CA 91125; (626) 395-6341; [ugadmissions@caltech.edu](mailto:ugadmissions@caltech.edu). Students may also download a copy of the application or apply online at <http://www.admissions.caltech.edu>. To be considered for admission, applications to the freshman class must be postmarked by January 1.

### *Early Action*

Students who have a preference for Caltech may want to consider application under the Early Action plan. The Early Action application process requires that the completed application be postmarked by November 1. Under this application plan, students will be notified in mid-December of the admission decision. Students admitted under Early Action have until May 1 to make their commitment to attend.

### *High School Requirements*

Students are expected to prepare for Caltech by successfully completing the following curriculum:

- Four years of mathematics (including calculus)
- One year of physics
- One year of chemistry
- Three years of English (four years recommended)
- One year of U.S. history/government (waived for international students)

21

### Standardized Exams

Applicants are required to take the following standardized tests by the October test series for Early Action consideration, and by the December test series for Regular Action consideration:

SAT I or ACT

SAT II: Math II C

One of the following SAT II subject exams: Biology, Chemistry, or Physics.

Information regarding the College Board examinations can be found in the Bulletin of Information, which may be obtained without charge at most high schools, or by contacting the College Board, 45 Columbus Avenue, New York, NY 10023-6992; (609) 771-7600; [sat@info.collegeboard.org](mailto:sat@info.collegeboard.org); <http://www.collegeboard.com>. For ACT, 500 ACT Drive, P.O. Box 168, Iowa City, IA 52243-0168; (319) 337-1270; <http://www.act.org>.

### Essays

The essays, which are required as a part of the application, are intended to provide students the opportunity to communicate their interests, experiences, and background. Since Caltech is interested in learning about each applicant, the essays are viewed as an important part of the admission decision process.

### Evaluations

Two evaluations and a Secondary School Report are required. One must be from a math or science teacher, and one from a humanities or social science teacher (see the instructions in the application). A Secondary School Report must be filled out by the applicant's high-school counselor or other school official.

### Additional Material

Descriptions of research projects and hands-on science and engineering experience are helpful, as is material that demonstrates experiences outside math and science. Additional material should be identified with name and date of birth.

### Acceptance

Caltech is a National Association for College Admissions Counseling member and therefore agrees to comply with the candidate's reply date of May 1. When accepting an offer of admission to Caltech, an admitted student is required to submit a nonrefundable matriculation fee of \$500, along with the matriculation form. Places in the entering class will not be held after May 1. Early Action applicants will be informed of their status in mid-December, and Regular Action applicants will be informed by April 1.

### Deferral of Entrance

For reasons of travel or work, Caltech will consider requests from admitted students for a one-year deferral of entrance. Students who request a deferment must submit a written request stating the purpose of postponement.

### Advanced Placement, International Baccalaureate, and College Credit

Caltech encourages all prospective undergraduate applicants to prepare by challenging themselves with the most rigorous course of study available, including the Advanced Placement (AP) and International Baccalaureate (IB) programs. However, college credit for AP or IB classes is not automatic. Course credit and/or placement in an accelerated program is *sometimes* granted as deemed appropriate by the department faculty. The awarding of Caltech course credit takes place at the time of registration each fall.

### Biology

Prospective biology majors who pass both Bi 8 and Bi 9 in their freshman year are considered to have met the core requirement of Bi 1.

### Chemistry

In exceptional cases, students with a particularly strong background in chemistry may elect to take Chemistry 21, the Physical Description of Chemical Systems, or Chemistry 41, Organic Chemistry, rather than Chemistry 1, General Chemistry. It is assumed that such students have reasonable competence in the following areas: 1) elementary theories of atomic structure and electronic theories of valence, 2) chemical stoichiometry, 3) computations based upon equilibrium relationships, and 4) elementary chemical thermodynamics. For those students who qualify for advanced placement in chemistry, the Institute requirement of 15 units of Ch 1 ab can be satisfied by completing with passing grades two terms of (i) Ch 21 abc (9 units each term), or (ii) Ch 41 abc (9 units each term). The student's qualification for advanced placement in chemistry will be determined by performance on a placement examination to be administered in the summer prior to registration and on subsequent approval by the instructors of the courses to be taken and the courses to be substituted. Similarly, qualified students, with the instructor's consent, are allowed to substitute either Ch 3 b or Ch 4 a for the "core" chemistry laboratory requirement (Ch 3 a).

### Mathematics

During the summer before the freshman year, entering freshmen are asked to take a diagnostic exam in basic calculus that will determine which students will be placed in a special section of Ma 1 a for those with less complete preparation, and later take Ma 1 d;

and if they are interested in advanced placement, they may also take an examination to determine whether they will begin the mathematics core sequence at an advanced level.

Normally, an entering freshman takes Ma 1 abc, Calculus of One and Several Variables and Linear Algebra. This course covers the calculus of functions of one and several variables; infinite series; vector algebra; basic and advanced linear algebra; derivatives of vector functions, multiple integrals, line and path integrals; and theorems of Green and Stokes. The course is divided into a lecture part and a recitation part that focuses mainly on problem-solving.

Students in need of additional problem-solving practice may be advised to take Ma 8 (in addition to Ma 1 a) in the first quarter.

### Physics

The required freshman physics course, Ph 1 abc, is considerably more rigorous than most advanced placement work, and entering freshmen are encouraged to take Ph 1. A test is administered during the summer to aid in the organization of Ph 1; students who have performed particularly well can discuss the possibilities for advanced placement with the physics representative during orientation. A second test may then be required.

## **New Student Orientation**

All freshmen and transfer students are expected to attend the New Student Orientation as a part of the regular registration procedure.

The orientation takes place the week prior to the beginning of classes. A large number of faculty members and upperclass student leaders participate, helping to introduce the new student to the Caltech community. The orientation period provides an opportunity for the new student to become acquainted with the campus, the Honor System governing personal conduct, and other aspects of life at Caltech. In addition, he or she can meet classmates, upperclass students, and faculty. Thus the new student can begin to feel at home at Caltech and to share in the common agreement on intellectual and moral standards before the pressure of academic work begins.

## **ADMISSION TO UPPER CLASSES BY TRANSFER**

### **Transfer Admissions**

Caltech admits transfer students for the fall term only. We require a completed application, letters of recommendation, an official transcript from the last secondary school attended and all colleges or universities attended, descriptions of all college-level math and science courses, and completion of the Caltech Transfer Entrance Examinations. Please review the section titled “Eligibility Criteria

for Admission” to determine whether you meet the eligibility requirements for transfer admissions consideration.

### *Academic Preparation*

The following is a list of the Caltech core curriculum, taken by all Caltech students during their first two years. It is expected that transfer students will have had exposure to mathematics and science courses on a comparable level prior to entry to Caltech. Any of the following core courses that have not been covered by incoming transfer students must be taken upon matriculation to Caltech. There are no specific topics expected to have been covered in humanities and social science classes.

An evaluation of each transfer student’s written English is required prior to registration and may result in an additional course requirement.

### *Freshman courses:*

Mathematics 1 abc  
Physics 1 abc  
Chemistry 1 ab  
Chemistry 3 a  
Biology 1  
Humanities and Social Science electives  
Menu science class (currently either Ay 1, Ch/APh 2, ESE 1, or Ge 1; can be taken freshman or sophomore year)

### *Sophomore courses:*

Mathematics 2 ab  
Physics 2 ab or Physics 12 abc  
Additional laboratory science  
Humanities and Social Science electives

### *Eligibility Criteria for Admission*

The Institute admits to its sophomore and junior classes a small number of students who have excellent records at other institutions of collegiate rank and who perform satisfactorily on the Caltech Transfer Admissions Entrance Examinations.

- Students must have completed their secondary school education, and have subsequently enrolled at a college or university and earned credit, in order to be considered for transfer admission.
- Transfer students are not admitted to the senior year at Caltech.
- Students who have already completed a bachelor’s degree in any subject are not eligible for transfer.

### *Standardized Test Requirements*

Transfer applicants are not required to submit SAT scores. The Test of English as a Foreign Language (TOEFL) is required of transfer applicants whose native language is not English and who have not been studying in an English-speaking country for two

years or more. The TOEFL should be taken by the February test date.

#### *Evaluation of Written English*

All entering transfer students will be required to undergo an evaluation of their written English prior to enrolling.

#### *Transfer Admissions Entrance Examinations*

All applicants are required to take Caltech Transfer Admissions Entrance Examinations in mathematics and physics. Further instructions are included with the Caltech Transfer Application.

#### *Transfer of Credit*

The courses for which transfer applicants will receive credit, and the corresponding class standing, will be determined at the time of enrollment. Faculty members review each course submitted for credit on an individual basis. It is not possible, therefore, to answer questions regarding the acceptability of coursework taken elsewhere. If the standard of work taken elsewhere is uncertain, additional examinations may be required before the question of credit is finally determined.

#### *Graduation Requirements*

Admitted transfer students must meet the following requirements in order to receive a Caltech Bachelor of Science degree.

- Regardless of the amount of credit awarded upon matriculation, transfer students must spend at least two years (six terms) in residence at Caltech. Students must also earn at least 216 units at Caltech, not including courses taken to satisfy math and science core curriculum requirements.
- Students must take, or have taken the equivalent of, all core curriculum courses.
- Students must satisfy all of their chosen option's degree requirements. Transfer students may choose from among all Caltech undergraduate options.

#### *Admissions Application*

Applications are available September 1. Completed applications should be received by the Office of Undergraduate Admissions by February 15. Applicants will be notified of the decisions of the Admissions Committee in early May. Questions about transfer admission and application should be directed to Transfer Information, Office of Undergraduate Admissions, Caltech, Mail Code 1-94, Pasadena, CA 91125, U.S.A.; (626) 395-6341; [ugadmissions@caltech.edu](mailto:ugadmissions@caltech.edu). Applications may also be downloaded from the admissions website at <http://www.admissions.caltech.edu>.

## **The 3/2 Dual Degree Plan**

Caltech invites students from a select group of liberal arts colleges to transfer to Caltech upon completion of their junior year. After two years in residence at Caltech, and the successful completion of our requirements, 3/2 students will be granted a Bachelor of Science degree from Caltech and a second bachelor's degree from their liberal arts college. Students may transfer into any of the Caltech options.

Students from the following institutions are eligible to apply to the 3/2 program:

Bowdoin College (ME)	Ohio Wesleyan University (OH)
Bryn Mawr (PA)	Pomona College (CA)
Grinnell College (IA)	Reed College (OR)
Haverford College (PA)	Spelman College (GA)
Mt. Holyoke College (MA)	Wesleyan University (CT)
Oberlin College (OH)	Whitman College (WA)
Occidental College (CA)	

Applications and a program description are available from the 3/2 liaison at each of the liberal arts college partners and from the Caltech Office of Undergraduate Admissions. Deadline for submission of 3/2 applications and support materials is April 1.

Admission to the 3/2 program is not guaranteed and will be determined by the Caltech Faculty Upperclass Admissions Committee. Students applying should have a record of superior academic achievement at their home institutions, and strong letters of recommendation from their 3/2 liaison and an additional faculty member. They must have completed a minimum of one year of calculus-based physics and mathematics (two years are recommended) including multivariable calculus and differential equations, and one year of chemistry.

## **Exchange Programs**

Exchange programs exist with Occidental College, Scripps College, and Art Center College of Design, permitting Caltech students to receive credit for courses taken at these colleges. Students from these colleges also may receive credit for courses taken at the Institute. Tuition payments are not required, but the student may have to pay any special fees. The student must obtain approval from the instructor of the exchange course. Exchange courses taken by Caltech students must have prior approval by the student's option, by the division providing courses most similar to the proposed course, and by the registrar. Students wishing to take such courses should obtain the appropriate form at the Registrar's Office, get the required signatures as above, and return it to the registrar. Freshmen at Caltech ordinarily cannot participate in this exchange.

## STUDY ABROAD

### *Cambridge Scholars Program*

The Caltech Cambridge Scholars Program offers qualified juniors and seniors the opportunity to spend a fall or winter term at the University of Cambridge in England. Students are hosted by and live in one of the Cambridge Colleges participating in the exchange. The participating colleges are Corpus Christi, Pembroke, St. Catharine's, and St. John's. Students pay Caltech room and board, tuition, and other standard Caltech fees for the term.

Students are admitted into one Cambridge department to take classes within the tripos, i.e., option, offered by that department. Students may only take courses in one tripos area. Students will find more information on the tripos structure in the Fellowships Advising and Study Abroad Office.

During their term at Cambridge, students take the equivalent of at least 36 Caltech units, usually four Cambridge courses, but the exact number of courses depends on Cambridge departmental tripos requirements. For this work, students receive a minimum of 36 Caltech units that can be used for general or option credit. Note that the final number of units and whether the units can be used to fulfill departmental requirements will be determined after faculty review upon a student's return to Caltech.

Caltech students have the use of all Cambridge facilities and are matriculated into the university for the term. A minimum 3.2 GPA is required to apply. Eligible sophomores and juniors interested in either the fall or winter term apply in February for the next academic year.

### *Copenhagen Scholars Program*

The Caltech Copenhagen Scholars Program offers qualified juniors and seniors the opportunity to spend the fall at the University of Copenhagen (KU) or the Danish Technical University (DTU). At KU, students may concentrate in the physical sciences, mathematics, biological sciences, or economics. At DTU, students can take courses in engineering or the applied sciences.

Both KU and DTU are on a semester system, and Caltech students attend from September 1 to mid-December. Students have a one-week vacation in mid-October, and many use this vacation week to travel in Denmark or Europe. All students live in University of Copenhagen dormitories. Students pay Caltech room and board, tuition, and other standard Caltech fees for the term.

Students take three or four courses in their Caltech option or a closely related subject (e.g., physics and mathematics) and a course in Danish language. Students may audit or take for credit a course

in Danish culture that in addition to lectures has field trips to interesting cultural and historical sites in the city. All upper level undergraduate or beginning graduate level courses at KU and DTU can be taught in English.

For this work, students receive a minimum of 36 Caltech units that can be used for general or option credit. Note that the final number of units and whether the units can be used to fulfill departmental requirements will be determined after faculty review upon a student's return to Caltech.

A minimum 3.0 GPA is required to apply. Eligible sophomores and juniors apply in February for the fall semester at KU.

### *University College London Scholars Program*

The Caltech University College London Scholars Program offers qualified juniors and seniors the opportunity to spend the fall at the University College London, which is located in the lovely Bloomsbury area of London. The University College London (UCL) is on a semester system, and Caltech students attend from about September 20 to mid-December. All students are required to attend a four-day orientation (Thursday through Sunday) before classes start. All students live in a UCL dormitory, which is located within a short walk of the academic buildings of the campus. Students pay Caltech room and board, tuition, and other standard Caltech fees for the term. There is a supplemental charged for housing due to the longer length of the term. The supplement varies yearly depending on prices and the exchange rate.

Students are admitted into one of UCL's academic departments in the physical, life, or engineering sciences. Note that students cannot be admitted into the economics department, but can be admitted into the statistical sciences department, which offers many economics courses; students can take two courses in the economics department.

Students take an additional two, or the equivalent of two, courses in their admitting department. Usually the admitting department is in a subject area that corresponds to the student's Caltech option, but this is not always the case if the student has enough academic or research background to gain admission to the admitting department.

Students take an additional two, or the equivalent of two, courses in either the admitting department, another area of the sciences or engineering, or the social sciences or humanities.

Students are also eligible with approval to take a fifth course in their option, a related area, or in the humanities or social sciences.

A typical UCL semester class is .5 course units or 4 credits. Caltech students must take a total of 16 credits or 2 course units during their semester at UCL. This would be equivalent to 36 Caltech units. For this work, students receive a minimum of 36 Caltech units that can be used for general or option credit. Note

that the final number of units and whether the units can be used to fulfill departmental requirements will be determined after faculty review upon a student's return to Caltech.

A minimum 3.0 GPA is required to apply. Eligible sophomores and juniors apply in February for the fall semester at UCL.

#### *University of Edinburgh Scholars Program*

The Caltech University of Edinburgh Scholars Program offers qualified juniors and seniors the opportunity to spend the fall at the University of Edinburgh. The University of Edinburgh is on a semester system, and Caltech students attend from about September 20 to mid-December. All students are required to attend a weeklong orientation held the week before classes start. All students live in university dormitories, which are a short walk from the George Square (humanities and social sciences) and the King's Buildings (science and engineering). Students pay Caltech room and board, tuition, and other standard Caltech fees for the term. There is a supplemental charged for housing due to the longer length of the term. The supplement varies yearly depending on prices and the exchange rate.

Students are admitted into one of Edinburgh's academic departments in the College of Science and Engineering. Note that students cannot be admitted into the economics department, but can take 20 credits in that department. Students take a minimum of 60 Edinburgh credits per semester and may, with permission, be able to take up to 80 credits, but no more than five courses. Students will take a minimum of 40 credits in their option or another science or engineering subject and can take 20 credits (one course) in College of Humanities and Social Sciences. Economics or BEM option students may take up to, but no more than, 40 credits in the Edinburgh economics department. Sixty credits is the standard load.

A minimum 3.0 GPA is required to apply. Eligible sophomores and juniors apply in February for the fall semester at UCL.

Further information on these programs, including application procedures and the exact deadline dates, is available from the Fellowships Advising and Study Abroad Office.

Please see the Financial Aid When Studying Abroad section, page 152, for details on applying and eligibility for financial aid related to study abroad.

### **ROTC**

Air Force Reserve Officer Training Corps (AFROTC) offers two-, three-, and four-year programs leading to a commission as a second lieutenant in the United States Air Force. The AFROTC program is open to almost all students pursuing baccalaureate and

graduate degrees. Classes consist of one hour of academics and two hours of leadership laboratory per week for freshmen and sophomores, and three hours of academics and two hours of leadership laboratory per week for juniors and seniors. AFROTC offers a variety of one- to four-year scholarships valued at up to 100% of annual tuition, along with a nontaxable monthly stipend. Air Force ROTC is offered on the campuses of the University of Southern California, California State University San Bernardino, Harvey Mudd College, Loyola Marymount University, and University of California-Los Angeles. You do not need to be a student at any of these colleges to attend AFROTC on their campuses. For more information contact the Department of Aerospace Studies at (213) 740-2670 or visit <http://www.usc.edu/afrotc>. No military commitment is incurred until entering the junior year of the program or receipt of a scholarship after freshman year.

The Army ROTC program at USC offers four-, three-, and two-year scholarships that pay tuition costs up to \$17,000 a year. In addition, the program pays all contracted cadets a stipend of \$2,500 to \$4,000 a year and an annual book allowance of another \$600. High-school students need to apply for the four-year scholarship during the fall of their senior year, and no later than November 15. All Caltech students interested in an Army ROTC three- or two-year on-campus scholarship need to apply early in their spring semester, and no later than March 15, for the next academic year. Completion of the program leads to a commission as a second lieutenant in one of 17 occupational branches in the Regular Army, Army Reserve, or the National Guard. These scholarship provisions are subject to change, and interested students are encouraged to contact the Department of Military Science at the University of Southern California for further information: PED 110, Los Angeles, CA 90098, (213) 740-1850.

### **REGISTRATION REGULATIONS**

#### **Procedures**

Students must register on the dates specified in the academic calendar. Students are not registered until they have both

- enrolled in an approved list of courses, *and*
- made satisfactory arrangements with the Bursar's Office for the payment of all fees due the Institute.

Any student who has not completed both phases of registration within one week after the first day of classes will be removed from the Institute rolls.

Students are required to maintain continuity of registration until the requirements for the Bachelor of Science degree are fulfilled, except in the case of an approved undergraduate student

sabbatical. If continuity is broken by withdrawal, reinstatement is required before academic work may be resumed.

### **Changes in Registration**

All changes in registration must be reported to the Registrar's Office by the student prior to the published deadlines. A grade of F will be given in any course for which a student registers and which he or she does not either complete satisfactorily or drop. A course is considered dropped when a drop card is completed and returned to the Registrar's Office. A student may not at any time withdraw from a course that is required for graduation in his or her option, without permission of the registrar.

A student may not add a course after the last day for adding courses, or withdraw from a course after the last date for dropping courses, without the approval of the Undergraduate Academic Standards and Honors (UASH) Committee. Registration for added courses is complete when an add card, signed by the instructor and the student's adviser, has been filed in the Registrar's Office. No credit will be given for a course for which a student has not properly registered. The responsibility for submitting drop cards and add cards to the Registrar's Office before the deadlines for dropping or adding courses each term rests entirely with the student. Failure to fulfill the responsibility because of oversight or ignorance is not sufficient grounds to petition for permission to drop or add courses after the deadline. It is the policy of the UASH Committee that no petitions for the retroactive dropping or adding of courses will be considered except under very extenuating circumstances.

### **Summer Research or Summer Reading**

Qualified undergraduate students who are regular students at the Institute are permitted to engage in research or reading during the summer, but in order to receive academic credit the student must have the approval of his or her division and must complete the registration process for such summer work before June 1. An undergraduate may not receive payment for research carried out for academic credit. Students who are registered for summer research or reading will not be required to pay tuition for the units. A student may apply up to 18 units of summer research per summer and 36 units in total toward Institute graduation requirements.

The Institute recognizes that students may want to take advantage of paid internships that provide unique off-campus educational opportunities that integrate and enhance the classroom experience. Students are encouraged to explore and discuss such opportunities with their academic adviser and the dean or associate dean of students. If appropriate, the adviser and dean or associate dean can approve such internships as integral to a Caltech educa-

tional experience. There is no academic credit for such work. The internships should commence after the end of the third term and end prior to the resumption of classes in the fall.

### **Undergraduate Student Sabbatical**

An undergraduate student sabbatical must be sought by written petition, which must be accompanied by a completed withdrawal card. The dean or associate dean of students may grant a sabbatical provided: (a) the student is in good standing, in other words does not have to meet special academic requirements as a result of reinstatement, (b) the sabbatical is for one year or less, and (c) the sabbatical extends over a period that includes at least one full term.

The dean or associate dean may also grant a leave for medical reasons provided the petition is approved by the director of health services or the director of counseling services. Return from a leave for medical reasons also requires the recommendation of the director of health services or the director of counseling services, and the final approval of the dean or the associate dean. A student returning from a leave for medical reasons will maintain the same academic standing that he or she had previously.

#### *Involuntary Leave*

The dean of students may place a student on an involuntary leave if persuaded by the evidence that such action is necessary for the protection of the Institute community or for the personal safety or welfare of the student involved. The withdrawal card may state a specific date after which the student may return or it may be indefinite as to term. The dean of students may stipulate conditions that must be met before the student may return. These conditions might include a letter of approval from the director of health services or the director of counseling services. A decision by the dean to place a student on involuntary leave is subject to automatic review within seven days by the vice president for student affairs (or his or her designee).

All other petitions pertaining to leaves should be addressed to the UASH Committee.

### **Withdrawal from the Institute**

Formal separation from the Institute is effected by filing a completed withdrawal card in the Dean of Students Office to be forwarded to the registrar and other appropriate offices. The effective date of a withdrawal is the date of the signature of the dean or associate dean of students. A student leaving the Institute at any time during the term without filing a formal withdrawal card will not be considered withdrawn. In such a case, any grades reported by the instructors will be recorded on the permanent record card, and the grade of F will be recorded for all other courses. A student who withdraws, or is absent for a term (or longer), without an

approved undergraduate student sabbatical, must petition for reinstatement to return to the Institute. Return from involuntary leave requires approval through the Dean of Students Office. Reinstatement rules are listed under scholastic requirements. If a student withdraws by the last day of classes in any term, no courses or grades for that term will appear on the permanent record of the student. However, the date of withdrawal and the number of units will be noted on the record. The record will also indicate whether an undergraduate student sabbatical was granted.

## SCHOLASTIC REQUIREMENTS

All undergraduates are required to meet certain scholastic standards as outlined below.

### *Eligibility for Registration*

Eligibility to register is determined by the student's record as of Registration Day of the term in which registration is sought.

Undergraduates who register for programs that make it appear they are no longer candidates for a B.S. degree or who are not making satisfactory academic progress may be refused further registration by the Undergraduate Academic Standards and Honors (UASH) Committee.

Freshmen are ineligible to register for subsequent terms

- if they have accumulated 24 or more units of E or F, exclusive of PE;
- if they have accumulated three or more course grades of E or F, exclusive of PE;
- if, in any term of their freshman year following a reinstatement, they obtain six or more units of E or F, exclusive of PE.

Ineligible freshmen must petition the UASH Committee for reinstatement if they wish to continue as students. The dean of students or associate dean may act on a petition if (i) it is the student's first ineligibility and (ii) the student has received fewer than 42 units of E or F, exclusive of PE. For other petitions, action must be taken by the UASH Committee.

Undergraduate students, except first- and second-term freshmen, are ineligible to register for another term

- if they fail during any one term to obtain a grade-point average of at least 1.4, or if they receive 27 or more units of E or F, exclusive of PE, during any one term;
- if they fail to obtain a grade-point average of at least 1.9 for the academic year, or if they accumulate 45 or more units of E or F, exclusive of PE, over the academic year (students who have completed at least three full terms of residence at the Institute and have been registered for their senior year shall no longer be

subject to the requirement that they make a grade-point average of at least 1.9 for the academic year—seniors must, however, receive a grade-point average of at least 1.4 or receive fewer than 27 units of E or F each term);

- if they have completed fewer than 36 units in the previous term and fewer than 99 units in the previous three terms in residence;
- if, once reinstated, they fail to complete a full load of at least 36 units in the following term with a grade-point average of at least 1.9.

If a late grade makes a student ineligible after the start of the next term, the permanent record card shall show the ineligibility and a reinstatement. If the late grade is reported to the registrar before midterm deficiency notices are due for the subsequent term, the student shall be held to the requirement as above to complete a full load of at least 36 units with a grade-point average of at least 1.9.

If a late grade received on or before the last day for adding classes makes a reinstated student eligible, the ineligibility and the reinstatement will be removed from the student's record.

No student ineligible to register on the first day of classes will be permitted to register unless a petition for reinstatement has been submitted and acted upon.

Students ineligible for registration because of failure to meet the requirements stated in the preceding paragraphs may submit a petition to the UASH Committee for reinstatement, giving any reasons that may exist for their previous unsatisfactory work and stating any new conditions that may lead to better results. Each such petition will be considered on its merits. *For the first such ineligibility*, the petition may be acted on by the dean of undergraduate students, after consultation with the student and examination of the record. At the dean's discretion, such cases may be referred to the UASH Committee for action. *All subsequent reinstatements must be acted upon by the Committee.* A second reinstatement by UASH will be granted only under exceptional conditions.

## Departmental and Option Regulations

### *Selection of Option*

By the middle of the third term, freshmen must notify the Registrar's Office of their selection of an option in engineering, humanities, social sciences, or science to be pursued in subsequent years. Upon the selection of an option, a freshman will be assigned an adviser in that option, whose approval must then be obtained for registration for the following year.

In exceptional circumstances an undergraduate may be allowed to major in two options for the Bachelor of Science degree. In order to do so the student must present a rationale for the double option and a plan of study leading to completion of the degree in

four years. The plan, and any substantive modifications, must be approved by a committee composed of the option representatives of the two options. The plan must meet the minimum requirements for both options as set forth in this *Catalog*, but the committee may impose additional requirements as well. The approved plan should be submitted to the registrar during the sophomore year, but in any case no later than the start of the senior year. The student will then be assigned an adviser by each option. Consult the registrar for appropriate procedures.

#### *Continuing in an Option*

Students whose grade-point averages are less than 1.9 at the end of an academic year in a specific group of subjects designated by their department or option may, at the discretion of their department, be refused permission to continue the work of that option. Such disbarment does not prevent the students from continuing in some other option or from taking additional courses to raise their average in their original option. Students without an option will fall under the direct jurisdiction of the dean of students. Students may remain without an option for no more than one year.

#### *Change of Option*

An undergraduate in good standing at the Institute shall be permitted to transfer into any option of his or her choice provided he or she has (a) a 1.9 GPA in subjects required for graduation in that option or in a specific group of subjects designated by that option or (b) permission of the option representative or committee. A change of option is effected by obtaining a Change of Option petition from the Registrar's Office. The completed petition must then be signed by the option representative for the new option (who will assign a new adviser), and filed with the Registrar's Office. Institute regulations require that a student who has made normal progress at the Institute be able to change options at any time up to the end of the sophomore year without penalty either as to time until graduation or as to excessive unit requirements in any term.

#### *Term Examinations*

Term examinations will be held in all subjects unless the instructor in charge of any subject shall arrange otherwise. No student will be exempt from these examinations. When conflicts exist in a student's schedule, it is the student's responsibility to report the conflict to the instructor in charge of one of the conflicting examinations and make arrangements for another time.

#### *Satisfactory Academic Progress*

A student will be declared ineligible to register if he or she has completed fewer than 36 units in the previous term and has completed fewer than 99 units in his or her three most recent terms in residence.

#### *Graduation Requirement*

To qualify for graduation a student must complete the prescribed work in one of the options with a passing grade in each required subject and with a grade-point average of 1.9. A grade of F in an elective course need not be made up, provided the student has received passing grades in enough other accepted units to satisfy the minimum total requirements of the option.

#### *Candidacy for the Bachelor's Degree*

A student must file with the registrar a declaration of candidacy for the degree of Bachelor of Science on or before the first Monday of November preceding the date on which he or she expects to receive the degree. All subjects required for graduation, with the exception of those for which the candidate is registered during the last term of his or her study, must be completed and the grade recorded, by the second Monday of May preceding commencement.

#### *Graduation in the Normally Prescribed Time*

Any undergraduate student who fails to complete the requirements for graduation at the end of 12 terms must petition the Undergraduate Academic Standards and Honors Committee for approval to register for further work each term.

#### *Requirement for a Second Bachelor of Science Degree*

Under exceptional circumstances a student may be permitted to return to study for a second Bachelor of Science degree. As a general rule this second degree must be in an option which is not in the same division as that of the original degree. To receive this permission the student must petition the Curriculum Committee. If the petition is approved, the student must then register for three consecutive terms of additional study, completing in each term at least 36 units, and must meet all the requirements for graduation in the second option. If additional time is needed to complete the degree, the student must also petition the Undergraduate Academic Standards and Honors Committee for an extension. A student admitted for a second Bachelor of Science degree in a particular option may not change to another option without first submitting a new petition to the Curriculum Committee and receiving the explicit approval of that committee.

#### *Graduation with Honor*

Students who have achieved a high scholastic standing or who have carried out creative research of high quality may be recommended to the faculty for graduation with honor by the Undergraduate Academic Standards and Honors Committee. The Committee shall consider for graduation with honor those students who have achieved an overall grade-point average of 3.5 and others who, on the basis of exceptional creativity, have been recommended to the Committee by a faculty member or by a division of the Institute.

*Excess of or Fewer Than Normal Units (Overloads and Underloads)*

An overload is defined as registration for more than 54 units by an upperclassman or more than 51 units by a freshman. An underload is registration for fewer than 36 units. A student who wishes to carry an overload in any term must obtain the approval of his or her adviser and of the dean or associate dean of students. Petitions for overloads will not be accepted later than the last day for adding classes in any term.

Underloads with 27 or more units may be approved by the dean or associate dean if the student has not previously had an underload. Seniors may take an underload by presenting for the registrar's approval a course plan for graduation the following June, provided that the plan does not require an overload in any term. In all other cases the student must petition the Undergraduate Academic Standards and Honors Committee for approval. The committee has the latitude to grant part-time status to a small number of exceptional, highly motivated students with at least junior standing, for reasons deemed valid by the committee.

**Allowance and Transfer of Credit**

*Transfer of Credit from Other Institutions*

Regularly enrolled students who want to obtain credit for college courses taken elsewhere should have a copy of the transcript of their work sent to the Registrar's Office. The student should then obtain an Allowance of Credit form from the Registrar's Office and take this, with the transcript, to the representative of the option in which credit is desired. Credit will be granted when this form, with the appropriate signatures, is returned to the office.

*Allowance of Credit in the Humanities and Social Sciences*

In general, Caltech students should fulfill Caltech course requirements by taking courses at Caltech. Students are expected to have a well-reasoned educational goal for taking classes elsewhere. The only exceptions are transfer students admitted to advanced standing. Credit for comparable work done at other institutions with similar academic standards is not granted automatically.

Students who wish to take courses elsewhere (whether on leave, in the summer, or during the academic year) should consult, in advance, with the executive officer for the humanities or the executive officer for the social sciences, or their designees, to minimize any misunderstanding regarding the nature of credit they may receive. Upon completion of the course, the student must obtain an Allowance of Credit form from the registrar, obtain the signed approval of the executive officer, or his or her designee, for transfer credit, and return the completed form to the Registrar's Office. The executive officers are the final authority in the allowance of credit.

Guidelines and specific information about allowance of credit are available from the Division of the Humanities and Social Sciences.

*Other Allowances of Credit*

Except for transfer credit and advanced placement credit upon admission, credit will not be granted for Caltech courses not registered for, except in special circumstances by arrangement with the instructor. Such arrangements must be approved by the Curriculum Committee, and the student must petition the Committee before the work is undertaken.

**UNDERGRADUATE EXPENSES**

For freshman and transfer students applying for admission, there is a \$60 application fee. This fee is nonrefundable.

A nonrefundable matriculation fee of \$500 for freshman and transfer students is payable upon notification of admission.

Housing contracts must be submitted to the senior director of campus life by the date specified in the instructions accompanying the contract.

**Expense Summary 2005-06**

*General:*

General Deposit .....	\$ 100.00 <sup>1</sup>
Tuition .....	27,309.00
	<u>\$ 27,409.00</u>

*Other:*

Student Housing: (Rates are subject to change)	
Room (on campus; other rates vary) .....	5,013.00
Board (provides 10 full meals and five continental breakfasts per week while Institute is in session).....	3,801.00
Books and Supplies (approx.) .....	1,047.00
Personal Expenses (approx.).....	1,923.00
Meals not on Board contract (approx.)	\$ 1,926.00

<sup>1</sup> This charge is made only once during residence at the Institute.

The following is a list of undergraduate student fees at the California Institute of Technology for the academic year 2005-06 together with the dates on which these charges are due. Fees are subject to change at the discretion of the Institute.

*First Term*  
September 26, 2005

	<i>Fee</i>
General Deposit .....	\$ 100.00
Tuition .....	9,103.00
Room and Board (for on-campus residence) .....	2,938.00

*Second Term*  
January 4, 2006

Tuition .....	9,103.00
Room and Board (for on-campus residence) .....	2,938.00

*Third Term*  
March 27, 2006

Tuition .....	9,103.00
Room and Board (for on-campus residence) .....	2,938.00

Tuition fees for fewer than normal number of units:

36 units or more .....	<i>Full Tuition</i>
Per unit per term .....	\$ 253.00
Minimum tuition per term .....	2,530.00

Contact Bursar's Office for audit fee.

## Refunds and Fees

### *Refunds and Repayments*

For all students, the institutional charges, e.g., tuition and room and board, will be prorated according to the amount of time the student spent in academic attendance before withdrawing. These prorated charges will be compared to the payments received on behalf of the student, and the Institute will determine whether the student is entitled to a refund or owes additional funds to Caltech.

For students receiving funds from federal Title IV, from Caltech, and/or from state programs, the Institute will follow federal and other applicable regulations to determine the amount of all program funds the student has earned at the time of withdrawal. In general, the amount of financial aid earned is based on the amount of time the student spent in academic attendance. If the amount of aid disbursed to the student is greater than the amount the student earned, unearned funds must be returned. If the amount the student was disbursed is less than the amount the student earned, the student is eligible to receive a postwithdrawal disbursement.

The Department of Education has provided a summary of these regulations in *The Student Guide* for the 2005–06 award year, available online at [http://www.ed.gov/prog\\_info/SFA/StudentGuide](http://www.ed.gov/prog_info/SFA/StudentGuide).

*Determining the Student's Last Date of Attendance or Withdrawal Date:* The Office of the Registrar is responsible for receiving a request for a withdrawal from the appropriate undergraduate or graduate dean and for processing official withdrawals.

In order to calculate the refund or repayment, Caltech will establish the student's withdrawal date. This date is one of the following:

- The date that the student began the withdrawal process prescribed by Caltech; or
- The date the student otherwise provided official notification to the registrar (written or oral) of his or her intent to withdraw; or
- The mid-point of the academic term if no official notification is provided; or
- The date determined by the registrar if there are special circumstances (illness, accident, grievous personal loss); or
- The date the registrar determines the student has not returned from an approved student sabbatical or if the student does not qualify for a sabbatical.

### *Academically Related Activities That Determine Academic Attendance:*

The Institute may use the last date of attendance at an academically related activity as the student's withdrawal date. This may occur if a student begins the withdrawal process and then attends an academically related activity after that date. Caltech considers an academically related activity to include the following:

- Attendance at a lab
- Attendance at a lecture
- Completing a quiz and/or test
- Participation in a study session
- Academic counseling session
- Academic advisement session
- Turning in a class assignment

*Determining the Return of Federal Funds:* The Financial Aid Office and/or the Graduate Office will calculate the federal funds that must be returned to the appropriate federal accounts.

If a student withdraws prior to the first day of classes for the period of enrollment, Caltech will return 100% of the student's federal financial aid in accordance with federal procedures, as well as Caltech and/or state grants/aid.

If a student withdraws any time after the first day of classes for the period of enrollment, the Institute will perform the following:

- Determine the percentage of the payment period that the student completed. If the student completed more than 60% of the period, he or she earned 100% of the aid for the period. If the student completed 60% or less, the percentage of the period completed is the percentage of aid earned. This percentage is determined by dividing the number of

days attended in the period of enrollment by the total days in the period.

- Apply the earned percentage to the amount of aid actually disbursed and the amount that could have been disbursed (“earned aid”).
- Subtract earned aid from aid that was actually disbursed. This results in the amount of unearned aid to be returned.

The Financial Aid Office and/or the Graduate Office (as appropriate) will allocate the return of funds back to the student aid programs in the following order:

1. Federal Direct Unsubsidized Stafford Loan Program
2. Federal Direct Subsidized Stafford Loan Program
3. Federal Perkins Loan Program
4. Federal Direct PLUS Loan Program
5. Federal Pell Grant Program
6. Federal SEOG Program
7. Other Title IV Programs

Any remaining refund will be returned to the other state, institutional, or private student assistance utilized. Federal Work Study is not included in any of these calculations.

*Appeals on Refunds:* Any questions or problems related to refunds should be directed to the Bursar’s Office.

For further information on refunds and repayments, please contact the Financial Aid Office, the Graduate Office, or the Bursar’s Office.

*Dropping a Course:* A student’s financial aid package will be adjusted to reflect any tuition adjustment made by the Bursar’s Office as well as any other adjustments required by law or by the applicable fund donor(s). In addition, students who are not enrolled full time as of the last day to add courses will have their aid revised.

Generally, students enrolling less than three-fourths time will have an increased work award. Additional information is available in the Financial Aid Office.

*Refund upon Withdrawal:* Should a student, for whatever reason, withdraw from Caltech during an academic term, a refund of tuition as well as room and board, if applicable, is calculated. The amount of refund is determined by how much of the term has elapsed. If the student is a recipient of student financial assistance, that assistance, if applicable, will be reduced as a result of his or her withdrawal. Recent federal legislation determines the amount of refund for recipients of federal Title IV student assistance. It is the purpose of this section to inform students of the financial implications of withdrawal.

If the student is not a recipient of federal student financial aid, the Institute’s refund policy returns any refund of tuition or room

and board first to the programs from which assistance has been received (i.e., scholarships, Caltech gift assistance). Any amount remaining will then be returned to the student. The non-Title IV portion will be distributed as appropriate, first to outside agencies, as required, then to the Caltech grant, scholarship, or loan, depending on the composition of the aid package. These distributions will occur as credits to the appropriate aid funds and charge(s) to the student’s Caltech account.

If the student is the recipient of federal Title IV student assistance, any refund must then be applied first to the federal aid program(s) in the prescribed order listed on page 142.

In the event that a student’s disbursed financial aid exceeds the direct costs on the student’s personal account, a credit balance will result. Withdrawal will result in the reversal or repayment of the resulting credit balance.

#### *General Deposit*

Each new student is required at his or her first registration to make a general deposit of \$100, to cover possible loss and/or damage of Institute property. Upon graduation or withdrawal from the Institute, any remaining balance of the deposit will be refunded.

#### *Fees for Late Registration*

Registration is not complete until the student has enrolled in a program approved by his or her adviser and has paid tuition and other fees. A penalty fee of \$50 is assessed for failure to register within five days of the scheduled dates. A \$50 late penalty will be charged by the Bursar’s Office for failure to clear a past-due account within five days of the beginning of instruction.

#### *Honor System Matters*

Monies owed to the Institute resulting from a Board of Control decision may be collected through the Bursar’s Office, at the request of the dean of students.

#### *Special Fees*

Students taking the Summer Field Geology course (Ge 120) should consult with the division about travel and subsistence arrangements and costs.

#### *Unpaid Bills*

All bills owed the Institute must be paid when due. Any student whose bills are past due may be refused registration for the term following that in which the past due charges were incurred. Transcripts will not be released until all bills have been paid or satisfactory arrangements for payment have been made with the Bursar’s Office.

## FINANCIAL AID

Caltech believes that qualified students who wish to attend the Institute should not be prevented from doing so for financial reasons. Although the Institute expects students and families to finance the cost of education to the fullest extent possible, the Institute will make every effort to assist those who need help, including those whose financial circumstances change during the year.

Demonstrated financial need is the difference between the annual cost of attending Caltech and the amount the student and parents can reasonably be expected to contribute toward those costs. Costs include actual tuition, room and board, an allowance for meals not covered in the board contract, books and supplies, personal expenses, and a travel allowance based on airfare for two round trips. (Caltech is unable to include a travel allowance for students whose residence is outside the United States, Mexico, or Canada.) Caltech's estimate of a family's ability to contribute is determined annually in accordance with nationally established guidelines.

Eligibility for each type of assistance varies, depending upon the source of funds. Assistance offered by Caltech includes federal, state, and institutional grants, subsidized part-time jobs, and low-interest loans. U.S. citizens or eligible noncitizens (as defined in the Free Application for Federal Student Aid [FAFSA]) may apply for state and federally funded programs. International students may apply for institutionally funded programs.

Students should not wait to be accepted for admission to Caltech before applying for financial aid. Applications for admission are evaluated separately from requests for financial aid. Students with complete financial aid applications on file will be considered for all applicable types of need-based assistance. A renewal application must be submitted each year. In addition to direct financial assistance, information is available, upon request, about education payment plans and financial-planning resources. (For information on non-need-based scholarships and prizes, see pages 152 and 165–173.)

All students who believe they will need assistance to attend Caltech are encouraged to submit financial aid applications.

The Financial Aid staff is happy to talk with students and their families at any time to explain the application process, Caltech's computations, and available programs. For further information on the determination of financial need and on application procedures, as well as on financial aid awards and programs, contact the Financial Aid Office, California Institute of Technology, Mail Code 110-87, Pasadena, CA 91125, call (626) 395-6280, or visit the Caltech Financial Aid Office home page at <http://www.finaid.caltech.edu>.

## How to Apply for Financial Aid

Slightly different procedures and deadlines exist for each category of students applying for financial aid. Detailed descriptions of these procedures and deadline dates may be found on the Caltech Financial Aid Office website at <http://www.finaid.caltech.edu>.

*Application Process for Caltech and Federal Financial Aid for Entering Students (U.S. citizens and eligible noncitizens)*

The College Scholarship Service (CSS) Financial Aid PROFILE application and the Free Application for Federal Student Aid (FAFSA) forms are both required of all applicants (with the exception of international applicants, who should review the specific procedures listed on page 146) for Caltech need-based assistance. These forms provide essential information about the applicant's family financial picture and enable the Financial Aid Office to determine eligibility for federal, state, and Caltech financial assistance.

Please note the following steps for filing the CSS Financial Aid PROFILE and FAFSA forms:

### Step 1

To receive a 2006–07 CSS Financial Aid PROFILE application, students may register by connecting to the College Board Online at <http://www.collegeboard.com> after October 1, 2006. Complete the PROFILE with Caltech's CSS Code 4034. Those filing online have several payment options: credit card (MasterCard, Visa, Discover, American Express); debit card (MasterCard, Visa); or online check. The electronic customized PROFILE application is available online within minutes of registering.

### Step 2

Complete the customized PROFILE application and submit it to CSS for processing. CSS will then report the financial information to the colleges listed.

### Step 3

Students must also complete the Free Application for Federal Student Aid (FAFSA) in early January. The Internet version of the FAFSA is available after January 1, 2006, at <http://www.fafsa.ed.gov>. Complete the FAFSA with Caltech's code 001131 and submit according to the schedule below. The completed FAFSA is required to determine eligibility for federal and state financial aid programs. As with the PROFILE, it is advisable to estimate income information in order to meet the priority deadline—please do not wait until federal tax returns are complete before filing your FAFSA.

CALTECH'S FINANCIAL AID PRIORITY MAILING DATES

Type of Applicant	Register and Submit PROFILE Application by	Submit FAFSA by	Receive conditional aid award information by
Early Action Applicant	November 15	January 15	February 1
Other Freshman Applicants	January 15	January 15	April 15
Transfer Applicants	March 2	March 2	June 15
Continuing 2005-06 CIT Students	Not applicable	March 2	Summer

International Applicants

International applicants will be sent the International Student Financial Aid Application along with their application for admission, or may download the form at <http://www.finaid.caltech.edu/forms.html>. Caltech does not require the CSS Certification of Finances.

International Freshman Student Financial Aid Deadline	postmarked by JANUARY 15
International Transfer and 3/2 Financial Aid Deadline	postmarked by MARCH 2

All international student financial aid applications and the international student supplemental form (freshman, transfer, and 3/2 program students) must be postmarked by the appropriate date (see table above).

International applicants who do not apply for financial aid by published deadlines, or who are denied aid for their first year at Caltech, are not eligible for aid for any other academic period while they are undergraduates at the Institute. Those offered financial aid will be eligible to apply for aid in subsequent years.

All students must reapply for aid each year.

Types of Aid Available

Once financial need has been determined, that need will be met either by a single type of aid or by a combination of grants or scholarships, student employment, and low-interest loans. Such a combination is called a financial aid “package.”

Grants and scholarships, which include those provided both through Caltech and by the federal and state governments, do not have to be repaid. Employment wages are funds earned during the academic year either on or off campus. Employment opportunities exist for students who wish to work to help meet their educational costs. Loans are a sound means of meeting a portion of current educational expenses by borrowing against future earnings. Loans, of course, must be repaid.

Disbursement of Funds

Financial aid funds are disbursed depending on the type of aid and its source:

Caltech grants, scholarships, and merit awards, as well as state and federal grants, are automatically credited to the student’s account, in equal amounts, at the beginning of each academic term.

Federal Perkins Loans, Direct Stafford Loans, and Caltech Loans are also credited each term, in equal amounts, to the student’s account.

- Federal Perkins and Caltech Loans require that the borrower complete a Borrower Data Sheet and sign a promissory note for each academic year loan. These forms are available at the Bursar’s Office.
- Federal Perkins Loan borrowers must read and sign an Entrance Interview form.
- Federal Direct Stafford Loan borrowers must complete the Entrance Interview process and must sign an Entrance Interview form prior to receiving their loan. The Entrance Interview is available online at <https://schools.dlssonline.com/index.asp> or in person.

Paychecks (for actual hours worked) from Federal Work Study and CIT Work Study earnings are disbursed to students at the work site on a biweekly basis.

Outside scholarships are disbursed according to the sponsor’s specifications. If the funds are sent to the Financial Aid Office, they will be credited to the student’s account.

Note: For information on Federal Direct PLUS loan disbursements, please see page 156.

Grants and Scholarships

Caltech Grants are gifts awarded from an institutional fund or endowment specifically established for the purpose of assisting undergraduates. The amount of the award depends entirely on

demonstrated financial need and is subject to available funds. Caltech Grants are renewable based on demonstrated financial need, which is assessed annually when students apply for financial aid.

“Named” *scholarships* replace need-based Caltech grants, and are awarded to undergraduates from money given by individuals or organizations for scholarship purposes and are named by or for the donor. All aid applicants who meet the specifications of the donor are considered for a named scholarship. No special application need be filed. Since many donors are lifelong friends of the Institute and enjoy hearing about student life at Caltech today, recipients may be asked to write a thank-you letter to one or more donors.

## Federal and State Grants

*The Federal Pell Grant Program* is for undergraduate students who have not yet completed a baccalaureate degree. Eligible students may receive Federal Pell Grants for the period of time necessary to complete a first undergraduate baccalaureate degree.

The Federal Pell Grant program is intended to be the “floor” of the student’s financial aid package. This is usually the first program for which a student’s eligibility is determined. Many other federal aid programs require that a student’s Federal Pell Grant eligibility be considered prior to determining eligibility for other aid. Application for a Federal Pell Grant is made by using the *Free Application for Federal Student Aid (FAFSA)*. Applicants will receive a Student Aid Report (SAR) directly from the FAFSA processor. Upon receipt of the SAR, students should review it for accuracy.

If eligible, the exact amount of the student’s award will be determined by the Financial Aid Office after verification of the data based upon the cost of attendance, the expected family contribution, and the student’s enrollment status.

In 2005–06, Pell Grant awards will range up to \$4,050 per year.

*The Federal Supplemental Educational Opportunity Grants (FSEOG) Program* provides grant funds for undergraduate students who have not completed their first baccalaureate degree and who are financially in need of this grant in order to pursue their education. Awards of FSEOG funds must be made first to students who show exceptional financial need (defined as those students with the lowest federal expected family contribution at the Institute). Priority for FSEOG funds must be given to Pell Grant recipients. No additional application is required. These grants are contingent upon federal appropriations. The minimum annual FSEOG award is \$100, and the maximum annual award is \$4,000.

*Cal Grants* are awarded to California residents by the California Student Aid Commission (CSAC). All students who are eligible to apply are required to do so each year at the time they apply for Caltech assistance. Students should complete a FAFSA and Cal Grant GPA Verification Form. Results from the FAFSA are sent by

the processor to the CSAC, where eligibility is determined. Renewal materials are mailed to current recipients at their permanent addresses each year in December. Students must renew their Cal Grant eligibility on an annual basis by completing the FAFSA. The Cal Grant deadline for new and continuing students is March 2.

Cal Grant A, which is awarded on the basis of financial need and academic achievement, is designed to assist with the cost of tuition and fees.

Cal Grant B is awarded to students from disadvantaged/low-income families. During the first year, Cal Grant B recipients are awarded a monthly stipend for living costs. Renewal Cal Grant B recipients are awarded the monthly stipend and, in addition, assistance with tuition and fees.

Many other states provide scholarships and grants. A complete list of state scholarship agencies and their addresses is available from the Financial Aid Office. Students should contact the agency in their state of residence regarding programs available and application procedures.

## Self-Help: Employment and Loans

A self-help award is a combination of loans and employment opportunities available to help meet school expenses. At Caltech, in order to meet their expected self-help contribution, students are offered a suggested combination of loan and employment opportunities. Students can choose how much they wish to earn and how much they wish to borrow, or they may decide to work or borrow less than the standard self-help amount. These choices will not affect the amount of their grant.

The amount of self-help expected of a student is established yearly by the Institute. For the 2005–06 academic year, a freshman typically was awarded \$3,250 (\$1,625 loan and \$1,625 work) toward educational expenses. An eligible student is first awarded a combination of work and/or loan, with any remaining need being met with grant assistance.

### *Employment*

Work programs offer students a double incentive—earning money to help meet college expenses plus gaining valuable job experience. In the competitive job market, employers look for applicants who have work experience in addition to their education.

Student employment is generally available to all students regardless of whether they apply for financial aid. Interested students should contact the Caltech Career Development Center. Undergraduate students must receive approval from the dean of students to work. Students typically work less than 10 hours per week. Freshman students may not work during fall term. In subsequent terms, they must receive permission from the dean of students to work before accepting their first work assignment.

The *Federal Work Study Program* provides jobs for eligible students who demonstrate need for such earnings to meet a portion of their educational expenses. Jobs may be located on campus or off campus. The employer may be Caltech; a federal, state, or local public agency (such as Caltech's Jet Propulsion Laboratory); or a private nonprofit organization, such as a community service agency. Beginning with the 1994–95 school year, Caltech placed an increased emphasis on placing Federal Work Study students in community service jobs.

The maximum amount of Federal Work Study wages that students may earn is determined by financial need. To locate a job, the student may contact the campus Career Development Center, the student newspaper, faculty, and offices on campus. *Summer Federal Work Study* is also available for continuing students.

The *Caltech Work Study Program* is funded by the Institute to provide part-time employment for international students who have demonstrated financial need. This program is limited to the campus or JPL. The program is designed to parallel the Federal Work Study Program, and the same guidelines apply to its administration. *Summer Caltech Work Study Program* funding is also available for continuing students.

### Loans

Loans are a valuable resource for many students and their families in financing a college education. Loans allow students to postpone paying a portion of their education costs until they complete their education or leave school. Loan repayment generally extends up to 10 years after students graduate or leave school.

*Federal Perkins Loans* are awarded by the Institute to students with demonstrated financial need. Funds are obtained from the federal government and from former Caltech students who have repaid or are in the process of repaying their loans. No interest is charged on the loan while a student maintains at least a half-time academic load. Repayment begins nine months after leaving school or dropping below half-time status. Interest is then charged at a rate of 5 percent on the unpaid balance. Federal Perkins Loans are limited to a total of \$4,000 annually during undergraduate study and \$6,000 during graduate study, a total of \$20,000 for all years of undergraduate study, and a maximum of \$40,000 for the entire undergraduate and graduate career. Students may be allowed up to 10 years to repay, based upon the amount they have borrowed. Information concerning deferment, repayment, postponement, and cancellation will be provided on each borrower's loan promissory note and in a disclosure statement given to students prior to disbursements of the loan.

*Caltech and Institute Loans* are used to supplement the Institute's Federal Perkins Loan funds. Generally, no interest is charged and no repayment of principal is required while a student maintains a

continuous course of study as an undergraduate at Caltech. Repayment begins nine months after leaving school or dropping below half-time status. For Caltech Loans, interest is then charged at a rate of 5 percent on the unpaid balance until the loan has been repaid in full. Institute Loans are interest-free. As with Federal Perkins Loans, if the student transfers to another institution or attends graduate school, no payments need be made on the principal or interest as long as half-time attendance is maintained. More specific information is provided to each borrower on the promissory note and in a disclosure statement given to students prior to disbursement of the loan.

*Cecil L. Kilgore Student Loans* are available to members of all undergraduate and graduate classes, including freshmen, under the same general guidelines established for Caltech Loans as described above. It is the fund's policy to make loans available at the lowest possible cost to the student, with priority given to students in the field of power engineering.

*Other Loans/Emergency Loans* may be available to students regardless of their eligibility for financial aid. The *Hoover Loan Fund* enables students to borrow small sums of money to cover unforeseen emergencies. These loans are usually payable within the same academic year and are administered by the dean of students on a case-by-case basis. Additional information and applications may be obtained from the Dean of Students' Office.

The Caltech Y also has a no-interest, 30-day, emergency-loan program. Maximum loans are \$50. Additional information and applications may be obtained from the Caltech Y.

The *Federal Direct Student Loan Program* is an opportunity for students to borrow money from the federal government to pay for a Caltech education. Under this program, the U.S. Department of Education makes loans, through Caltech, directly to students. Caltech will use the Federal Direct Loan to pay tuition and fees, as well as room and board charges, and will give any remaining money to the student for personal expenses. Federal Direct Loans simplify loan repayment—payments go directly to the federal government.

For detailed information on Direct Loan programs and repayment plans, please see pages 154–164.

### Alternative Loan and Payment Options

Several private organizations offer a variety of financing options (such as monthly payment plans and long-term loans) to assist students and families in meeting college expenses. Information describing these programs is available upon request from the Caltech Financial Aid Office and on the Caltech Financial Aid home page at <http://www.finaid.caltech.edu>.

## Merit Awards

Merit Awards are awarded annually to *returning* students solely on the basis of academic merit. Financial need is not considered in the selection process. These Upperclass Merit Awards include the endowed Caltech Upperclass Merit Awards, Carnation Scholarships, Rosalind W. Alcott Awards, and the John Stauffer Scholarship (chemistry major). The Faculty Committee on Scholarships and Financial Aid recommends a number of Caltech's most academically talented students for receiving merit awards their sophomore, junior, and/or senior year. In 2005–06, students were awarded Caltech Merit Awards in amounts ranging from three-fourths of tuition to full tuition, and room and board. The honor is recorded on academic transcripts and listed in the commencement program when the scholar graduates.

In addition, the Freshman Admissions Committee selects admitted freshmen for a limited number of merit-based awards. No separate application is required. Selected students will be notified by the Admissions Office.

Several corporations offer partial- or full-tuition scholarships to students demonstrating particular talent in the options that represent the types of expertise the corporations need in their research and development groups. As these and other organizations announce competitions throughout the year, eligibility criteria and deadlines are advertised by the Financial Aid Office in the student newspaper—the *California Tech*—and on the Financial Aid Office home page at <http://www.finaid.caltech.edu>.

## Financial Aid When Studying Abroad

Caltech provides student financial aid (in the form of grants, scholarships, and loans) to those undergraduates with demonstrated financial need who desire to participate in the Institute-sponsored Caltech Cambridge Scholars Program, Caltech Copenhagen Scholars Program, or Caltech University College London Scholars Program. Enrollment in a study-abroad program approved for credit by Caltech will be considered enrollment at the Institute, for the purpose of applying for and receiving federal student financial assistance. To be eligible for consideration in Caltech's Cambridge, Copenhagen, or University College London Scholars Program, students must be in good academic standing, as defined in the *Caltech Catalog* and as certified by the Institute's registrar. They must also meet the minimum GPA requirement as outlined in the information provided by the Fellowships Advising and Study Abroad Office. In addition, students selected to be Cambridge, Copenhagen, or University College London Scholars will be provided a Memo of Understanding outlining the terms of their study abroad participation. (For more information on study abroad, see pages 128–130.)

For eligible students wishing to study abroad, the costs will not exceed the prorated costs of attending Caltech for the same academic period. These costs include but are not limited to tuition, fees, room, board, additional meals not covered by a board contract, books, supplies, personal expenses, and a standard transportation allowance from the student's home to Caltech. Transportation expenses related to the student's travel between Caltech and the study abroad institution are the responsibility of the student. The eligible student will have his or her expected family contribution and financial package calculated in the same manner as other students. Because students are usually unable to work while out of the country, they will receive a larger loan component as part of their financial aid award to compensate for their inability to work. Students studying abroad are subject to the standard Caltech policy of a maximum of 12 terms of eligibility for financial aid.

Cambridge, Copenhagen, and University College London Scholars candidates must meet all financial aid priority deadlines and eligibility requirements to receive aid. It is the student's responsibility to ensure that all necessary documents are filed and complete with regard to their application for financial aid. Cambridge, Copenhagen, University College London, and University of Edinburgh Scholars will continue to be considered for available federal, state, and Caltech grant, scholarship, and loan funds. The Fellowships Advising and Study Abroad Office will make the necessary arrangements with the Bursar's Office to ensure that scholars who may be eligible for funds in excess of the direct charges to the Institute receive those funds prior to their departure.

## Other Resources

A number of both local and national organizations offer *outside scholarships* to continuing students throughout the year, some of these regardless of need. The student newspaper, the *California Tech*, announces eligibility criteria for several such scholarships. Those relevant to undergraduate students will also be posted in the *Scholarship News* section of the Caltech Financial Aid Office home page. Such scholarships can also often be found with the help of a search service. We recommend FastWeb, SRN, ExPAN, MACH25, CASHE, and Fund Finder. (For more information on scholarship services, go to <http://www.finaid.org>.) Outside scholarships acquired by students are considered, by federal regulation, to be a resource available during the academic year. In general, the amount of each outside merit award will be used to replace a like amount of the self-help (work and/or loan) portion of the financial aid award. If the amount of the outside award exceeds the self-help portion, the excess amount will replace Caltech grant eligibility (it will not replace the expected family contribution).

## Satisfactory Academic Progress

In order to continue to receive financial aid at Caltech, students must maintain satisfactory academic progress toward completion of the baccalaureate degree as defined on pages 136–137 and 173. Whenever this is not maintained, approval for reinstatement by the Undergraduate Academic Standards and Honors Committee, the registrar, or the dean of students (as described on pages 133–135) shall reestablish satisfactory progress for purposes of financial aid eligibility.

In general, assistance is available to eligible students for the first 12 terms of enrollment (or the equivalent for transfer or less-than-full-time students). Exceptions may be approved after submission of a petition to the Financial Aid Office. Petition forms are available in the Financial Aid Office.

### Class Level

For loan purposes, undergraduate students are classified according to the number of units earned and the number of terms of residence at Caltech. Both these criteria must be satisfied for class-level eligibility. Students are regarded as freshmen until eligible for sophomore status, and as sophomores, juniors, or seniors if they meet the corresponding criteria set below. Units earned are defined as units completed with a passing grade.

<i>Classification</i>	<i>Minimum Units Earned</i>	<i>Minimum Terms in Residence</i>
Sophomore	108	3
Junior	216	6
Senior	324	9

### Part-Time Enrollment (Underloads)

Underloads (see page 138) must be approved by the registrar or the Undergraduate Academic Standards and Honors Committee. Students enrolled half-time (taking 18 to 26 units) will be expected to work additional hours during the academic year, as well as to accept a reduction in the books and supplies allowance of their college expense budget. All students planning to carry an underload (less than 36 units) should contact the Financial Aid Office.

## Direct Loan Programs and Repayment Plans

Direct loans include

1. the Federal Direct Stafford Loan Program;
2. the Federal Direct Unsubsidized Stafford Loan Program;
3. the Federal Direct PLUS Loan Program; and
4. the Federal Direct Consolidation Loan Program.

### Federal Direct Stafford Loan

The Federal Direct Stafford Loans (subsidized and unsubsidized) are available to both graduate and undergraduate students. The federal government “subsidizes” a loan by paying the interest while the student is in school, during the grace period, and during periods of deferment. For an unsubsidized loan, the government does not provide the subsidy; therefore, interest on the loan accrues during those periods. The calculated family contribution is taken into consideration when determining a student’s need for a subsidized loan. To determine eligibility for an unsubsidized loan, the family contribution is not considered. Other than these two differences, the provisions of the Federal Direct Stafford Loan Program apply to both subsidized and unsubsidized loans (i.e., loan limits, deferment provisions, etc.).

Before Caltech can determine loan eligibility, a determination of the student’s eligibility for a Federal Pell Grant must be made. In order to make this determination, the applicant must complete a Free Application for Federal Student Aid (FAFSA). *Subsidized* Federal Direct Stafford Loans may not be used to substitute for the federally calculated expected family contribution; however, Federal Direct *Unsubsidized* Stafford Loans may be used in this capacity. Before a student can apply for a Federal Direct Unsubsidized Stafford Loan, eligibility for a subsidized loan will be determined. To reiterate, Federal Direct *Unsubsidized* Stafford Loan borrowers are not required to demonstrate need in order to be eligible. However, if the student is eligible for a *Subsidized* Federal Direct Stafford Loan, he or she will be awarded that loan first, and this award will be taken into consideration when determining eligibility for the Federal Direct Unsubsidized Stafford Loan. The amount borrowed under the subsidized and unsubsidized loans combined may not exceed the annual/aggregate loan limits, or the total cost of education.

The following chart summarizes loan limits for Federal Direct Stafford Loans and Federal Direct Unsubsidized Stafford Loans.

### Maximum Loan Amount for a Full Academic Year

	<i>Dependent Student</i>	<i>Independent Student</i>
	<i>Maximum combined subsidized &amp; unsubsidized Federal Direct Stafford Loan</i>	<i>Maximum combined subsidized &amp; unsubsidized Federal Direct Stafford Loan</i>
<i>1st year undergraduate</i>	\$2,625	\$6,625
<i>2nd year undergraduate</i>	\$3,500	\$7,500
<i>3rd &amp; 4th year undergraduate</i>	\$5,500	\$10,500
<i>Graduate/Professional</i>	N/A	\$18,500



### *Graduated Repayment*

Minimum monthly payment	\$25
Maximum number of monthly payments	see table above

Under the Graduated Repayment Plan, payments are lower at first and will increase over a period of time that varies depending on the amount borrowed. The minimum monthly payment is the larger of 50 percent of the amount that would be required under the Standard Repayment Plan or the amount of interest that accrues monthly on the loan. The maximum number of months the borrower will pay excludes periods of deferment and forbearance and depends on the loan amount (see table above). With this plan the monthly payment amount during the earlier portion of the repayment period is reduced. Later in the repayment period, the monthly payment amount will increase, but will never be more than 150 percent of the amount required by the Standard Plan. The monthly repayment amount is increased (graduated) every two years. The number of monthly payments will be adjusted to reflect changes in the variable interest rate. This means that as the rate varies, the monthly amount will remain the same unless the borrower requests that the repayment amount be changed.

### *Income Contingent Repayment*

Minimum monthly payment	Generally none (in certain circumstances, \$15—see table, page 162)
Maximum number of monthly payments	300 months (25 years)

Federal Direct PLUS Loans and Federal Direct PLUS Consolidation Loans are not eligible for Income Contingent Repayment (ICR).

Effective July 1, 1996, borrowers who enter repayment will pay an amount based on the Adjusted Gross Income (AGI) they report on their federal tax return, or, if they submit alternative documentation of income, they will pay an amount based on current income. If the borrower is married, the amount he or she will pay will be based on the borrower's income and the spouse's income.

Under this ICR Plan, the borrower will pay the lesser of

1. the amount one would pay if he or she repaid his or her loan in 12 years multiplied by an income percentage factor that varies with annual income, or
2. 20 percent of the borrower's discretionary income, which is the AGI minus the poverty level for the family size.

If the borrower is in his or her first year of repayment, he or she will be required to submit alternative documentation of current income (that is, other than IRS-reported AGI) to the Department of Education. He or she will probably be required to submit alternative documentation in the second year of repayment also. Such documentation includes pay stubs, canceled checks, or, if these are

unavailable, a signed statement explaining income sources. The reason for this requirement is that if the borrower filed a tax return for years that included time while in school (and probably not working full-time), the AGI the department would receive from the IRS would be unlikely to reflect current income.

If the borrower is not in his or her first year of repayment, he or she may still be required to submit alternative documentation of income if the AGI is not available or if the AGI does not reasonably reflect current income. In addition, the borrower may choose to submit alternative documentation of current income, if special circumstances, such as loss of employment for the borrower or his or her spouse, warrant an adjustment to the monthly payment.

Please note that if the borrower is married and submits alternative documentation of income for any of the reasons discussed above, he or she will also be required to submit alternative documentation for his or her spouse.

If the borrower's income is less than or equal to the poverty level for the borrower's family size, the monthly payment will be zero. If the calculated monthly payment is greater than zero but less than \$5, the borrower will be required to make a \$5 monthly payment. If the monthly payment is calculated to be more than \$5, he or she will be required to pay that calculated amount.

The total AGI of both the borrower and his or her spouse (if married) will be used to calculate the monthly payments under the ICR Plan. The borrower will be required to provide his or her spouse's written consent to disclose tax-return information. Further, if the borrower submits alternative documentation as noted above, he or she will be required to submit alternative documentation of spouse's income.

If the borrower's spouse has a Direct Loan, he or she can repay loans jointly. The repayment will be based on the joint income. While one is not required to repay loans jointly, it is important to remember that if only one spouse chooses to repay under the ICR Plan, the Department of Education will use the AGI (or alternative documentation of income) of the borrower and his or her spouse to determine the monthly payments.

### *Choosing a Repayment Plan*

In selecting a repayment plan, there are several factors to understand before making a decision.

The *Standard Repayment Plan* has a shorter repayment term than under the other plans. This means the loan is paid off more quickly, and the amount of interest paid will be less than if the other plans were selected. However, the Standard Repayment Plan requires higher monthly payment amounts. If one will be able to pay a higher monthly amount, the Standard Repayment Plan may be best. If the higher repayment amount would be difficult or uncertainty exists about income level, one of the other repayment plans may be best.

The *Extended or Graduated Plan* features a longer repayment term. As a result, the monthly payment is lower than under the Standard Plan (unless the minimum monthly payment applies), but more interest over the life of the loan will be repaid. Under the Extended Plan, the payments are fixed amounts and less interest is paid than under the Graduated Plan.

The *Income Contingent Repayment Plan* features monthly repayment that will vary with the borrower's income. When income is low, one probably will have a longer repayment period than under one of the other repayment plans. As a result, a greater amount of interest is repaid over the repayment period but it may be easier to keep up with the monthly payments. If the borrower's income grows, the monthly repayment amount increases. This would reduce the repayment period and result in repaying a smaller total amount of interest over the repayment period. If the borrower's income is high and he or she chooses to limit the monthly repayment to the amount he or she would be required to pay if the loan was repaid over 12 years in equal monthly installments, the repayment period is extended, which results in more total interest paid. However, this also helps to ensure that one's payment will be manageable.

If a consistent monthly payment amount is important throughout the repayment period, select either the Standard or the Extended Plan. On the other hand, if the borrower's income is expected to increase as time passes, it might be preferable to make smaller loan payments at first and larger payments later in one's career. If so, select the Graduated Repayment Plan.

Remember: One can prepay all or part of a student loan at any time without a prepayment penalty.

For more details, see the chart on page 162, "Examples of Debt Levels, Beginning Monthly Payments, and Total Amounts Repaid for all Direct Loan Repayment Plans."

If a plan is not selected, the Standard Repayment Plan will be assigned. For help deciding which repayment plan to choose, call the Direct Loan Servicing Center at (800) 848-0979. If none of these plans seems feasible, the Direct Loan Servicing Center will help create a plan that meets a borrower's individual needs.

### *Changing Repayment Plans*

One may experience significant changes in life during the repayment period. The borrower may change or lose jobs, receive salary increases or promotions, or choose to work in a career that provides less income than expected when a repayment plan was selected. The borrower can change repayment plans annually to adjust to these changing circumstances (unless repaying a defaulted loan under the Income Contingent Repayment Plan). There is no limit to the number of times plans can be changed. If repaying under the Income Contingent Repayment Plan, one can choose

the 12-year payment limit or remove the limit on the monthly amount once per year.

To change plans, the borrower can

- change to the Income Contingent Repayment Plan at any time. The repayment term will be 25 years, less any time previously spent in the Income Contingent, Standard, and/or Extended (12 year period only) Repayment Plans. Time spent in the Extended Plan under the 15- to 30-year periods and the Graduated Repayment Plan does not count toward the 25-year maximum term;
- change to another plan as long as that plan has a repayment term greater than the amount of time one already has been in repayment. For example, the borrower can change from the Extended Plan to the Standard Plan only if he or she has been in the Extended Plan less than 10 years. If this type of change is made, the remaining repayment term will be determined by subtracting the amount of time already in repayment from the term allowed for the new plan. For example, if the borrower has been on the Extended Plan for three years and then converts to the Standard Plan in order to pay off the loan more quickly and reduce the interest expense, he or she will have a maximum of seven years left to repay the loan.

If repaying a Federal Direct Consolidation Loan (Direct Consolidation Loan) that one agreed to repay under the Income Contingent Repayment Plan due to a previous defaulted loan, the borrower must make six consecutive monthly payments before changing to another plan.

### *Loan Consolidation*

If the borrower has several student loans (including other federal education loans), it may be to his or her advantage to consolidate loans into a single Direct Consolidation Loan. Consolidation means making only a single monthly payment to cover all of one's federal loans.

Because the interest rate will be the same as for Direct Loans, the borrower may also be able to pay less interest than he or she is paying on current loans. The borrower can choose the repayment plan that best suits his or her financial circumstances.

Note: If the borrower wants to consolidate during the grace period, he or she should wait until the last month of the grace period to apply. Repayment on consolidation loans begins within 60 days of the first loan disbursement, which means the grace period would be cut short if the borrower applied too early.

Once the borrower leaves school, he or she can consolidate a Federal Family Education Loan (FFEL) under Direct Loans only if an FFEL consolidation loan or an FFEL consolidation loan with income-sensitive repayment terms acceptable to him or her cannot be obtained.

**Examples of Debt Levels, Beginning Monthly Payments, and Total Amounts Repaid for All Federal Direct Stafford Loan Repayment Plans<sup>1</sup>**

Initial debt when loan enters repayment	Income Contingent <sup>2</sup>															
	Standard			Extended			Graduated			Income Contingent <sup>2</sup>						
	Per month	Total	Per month	Total	Per month	Total	Per month	Total	Per month	Total	Income = \$15,000		Income = \$45,000			
											Single	Married/HOH <sup>3</sup>	Single	Married/HOH <sup>3</sup>		
\$ 2,500	\$ 50	\$ 3,074	\$ 50	\$ 3,074	\$ 25	\$ 4,029	\$ 17	\$ 5,927	\$ 23	\$ 4,462	\$ 22	\$ 4,514	\$ 28	\$ 3,799	\$ 28	\$ 3,808
5,000	61	7,369	55	7,893	35	8,655	35	11,853	46	8,925	44	9,028	56	7,599	56	7,616
7,500	92	11,039	82	11,839	53	12,982	50	17,730	69	13,387	66	13,541	84	11,398	84	11,425
10,000	123	14,718	97	17,463	70	19,085	67	23,640	92	17,850	88	18,055	112	15,197	111	15,233
15,000	184	22,077	146	26,194	105	28,628	73	34,461	137	26,775	131	27,083	168	22,796	167	22,849
20,000	245	29,437	170	40,899	140	44,115	73	43,268	183	35,700	175	36,111	225	30,395	223	30,465
25,000	307	36,796	213	51,124	175	55,144	73	50,414	229	44,625	219	45,138	281	37,994	278	38,082
30,000	368	44,155	256	61,349	210	66,173	73	64,529	275	53,549	240	55,316	337	45,592	334	45,698
40,000	491	58,873	315	94,614	280	100,567	73	93,300	355	78,460	240	88,857	449	60,790	445	60,931
50,000	613	73,592	394	118,268	350	125,708	73	119,127	455	103,127	240	133,007	562	75,987	557	75,164
75,000	920	110,387	563	202,842	526	212,324	73	185,647	685	172,253	240	157,204	619	127,816	573	133,802
100,000	1,227	147,183	751	270,456	701	283,098	73	265,814	885	181,099	240	161,266	619	214,977	573	231,471

NOTES:

<sup>1</sup> Payments are calculated using the maximum interest rate for student borrowers, 8.25 percent. The interest rate for loans on repayment from July 1, 2005 to June 30, 2006 was calculated at 5.3 percent. The interest rate is adjusted each year on July 1.

<sup>2</sup> Assumes a 5 percent annual income growth (Census Bureau).

<sup>3</sup> HOH is Head of Household. Assumes a family size of two.

Similar conditions apply to parents. They must have an outstanding balance on a Direct PLUS Loan or a Federal PLUS Loan (under the FFEL Program). Parents must not have an adverse credit history or, if they do, must either obtain an endorser for the loan who does not have an adverse credit history, or must document extenuating circumstances.

Even defaulted loans may be consolidated if the borrower agrees either to repay the loan under the Income Contingent Repayment Plan, or the borrower makes satisfactory arrangements to repay the loan (for consolidation purposes, defined as three consecutive, voluntary, on time, full monthly payments).

Note: Married couples may consolidate their loans jointly if at least one spouse meets the requirements for loan consolidation. Both spouses will be responsible for repayment of the loan, even if one spouse dies or they separate or divorce.

Listed below are the types of loans that may be consolidated:

- Direct Stafford/Ford Loans (subsidized and unsubsidized)
- FFEL Stafford Loans (subsidized and unsubsidized)
- Direct and Federal PLUS Loans
- Guaranteed Student Loans (GSL)
- Federal Insured Student Loans (FISL)
- Federal Supplemental Loans for Students (SLS)
- Auxiliary Loans to Assist Students (ALAS)
- Federal Perkins Loans
- National Direct/Defense Student Loans (NDSL)
- Health Professions Student Loans (HPSL)
- Health Education Assistance Loans (HEAL)
- Loans for Disadvantaged Students (LDS)
- Loans made under Subpart II of Part B of Title VIII of the Public Health Service Act, including nursing loans
- Direct and Federal Consolidation Loans

Borrowers can consolidate their loans at any time while they are still in school, during their six-month grace period, or after they begin repayment. If borrowers want to consolidate while they are in school, and they are attending a Direct Loan school, they must have at least one Direct Loan or FFEL that is in an “in-school period.” If borrowers are attending a non-Direct Loan school, they must have a Direct Loan in an “in-school period.” An “in-school period” begins when the loan is disbursed and ends when the borrower ceases to be enrolled half-time. Borrowers can consolidate only Direct Loans and FFELs while they are in school; the other types of loans listed above may be consolidated after they leave school.

This allows the borrower to extend his or her repayment term, reduce his or her monthly payments, and work with a single lender instead of several different lenders. Last, if the borrower is interested in a Direct Consolidation Loan, contact the Consolidations Department of the Direct Loan Servicing Center at (800) 557-7392 or at <http://www.loanconsolidation.ed.gov>.

### *Loan Deferments*

Once the borrower is no longer enrolled at least half-time in college and a six-month grace period has ended, loan repayment for Federal Direct Stafford Loans may be deferred

- during any period in which one is pursuing at least a half-time course of study as determined by the institution;
- during any period in which the borrower is pursuing a course of study under an approved graduate fellowship program or rehabilitation training program for disabled individuals;
- for up to three years during periods in which one is actively seeking but unable to find full-time employment;
- for up to three years for any reason, which Caltech determines, that has caused or will cause the borrower to have an economic hardship;
- for up to three years during periods in which the borrower who is serving as a member of the Armed Forces is called or ordered to active military service for a period of more than 30 days.

Unlike the Federal Perkins Loan program, which provides for a six-month grace period following each period of statutory deferment, there are no postdeferment grace periods for Federal Direct Stafford Loans.

More specific information of repayment and deferments is included in the loan promissory note and the loan disclosure statement provided to student borrowers.

### *Loan Ombudsman*

The student financial assistance (SFA) ombudsman works with student loan borrowers to informally resolve loan disputes and problems. The office of the ombudsman helps borrowers having problems with the following federal loans: Direct loans (subsidized and unsubsidized Direct student loans, Direct PLUS loans, and Direct consolidation loans); Federal Family Education loans (subsidized and unsubsidized Stafford loans, FFEL PLUS loans, and FFEL consolidation loans); guaranteed student loans, SLS loans, and Federal Perkins loans.

If a student needs the assistance of the ombudsman in order to resolve disputes or problems, he or she may contact the office at U.S. Department of Education, FSA Ombudsman, 830 First St., NE, Washington, D.C., 20202-5144; (202) 377-3800 or (877) 557-2575; [fsaombudsmanoffice@ed.gov](mailto:fsaombudsmanoffice@ed.gov); or visit the website at <http://www.ombudsman.ed.gov>.

## **PRIZES**

### *Rosalind W. Alcott Merit Scholarship, Caltech Upperclass Merit Scholarships, Carnation Scholarships, and John Stauffer Merit Scholarship*

Each year Caltech awards these prizes for academic excellence to continuing students. They are based solely on merit (selection is made on the basis of grades, faculty recommendations, and demonstrated research productivity) with no consideration given to need or any other nonacademic criterion.

### *Robert P. Balles Caltech Mathematics Scholars Award*

An annual prize of \$1,000 is awarded to the mathematics major entering his or her senior year who has demonstrated the most outstanding performance in mathematics courses completed in the student's first three years at Caltech. The executive officer for mathematics, in consultation with the faculty, determines the recipient. The prize is made possible by a gift from Mr. Robert P. Balles.

### *Mabel Beckman Prize*

The Mabel Beckman Prize is given in memory of Mrs. Beckman's many years of commitment to Caltech's educational and research programs. The \$3,000 prize is awarded to an undergraduate woman who, upon completion of her junior or senior year at Caltech, has achieved academic excellence and demonstrated outstanding leadership skills, a commitment to personal excellence, good character, and a strong interest in the Caltech community.

### *Eric Temple Bell Undergraduate Mathematics Research Prize*

In 1963 the department of mathematics established an Undergraduate Mathematics Research Prize honoring the memory of Professor Eric Temple Bell, and his long and illustrious career as a research mathematician, teacher, author, and scholar. His writings on the lives and achievements of the great mathematicians continue to inspire many hundreds of students at Caltech and elsewhere.

A prize of \$500 is awarded annually to one or more juniors or seniors for outstanding original research in mathematics, the winners being selected by members of the mathematics faculty. The funds for this prize come from winnings accumulated over the years by Caltech undergraduate teams competing in the William Lowell Putnam Mathematics Contest, an annual nationwide competition.

### *Bhansali Prize in Computer Science*

The Bhansali Prize was established in 2001 by Vineer Bhansali (B.S. '87, M.S. '87) in memory of his grandfather, Mag Raj Bhansali. The prize and honorarium are awarded to an undergraduate student for outstanding research in computer science in the

current academic year. Awardees are selected by a committee of computer science faculty.

#### *Marcella and Joel Bonsall Prize for Technical Writing*

The Marcella and Joel Bonsall Prize for Technical Writing was established by the late Marcella Bonsall to encourage SURF students to develop excellent technical writing skills. Mentors may nominate their students' papers for consideration. A faculty committee recommends the winning papers. Five prizes can be awarded annually, a first prize of \$500; second prize, \$300; and three \$200 third prizes.

#### *Richard G. Brewer Prize in Physics*

The Richard G. Brewer Prize is awarded to the freshman with the most interesting solutions to the Physics 11 "hurdles," in recognition of demonstrated outstanding intellectual promise and creativity at the very beginning of his or her Caltech education.

The award is a stipend that will support the student for the summer while he or she works on an independent Physics 11 project. This award is made possible by a gift from Dr. Richard G. Brewer, a Caltech alumnus who received his B.S. degree in chemistry in 1951.

#### *Fritz B. Burns Prize in Geology*

This prize is awarded to an undergraduate who has demonstrated both academic excellence and great promise of future contributions in the fields represented by the Division of Geological and Planetary Sciences.

#### *Bonnie Cashin Prize for Imaginative Thinking*

This \$5,000 prize, established in 1997 by Bonnie Cashin, is awarded each year to the entering freshman who has written the most imaginative essays in the Application for Freshman Admission. The Freshman Admissions Committee will nominate awardees to the vice provost, who will approve the selection. The award may be shared if there is more than one deserving student in a particular year.

#### *Donald S. Clark Memorial Awards*

From a fund contributed by the Caltech Alumni Association, annual awards of \$1,000 are made to two juniors in engineering options. The award recognizes service to the campus community and a grade point average equal to or greater than that required for graduation with honor. The awards honor the work of Professor Clark, class of 1929, both in the field of engineering and in his service to the Alumni Association.

#### *Deans' Cup and Campus Life and Master's Award*

Two or more awards, selected by the deans, the assistant vice president for campus life, and the master of student houses, respectively, are presented to undergraduates whose concern for their fellow students has been demonstrated by persistent efforts to improve the quality of undergraduate life and by effective communication with members of the faculty and administration.

#### *Doris Everhart Service Award*

The Doris Everhart Service Award is given annually to an undergraduate who has actively supported and willingly worked for organizations that enrich not only student life, but also the campus and/or community as a whole, and who has, in addition, exhibited care and concern for the welfare of students on a personal basis. The award was made possible by Sally V. Ridge and was established to honor Doris Everhart.

#### *Richard P. Feynman Prize in Theoretical Physics*

This prize was established through gifts in memory of Richard P. Feynman and the senior class gift of the class of 1989. It is awarded annually to a senior student on the basis of excellence in theoretical physics. The prize consists of a cash award and a copy of the three-volume set *The Feynman Lectures on Physics*.

#### *Haren Lee Fisher Memorial Award in Junior Physics*

Mr. and Mrs. Colman Fisher established the Haren Lee Fisher Memorial Award in Junior Physics in memory of their son. The General Electric Foundation also contributed to the fund under the matching plan of their Corporate Alumnus Program. A prize of \$350 will be awarded annually to a junior physics major, who is selected by a physics faculty committee as demonstrating the greatest promise of future contributions to physics.

#### *Henry Ford II Scholar Awards*

Henry Ford II Scholar Awards are funded under an endowment provided by the Ford Motor Company Fund, a nonprofit organization supported primarily by contributions from the Ford Motor Company. Each award, up to \$5,000, will be made annually either to the engineering student with the best academic record at the end of the third year of undergraduate study, or to the engineering student with the best first-year record in the graduate program. The chair of the Division of Engineering and Applied Science names the recipient.

#### *Jack E. Froehlich Memorial Award*

The family and friends of the late Jack E. Froehlich, who did his undergraduate and graduate work at Caltech and was later the project manager for Explorer I for the Jet Propulsion Laboratory,

established a prize fund that provides an award of \$1,000 to a junior in the upper 5 percent of his or her class who shows outstanding promise for a creative professional career. The student is selected by the division chairs and the deans, together with the Undergraduate Academic Standards and Honors Committee.

*George W. and Bernice E. Green Memorial Prize*

The George W. and Bernice E. Green Memorial Prize was established in 1963 with contributions given in memory of George W. Green, who for 15 years served on the staff of the Caltech business office and was vice president for business affairs from 1956 to 1962. The prize of \$1,200 is awarded annually to an undergraduate student in any class for original research, an original paper or essay, or other evidence of creative scholarship beyond the normal requirements of specific courses. The student is selected by the division chairs and the deans, together with the Undergraduate Academic Standards and Honors Committee.

*Lucy Guernsey Service Award*

Awarded to one or two students who have provided exceptional service to the Caltech Y and/or the community, are involved with service projects, have demonstrated leadership in community and volunteer service efforts, and who exemplify a spirit of service. Established by the Caltech Y ExComm in honor of Lucy Guernsey, the Y's executive director from 1989 to 1991.

*Arie J. Haagen-Smit Memorial Fund*

The Arie J. Haagen-Smit Memorial Award was established in 1977 to honor the memory of the pioneering bioorganic chemist who discovered the chemical constituents of smog. Dr. Haagen-Smit was a member of the Caltech faculty for 40 years, and his family and friends have arranged for a prize of \$750 to be given at the end of the sophomore or junior year to a student in biology or chemistry who has shown academic promise and who has made recognized contributions to Caltech. The selection is made by a committee of representatives from the biology and chemistry divisions, and the deans.

*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 20 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 throughout his or her undergraduate years at the Institute has made the greatest contribution to 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, consists of a cash award and a certificate.

*Alexander P. and Adelaide F. Hixon Prize for Writing*

The Hixon Prize for Writing was established in 2000 by Alexander P. and Adelaide F. Hixon. The prize will be awarded annually to an undergraduate student for the best composition in a freshman humanities course. The prize is administered by the writing center, and the winner will be chosen by a committee from the Humanities division, with preference given to the paper best illustrating the relationship between the humanities and science and/or engineering.

*Bibi Jentoft-Nilsen Memorial Award*

Family and friends of Bibi Jentoft-Nilsen, class of 1989, have provided this award in her memory. The cash award of \$500 is for an upperclass student who exhibits outstanding qualities of leadership and who actively contributes to the quality of student life at Caltech.

*Scott Russell Johnson Undergraduate Mathematics Prize*

This prize of \$2000 is awarded to the best graduating mathematics major. The prize may be split between two students. In deciding on the winner, special consideration will be given to independent research done as a senior thesis or SURF project. The executive officer for mathematics, in consultation with the faculty, determines the recipient. The prize is made possible by a gift from Steve and Rosemary Johnson in memory of Scott Johnson, B.S. '83.

*D. S. Kothari Prize in Physics*

This prize was established in 1998 in memory of Dr. D. S. Kothari, who received his Ph.D. under Lord Rutherford in 1933, and subsequently made significant contributions in theoretical astrophysics and science education. The award of \$500 is given each year to a graduating senior in physics who has produced an outstanding research project during the past year.

*Margie Lauritsen Leighton Prize*

From a fund established by Dr. Fay Ajzenberg-Selove and Dr. Walter Selove, the departments of physics and astrophysics will annually award the Margie Lauritsen Leighton Prize to one or two undergraduate women who are majoring in physics or astrophysics, and who have demonstrated academic excellence. The prize consists of a cash award and will be made at the end of the sophomore year.

#### *Dorothy B. and Harrison C. Lingle Scholarship*

Each year, the Freshman Admissions Committee selects one incoming freshman for a \$7,500 annual merit award. The Lingle Scholarship is awarded in recognition of interest in a career in science or engineering, outstanding academic record, demonstrated fair-mindedness, good work ethic, and unquestioned integrity. The award is renewable for three years, regardless of financial need, contingent upon continuing high academic performance. Such performance is defined as not failing any courses and maintaining honors standing. All admitted freshman applicants will be considered. No special application is required.

#### *Mary A. Earl McKinney Prize in Literature*

The Mary A. Earl McKinney Prize in Literature was established in 1946 by Samuel P. McKinney, M.D., of Los Angeles. Its purpose is to promote proficiency in writing. The terms under which it is given are decided each year by the literature faculty. It may be awarded for essays submitted in connection with regular literature classes, or awarded on the basis of a special essay contest. The prize consists of cash awards amounting to \$750.

#### *Galina D. Moller Memorial Fund for Women*

The Galina D. Moller Memorial Fund was established to honor Dr. Galina Moller (M.S. '74, Ph.D. '80), an alumna who was keenly aware of the special challenges encountered by professional women. The fund provides support for activities related to study, research, or professional development of undergraduate women. For example, the funds could help defray the cost of attending a conference or seminar. The deans will allocate the funds as appropriate.

#### *Robert L. Noland Leadership Award*

The Robert L. Noland Leadership Award is a cash award of \$2,000 for upperclass students who exhibit qualities of outstanding leadership. The kind of leadership to be recognized is most often expressed in personal actions that have helped other people and that have inspired others to fulfill their leadership capabilities. The scholarship was set up by Ametek in 1978 in honor of its president, Robert L. Noland, a Caltech alumnus. Two or more awards are generally made each year.

#### *Rodman W. Paul History Prize*

The Rodman W. Paul History Prize was established in 1986 by some of his many colleagues and friends to honor Professor Paul's 35 years of teaching and research at the Institute. The prize is awarded annually to a junior or senior who has shown unusual interest in and talent for history.

#### *Doris S. Perpall SURF Speaking Prize*

Robert C. Perpall (B.S. '52, M.S. '56) endowed this prize in memory of his late wife, Doris S. Perpall, to encourage students to prepare excellent SURF presentations. SURF Seminar Day is the first round of the Perpall Speaking Competition. The best presentations in each session are nominated for advancement to a second round, held in November. The final round is held in January. Three prizes are awarded annually, a first prize of \$500; second prize, \$300; third prize, \$200.

#### *Howard Reynolds Memorial Prize in Geology*

The Howard Reynolds Memorial Prize in Geology is awarded to a sophomore or junior who demonstrates the potential to excel in the field of geology, and who actively contributes to the quality of student life at Caltech.

#### *Herbert J. Ryser Scholarships*

The Herbert J. Ryser Scholarships were established in 1986 in memory of H. J. Ryser, who was professor of mathematics at Caltech from 1967 to 1985. Professor Ryser contributed greatly to combinatorial mathematics and inspired many students with his carefully planned courses. The scholarships are given on the basis of merit, preferably in pure mathematics. Recipients are selected by the executive officer for mathematics after consulting the faculty. This year the scholarship is worth \$6,000.

#### *Richard P. Schuster Memorial Prize*

This award is made from a fund established by family, friends, and colleagues of Richard P. Schuster, Jr., a graduate of Caltech and the Institute's director of development at the time of his death. The recipient is a junior or senior in chemistry or chemical engineering; selection is based on financial need and a demonstration of academic promise.

#### *Eleanor Searle Prize in Law, Politics, and Institutions*

The Eleanor Searle Prize was established in 1999 by friends and colleagues to honor Eleanor Searle, who was the Edie and Lew Wasserman Professor of History at Caltech. The prize will be awarded annually to an undergraduate or graduate student whose work in history or the social sciences exemplifies Eleanor Searle's interests in the use of power, government, and law.

#### *Don Shepard Award*

Relatives and friends of Don Shepard, class of 1950, have provided this award in his memory. The award is presented to a student, the basic costs of whose education have already been met but who would find it difficult, without additional help, to engage in extracurricular activities and in the cultural opportunities afforded by the community. The recipients—freshmen, sophomores, and

juniors—are selected on the basis of their capacity to take advantage of and to profit from these opportunities, rather than on the basis of their scholastic standing.

#### *Sigma Xi Award*

In accordance with the aim of Sigma Xi, the Scientific Research Society, to encourage original investigation in pure and applied science, the Institute chapter of the society annually awards a prize of \$1,200, funded from membership dues, to a senior selected for an outstanding piece of original scientific research. The student is selected by the division chairs and the deans, together with the Undergraduate Academic Standards and Honors Committee.

#### *Hallett Smith Prize*

The Hallett Smith Prize was established in 1997 to commemorate Professor Smith's long career as one of this century's most distinguished Renaissance scholars. The cash prize is given annually by the literature faculty to the student who writes the finest essay on Shakespeare.

#### *Paul Studenski Memorial Fund Prize*

This travel grant is awarded to a Caltech undergraduate who would benefit from a period away from the academic community in order to obtain a better understanding of self and his or her plans for the future. The recipient is selected by the Caltech Y Studenski Committee.

#### *Alan R. Sweezy Economics Prize*

The Alan R. Sweezy Economics Prize was established in 1995 by family, friends, and colleagues to honor Professor Sweezy for his 36 years of teaching and research at the Institute. The prize is awarded annually to a junior or senior who has shown unusual interest in and talent for economics.

#### *Frank Teruggi Memorial Award*

The Frank Teruggi Memorial Award was established in 1998 by friends and classmates of the late Frank Teruggi, a Caltech undergraduate who was murdered in Chile in 1973, during the military coup led by Augusto Pinochet.

The annual award of \$500 honors the spirit of Frank's life, especially "in the areas of Latin American Studies, radical politics, creative radio programming, and other activities aimed at improving the living conditions of the less fortunate." The awardee is chosen by a faculty committee from the Division of the Humanities and Social Sciences.

#### *Morgan Ward Prize*

The Morgan Ward Prize was established by the department of mathematics in 1963 to honor the memory of Professor Morgan Ward in recognition of his long service to mathematics and to the

Institute. The competition is open only to freshmen and sophomores. An entry consists of a mathematical problem together with a solution or a significant contribution toward a solution. One or more winners are selected by a faculty committee acting on the advice of student judges. Each prize of \$75 is funded by the same source used to sponsor the Eric Temple Bell Prize.

#### *Fredrick J. Zeigler Memorial Award*

The Fredrick J. Zeigler Memorial Award was established in 1989 to honor Fredrick J. Zeigler, a member of the class of 1976 and an applied mathematics major. The award, which carries a cash prize of \$2,500, is given to a pure or applied mathematics student in his or her sophomore or junior year. Selected by the faculty in pure and applied mathematics, the award recognizes excellence in scholarship as demonstrated in class activities or in the preparation of an original paper or essay in any subject area.

Note: Prizes and awards may be subject to federal and state income tax.

## **GRADUATION REQUIREMENTS, ALL OPTIONS**

To qualify for a Bachelor of Science degree at the Institute, students must obtain passing grades in each of the required courses listed below; must satisfy the additional requirements listed under the undergraduate options; and must achieve a grade-point average of not less than 1.9. Students must also register for the appropriate number of units that results in normal progress toward a B.S. degree.

The requirements for the B.S. degree are the ones stated in the catalog published in the first year of a student's enrollment at Caltech, under normal circumstances. Changes to those requirements can occur due to actions and decisions made by the student's option, the registrar, the Curriculum Committee, or the Faculty Board. A student may elect to satisfy the requirements stated in a catalog from a different year than that under which the student was registered by first obtaining approval from the Registrar's Office.

Students must register for the Institute requirements in the year specified, unless they have previous credit. If for some reason they are not able to complete the requirements during the proper year, they must register at the earliest possible opportunity. (The Curriculum Committee may in unusual cases excuse undergraduate students from any of the following Institute or option requirements upon presentation of petitions.)

The Institute unit system is described in the opening paragraphs of section five.

## Core Institute Requirements, All Options

The following requirements are applicable to incoming freshmen for 2005–06 and subsequent years. Some information for continuing students has been provided as footnotes, but guidance on special cases must be sought. Courses used to satisfy core requirements may not be used to satisfy option electives.

<i>Course</i>	<i>Units</i>
1. Freshman Mathematics (Ma 1 abc).....	27
2. Sophomore Mathematics (Ma 2 ab).....	18
3. Freshman Physics (Ph 1 abc).....	27
4. Sophomore Physics (Ph 2 ab or Ph 12 abc <sup>1</sup> ) .....	18
5. Freshman Chemistry (Ch 1 ab).....	15
6. Freshman Biology (Bi 1) <sup>2</sup> .....	9
7. Menu Class (currently Ay 1, Ch/APh 2, ESE 1, or Ge 1) .....	9
8. Freshman Chemistry Laboratory (Ch 3 a) <sup>3</sup> .....	6
9. Additional Introductory Laboratory .....	6
10. Scientific Writing <sup>4</sup> .....	3
11. Humanities Courses (as defined below).....	36
12. Social Sciences Courses (as defined below) .....	36
13. Additional Humanities and Social Sciences Courses.....	36
14. Physical Education .....	9

<sup>1</sup> Students taking Ph 12 a but not Ph 12 c must take one term in Statistical Physics or Thermodynamics from the list: Ph 2 a, APh 17 a, Ch 21 c, Ch 24 a, or ME 18 a.

<sup>2</sup> Bi 8 and Bi 9, if taken in the freshman year, are an acceptable alternative to Bi 1.

<sup>3</sup> This requirement can also be met by completing Ch 3 b or Ch 4 a.

<sup>4</sup> This requirement may be met either by taking a course approved by the student's option to satisfy this requirement, or by taking En 84.

### Introductory Laboratory Requirement

All students are required to take at least 12 units of laboratory work in experimental science during their freshman and sophomore years. Ch 3 a (6 units) shall be taken during the freshman year. The additional 6 units must be chosen from one of the following: APh/EE 9 (6 units), APh 24 (6 units), Bi 10 (6 units), Ch 3 b (6 units), Ch 4 ab (6 units per term), ChE 10 (3 units), Ph 3 (6 units), Ph 5 (6 units), or a more advanced laboratory. Computational laboratory courses may not be used to satisfy this requirement.

### Humanities and Social Sciences Requirements

All students must complete satisfactorily 108 units in the Division of the Humanities and Social Sciences. Of these, 36 must be in the humanities (art, English, history, history and philosophy of science, humanities, music, philosophy, and, with certain restrictions, languages) and 36 in the social sciences (anthropology, economics, law, political science, psychology, social science), in each case divided equally between introductory and advanced courses. The remaining 36 may be drawn from humanities and social sciences,

including HSS tutorial courses and (to the limit of 27 units) courses in business economics and management. They may *not* include reading courses unless credit has been granted by petition to the Humanities or Social Science faculty. In general, no more than 18 units of freshman humanities may be counted toward the 108-unit requirement.

Entering freshmen are required to take two terms of freshman humanities; that is, humanities courses numbered 10 or below in the *Catalog*. These classes introduce students to the basic issues in the three core disciplines of English, history, and philosophy. Successful completion of two terms of freshman humanities is a prerequisite for all advanced humanities courses, except for foreign languages. It is *not* a prerequisite, however, for introductory social sciences. The freshman humanities classes may be taken in any two terms of the freshman year.

To encourage breadth, students will have to take their two freshman humanities classes in different disciplines, the disciplines for the freshman classes being English, history, and philosophy.

A student must take 18 units of advanced humanities courses as well. The classes that count as advanced humanities courses are those numbered 99 or above in English, history, history and philosophy of science, humanities, and philosophy. The advanced humanities classes also include all foreign language classes beyond the fourth term, whether or not the student has taken any of the preceding terms in the sequence for that language. The first four terms of a foreign language sequence do not count toward the 36-unit humanities requirement; however, every term receives credit toward the final 36 units of the 108-unit requirement in HSS.

Since writing is a crucial skill, all humanities courses, with the exception of some foreign languages and courses numbered between 29 and 99, require at least 4,000 words of composition. Instructors give extensive feedback on written work and help students improve their prose. As entering students may not be fully prepared for the writing in freshman humanities, all freshmen and transfer students take a writing assessment before the beginning of the fall term. On the basis of this assessment, some students may be required to pass En 1 ab, English as a Second Language, or En 2, Basic English Composition, before entering freshman or advanced humanities classes. (En 1 ab and En 2 count as general Institute credit only.) At the discretion of the instructor, students in freshman humanities who do not meet expectations for writing may be required to seek additional instruction in consultation with the writing center, or to pass En 1 ab or En 2, or another suitable composition class, before continuing with their freshman or advanced humanities classes. Any student who has taken En 1 a, En 1 b, or En 2 may not subsequently enroll in more than one freshman humanities class per term.

Students are required to take two introductory social science courses and 18 units of related advanced undergraduate social science courses. The introductory social science courses must be drawn from the following list: either An 22 or An 23, Ec 11, Law 33, PS 12, either Psy 15 or Psy 20, SS 13. The 18 units of advanced undergraduate social science courses (numbered 100 and above), in fields following at least one of their introductory courses, must be taken as indicated below.

<i>Introductory Course</i>	<i>Following Course</i>
An 22 or An 23	advanced anthropology
Ec 11	advanced economics
Law 33	advanced law
PS 12	advanced political science
Psy 15 or Psy 20	advanced psychology
SS 13	advanced economics or political science, or H/SS 154

For instance, a student who has taken An 22 and Ec 11 may use 18 units of advanced anthropology courses, or 18 units of advanced economics, or 9 units of advanced anthropology and 9 units of advanced economics to fulfill the advanced social science requirement.

#### *Physical Education Requirement*

Before graduation each undergraduate is required to successfully complete 9 units of physical education. This requirement may be satisfied entirely or in part by participation in intercollegiate athletics, or successful completion of physical-education class coursework. All grades are issued pass/fail. A maximum of 6 units per term may be applied toward graduation requirements with the total not to exceed 36 units. Participation as a bona fide member of an intercollegiate team for the period covered by the sport in a given term satisfies the requirement for that term.

A broad program of instruction is provided each term. Late registration is permitted during the first week of each term, provided there is space available and with permission of the instructor. Standards for evaluation of student performance will be clearly defined at the beginning of each class.

#### *Scientific Writing Requirement*

The scientific writing requirement can be satisfied by taking an appropriate course offered by any division, or by taking En 84. All options also require a three-unit course in oral communication. Some options combine these two requirements into one course. At the discretion of the option, the scientific writing requirement can be satisfied by three units of additional work associated with a senior thesis, focused on effective written scientific communication.

<i>Options</i>	<i>Requirements</i>	
	<i>Oral</i>	<i>Written</i>
ACM, APH, CS, EE, E&AS, ME	E 10	E 11
Ay	Ay 30	Ay 31
Bi	Bi 80	Bi 24
BEM, Ec, SS	BEM/Ec/SS 20	same
ChE	ChE 126	Ch/ChE 91
Ch	Ch 90	Ch/ChE 91
En, H, HPS, PI	En 84	same
GPS	Ge 109	Ge 13
Ma	Ma 10	Ma 11
Ph	Ph 70	same

### **First-Year Course Schedule, All Options**

Differentiation into the various options begins in the second year.

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
Ma 1 abc	Freshman Mathematics	9	9	9
Ph 1 abc	Freshman Physics	9	9	9
Ch 1 ab	General Chemistry	6	9	0
Bi 1	Drugs and the Brain	0	0	9
Ch 3 a	Fundamental Techniques of Experimental Chemistry <sup>1</sup>	6	or 6	or 6
	Introductory courses in the humanities and social sciences. A wide choice of alternatives will be available to students; the registrar will announce the offerings for each term.	9	9	9
	Introductory Laboratory Courses <sup>2</sup>	x	x	x
	Menu Course <sup>3</sup> or Additional Electives <sup>4</sup>	x	x	x
PE	Physical Education <sup>5</sup>	3	3	3

x—Except for the minimum laboratory unit requirement, the number of units chosen here is optional. If a student chooses no electives except physical education and takes the minimum permissible laboratory courses, the total unit requirement will usually be in the range of 39 to 45. A total load—including electives—of more than 48 units per term is considered a heavy load. Loads of more than 51 units for freshmen or 54 units for upperclass students require approval by the dean of students.

<sup>1</sup> This course is offered in each of the three terms.

<sup>2</sup> The additional 6 units must be chosen from one of the following: APH/EE 9 (6 units), Bi 10 (6 units), Ch 3 b (6 units), Ch 4 ab (6 units per term), Ph 3 (6 units), or a more advanced laboratory course.

<sup>3</sup> Students entering 1996-97 or later years must take a menu course (currently Ay 1, Ch/APh 2, ESE 1, or Ge 1) in their freshman or sophomore year. These courses are offered third quarter only. It is also possible to take one of these courses as an elective.

<sup>4</sup> A partial list of electives particularly recommended for freshmen includes the following: Ay 1, Bi 8, CbE 10, Cb/APb 2, Cb 10, CS 1, CS 2, CS 3, ESE 1, Ge 1, Ph 10, Ph 20, Ph 21, Ph 22.

<sup>5</sup> Three terms (9 units) of PE are required for the B.S. degree. Students need not elect to take the required PE in the freshman year. It may be taken in any three terms before graduation.

## Applied and Computational Mathematics Option

The undergraduate option in applied and computational mathematics is for those students who want to combine their basic studies in mathematics with considerable involvement in applications. The program is similar in general outline to the mathematics option, with additional requirements to ensure a balance between courses that develop mathematical concepts and courses that show the interplay of these concepts with a variety of applications. Complete programs will be worked out with faculty advisers.

### Option Requirements

1. Ma 5 abc or Ma 108 abc, and ACM 95 abc, ACM 101 abc, and E 10.
2. An approved sequence of three one-quarter courses to be selected from the following: ACM 104, ACM 105, ACM 106 abc, ACM 113, ACM 116, ACM/ESE 118, ACM 126 ab, ACM 151 ab.
3. One of the following (or an approved three-term combination totalling at least 27 units): Ma/CS 6 abc, Ma 109 abc, Ma 110 abc, Ma 120 abc, Ma 121 abc, Ma 122 a, EE/Ma 126 ab, EE/Ma 127 ab, CS/EE/Ma 129 abc, Ma 151 abc.
4. One 27-unit 100 or higher level course in science or engineering not in ACM or Ma and approved by the student's adviser.
5. Passing grades must be obtained in a total of 483 units, including the courses listed above.

### Typical Course Schedule

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	0
Ph 2 ab	Sophomore Physics	9	9	0
Ma 5 abc	Introduction to Abstract Algebra	9	9	9
	HSS Electives	9	9	9
	Electives	9	9	27
		45	45	45
<i>Third Year</i>				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	HSS Electives	9	9	9
	Electives	18	18	18
		39	39	39

### Fourth Year

ACM 101 abc	Methods of Applied Mathematics I	9	9	9
	HSS Electives	9	9	9
	Electives <sup>1</sup>	27	27	27
		45	45	45

<sup>1</sup> See items 2 and 3 under option requirements.

## Applied Physics Option

The applied physics option is designed to connect what are conventionally considered “engineering” and “pure physics.” Research in applied physics is an effort to answer questions related to problems of technological concern. Since the interests of both engineering and pure physics cover fields that overlap, a definite dividing line cannot be drawn between them. Realizing this, the applied physics option draws its faculty from the Divisions of Physics, Mathematics and Astronomy; Engineering and Applied Science; Chemistry and Chemical Engineering; and Geological and Planetary Sciences. This interdivisional aspect of the option allows a flexibility and range in curriculum, appropriate to the student's particular research interests, that may result in a mixture of courses and research in different divisions.

Specific subject areas of interest in the program cover a broad spectrum of physics related to important fields of technology. Photonics areas include multiwavelength fiber telecommunications, integrated microphotonic and nanophotonic devices, holographic data processing and storage, and optical approaches to quantum computation. Solid state materials and device work is focused on nanostructured materials and devices, wide bandgap semiconductors and heterostructures for optoelectronics, photovoltaics, novel memory devices, and spin-dependent transport. Biophysics topics include single molecule scale studies of the mechanics of DNA, proteins, and their assemblies. Plasma physics research is concentrated on spheromak plasmas for fusion application, plasma processes occurring in the sun, and dynamics of pure electron plasmas. Applied physics research also encompasses fluid dynamics in liquids and gases for applications ranging from aeronautics to thin-film growth processes.

The undergraduate curriculum attempts to reflect and maintain a close relationship with the various disciplines. This facilitates a transition to or from any of these, if at any time in the student's course of study and research this would be considered beneficial.

Attention is called to the fact that any student whose grade-point average is less than 1.9 at the end of the academic year in the subjects listed below under option requirements may be refused permission to continue work in this option.

## Option Requirements

- Any three of the following: APh/EE 9 b, APh 24, Ph 3, Ph 5, Ph 6, Ph 7; and E 10.
- APh 17 abc, APh 125 ab or Ch 125 ab or Ph 125 ab, and Ph 106 abc.
- ACM 95 abc.
- Either APh 78 abc or one term of APh 77 and one chosen from the following: APh 77, Ph 77, EE 91, Ch 6, Ae/APh 104 bc, MS 125.
- 27 additional units of APh courses numbered over 100, which must include one of the following sequences: APh 101 abc, APh 105 abc, APh 114 abc, APh 156 abc, APh/BE 161, APh/BE 162, APh/EE 183 abc, APh 190 abc, or the sequence APh/EE 130, APh/EE 131, APh/EE 132. Note that APh 100 and APh 200 do not satisfy this requirement.
- Passing grades must be earned in a total of 486 units, including the courses listed above. None of the courses taken to satisfy option requirements may be taken on a pass/fail basis.

## Typical Course Schedule

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ph 2 ab	Sophomore Physics	9	9	0
Ma 2 ab	Sophomore Mathematics	9	9	0
	HSS Electives	9	9	9
	Laboratory Electives <sup>1</sup>	6	6	6
APh 17 abc	Thermodynamics	9	9	9
	Other Electives	9	9	27
		51	51	51
<i>Third Year</i>				
Ph 125 ab	Quantum Mechanics	9	9	-
APh 110 abc	Topics in Applied Physics	2	2	2
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	HSS Electives	9	9	9
	Other Electives <sup>2</sup>	18	18	27
		50	50	50
<i>Fourth Year</i>				
APh 78 abc	Senior Thesis, Experimental <sup>3</sup>	9	9	9
or				
APh 77	Laboratory in Applied Physics <sup>3</sup>	-	9	9
Ph 106 abc	Topics in Classical Physics	9	9	9
	Electives <sup>2</sup>	9	9	9
	HSS Electives	9	9	9
	Other Electives	18	9	9
		54	54	54

<sup>1</sup> See item 1, option requirements.

<sup>2</sup> See item 5, option requirements.

<sup>3</sup> See item 4, option requirements.

## Suggested Electives

The student may elect any course that is offered in any term provided he or she has the necessary prerequisites for that course. The following subjects are especially suitable for a well-rounded course of study. They need not be taken in the year suggested.

<i>Second Year</i>	<i>Third Year</i>	<i>Fourth Year</i>
APh 23, APh 24, Ma 5 abc, MS 115 ab	APh 77, Ph 77 abc, EE 114 abc, Ch 6 ab, Ge 101, APh 100, ME 19 ab	APh 77, APh 100, APh 101 abc, APh 105 abc, APh 114 abc, ACM 101 abc, ACM 104, Ch 125 abc, Ph 125 abc, Ph 129 abc, Ph 77 abc

### *More Specialized Courses*

APh 156 abc, APh/BE 161, APh/EE 183 abc, APh 190 abc, APh/EE 130, APh/EE 131, APh/EE 132, ChE 103 abc, EE 91 ab, Ge 102, Ge 103.

## Astrophysics Option

Modern astronomy—certainly as practiced at Caltech—is essentially astrophysics. With the goal of understanding the physical processes that govern the universe, its constituents, and their evolution, astronomy uses the apparatus and methodology of physics to gather and interpret data.

The astrophysics option is designed to give the student an understanding of the basic facts and concepts of astronomy today, to stimulate his or her interest in research, and to provide a basis for graduate work in astronomy/astrophysics. The sequence (Ay 20, 21) constitutes a solid introduction to modern astrophysics and may be taken either sophomore or junior year, with more advanced courses (Ay 101, 102, plus Ay electives) taken in the junior and senior years. It is desirable for a student to gain as broad a background as possible in related fields of science and engineering.

Attention is called to the fact that any student whose grade-point average is less than 1.9 at the end of an academic year in the subjects listed in the Division of Physics, Mathematics and Astronomy may, at the discretion of his or her department, be refused permission to continue the work in this option.

## Option Requirements

- Ay 20, Ay 21, Ay 101, Ay 102, Ay 30 or Ay 141, Ay 31, Ph 125 abc or APh 125 abc, and Ph 106 abc.
- Ph 3 plus any two of Ph 5, Ph 6, Ph 7, or Ay 105. APh 23 and 24 taken as a pair may be substituted for one of these labs.
- 54 additional units of Ay or Ph courses.
- 27 additional units of science or engineering electives, of which 18 must be outside the Division of Physics, Mathematics and

Astronomy. Core classes (e.g., Ay 1, Ge 1, Bi 1) do not count towards fulfillment of this requirement.

5. Passing grades must be earned in a total of 486 units, including the courses listed above.

### Typical Course Schedule

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ph 2 ab	Sophomore Physics	9	9	-
or				
Ph 12 abc				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ay 20	Basic Astronomy and the Galaxy	9	-	-
Ay 21	Galaxies and Cosmology	-	9	-
Ay 30	Current Trends in Astronomy	-	3	-
	Physics Laboratory	6-9	6-9	6-9
	Core Menu Course	-	-	9
	HSS Electives	9	9	9
	Electives	0-6	0-3	15-21
		42-51	45-51	39-48
<i>Third Year</i>				
Ph 125 abc	Quantum Mechanics	9	9	9
Ph 106 abc	Topics in Classical Physics	9	9	9
Ay 101	The Physics of Stars	11	-	-
Ay 105	Astronomy Instrumentation Lab	-	9	-
	HSS Electives	9	9	9
	Electives	9-12	9-15	18-24
		47-50	45-51	45-51
<i>Fourth Year</i>				
Ay 31	Written Communication	-	-	3
Ay 102	Physics of the Interstellar Medium	-	9	-
	Astronomy or Physics Electives	18	18	18
	HSS Electives	9	9	9
	Electives	18-24	9-15	15-21
		45-51	45-51	45-51

An ability to present one's work is vital to a successful career in research and teaching. Ay 30 satisfies the oral communications requirement, but for further development, students are *also* urged to sign up for Ay 141 in their junior and senior years. Ay 31 satisfies the written communication requirement. Students are encouraged (but not required) to undertake research leading to a senior thesis; credit for this work is provided through Ay 78. Non-thesis research credits may be earned through Ay 142 with a maximum of 9 units per term. Computational skills may be acquired through Ph 20-21 and/or ACM 106.

### Suggested Electives

The student may elect any course offered in any division in a given term, provided that he or she has the necessary prerequisites for that course. The following courses are useful to work in various fields of astronomy and astrophysics: ACM 95, ACM 106, APh 23/24, Ay 105, Ay 121-127, EE 20, EE 91, EE/Ge 157, Ge/Ay 11 c, Ge 103, Ge/Ch 128, Ge 131, Ge/Ay 132, 133, 137, Ma 4, Ma 12, Ma 112, Ph 20-22, Ph 77, 101, 127, 129, 136, 199.

### Biology Option

The undergraduate option in biology is designed to build on a solid foundation in mathematics and physical science by providing an introduction to the basic facts, concepts, problems, and methodologies of biological science. The option serves as a basis for graduate study in any field of biology or for admission to the study of medicine. Instruction is offered in the form of participation in the ongoing research programs of the division, as well as in formal course work. Course work emphasizes the more general and fundamental properties of living organisms, and areas of current research interest, rather than the traditional distinct fields within the life sciences.

The division encourages undergraduate participation in its research program and believes that research participation should be a part of each student's program of study. Students may elect to prepare an undergraduate thesis (Bi 90). Research opportunities may be arranged with individual faculty members, or guidance may be obtained from a student's individual faculty adviser in the division or from the biology undergraduate student adviser.

The requirements listed below for the biology option are minimal requirements. An adequate preparation for graduate work in biology will normally include additional elective research or course work in biology and/or advanced course work in other sciences or in mathematics. Flexibility to accommodate varied individual scientific interests, within the broad scope of biology, is achieved through the provision of elective courses, arrangements for individual research (Bi 22), and tutorial instruction (Bi 23). In addition, arrangements may be made to take courses at neighboring institutions in fields of biology that are not represented in our curriculum.

### Premedical Program

The undergraduate course for premedical students is essentially the same as that for biology students and is intended as a basis for later careers in research as well as in the practice of medicine. It differs in some respects from premedical curricula of other schools; however, it has been quite generally accepted as satisfying admission requirements of medical schools.

It is recommended that all students contemplating application to medical school consult with the premed adviser, Angela Wood, at the Career Development Center.

### Option Requirements

1. Bi 8, Bi 9, Bi/Ch 110, Bi 117, Bi 122, Bi/CNS 150, and Ch 41 abc.
2. One advanced laboratory course chosen from Bi 123, Bi/CNS 161, Bi/CNS 162, Bi 180, Bi 227, or at least 9 units of independent research such as Bi 22.
3. Three courses chosen from Bi/Ch 111, Bi/Ch 113, Bi 114, Bi/Ch 132, Bi 156, BMB/Bi/Ch 170, Bi 182, Bi 188, or Bi 190. Only one of the three may be a six-unit course (these are 182, 188, and 190).
4. 3 units of Biology Major Seminar, Bi 80.
5. 34–49 elective units in Biology courses numbered above 20, to reach a total of 143 units of Biology course work. Pass/fail grading may be elected, in the manner specified on page 41, for these Biology course electives, but not for courses taken to fulfill requirements 1 to 4.
6. Passing grades must be earned in a total of 486 units, including the courses listed above.

### Typical Course Schedule

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
	HSS Electives	9	9	9
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
Ch 41 abc	Organic Chemistry	9	9	9
Bi 8	Introduction to Molecular Biology <sup>1</sup>	-	9	-
Bi 9	Cell Biology <sup>1</sup>	-	-	9
Bi 10	Cell Biology Laboratory <sup>2</sup>	-	-	6
	Electives <sup>3</sup>	9-15	0-6	9-18
		45-51	45-51	42-51
<i>Third Year</i>				
	HSS Electives	9	9	9
Bi 117	Developmental Biology	-	9	-
Bi/Ch 110	Intro. to Biochemistry	12	-	-
Bi 122	Genetics	9	-	-
Bi 123	Genetics Laboratory <sup>4</sup>	-	12	-
Ch 24 ab	Introduction to Biophysical Chemistry <sup>5</sup>	-	9	9
	Electives <sup>6,7</sup>	15-21	15-21	27-33
		45-51	54-60	45-51

### Fourth Year

	HSS Electives	9	9	9
Bi 80	Biology Major Seminar	3	-	-
Bi/CNS 150	Neurobiology Electives <sup>6,7</sup>	10	-	-
		23-26	36-42	36-42
		45-48	45-51	45-51

### Suggested Electives

*Second Year:* Bi 23, Ch 4 ab.

*Third Year:* Bi 22, Bi 23, Bi/Ch 111, Bi/Ch 113, Bi 114, Bi 115, Bi 123, Bi 152, Bi 156, Bi/CNS 157, Bi/CNS 158, Bi/CNS 161, Bi/CNS 162, Ch 7.

*Fourth Year (in addition to those listed for the third year):* Bi 90, Bi 125, Bi/Ch 132, BMB/Bi/Ch 170, Bi 180, Bi 188, Bi 190, Bi/CNS 217, Bi 218, Bi 219, Ch 145, Ch 146, CNS/Bi/EE 186.

<sup>1</sup> Many biology majors choose to take Bi 8 and Bi 9 in their freshman year.

<sup>2</sup> Bi 10 is not required for the biology option but is commonly taken by biology students to meet the Institute Introductory Laboratory requirement.

<sup>3</sup> Second-year electives should include an Institute core elective, if this requirement was not met during the first year.

<sup>4</sup> Recommended for students planning to take any additional courses in genetics.

<sup>5</sup> Strongly recommended for students interested in postgraduate work in biology, as most graduate programs expect entering students to have taken a course in physical chemistry.

<sup>6</sup> Electives must include courses to satisfy option requirements (2) and (3), and sufficient additional units of work in biology to satisfy the total of 143 units as specified by requirement (5). Note that Bi 1, Bi 2, and Bi 10 are not counted toward this total.

<sup>7</sup> The sequence of courses Bi/CNS 150, Bi 152, Bi 156, and Bi/CNS 157 is intended to provide a comprehensive introduction to the field of neurobiology.

### Business Economics and Management Option

The business economics and management (BEM) option provides students with the analytical tools to operate successfully in a modern, volatile, business environment. The emphasis is on strategy, design (markets, organizations, networks), finance, and law in a free-market competitive or strategic situation, as well as in a highly politicized environment. Today's business environment is complex; the required courses in this option are therefore highly analytical. The formal nature of the required courses can be complemented by case-study courses.

### Option Requirements

1. Ec 11, PS/Ec 172, BEM/Ec/SS 20, BEM 101, Law 33.
2. BEM 103, BEM 106.
3. ACM/ESE 118.
4. Six courses, to be chosen from the menu: BEM courses (excluding the ones listed under [1] and [2] above), Ec 105, Ec 121 ab, Ec 122, Ec 123, Ec 145, Ec 155, Ec/PS 160 abc, PS 12, PS/Ec 173, Psy 15, Psy 20, ACM 113, ACM 116, Ma 112 a.

- 45 additional units of science (including anthropology, economics, political science, psychology, social science), mathematics, and engineering courses; this requirement cannot be satisfied by courses listed as satisfying the introductory laboratory requirement or by any course with a number less than 10.
- Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

### Typical Course Schedule

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
	Menu Course	-	-	9
Ec 11	Introduction to Economics	9	-	-
BEM 101	Introduction to Accounting	9	-	-
Law 33	Introduction to the Law	9	-	-
BEM 106	Competitive Strategy	-	-	9
PS/Ec 172	Noncooperative Games	-	9	-
	Electives <sup>1</sup>	-	18	27
		45	45	45
<i>Third Year</i>				
BEM 103	Introduction to Finance	9	-	-
ACM/ESE 118	Methods in Applied Statistics and Data Analysis	9	-	-
	Electives <sup>1</sup>	27	45	45
		45	45	45
<i>Fourth Year</i>				
BEM/Ec/SS 20	Scientific Writing	-	6	-
	Electives <sup>1</sup>	45	39	45
		45	45	45

<sup>1</sup>See option requirements 4 and 5.

### Chemical Engineering Option

The chemical engineering option is designed to prepare its students for either graduate study or research and development work in industry. It accomplishes this by providing a broad and rigorous training in the fundamentals of chemical engineering while maintaining a balance between classroom lectures and laboratory experience. The program also strives to develop in each student self-reliance, creativity, professional ethics, an appreciation of the societal impact of chemical engineering, and the importance of continuing intellectual growth.

Chemical engineering involves applications of chemistry, physics, mathematics, and, increasingly, biology and biochemistry. In addition to basic physics, chemistry, and mathematics, the

chemical engineering curriculum includes the study of applied and computational mathematics, fluid mechanics, heat and mass transfer, thermodynamics, chemical kinetics and chemical reactor design, and process control. Because of this broad-based foundation that emphasizes basic and engineering sciences, chemical engineering is perhaps the broadest of the engineering disciplines.

Because many industries utilize some chemical or physical transformation of matter, the chemical engineer is much in demand. He or she may work in the manufacture of inorganic products (ceramics, semiconductors, and other electronic materials); in the manufacture of organic products (polymer fibers, films, coatings, pharmaceutical, hydrocarbon fuels, and petrochemicals); in other process industries; or in the biotechnology, pharmaceuticals, or biomedical industries. Chemical engineering underlies most of the energy field, including the efficient production and utilization of coal, petroleum, natural gas, and newer technologies like fuel cells. Air and water pollution control and abatement are also within the domain of expertise of chemical engineers. The chemical engineer may also enter the field of biochemical engineering, where applications range from the utilization of microorganisms and cultured cells, to enzyme engineering and other areas of emerging biotechnology, to the manufacture of foods, to the design of artificial human organs.

Freshman and sophomore students normally take the core courses in mathematics, physics, chemistry, and biology (Ma 1 abc, Ma 2 ab, Ph 1 abc, Ph 2 ab, Ch 1 ab, and Bi 1). They also take the second-year chemistry course, Ch 41 abc, and the basic chemical engineering courses, ChE 63 ab and ChE 64. It is strongly recommended that they also take a course in computer programming (e.g., CS 1 or CS 2).

Undergraduate research is emphasized, and students are encouraged, even in the freshman year, to participate in research with the faculty. In order to obtain a basic intellectual background, all students take courses in the fundamentals of chemical engineering through the junior year. During the senior year, students can diversify into one of four tracks to achieve concentrated study in areas of chemical engineering. An optional senior thesis is a unique aspect of the chemical engineering program.

Attention is called to the fact that any student whose grade-point average is less than 1.9 at the end of an academic year in the subjects listed under the Division of Chemistry and Chemical Engineering may, at the discretion of the faculty in this division, be refused permission to continue the work in this option.

### Option Requirements

- Ch 3 b, Ch 41 abc, ChE 63 ab, ChE 64, ACM 95 abc, Ch 21 ab, ChE 101, ChE 103 abc, ChE 105, and either Ec 11, BEM 101, or BEM 103<sup>1</sup>.
- Completion of a track (biomolecular, environmental, process systems, or materials).

3. Passing grades must be earned in all courses required by the Institute and the option. None of the courses satisfying option requirements may be taken pass/fail.

<sup>1</sup> These 9 units partially satisfy the Institute requirements in humanities and social sciences.

### Typical Course Schedule

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
Ch 3 b	Experimental Procedures of Synthetic Chemistry	-	-	8
Ch 41 abc	Organic Chemistry	9	9	9
ChE 63 ab	Chemical Engineering Thermodynamics	9	9	-
ChE 64	Principles of Chemical Engineering	-	-	9
	HSS Electives	9	9	18
		45	45	44
<i>Third Year</i>				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
Ch 21 ab <sup>1</sup>	Physical Description of Chemical Systems	9	9	-
ChE 103 abc	Transport Phenomena	9	9	9
ChE 101	Chemical Reaction Engineering	-	9	-
CDS 110 a	Introductory Control Theory	9	-	-
	Science Writing	-	-	3
	HSS Electives	-	9	18
		39	49	42

### Fourth Year

Fourth-year courses of study are based on particular areas (tracks) of chemical engineering:

#### Biomolecular Track

Bi/Ch 110	Intro. to Biochemistry	12	-	-
BE 201 abc	Physiology for Bioengineering	9	9	9
BE/ChE 163	Intro. to the Design of Biological Molecules and Systems	-	9	-
or				
ChE/BE 210	Cellular Engineering	9	-	-
ChE 126 a	Chemical Engineering Laboratory	9	-	-
and ChE 130	Biomol. Engineering Laboratory	-	-	9
or				
ChE 126 a	Chemical Engineering Laboratory	9	9	9
and ChE 90 ab	and Senior Thesis	-	9	9
	Bioengineering Electives	-	9	9
	HSS Electives	-	9	9
	Science/Engineering Electives	9	9	9
		48	45-54 <sup>2</sup>	36-45 <sup>2</sup>

<sup>1</sup> May be taken during fourth year.

<sup>2</sup> Typically second and third term total number of units will be at least 78.

#### Environmental Track

ChE 126 a	Chemical Engineering Laboratory	9	-	-
ESE 159	Environmental Analysis Lab	-	-	9
or Senior Thesis				
		-	9	9
ESE/Ge 148 abc	Global Environmental Science	9	9	9
	ESE Courses <sup>1</sup>	9	18	9
	HSS Electives	9	-	9
	Science/Engineering Electives	9	9	9
		45	36-45	45

<sup>1</sup> Recommended ESE courses include ESE 142, ESE 144, ChE/ESE 158, ESE/Bi 166, ESE/Bi 168, ESE/Ge/Cb 171, ESE/Ge/Cb 172, ESE/Ge/Cb 175 ab.

#### Process Systems Track

ChE 110 ab	Optimal Design of Chemical Systems	-	9	9
ChE 126 ab	Chemical Engineering Laboratory	9	9	-
or				
ChE 126 a	Chemical Engineering Laboratory	9	9	9
and ChE 90 ab	and Senior Thesis			
	HSS Electives	9	-	9
	Engineering Electives	18	9-18 <sup>1</sup>	9
	Science/Engineering Electives	9	9	9
		45	36-45 <sup>2</sup>	36-45 <sup>2</sup>

<sup>1</sup> If ChE 90 ab option, then 9 units.

<sup>2</sup> Typically second and third term total number of units will be at least 81.

#### Materials Track

ChE 126 ab	Chemical Engineering Laboratory	9	9	-
or				
ChE 126 a	Chemical Engineering Laboratory	9	9	9
and ChE 90 ab	and Senior Thesis			

#### Advanced Materials Courses<sup>1</sup>

##### 1-Polymers

Ch 120 a	Nature of the Chemical Bond	9	-	-
Ch/ChE 147	Polymer Chemistry	-	9	-
ChE/Ch 148	Polymer Physics	-	-	9

##### 2-Electronic Materials

APh 114 ab	Solid-State Physics	9	9	-
ChE 189	Special Topics in Materials Processing	-	-	9

### 3--Structural Materials

MS 131	Structure and Bonding in Materials	9	-	-
MS 132	Diffraction and Structure of Materials	-	12	-
MS 133	Kinetic Processes in Materials	-	-	9
	HSS Electives	9	-	9
	Science/Engineering Electives	9	9	9
		45	36-48 <sup>2</sup>	27-45 <sup>2</sup>

<sup>1</sup> One complete track (1, 2, or 3) and two elective courses from each of the tracks not completed (ChE 90 b can substitute for 9 units of Science/Engineering Electives).

<sup>2</sup> Typically second and third term total number of units will be at least 81.

## Chemistry Option

Study in the chemistry option leads, especially when followed by graduate work, to careers in teaching and research at colleges and universities, in research for government and industry, in the operation and control of manufacturing processes, and in management and development positions in the chemical industry.

A first-year general chemistry course is taken by all freshman students. The emphasis is on fundamental principles and their use in systematizing descriptive chemistry. Students who show themselves to be qualified and receive the instructor's consent may elect to take an Advanced Placement chemistry course (at least two terms from Ch 21 ab or Ch 41 ab). The one-term required laboratory course (Ch 3 a) presents basic principles and techniques of synthesis and analysis and develops the laboratory skills and precision that are fundamental to experimental chemistry. The laboratory in the following two terms (Ch 4 ab), normally taken concurrently with Ch 41, introduces the student to methods of synthesis, separation, and instrumental analysis used routinely in research. Qualified students, with the instructor's consent, are allowed to substitute either Ch 3 b or Ch 4 a for the core requirement of Ch 3 a. Students who take Ch 10 c need not take Ch 3 a but can take Ch 3 b instead.

Beyond the freshman year, each student in the chemistry option, in consultation with his or her adviser, selects a suitable course of study under the supervision of the division. The requirements of the option are listed below. A student wishing to deviate from these requirements should submit an alternate curriculum, with justifications, for consideration by his or her adviser and the Undergraduate Study Committee.

Undergraduates in the option must also take chemistry courses below the 100 level for a letter grade with the exception of the following courses, which are only offered on a pass/fail basis: Ch 1, Ch 3 a, Ch 90, and, if taken during the first or second terms of the freshman year, Ch 4 ab, Ch 21 ab, and Ch 41 ab. Within the total period of undergraduate study there are additional Institute requirements for Ma 1 abc, Ph 1 abc, Ma 2 ab, Ph 2 ab, and 108 units of humanities and/or social science as well as 9 units of PE.

### Double Majors

For students simultaneously pursuing a degree in a second option, courses taken as *required* courses for that option can also be counted as chemistry electives (requirement 3, below) where appropriate. However, courses that count toward the electives requirement in the other option cannot simultaneously be counted toward satisfying the elective requirement in chemistry.

The courses listed below would constitute a common core for many students in the option.

Any student of the chemistry option whose grade-point average is less than 1.9 will be admitted to the option for the following year only with the special permission of the Division of Chemistry and Chemical Engineering.

### Option Requirements

- Ch 14, Ch 21 abc (or Ch 21 a, Ch 24 ab), Ch 41 abc, Ch 90.
- A minimum of five terms of laboratory work chosen from Ch 4 ab, Ch 5 ab, Ch 6 ab, Ch 7, Ch 10 c (if taken freshman or sophomore year), Ch 15, and Bi 10.
- A minimum of five terms of advanced chemistry electives taken for a letter grade from chemistry course offerings at the 100 and 200 level, including cross-listed offerings such as Bi/Ch 110, Bi/Ch 111, Bi/Ch 113, Bi/Ch 132, and ChE/Ch 164, but excluding Ch 180, Ch 280, CNS/Bi 176.
- Passing grades must be earned in the courses that constitute the approved program of study, including those listed above. None of the courses satisfying option requirements may be taken pass/fail.
- Passing grades must be earned in a total of 486 units, including courses listed above.

### Typical Course Schedule

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ch 41 abc	Organic Chemistry	9	9	9
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
Ch 4 ab	Synthesis and Analysis of Organic and Inorganic Compounds	-	9	-
Ch 5 ab	Advanced Techniques of Synthesis and Analysis	-	9	12
Ch 14	Chemical Equilibrium and Analysis	-	-	6
	Electives	6-9	6-9	24-27
	Physical Education	3	3	3
		36-39	54-57	54-57

<i>Third Year</i>				
Ch 15	Chemical Equilibrium and Analysis Laboratory	10	-	-
Ch 21 abc	Physical Description of Chemical Systems	9	9	9
Ch 90	Oral Presentation Electives	-	3	-
		24-28	36-40	36-40
		43-47	48-52	45-49
<i>Fourth Year</i>				
Ch 6 a	Application of Physical Methods to Chemical Problems	-	10	-
	Electives	47-51	37-41	47-51
		47-51	47-51	47-51

This typical program is not specifically required for graduation in the option, nor is it in any sense a complete program. Students are expected to work out individual programs suitable for their interests and professional goals in consultation with their advisers. Several representative programs, including sets of possible electives, are shown below. These may well approximate choices by students who intend to do graduate work in conventional areas of chemistry.

### Suggested Representative Courses of Study for Those Intending Graduate Work in Particular Areas of Chemistry<sup>1,2</sup>

	<i>Second Year</i>	<i>Third Year</i>	<i>Fourth Year</i>
<i>Inorganic Chemistry</i>	Ch 4 ab, Ch 5 a, Ch 41abc, Ch 102, Ma 2 ab, Ph 2 ab, HSS elective, other elective	Ch 5 b <sup>3</sup> , Ch 14, Ch 21 abc, Ch elective(s) <sup>4</sup> , Ch laboratory <sup>5</sup> , Ch 80 <sup>6</sup> , Ch 90, HSS elective	Ch 6 a or 6 b, Ch electives <sup>4,5</sup> , Ch 80 <sup>6</sup> , HSS elective
<i>Chemical Physics</i>	Ch 4 ab, Ch 21 abc <sup>7</sup> , Ch 6 ab <sup>7</sup> , Ch 14, Ma 2 ab, Ph 2 ab, HSS elective	Ch laboratory <sup>8</sup> , Ch 41 abc <sup>7</sup> , Ch elective(s) <sup>9</sup> , Ch 80 <sup>6</sup> , Ch 90, HSS elective, ACM 95 abc	Ch 125 abc, Ch electives <sup>8,9</sup> , Ch 80 <sup>6</sup> , HSS elective
<i>Organic Chemistry</i>	Ch 4 ab <sup>3</sup> , Ch 5 a, Ch 41 abc, Ch 102, Ma 2 ab, Ph 2 ab, HSS elective, other elective	Ch 5 b or Ch 7, Ch 14, Ch 21 abc, Ch elective(s) <sup>10</sup> , Ch laboratory <sup>5</sup> , Ch 80 <sup>6</sup> , Ch 90, HSS elective	Ch 6 a or 6 b, Ch electives <sup>5,10</sup> , Ch 80 <sup>6</sup> , HSS elective

<i>Biochemistry</i>	Ch 4 ab, Ch 5 a or Bi 10, Ch 41 abc, Bi 1, Bi 9, Ma 2 ab, Ph 2 ab, HSS elective	Ch laboratory <sup>11</sup> , Ch 7, Ch 14, Ch 21 a, Ch 24 ab (or Ch 21 bc), Ch 80 <sup>6</sup> (or Bi 22), Ch 90, Bi/Ch 110, Bi/Ch 111, Bi/Ch 113, Bi 10, HSS elective	Ch 6 a or 6 b, Ch (Bi) electives <sup>11, 12</sup> , Ch 80 <sup>6</sup> (or Bi 22), HSS elective
---------------------	---	--	--

<sup>1</sup> A significant fraction of the chemical literature, especially in organic chemistry, is in German. A reading knowledge of German is therefore useful in research at the doctoral level. Russian is another important language for chemistry; however, the leading Russian periodicals are translated and published in English.

<sup>2</sup> Experience in computer programming and use is now important to all areas of chemistry.

<sup>3</sup> Requires Ch 4 ab.

<sup>4</sup> Ch 112, Ch 117, Ch 120 ab, Ch 121 ab, Ch 122 abc, Ch 135 ab, Ch/CbE 140, Ch 143, Ch 144 ab, Ch/CbE 147, Ch 154 ab, ChE/Cb 155, ESE/Cb/Ge 175 abc, Ch 212, Ch 213 abc, Ch 221.

<sup>5</sup> Ch 6 ab, Ch 7, Ch 15, Bi 10.

<sup>6</sup> See "Research Opportunities for Undergraduates in Chemistry," which may be obtained from the Chair of the Undergraduate Studies Committee. No more than 27 units of Ch 80 will count toward the 486-unit graduation requirement without a senior thesis.

<sup>7</sup> Students without sufficient math preparation may delay Ch 21 abc and Ch 6 ab until their junior year and take Ch 5 ab and Ch 41 abc during their sophomore year.

<sup>8</sup> Ch 5 ab, Ch 15, Bi 10.

<sup>9</sup> Ch 120 ab, Ch 121 ab, Ch 126, Ge/Cb 128, Ch 130, Ch 135 ab, Ch/CbE 140, Ch 144 ab, Ch/CbE 147, ChE/Cb 148, ChE/Cb 164, Ch 165, Ch 221, Ch 227 ab, Ph 106 abc.

<sup>10</sup> Ch 112, Ch 120 ab, Ch 121 ab, Ch 122 abc, Ch 135 ab, Ch 143, Ch 144 ab, Ch 145, Ch 146, Ch/CbE 147, Ch 154 ab, ChE/Cb 155, ESE/Cb/Ge 175 abc, Ch 242 ab, Ch 247.

<sup>11</sup> Ch 5 b, Ch 15, Ch 6 ab, Ch 7.

<sup>12</sup> Ch 122 ab, Bi/Ch 132, Ch 143, Ch 144 ab, Ch 145, Ch 146, Ch 154 ab, BMB/Bi/Ch 170, BMB 176, Ch/Bi 231, Ch 242 ab, Ch 244, Ch 247.

### Suggested Elective Courses for the Chemistry Option

- Chemical Engineering*: ChE 10, ChE 63, ChE 80, ChE 101, ChE 103, ChE 151, ChE 174.
- Biology*: Bi 9, Bi 122, Bi 114, Bi 156, Bi 180.
- Engineering*: ACM 95, APh/EE 9, CS 1, CS 2.
- Physics*: Ph 3, Ph 4, Ph 5, Ph 6, Ph 7, Ph 106, Ph 125, Ph 129, Ph 127.
- Humanities*: Ec 11, L 102 or L 130.
- Miscellaneous*: Ay 1, Ch/APh 2, Ch 10, ESE 1, MS 115, Ge 1, Ge 140, Ma 108.

### Computer Science Option

The undergraduate option in computer science is designed to introduce students to the mathematical and engineering foundations of this discipline. The program provides considerable flexibility in course selection, together with a capstone project giving an opportunity for independent work in an area of the student's choice. Individual programs will be worked out in consultation

with faculty advisers (the materials at [www.cs.caltech.edu/academics/undergrad\\_study.html](http://www.cs.caltech.edu/academics/undergrad_study.html) may be helpful for this purpose).

Any student of the computer science option whose grade-point average is less than 1.9 at the end of the academic year in the subjects listed in the option requirements may be refused permission to continue work in the option.

### Option Requirements

1. CS 1; CS 2; Ma/CS 6 a or Ma 121 a; CS 21 or CS/EE/Ma 129 a; CS 24; CS 38; E 10, E 11.
2. One of the following:
  - a. Any of the following three-quarter sequences involving a large project in their last quarter: CS 141 abc; CS/EE 181 abc; CS/EE/Ma 129 abc; CS 134 abc; CS 136 abc; CS 139 abc; CS/CNS 174 and two other CS 170-series courses; CS/EE 145 ab and one quarter of a networking project.
  - b. A laboratory project in computer science extending at least two quarters and totaling at least 18 units (normally in CS 81 or CS 90), approved for this requirement by the student's adviser and the CS undergraduate option representative.
  - c. Thesis (EE/CS 80 abc) supervised by a CS faculty member.
3. A total of 63 CS units that are not applied to requirement (1), and that are either numbered CS 114 and above or are in satisfaction of requirement (2).
4. In addition to the above requirements, 36 units in Ma, ACM, or CS; 18 units in E&AS or Ma; and 18 units not labeled PE or PA.
5. Units used to fulfill the Institute Core requirements do not count toward any of the option requirements. Pass/fail grading cannot be elected for courses taken to satisfy option requirements. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

### Typical Course Schedule

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
CS 1	Intro. to Computation <sup>1</sup>	9	-	-
CS 2	Intro. to Programming Methods <sup>1</sup>	-	9	-
Ma/CS 6 a	Intro. to Discrete Math	9	-	-
CS 21	Decidability and Tractability	-	9	-
CS 24	Intro. to Computing Systems	-	-	9
CS 38	Introduction to Algorithms	-	-	9
	HSS Electives	9	9	9
	Other Electives	-	-	9
		45	45	36

### Third Year

	CS Courses	9	9	9
	CS Project	9	9	9
	HSS Electives	9	9	9
E 10	Technical Seminar Presentations	-	-	3
	E&AS/Ma Courses	9	9	9
	Other Electives	9	9	-
		45	45	39

### Fourth Year

	CS Courses	9	-	-
	HSS Electives	9	9	9
	E&AS/Ma Courses	9	9	9
	Other Electives	18	18	18
		45	36	36

<sup>1</sup> Commonly taken during the freshman year.

## Control and Dynamical Systems Minor

Control and dynamical systems (CDS) may be pursued as a minor by undergraduates who are taking degrees in science, mathematics, or engineering. The CDS minor is intended to supplement one of Caltech's undergraduate degrees and is designed for students who wish to broaden their knowledge beyond their normal major or who may wish to pursue a graduate program involving control or dynamical systems. Students completing the CDS minor requirements will have the phrase "minor in control and dynamical systems" added to their transcripts.

### CDS Minor Requirements

1. Complete either CDS 110 ab and CDS 140 a, or CDS 101 and CDS 140 ab.
2. Complete either a three-term senior thesis approved by the CDS faculty, or Ae/CDS 125 abc.

All CDS courses to be applied to fulfill the CDS minor requirements must be taken for grades, and students must obtain a grade of B or higher. Students may substitute CDS 110 a for CDS 101 in the above requirements if desired. The senior thesis requirement may be satisfied either by completing a three-term senior thesis in the student's major option but on CDS subject matter, with approval of the thesis topic by the CDS option representative, or by taking CDS 90 abc.

Courses that are used to satisfy the CDS minor cannot be used to satisfy course requirements in the major options, with the exception that CDS 110 a may be used in E&AS options where this course is part of their requirements (e.g., ChE, EE, ME) and the senior thesis requirement may be used to satisfy requirements for major options that require a senior thesis. Courses taken as part of the CDS minor are counted toward the total 486-unit Institute graduation requirements.

A typical course sequence would be to take either CDS 110 ab or CDS 140 ab in the junior year, followed by the remaining course and the senior thesis in the senior year. Alternatively, it is possible to take all requirements in the senior year. In addition to the requirements above, CS 1 and CS 2 are highly recommended.

### Economics Option

The economics option provides students with an understanding of the basic principles underlying the functioning of economic institutions. It offers a modern and quantitative approach to economics seldom available to undergraduates. The emphasis on economic principles and modern methodology provides students with an excellent preparation for graduate study in economics or for professional study in the fields of business or law and economics.

The option is sufficiently flexible that students can combine their pursuit of economics with studies in other areas, such as engineering, physics, or mathematics. The core of the option consists of Ec 11, Ec 121, Ec 122, and Ec 123. Students are strongly encouraged to supplement this core with additional electives in economics, political science, and mathematics.

#### Option Requirements

1. Ec 11, Ec 121 ab, Ec 122, Ec 123, BEM/Ec/SS 20.
2. Ma 112 a.
3. Ec 105 or Ec 145.
4. 54 additional units of advanced economics and social science courses. (Courses that are used to fulfill the Institute advanced social science requirement [courses numbered 100 and above] will also count toward the 54 additional units required under the economics and social science options.) Students may also take classes from the following list in partial fulfillment of this requirement: any BEM course except BEM 101; ACM 113, ACM 116, or ACM/ESE 118 .
5. 45 additional units of science, mathematics, and engineering courses. The requirement cannot be satisfied by courses listed as satisfying the introductory laboratory requirement or by any course with a number less than 10.
6. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

#### Typical Course Schedule

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
	Menu Course	-	-	9
Ec 11	Introduction to Economics	9	-	-
PS 12	Introduction to Political Science	-	-	9
	Electives <sup>1</sup>	18	27	27
		45	45	45

#### Third Year

Ec 105	Industrial Organization	9	-	-
Ec 121 ab	Theory of Value	9	9	-
Ec 122	Econometrics	-	9	-
Ec 123	Macroeconomics	-	-	9
Ma 112 a	Statistics	9	-	-
	Electives <sup>1</sup>	27	27	27
		54	45	36

#### Fourth Year

BEM/Ec/SS 20	Scientific Writing	-	6	-
	Electives <sup>1</sup>	45	39	45
		45	45	45

<sup>1</sup> See option requirements 4 and 5.

### Electrical and Computer Engineering Option

Students interested in electrical and computer engineering are directed toward the computer science or electrical engineering options. Students who enrolled under earlier catalogs offering a degree in electrical and computer engineering can continue to pursue that degree; due to changes in course offerings, the following substitutions will be allowed.

- CS 21 for CS 20 a
- CS 38 for CS 20 b
- ACM 106 a for CS 20 c
- CS 150 or CS 151 for CS 138 b

### Electrical Engineering Option

The electrical engineering option is designed to prepare its students for either graduate study or research and development work in government or industrial laboratories. It accomplishes this by building on the core curriculum to provide a broad and rigorous exposure to the fundamentals of electrical engineering. It strives to maintain a balance between classroom lectures and laboratory and design experience, and emphasizes the problem formulation and solving skills that are essential to any engineering discipline. The program also strives to develop in each student self-reliance, creativity, professional ethics, and an appreciation of the importance of continuing intellectual growth.

Students electing this option will normally choose to take Aph/EE 9 as a freshman-year elective. Freshmen interested in digital electronics might also consider taking EE/CS 51. Then in the sophomore year, the formal study of electrical engineering will begin with the theory and laboratory practice of analog and digital electronics, EE 20 ab and EE/CS 51/52, respectively; and an introduction to solid-state sensors and actuators, EE 40. The junior year features EE 111; a course on feedback control systems (either CDS 110 a or EE 113); an introduction to analog and digital communications, EE 160; and an analog electronics laboratory, EE 90.

In the senior year, the student will take electromagnetic engineering, EE 151; and will also be asked to demonstrate his or her ability to formulate and carry out an independent research or design project through either a senior thesis, EE/CS 80 abc, or the senior project design laboratory, EE 91 ab. In addition, the student, especially in the senior year, will have a significant opportunity to take elective courses that will allow him/her to explore earlier topics in depth, or to investigate topics that have not been covered previously. (See the “suggested electives” section, page 199.)

A student whose interests lie in the electrical sciences but who wishes to pursue a broader course of studies than that allowed by the requirements of the electrical engineering option may elect the engineering and applied science option.

Attention is called to the fact that any student who has a grade-point average less than 1.9 at the end of the academic year in the subjects listed under electrical engineering may be refused permission to continue work in this option.

### Option Requirements

1. E 10 and E 11.
2. ACM 95 abc.
3. EE 20 ab, EE 40, EE 111, EE 151, EE 160, and either EE 113 or CDS 110 a.
4. EE/CS 51, EE/CS 52, EE 90.
5. EE 80 abc, or two courses selected from EE 91 ab, EE/CS 53, and CS/EE/ME 75 c (note that only CS/EE/ME 75 c may replace one term of EE 91 and EE/CS 53).
6. APh/EE 9 ab.
7. In addition to the above courses, 27 units selected from any EE course numbered over 100, or any cross-listed courses numbered over 100 that include EE in the listing. Also, CDS 111 is acceptable.
8. Passing grades must be earned in a total of 486 units, including courses listed above.

### Typical Course Schedule<sup>1</sup>

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS Electives <sup>2</sup>	9	9	9
EE 20 ab	Electronics Laboratory	9	9	-
EE 40	Intro. to Solid-State Sensors and Actuator-	-	-	9
EE/CS 51	Principles of Microprocessor Systems	-	9	-
EE/CS 52	Microprocessor Systems Laboratory	-	-	12
	Electives	-	-	15
		36	45	45

### Third Year

ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	HSS Electives <sup>2</sup>	9	9	9
EE 111	Signals, Systems, and Transforms	9	-	-
EE 90	Analog Electronics Project Lab	-	-	9
EE 160	Communication-System Fundamentals	-	9	-
EE 113	Feedback and Control Circuits	9	-	-
or				
CDS 110 a	Introductory Control Theory			
	Electives	-	9	9
		39	39	39

### Fourth Year

	HSS Electives <sup>2</sup>	9	9	9
E 10	Technical Seminar Presentations	-	3	-
EE 91 ab <sup>3</sup>	Experimental Projects in Electronic			
	Circuits	12	12	-
EE 151	Electromagnetic Engineering	12	-	-
	Electives	9	18	36
		42	42	45

<sup>1</sup> A student who follows this “typical schedule” exactly, and who takes APh/EE 9 ab as a freshman, will have taken about 540 units prior to graduation, whereas only 486 are required. This means that by taking fewer electives than given in the typical schedule, the student can take lighter loads and have considerable flexibility in arranging his or her individual schedule.

<sup>2</sup> See Institute requirements for specific rules regarding humanities and social sciences.

<sup>3</sup> See option requirement 5.

### Suggested Electives

First-year students interested in electrical engineering should consider taking APh/EE 9 ab, which is an EE option requirement (though it need not be taken freshman year).

Suggested elective courses for the second, third, and fourth year for various specializations within electrical engineering are given below. Students interested in other areas of specialization or interdisciplinary areas are encouraged to develop their own elective program in consultation with their faculty adviser.

#### Communications and Signal Processing

*Second Year:* Selected from APh 17 abc, APh 23, APh 24, EE/CS 53

*Third and Fourth Year:* EE 112 ab, ACM/EE 116, EE/Ma 126, EE/Ma 127 ab, EE 161, EE 163 ab, EE 164, EE 167, APh/EE 130, 131, 132, and selections from APh/EE 132, EE/CS 54, Ma 112 a.

#### Control

*Second Year:* APh 17 abc

*Third and Fourth Year:* CDS 110 ab, CDS 111, and selections from EE 112 ab, ACM/EE 116, EE 164.

### *Electronic Circuits*

*Second Year:* APh 17 abc

*Third and Fourth Year:* CDS 111, EE 112 ab, EE 114 ab, and selections from EE 119 abc, EE 153, CS/EE 181 abc, CS 185 abc, APh/EE 183 ab.

### *Microwave and Radio Engineering*

*Second Year:* APh 23, APh 24, APh 17 abc

*Third and Fourth Year:* EE 153, EE/Ge 157 abc, EE/Ge 158 ab, EE 114 ab, APh/EE 130, 131, 132, APh/EE 183 ab.

### *Optoelectronics*

*Second Year:* APh 23, APh 24, APh 17 abc

*Third and Fourth Year:* APh/EE 130, 131, 132, APh 105 abc, APh 114 abc, APh/EE 183 ab, APh 190 abc, EE 153.

### *Solid-State Electronics*

*Second Year:* APh 17 abc

*Third and Fourth Year:* APh/EE 183 ab, and selections from APh 105 abc, APh 114 ab, EE 153.

## **Engineering and Applied Science Option**

The engineering and applied science (E&AS) option offers students the opportunity for study in a wide variety of challenging areas of science and technology and includes concentrations in aeronautics, computation and neural systems, environmental science and engineering, materials science, and structural mechanics. In addition, the E&AS option offers students the possibility of designing a customized course of study that has breadth, depth, and rigor similar to the concentrations listed above.

The aim of the E&AS option is to prepare students for research and professional practice in an era of rapidly advancing interdisciplinary technology. The program builds on the core curriculum to combine individual depth of experience and competence in a particular chosen engineering specialty, and a strong background in the basic and engineering sciences, with laboratory and design experience. It strives to develop professional independence, creativity, leadership, and the capacity for continuing professional and intellectual growth.

The first year of the four-year course of study leading to a Bachelor of Science degree is common for all students of the Institute, although freshman elective subjects are available as an introduction to various aspects of engineering and applied science. At the end of the first year, students who elect the E&AS option are assigned advisers as close to their expressed field of interest as possible, and together with their advisers develop programs of study for the next three years. Beyond the Institute-wide requirements of physics, mathematics, and humanities, the E&AS option

requires one year of applied and computational mathematics and a prescribed number of units selected from a wide variety of engineering and applied science courses. Engineering design (synthesis), as distinct from analysis, is considered an essential part of every engineer's capability. Advisers will expect students to select a sufficient number of courses that place emphasis on design.

Any student in the E&AS option whose grade-point average is less than 1.9 at the end of the academic year in the subjects listed in the option requirements may be refused permission to continue to work in the E&AS option.

### **Option Requirements**

Students who have elected the E&AS option must either choose one of the approved areas of concentration (see item 6 a below), or by the end of the third term of the sophomore year submit a written proposed customized course of study and obtain approval for it from the E&AS option oversight committee (see item 6 b below).

The course of study must include each of the following elements:

1. Demonstration of computer programming competency by taking CS 1, or by taking an approved alternative course, or by passing a placement exam administered by the computer science option by first term of sophomore year.
2. a. 27 units of advanced E&AS courses with the prefixes Ae, ACM, AM, APh, BE, CE, CNS, CS, CDS, EE, ESE, MS, or ME;  
and  
b. 27 additional units of either advanced E&AS courses or advanced science courses offered by the Biology, CCE, GPS, or PMA divisions.
3. a. 9 units of laboratory courses taken from the following list: APh 77 bc, Ae/APh 104 bc, CE 95, CE 180, CS 40 ab, CS 47, CS 134 b, CS/CNS 171, 173, and 174, CS/EE 137 b, EE 20 ab, EE/CS 52, 53, 54, EE 90, EE 91 ab, ESE 159, MS 90, MS 125, ME 72, ME 90 bc, ME/CE 96;  
and  
b. 9 units of additional laboratory courses either from the list in 3 a or from E&AS courses with the word "laboratory" in the title, but excluding those courses for which freshman laboratory credit is allowed.
4. ACM 95 abc or Ma 108 abc or Ma 109 abc. None of these course sequences may be taken pass/fail.
5. E 10 or equivalent; E 11 or equivalent.
6. Courses used to satisfy requirements 1–5 above must also satisfy a depth requirement, which must be met by either:
  - a. the concentration requirements listed below for one of the following disciplines: aeronautics<sup>†</sup>, computation and neural systems<sup>\*</sup>, environmental science and engineering<sup>†</sup>, materials science<sup>†</sup>, structural mechanics<sup>†</sup>

or

- b. a customized schedule of requirements that is similarly rigorous to 6 a, has both breadth and depth, and that includes a senior thesis or design project, such as, but not restricted to EE/CS 80 abc, ME 90 abc, or two terms chosen from EE 91 ab and EE/CS 53. To select this alternative, the student must submit a written proposal to, and obtain the approval of, the E&AS option oversight committee. This approval must be obtained by the end of the third term of the sophomore year.

(Note: Students who meet the depth requirement by satisfying one of the five concentration requirements listed in 6 a will have both the E&AS option and the name of the concentration listed on their transcript while students who satisfy the depth requirement using 6 b will have only the E&AS option listed on their transcript.)

7. At least 117 units of E&AS courses not including those used to satisfy requirements 3, 4, and 5 above. Concentrations marked with a dagger (†) in both 6 a and the list below include sufficient E&AS courses to automatically satisfy this requirement; concentrations marked with an asterisk and also the customized schedule given in 6 b do not do so, in which case students will have to select sufficient additional E&AS courses to bring the total to 117 units. Courses in ChE count toward this requirement.
8. Passing grades must be earned in at least 486 units, including those listed in requirements 1–7 above.

**Discipline Concentration Requirements** (to satisfy requirement 6 a above)

*Aeronautics*<sup>†</sup>

ME 35 abc, ME 18 ab or APh 17 abc, ME 71, ME 19 ab, EE20 a, ME 65, CDS 110 a, and Ae 103 abc or an alternative three-term 100-level aeronautics course with approval by the concentration representative.

*Computation and Neural Systems*<sup>\*</sup>

CNS 100, Bi/CNS 150, CNS/Bi/Ph/CS 187, CNS/Bi/EE 186, CNS/CS/EE 188 a, EE 111, CDS 101, and Bi 8. CS 2 is required in addition to CS 1 for the CNS concentration. In addition, the laboratory course Bi/CNS 162 is required.

*Environmental Science and Engineering*<sup>†</sup>

Thermodynamics (ChE 63 ab or ME 18 ab), transport processes (ChE 103 abc or ME 19 ab), environmental laboratory (ESE 159); a total of 4 courses covering all three of the areas of environmental chemistry (ESE 142, ESE/Ge/Ch 171, 172, or ESE/Ch/Ge 175),

environmental physics (ESE/Ge 148 a, ESE/Ge 148 b, or ChE/ESE 158), and environmental biology (ESE/Ge 148 c, ESE/Bi 166, or ESE/Bi 168); ESE 90 (senior thesis) 18 units. Substitution of courses may be approved at the discretion of the concentration representative, provided they meet the overall E&AS requirements.

*Materials Science*<sup>†</sup>

Aph 17 ab or ChE 63 ab or ME 18 ab, MS 115 ab, MS 90, and three terms of MS 78. In addition, the student shall complete 45 units from the following list of restricted electives: ME 35 abc, APh 105 abc, APh 114 abc, APh/EE 130 ab, APh/EE 183, Ch 120 abc, Ch 121 ab, Ch 125 abc, Ch/ChE 147, ChE/Ch 148, CS 11, Ge 114 ab, MS 105, MS 125, MS 130–133, MS 142, Ph 125 abc. Substitution of courses may be approved at the discretion of the concentration representative, provided they meet the overall E&AS requirements.

*Structural Mechanics*<sup>†</sup>

ME 35 abc, ME 71, ME 19 ab, ME 65 or ME 66, CE 90 abc, MS 115 a, ME/CE 96 or CE 180, Ae/AM/CE/ME 102 abc or CE 160 abc or AM 151 abc. ME/CE 96 or CE 180 satisfies 9 units of the 18-unit E&AS laboratory requirement; both courses may be taken to satisfy the full requirement. Credit for ME 65 is not allowed if Ae/AM/CE/ME 102 is taken. Credit for ME 66 is not allowed if AM 151 is taken.

**Typical Course Schedules**

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
	HSS Electives	9	9	9
	Electives	18	18	36
		45	45	45
<i>Third Year</i>				
ACM 95 abc or Ma 108 abc or Ma 109 abc		12	12	12
	HSS Electives	9	9	9
	Electives	24	24	24
		45	45	45
<i>Fourth Year</i>				
E 10	Technical Seminar Presentations	-	3	-
	HSS Electives	9	9	9
	Electives	33	33	33
		42	45	42

## Typical Course Schedules by Concentration

Variation of the course schedule from these examples should be made in consultation with the student's academic adviser and must satisfy the discipline concentration requirements listed above.

### Aeronautics

	<i>First Term</i>	<i>Second Term</i>	<i>Third Term</i>
First Year <sup>1</sup>	Elective	Elective	Elective
Second Year <sup>2</sup>	ME 35 a ME 18 a	ME 35 b ME 18 b	ME 35 c ME 71
Third Year <sup>3</sup>	ME 19 a EE 20 a ACM 95 a	ME 19 b ACM 95 b	ACM 95 c
Fourth Year <sup>4</sup>	Ae 103 a CDS 110 a ME 65	Ae 103 b	Ae 103 c E 10

<sup>1</sup> Recommend CS 1 or CS 11.

<sup>2</sup> Suggested electives include APb 23, APb 24.

<sup>3</sup> Suggested electives include CS 3, MS 90, MS 115 ab.

<sup>4</sup> Suggested electives include Ae/APb/CE/ME 101 abc, Ae/AM/CE/ME 102 abc, Ae/APb 104 abc, ACM 101 abc, EE 111, Ae 121 abc, ME 20, ME/CE 96, ME 115, ME 171.

### Computation and Neural Systems

	<i>First Term</i>	<i>Second Term</i>	<i>Third Term</i>
First Year	CS 1	CS 2	Elective
Second Year	CNS 100 EE 111	Bi 8	Elective
Third Year	Bi/CNS 150 CDS 101 ACM 95 a	CNS 186 <sup>1</sup> ACM 95 b	Bi/CNS 162 <sup>1</sup> ACM 95 c
Fourth Year	CNS 187 E 10	CNS 188 a	Elective

<sup>1</sup> Offered biannually.

### Environmental Science and Engineering

	<i>First Term</i>	<i>Second Term</i>	<i>Third Term</i>
First Year	CS 1	Ch 3	ESE 1
Second Year	ChE 63 a or ME 18 a Engineering Elective	ChE 63 b or ME 18 b Engineering Elective	Engineering Elective

Third Year	ACM 95 a ChE 103 a or ME 19 a ESE Core	ACM 95 b ChE 103 b or ME 19 b ESE Core	ACM 95 c ChE 103 c ESE Core ESE Lab
------------	---	---	--

Fourth Year	ESE Core	ESE 90 E 10	ESE 90 ESE Lab
-------------	----------	----------------	-------------------

### Materials Science

	<i>First Term</i>	<i>Second Term</i>	<i>Third Term</i>
Second Year	APH 17 a MS 115 a	APH 17 b MS 115 b	Restricted Elective or MS 90
Third Year	ACM 95 a Restricted Elective	ACM 95 b Restricted Elective	ACM 95 c Restricted Elective or MS 90
Fourth Year	MS 78 a MS 131	MS 78 b MS 132 E 10	MS 78 c MS 133

### Structural Mechanics

	<i>First Term</i>	<i>Second Term</i>	<i>Third Term</i>
Second Year	ME 35 a	ME 35 b	ME 35 c ME 71
Third Year <sup>1</sup>	ACM 95 a CE 90 a ME 19 a MS 115 a	ACM 95 b CE 90 b ME 19 b	ACM 95 c CE 90 c ME 66 ME/CE 96
Fourth Year <sup>2</sup>	Ae/AM 102 a E 10	Ae/AM 102 b	Ae/AM 102 c

<sup>1</sup> CE 180 may be taken in place of ME/CE 96.

<sup>2</sup> AM 151 or CE 160 may be taken in place of Ae/AM 102.

### English Option

Students majoring in English can take a broad range of courses in English and American literature. During the senior year, English majors will enroll in En 99 ab with a faculty member chosen by mutual agreement. En 99 a is devoted to research and En 99 b to writing a substantial research paper. All courses to be counted toward the option in English must be taken for grades except for Hum/En 5 or Hum/En 6 when taken in the first two quarters of the freshman year.

All students are assigned an adviser who will help them select the courses best suited to their needs, including courses in fields

such as history that may be relevant for work in the English option. Students will be expected to consult their adviser before registering for each quarter's work. It is recommended that English majors take at least one English or related course per term. Those who are preparing for graduate work in English should take more than the minimum requirements listed below, and should be prepared to take courses in several periods of English and American literature.

### Option Requirements

1. En 99 ab and one term of En 114.
2. 81 additional units of English courses numbered 98 and above. Majors may substitute 18 units of courses in foreign literature (in the original or in translation) and, with authorization, certain humanities courses numbered above 99, for 18 units of English courses. Students may also take either Hum/En 5 or Hum/En 6 for 9 units of these additional 81 units.
3. 54 additional units of science, mathematics, and engineering courses. This requirement cannot be satisfied by courses listed as satisfying the introductory laboratory requirement or by a course with a number less than 10.
4. Three units of oral communication. En 84 satisfies this requirement as do oral communication courses offered by other options.
5. Passing grades must be earned in a total of 486 units, including the courses listed above.

### Geology, Geobiology, Geochemistry, Geophysics, and Planetary Science Options

The aim of this undergraduate program is to provide thorough training in the geological and planetary sciences and, wherever possible, to integrate these studies with, and build upon, the courses in mathematics, physics, chemistry, and biology taken during the student's earlier years at the Institute. Active involvement in research, particularly during the summer, is encouraged. For geologists, field work is emphasized because it provides firsthand experience with geological phenomena that can never be satisfactorily grasped or understood solely from classroom or laboratory treatment. Options are offered in geology, geobiology, geochemistry, geophysics, and planetary science. Electives permit students to follow lines of special interest in related scientific and engineering fields. Those who do well in the basic sciences and at the same time have a compelling curiosity about the earth and the other planets are likely to find their niche in these options, especially if they enjoy grappling with complex problems involving many variables. Most students majoring in the earth and planetary sciences now pursue further training at the graduate level.

Under the geobiology option a student can be associated with either Biology or GPS. This association formally will only affect

which course the students elect to satisfy the institute-wide oral presentation requirement; all other geobiology option requirements are independent of GPS or Biology affiliation. In practice, however, we expect that students' affiliation with one division or another will significantly shape their choice of elective courses.

For students beginning their junior year, it is possible to complete the requirements for all but the geobiology option within two years, but there are benefits from starting with Ge 11 abc in the sophomore year.

Passing grades must be earned in a total of 486 units, including courses listed below. Any student whose grade-point average in science and mathematics courses is less than 1.9 at the end of an academic year may be refused permission to register in the geological and planetary science options.

### Division and Option Requirements

#### Typical Course Schedule

#### Division Requirements (All Options)

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ge 11 ab,	Introduction to Earth and Planetary	9	9	9
Ge/Ay 11 c	Sciences			
Ge 13	Scientific Writing Tutorial	-	-	3
Ge 109 <sup>1</sup>	Oral Presentation	-	-	3
		9	9	15

#### *Third Year*

ACM 95 abc <sup>2</sup>	Intro. Methods of Applied Math.	12	12	12
-------------------------	---------------------------------	----	----	----

<sup>1</sup> For geobiology students associated with the Biology division, Bi 80 will satisfy this requirement.

<sup>2</sup> Geobiology students may substitute Cb 41 abc plus Bi/Cb 110 for ACM 95 abc.

#### Geology Option Requirements

		Units per term		
		1st	2nd	3rd
<i>Third Year</i>				
Ge 112	Geomorphology and Stratigraphy	12	-	-
Ge 114 ab	Mineralogy	12	-	-
Ge 106 <sup>3</sup>	Introduction to Field and Structural Geology	-	-	12
Ge 115 a	Igneous Petrology	-	12	-
Ge 111 a	Applied Geophysics Seminar	-	6	-
Ge 115 b	Metamorphic Petrology	-	-	12
		24	18	24

Summer (Recommended in Third Year)

spring break

Ge 111 b	Applied Geophysics Field Course	-	9	-
----------	---------------------------------	---	---	---

summer

Ge 120	Summer Field Geology	-	-	12
		-	9	12

Fourth Year

Ge 121 ab <sup>4</sup>	Advanced Field and Structural Geology	-	12	12
------------------------	---------------------------------------	---	----	----

<sup>3</sup> Students wishing to take Ge 120 in the summer before their third year should take Ge 106 in their second year.

<sup>4</sup> Ge 122 can substitute for one term of Ge 121 ab.

**Geobiology Option Requirements**

Units per term  
1st 2nd 3rd

Second Year

Ge 11 ab,	Introduction to Earth and Planetary	9	9	9
Ge/Ay 11 c	Sciences			
Bi 8	Introduction to Molecular Biology	-	9	-
Bi 9	Cell Biology	-	-	9
Bi 10	Cell Biology Laboratory	-	-	6
Ch 41 abc <sup>5</sup>	Organic Chemistry	9	9	9
		18	27	33

Third Year

ESE/Bi 166	Microbial Physiology	9	-	-
Ge 114 a	Mineralogy	9	-	-
Bi/Ch 110 <sup>5</sup>	Introduction to Biochemistry	12	-	-
ESE/Bi 168	Microbial Metabolic Diversity	-	9	-
	Geobiology Electives <sup>6</sup>	-	9	9
		30	18	9

Fourth Year

Bi 117	Developmental Biology	-	9	-
Bi 122	Genetics	9	-	-
Ge 112	Geomorphology and Stratigraphy	12	-	-
	Geobiology Electives <sup>6</sup>	-	9	9
		21	18	9

<sup>5</sup> Students affiliated with the GPS division will substitute Ch 41 abc and Bi/Ch 110 for the GPS ACM 95 abc requirement.

<sup>6</sup> Geobiology electives: 36 units of geobiology electives in geology, biology, chemistry, and/or environmental engineering to be chosen in consultation with adviser from Ge 11 d, Ge 40, Ge 41 abc, Ge 100 abc, Ge 106, Ge 114 b, Ge 115 ab, Ge 120, Ge 121 ab, Ge 124 ab, Ge 140, Ge 142, Ge/ESE 149, Ge 203, Ge/Bi 244, Ge/Bi 246, Ge 282 abc, BMB/Bi/Ch 170, Bi 22, Bi 80, Bi 90 abc, Bi/Ch 111, Bi/Ch 113, Bi 115, Bi 123, Bi/CNS 150, Bi 152, Bi/CNS 158, Bi 180, Bi 182, Bi 188, Bi 190, Bi 204, Bi 212, Bi/CNS 216, ESE 142, ESE/Ge 148 ab, ESE/Ge 152, ESE/Ge/Ch 171, ESE/Ge/Ch 172, ESE/Ge/Ch 175 ab, Ch 4 ab, Ch 5 ab, Ch 7, Ch 14, Ch 15, Ch 21 abc, Ch 24 ab, Ch 112, Ch 145, Ch 146, Ch 154 ab, Ch 212; Occidental College Ge 365. Of these, at least 9 units must come from the following laboratory courses: Bi 123, Bi 180, Ch 4 ab, Ch 5 ab, Ch 7, Ch 15, Ge 121 ab.

**Geochemistry Option Requirements**

Units per term  
1st 2nd 3rd

Second Year

Ch 4 a	Synthesis and Analysis of Organic and Inorganic Compounds	-	-	9
Ch 41 abc	Organic Chemistry	9	9	9
		9	9	18

Third Year

Ch 14	Chemical Equilibrium and Analysis	6	-	-
Ch 21 abc	Physical Description of Chemical System	9	9	9
Ch 4 b	Synthesis and Analysis of Organic and Inorganic Compounds	-	9	-
	Geochemistry Courses <sup>7</sup>	9	9	9
		24	27	18

Fourth Year

Ch 6 ab	Application of Physical Methods to Chemical Problems	-	10	10
Ch 15	Chemical Equilibrium and Analysis Laboratory	10	-	-
	Geochemistry Courses <sup>7</sup>	9	9	9
		19	19	19

<sup>7</sup> Geochemistry courses: The required 54 units of geochemistry courses should be selected in consultation with adviser from Ge 41, Ge 114 ab, Ge 115 ab, Ge/Cb 127, Ge/Cb 128, Ge 140, Ge/ESE 149, ESE 142, ESE/Ge 148 c, ESE/Ge/Cb 171, ESE/Ch/Ge 175 ab.

**Geophysics Option Requirements**

Units per term  
1st 2nd 3rd

Third Year

	Physics or Mechanics Electives <sup>8</sup>	9	9	9
Ge 111 a	Applied Geophysics Seminar	-	-	6
Ge 11 d	Geophysics	-	9	-
		9	18	15

Summer (Recommended in Third Year)

Ge 111 b	Applied Geophysics Field Course	-	-	9
----------	---------------------------------	---	---	---

Fourth Year

	Geophysics Electives <sup>9</sup>	18	9	9
--	-----------------------------------	----	---	---

<sup>8</sup> Any non-GPS course numbered 100 or greater, relevant to the option and approved by the option representative, including ME 65, ME 66, AM 125 abc, Ae/GE/ME 160, Ph 106 abc.

<sup>9</sup> Geophysics electives (selected in consultation with adviser): Ge 161, Ge 162, Ge 163, Ge 165, Ge 166, Ge 168, Ge 211, 200-level courses.

## Planetary Science Option Requirements

	Units per term		
	1st	2nd	3rd
<i>Third Year</i>			
Advanced Science <sup>10</sup>	9	9	9
Planetary Science <sup>11</sup>	18	9	9
	27	18	18
<i>Fourth Year</i>			
Planetary Science <sup>11</sup>	9	9	9
Additional Science and Engineering <sup>12</sup>	9	9	9
	18	18	18

<sup>10</sup> Advanced science courses (27 units) can be taken third or fourth year, selected from Ae/APh/CE/ME 101 abc, Ae/Ge/ME 160 ab, Ch 21 abc, Ph 101, Ph 106 abc, Ph 125 abc. Must include two consecutive terms of one of the multiterm courses.

<sup>11</sup> Planetary science courses (63 units) selected from Ge 102, Ge/Cb 128, Ge 131, Ge/Ay 132, Ge/Ay 133, ESE/Ge 148 abc, Ge 150, Ge 151, ESE/Ge 152, ESE/Ge 153, ESE/Ge 173, Ge 225 abc.

<sup>12</sup> Additional science and engineering courses (27 units selected in consultation with adviser and planetary science option representative). Choose additional courses from footnote 9, appropriate Ge courses, or any of the following: ACM 101 abc, ACM/ESE 118, ME 35 abc, APh 17 abc, Ay 20, Ay 21, Ay 101, Ay 102, ChE 63 ab, Ch 6 ab, CS 1, CS 2, CS 3, Ma 112 ab, ME 18 ab, ME 19 ab.

## History Option

History majors must take not less than 99 units of history courses (including Freshman Humanities) during their four years as undergraduates. Of these, not less than 45 *must* be in junior and senior tutorial (H 97 ab and H 99 abc), and another 18 *may* be in H 98 ab if students wish and their instructors agree.

The courses and tutorials in the history option concentrate on three areas: Europe, the United States, and Asia. Each history major will concentrate in one of these areas and write a research paper in it; each student must also take at least 36 units of history in other areas as approved by the adviser or as required by the history option.

A student considering the history option when he or she comes to Caltech will be well advised to take one course from Hum/H 1, 2, or 3. In the sophomore year the student should take upper-level history courses, but this is also a good time to pursue the study of English or philosophy, to begin or continue a foreign language (particularly desirable if the area of concentration is to be Europe or Asia), and to do introductory work in the social sciences. A student will normally make a commitment to an area of concentration early in the junior year, exploring this area through regular course work supplemented during the second and third terms by tutorial study in H 97 ab. At the beginning of the senior year, a history major will enroll in H 99 abc and be assigned to a faculty member in the student's chosen area. The first term will be devoted to preparation, the second to research, and the third to the writing of a substantial research paper.

Since statistics can be a useful tool in historical analysis, the option recommends that some of the science and math courses that a history major takes beyond the sophomore year (to satisfy the 54-unit Institute requirement) be in that area. Students who wish to write their senior research papers in the history of science are encouraged to use the rest of the 54 units to advance their understanding of one or two particular scientific disciplines.

## Option Requirements

1. H 97 ab, H 99 abc.
2. 54 additional units of history courses (including, if appropriate, H 98 ab).
3. 36 of the total history units must be in an area or areas other than the area of concentration. At the discretion of the adviser and the history option representative, a student may use H 97 ab (but not H 99 abc) to help satisfy this requirement.
4. 54 additional units of science, mathematics, and engineering courses. This requirement cannot be satisfied by courses listed as satisfying the introductory laboratory requirement or by Ay 1, ESE 1.
5. Three units of oral communication. En 84 satisfies this requirement as do oral communication courses offered by other options.
6. Passing grades must be earned in a total of 486 units, including the courses listed above.

## History and Philosophy of Science Option

The option in history and philosophy of science (HPS) provides students with a broad education in the historical and philosophical issues arising in connection with science and technology. Students take courses addressing fundamental questions about scientific concepts and practice, such as the following: To what extent was the scientific revolution revolutionary? What is a scientific explanation and how do scientists go about constructing and justifying one? How have conceptions of scientific experimentation changed over time? How and why did modern physics (or chemistry or biology) emerge in the form that it did? How should the theory of evolution inform our conception of the modern mind and brain? What role can the neurosciences be expected to play in solving the "mind-body" problem? The option thus aims to give students a broad basic understanding of the ways in which science is practiced, and the ways in which that practice has changed over time. It is designed to complement the regular curriculum at Caltech, offering students the opportunity to enlarge upon and to contextualize the strong technical skills they acquire in other courses and options.

The HPS option provides excellent preparation for students going into law, business, medicine, and public affairs, as well as

solid preparation for graduate work in history and/or philosophy of science. In addition, and because of its emphasis on essay writing and the formulation of complex philosophical and historical arguments, it aids budding scientists and engineers in developing the writing and communication skills that are increasingly vital today.

### Option Requirements

1. Hum/H/HPS 10, HPS 102 ab, HPS/PI 120, and HPS 103 (normally for 9 quarters). HPS 102 b fulfills the Institute scientific writing requirement.
2. Three advanced courses in the history of science, chosen from HPS/H offerings with a course number of 99 or higher.
3. Three advanced courses in philosophy of science, chosen from HPS/PI offerings with a course number of 99 or higher.
4. 45 units of courses in science, mathematics, and engineering. This requirement cannot be satisfied by courses listed as satisfying the introductory laboratory requirement or by a course with a number less than 10.
5. Three units of oral communication. En 84 satisfies this requirement as do oral communication courses offered by other options.
6. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

### Explanatory Notes

1. It is desirable that students enter the option in their sophomore year. However, students may also enter the option in their junior year if they can complete the option's requirements in time for graduation.
2. Students in the option will normally take HPS 103 each quarter, beginning in the sophomore year, for a total of 9 quarters. HPS 103 is graded on attendance and may only be taken pass/fail. To pass the course, student must attend four lectures by outside speakers on HPS topics. HPS 103 is thus an excellent way for students to learn about a broad variety of HPS issues, past and present.
3. HPS 102 ab is a two-quarter course devoted to the writing of a senior research paper. It is taught as a tutorial, with students developing their papers under the guidance of a faculty adviser. The senior research paper stresses independent work and can cover any one of a number of topics from a historical and/or philosophical perspective. Areas in which research could be conducted include the following: the nature and growth of scientific institutions and knowledge, theories of cognition, language and perception, and theories of scientific practice, broadly construed. In researching their senior theses, students are encouraged to form collaborations with other members of the Caltech community and to bring to bear knowledge acquired in

other classes (e.g., a student writing on the history of quantum mechanics might be encouraged to interview members of the Caltech physics department; those writing on neurophilosophy or genetic determinism would be expected to incorporate material learned in biology classes into their research). Among the other resources available for writing the senior paper is the Caltech Archives, which contains a substantial collection of rare books in the history of science going back to the 16th century, and which houses the correspondence and other papers of a number of distinguished scientists, including George Ellery Hale, Robert Millikan, Richard P. Feynman, Lee A. DuBridge, and Max Delbrück. Also potentially of interest to both historians and philosophers of science is the Huntington Library's rich collection of scientific books and manuscripts, and the Einstein Papers Project's complete archive of Einstein's scientific papers and correspondence, now housed at Caltech.

### Typical Course Schedule

#### First Year

It is recommended that students intending to follow the HPS option take Hum/H/HPS 10 as one of their freshman humanities courses. Students making the decision to take this option in their sophomore year should take Hum/H/HPS 10 and HPS/PI 120 as early as possible in that year.

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
HPS 10	Introduction to History of Science <sup>1</sup>	9	-	-
HPS/PI 120	Introduction to Philosophy of Science <sup>1</sup>	-	9	-
	Advanced HPS/History	-	-	9
HPS 103	Public Lecture Series	1	1	1
	Menu Course	-	-	9
Ec 11 or PS 12	Introductory Social Science	9	-	-
	Other Electives	9	18	27
		46	46	46
<i>Third Year</i>				
HPS 103	Public Lecture Series	1	1	1
	Advanced HPS/History	-	9	9
	Advanced HPS/Philosophy	9	9	9
	Science, Math, Engineering	9	9	9
	Advanced Social Science <sup>2</sup>	9	-	-
	Other Electives	18	18	18
		46	46	46

#### Fourth Year

HPS 103	Public Lecture Series	1	1	1
HPS 102 ab	Senior Research Seminar <sup>3</sup>	-	12	12
	Advanced Social Science <sup>2</sup>	9	-	-
	Science, Math, Engineering	9	9	9
	Other Electives	27	18	18
		46	40	40

Note: Not all required courses are offered each term; students should consult the current Catalog to determine which terms required courses are being offered, and should construct their course plan for the year accordingly.

<sup>1</sup> If not taken in first year, otherwise one additional HPS or elective.

<sup>2</sup> It is recommended that students choose their advanced social science electives from among courses that will enlarge their perspective on topics related to HPS (e.g., Ec/SS 129, Ec/SS 130, Psy 101, Psy 125, Psy/CNS 130, PS 120, PS 121, PS 122, An 22).

<sup>3</sup> HPS 102 ab may be taken in any two consecutive terms in the senior year. Students should coordinate with their HPS adviser to determine their course schedule.

### Independent Studies Program

The Independent Studies Program (ISP) is an undergraduate option that allows the student to create his or her own scholastic requirements, under faculty supervision, and to pursue positive educational goals that cannot be achieved in any of the other available options. A student's program may include regular Caltech courses, research courses, courses at other schools, and independent study courses (item 5 next page). In scope and depth, the program must be comparable to a normal undergraduate program, but it need not include all of the specific courses or groups of courses listed in the formulated Institute requirements for undergraduates.

The Curriculum Committee, a standing committee of the faculty, has overall responsibility for the program. In addition, each student has his or her own committee of three advisers, two of whom must be professorial faculty. Application material may be obtained at the Registrar's Office or from the dean of students.

### Administrative Procedures and Guidelines

1. An interested student must recruit three individuals, representing at least two divisions of the Institute, who approve of his or her plans and agree to act as an advisory "committee of three." The committee of three forms the heart of the program and bears the chief responsibility for overseeing the student's progress. The chair and one other member must be on the professorial staff. The third member may be any qualified individual, such as a postdoctoral fellow, graduate student, or faculty member of another institution.
2. The student must submit a written proposal to the dean of students, endorsed by the committee of three, describing his or her goals, reasons for applying, and plan of study for at least the next year. If persuaded that the proposal is sound and workable, the dean endorses it and passes it on to the Curriculum Committee. This committee, in turn, reviews the proposal and,

if it is acceptable, assumes responsibility for oversight of the program.

3. To implement the program, a written contract is now drawn up between the student, the committee of three, and the Curriculum Committee. This contract includes the agreed-upon content of the student's program and the methods for ascertaining satisfactory progress for those parts of the student's program that are not standard Institute courses. This contract may of course be amended, but any amendments must be approved by the committee of three and the Curriculum Committee. Copies of each student's contract and of all amendments thereto, along with all ISP records for each student and his or her transcript, are kept in the permanent files of the Registrar's Office.
4. The progress of each student in the ISP is monitored each quarter by the registrar, and any deviations from the terms of the contract are reported to the Chair of the Curriculum Committee. Standards for acceptable progress and for satisfactory completion of the terms of the contract are the responsibility of the Curriculum Committee. When the Committee is satisfied that the terms of the contract have been fulfilled by the student, it recommends the student to the faculty for graduation.
5. A plan of study may include special ISP courses to accommodate individual programs of study or special research that falls outside ordinary course offerings. In order that credit be received for an ISP course, a written course contract specifying the work to be accomplished, time schedule for progress reports and completed work, units of credit, and form of grading must be agreed upon by the instructor, the student, and the committee of three, and submitted to the registrar prior to initiating the work in the course. ISP courses are recorded on the student's transcript in the same manner as are other Caltech courses.

### Mathematics Option

The four-year undergraduate program in mathematics leads to the degree of Bachelor of Science. The purpose of the undergraduate option is to give students an understanding of the broad outlines of modern mathematics, to stimulate their interest in research, and to prepare them for later work, either in pure mathematics or allied sciences. Unless students have done exceptionally well in their freshman and sophomore years, they should not contemplate specializing in mathematics. An average of at least "B" in mathematics courses is required of students in order to major in mathematics.

Since the more interesting academic and industrial positions open to mathematicians require training beyond a bachelor's degree, students who intend to make mathematics their profession

must normally plan to continue with graduate study. Some students use their background in mathematics as an entry to other fields such as physics, computer science, software engineering, economics, business, finance, medicine, or law.

The schedule of courses in the undergraduate mathematics option is flexible. It enables students to adapt their programs to their needs and mathematical interests and gives them the opportunity of becoming familiar with creative mathematics early in their careers. In particular, students are encouraged to consider courses in areas such as applied and computational mathematics, physics, finance, economics, control and dynamical systems, computer science, electrical engineering, and computation and neural systems.

During each term of their junior and senior years, students normally take 18 units of courses in mathematics or applied and computational mathematics, including the required courses Ma 108 abc and 109 abc. Any course listed under applied and computational mathematics is regarded as an elective in mathematics and not as an elective in science, engineering, or humanities. Those who have not taken Ma 5 as sophomores must do so as juniors. Overloads in course work are strongly discouraged; students are advised instead to deepen and supplement their course work by independent reading.

A student whose grade-point average is less than 1.9 at the end of the academic year in the subjects under mathematics and applied and computational mathematics may, at the discretion of the department, be refused permission to continue work in the mathematics option.

### Option Requirements

1. Ma 5 abc, Ma 10, Ma 108 abc, Ma 109 abc.
2. Ma/CS 6 a or Ma 121 a.
3. Ma/CS 6 c or Ma 116 a or Ma/CS 117 a.
4. 45 additional units in Ma or ACM numbered 90 or above (other than Ma 98). Courses in other options with high mathematical content may be used to fulfill this requirement with the approval of the executive officer for mathematics. Of these 45 units, at most 18 can be in ACM or other courses outside Ma.
5. Math majors must take two quarters (18 units) of a single course, chosen from the Ma course listings with numbers between 110 and 190, inclusive. (In years where one of these courses is given as a one-term course only, it cannot be used to satisfy this requirement.) These two quarters may be used to meet requirements 2, 3, or 4.
6. Passing grades must be earned in a total of 483 units, including the courses listed above.

### Typical Course Schedule

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
Ma 5 abc	Introduction to Abstract Algebra	9	9	9
	HSS Electives	9	9	9
	Electives <sup>1</sup>	9	9	27
		<hr/>	<hr/>	<hr/>
		45	45	45
<i>Third Year</i>				
Ma 10	Oral Presentation	3	-	-
Ma 108 abc	Classical Analysis	9	9	9
Ma/CS 6 ac	Introduction to Discrete Mathematics	9	-	9
	HSS Electives	9	9	9
	Electives <sup>1</sup>	18	27	18
		<hr/>	<hr/>	<hr/>
		48	45	45
<i>Fourth Year</i>				
Ma 109 abc	Introduction to Geometry and Topology	9	9	9
	HSS Electives	9	9	9
	Electives <sup>1</sup>	27	27	27
		<hr/>	<hr/>	<hr/>
		45	45	45

<sup>1</sup> Includes menu course (second year, if not taken in freshman year). Also must include courses to meet option requirements 4, 5.

### Mechanical Engineering Option

The aim of the undergraduate program in mechanical engineering is to prepare students for research and professional practice in an era of rapidly advancing interdisciplinary technology. The program builds on the core curriculum to combine individual depth of experience and competence in a particular chosen mechanical engineering specialty with a strong background in the basic and engineering sciences. It maintains a balance between classroom lectures and laboratory and design experience, and emphasizes the problem formulation and solving skills that are essential to any engineering discipline. The program also strives to develop in each student self-reliance, creativity, leadership, professional ethics, and the capacity for continuing professional and intellectual growth.

Mechanical engineering is the branch of engineering that is generally concerned with understanding forces and motion and their application to solving problems of interest to society. The field includes aspects of thermodynamics, fluid and solid mechanics, mechanisms, materials, and energy conversion and transfer, and involves the application of physics, mathematics, chemistry, and

increasingly biology and computer science. Importantly, the field also emphasizes the process of formulation, design, optimization, manufacture, and control of new systems and devices.

Technical developments in the last decade have established the importance of interdisciplinary engineering and science, and as a result, new technical disciplines within mechanical engineering have emerged. These new areas build on an understanding of the fundamental behavior of physical systems; however, the focus of this work is at the interfaces of the traditional disciplines. Examples of the new disciplines include micro- and nanomechanical systems, simulation and synthesis, integrated complex distributed systems, and biological engineering.

Mechanical engineers can be found in many fields, including automotive, aerospace, materials processing and development, power production, consumer products, robotics and automation, semiconductor processing, and instrumentation. Mechanical engineering can also be the starting point for careers in bioengineering, environmental and aeronautical engineering, finance, and business management.

At the end of the first year, students who elect the mechanical engineering option are assigned advisers as close to their expressed field of interest as possible, and together they develop programs of study for the next three years. Beyond the Institute-wide requirements of physics, mathematics, and humanities, these programs require one year of applied and computational mathematics and additional course requirements listed below.

A student whose interests relate to mechanical engineering, but who wishes to pursue a broader course of study than that allowed by the requirements below, may elect the engineering and applied science option.

Attention is called to the fact that any student whose grade-point average is less than 1.9 at the end of the academic year in the required courses listed below may be refused permission to continue work in this option.

### Option Requirements

1. E 10, E 11.
2. ACM 95 abc or Ma 108 abc or Ma 109 abc.
3. 9 units from CS 1, CS 2, CS 11, EE/CS 51, Ph 20–22.
4. ME 35 abc, ME 18 ab, ME 19 ab, ME 71, ME 65, and CDS 110 a.
5. 9 units of ME/CE 96 and 9 units of additional laboratory<sup>1</sup> (such as CS/EE/ME 75 abc, MS 90, ME 72), or an experimental senior thesis (ME 90 abc).
6. In addition to the above courses, 27 units selected from Ae/APh/CE/ME 101 abc, Ae/AM/CE/ME 102 abc, Ae/ME 120 ab, AM 151 abc, CDS 110 b, CDS 140, ME 20, ME 66, ME 90 abc, ME 91 abc, ME 115 ab, ME 118, ME 119 ab, ME 171, MS 115 ab, or an advanced engineering course approved in advance by the mechanical engineering faculty.

7. A design project. This requirement may be fulfilled by taking one of the following: ME 72, E/ME 105, CS/EE/ME 75 abc. When appropriate, students may also seek consent from the ME undergraduate option representative and the student's adviser to fulfill this requirement by taking ME 90 abc, ME 91 abc, or another suitable project course. If ME 72, CS/EE/ME 75 abc, or ME 90 is chosen, these units may also be used to fulfill requirement 5.
8. None of the courses satisfying requirements 2 through 7 may be taken pass/fail.
9. Passing grades must be earned in a total of 486 units, including courses listed above.

<sup>1</sup> Excluding courses for which freshman laboratory credit is allowed.

### Typical Course Schedule

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
	HSS Electives	9	9	9
	Menu class	-	-	9
ME 35 abc	Statics and Dynamics	9	9	9
ME 18 ab	Thermodynamics	9	9	-
ME 71	Introduction to Engineering Design	-	-	9
		45	45	36
<i>Third Year</i>				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
ME 19 ab	Fluid Mechanics	9	9	-
	HSS Electives	9	9	9
	Elective	-	9	9
	Laboratory	-	-	9
	Science Writing	-	3	-
		30	42	39
<i>Fourth Year</i>				
E 10	Technical Seminar Presentation	-	3	-
ME 65	Mechanics of Materials	9	-	-
CDS 110 a	Introductory Control Theory	9	-	-
ME/CE 96	Mechanical Engineering Lab	-	-	9
	HSS Electives	9	9	9
	ME Electives	9	9	-
	Electives	9	18	18
		45	39	36

## Suggested Electives

Elective courses for the third and fourth year should be selected in consultation with the student's faculty adviser to pursue an interdisciplinary topic or a specialization of interest to the student. Such specializations include micro- or nanomechanical systems, simulation and synthesis, integrated complex distributed systems, kinematics, dynamics, fluid mechanics, solid mechanics, mechanical systems, control systems, engineering design, thermal systems, energy systems, combustion, or biological engineering.

## Philosophy Option

Philosophy majors must take at least 99 units of philosophy courses during their four years as undergraduates. These must include 18 units of PI 90 ab, to be taken in any two consecutive terms in the senior year. The 99 units may include 9 units of either Hum/PI 8 or Hum/PI 9, up to 9 units of PI 30, and up to 18 units of study in related disciplines, such as history of science, logic, physics, math, psychology, or biology.

The courses in the philosophy option concentrate on three areas: philosophy of science; philosophy of mind, brain and behavior; and moral and political philosophy. Students may choose to specialize in one of these areas, but broader courses of study are also encouraged. Depending on their interests, philosophy majors may be required by the option representative or their advisers to take up to 18 units in one or more related areas. For example, students writing on political philosophy or philosophy of neuroscience will be expected to have the appropriate political science/ or neuroscience background. Students whose primary interest lies in the philosophy of science—particularly, in the philosophy of particular sciences such as physics or biology—will have their intellectual interests best served by taking classes in both the history and philosophy of science. Such students are encouraged to pursue the HPS option; or, if they choose the philosophy option, they may be required to take some history of science courses toward their 99-unit requirement.

Students considering the philosophy option will be well advised to take either Hum/PI 8 or Hum/PI 9 as one of their freshman humanities courses. From the sophomore year onward, they should plan on taking one philosophy course per term, culminating in two terms of PI 90 ab in the senior year. Students in PI 90 ab work with a faculty adviser to write a 10,000–12,000 word paper on a topic of mutual interest. Senior theses are expected to be of a high standard and to form the basis of students' applications to graduate study in philosophy, should they so desire.

## Option Requirements

1. PI 90 ab.
2. 63 units of advanced philosophy courses, numbered 99 or

above. (Up to 9 units of Hum/PI 8 or Hum/PI 9 and/or up to 9 units of PI 30 may be substituted for up to 18 of these advanced units.)

3. 18 units of advanced philosophy courses numbered 99 or above, or advanced non-philosophy courses that are closely related to the student's area(s) of philosophical interest. (Students wishing to count non-philosophy courses towards their option requirements must obtain prior approval from the philosophy option representative or their adviser. Students will normally not be permitted to satisfy this requirement with core courses.)
4. 54 units of science, mathematics, and engineering courses in addition to the core. This requirement cannot be satisfied by core or menu courses, or by courses listed as satisfying the introductory laboratory requirement. Students are strongly encouraged to choose their additional courses in areas that complement their philosophy studies.
5. Three units of oral communication. En 84 satisfies this requirement as do oral communication courses offered by other options.
6. Passing grades must be earned in a total of 486 units, including the courses listed above.

## Physics Option

The physics option offers instruction in the fundamentals of modern physics and provides a foundation for graduate study, which is generally necessary for a career in basic research. Many individuals have also found that the physics program forms an excellent basis for future work in a variety of allied fields.

While all Caltech students must take the five terms of introductory courses, an intensive version of the sophomore course (waves, quantum mechanics, and statistical mechanics) is offered for those planning further study in physics. The required junior-level courses give a thorough treatment of fundamental principles. Elective courses taken during the junior and senior years allow students to explore their particular interests. Some electives offer broad surveys, while others concentrate on particular fields of current research. A choice of laboratory courses is offered at several levels. Students are encouraged to become active participants in research on campus. Academic credit for physics work done outside of the classroom can be awarded in a variety of ways.

Students must maintain a grade-point average of 1.9 or better each year in the subjects listed under this division to remain in the physics option.

## Option Requirements

The first three requirements should be completed by the end of the second year. In planning a program, note that Ph 6 and Ph 7 are each offered only once per year, in the second and third terms, respectively.

1. Ph 3.
2. Ph 6<sup>1</sup> or APh 24.
3. Ph 7.
4. 18 units of Ph 78, or 18 units of Ph 77, or 9 units of Ph 77 and 9 units from APh 77 or Ay 105.
5. Ph 70<sup>2</sup>.
6. Ph 106.
7. Ph 125.

<sup>1</sup> Some laboratory courses from other options have considerable physics content, and students wishing to satisfy this requirement with such a course may petition the Physics Undergraduate Committee for approval.

<sup>2</sup> Other communication courses (e.g., E 10, Ay 30, Ma 10) may be substituted for Ph 70.

### Required Electives

1. 90 units, in addition to the above, of any of the following: any Ph, Ay, or APh course numbered 100 or above, or any of Ph 5, Ph 78, Ph 79, ACM 95, ACM 101, or up to 9 units of Ph 20–22. 9 units toward the 90-unit requirement will be given for taking three terms of Ph 77. Students are encouraged to take ACM 95 as part of this requirement. The pass/fail option cannot be exercised on any courses used for this requirement, with the exception of ACM 95. No more than 9 units of Ph 171–173 may apply toward this requirement without permission from the Physics Undergraduate Committee. In individual cases, this committee may allow other courses with substantial physics content to apply toward the requirement; seniors must submit their petitions for this purpose before the first day of third term.
2. 9 units of science or engineering electives outside of Ph, APh, Ma, and ACM. These units are in addition to the required Core Science Electives.
3. Passing grades must be earned in a total of 486 units, including the courses listed above.

### Typical Course Schedule<sup>1</sup>

		Units per term		
		1st	2nd	3rd
<i>Second Year</i>				
Ph 12	Waves, Quantum Physics, and Statistical Mechanics	9	9	9
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS and/or PE Electives	15	9	9
	Physics Laboratory	0	9	9
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	Core Science Elective if not taken earlier	-	-	9
		45	48	48

<sup>1</sup> In addition to the required courses listed here, facility with computer programming at the level of CS 1 is strongly recommended, and further computer-related course work such as CS 2, or Ph 20–22 is highly desirable. Facility with electronics at the level of Ph 5 also is recommended.

### Third Year

Ph 106 abc	Topics in Classical Physics	9	9	9
Ph 125 abc	Quantum Mechanics	9	9	9
	HSS and/or PE Electives	9	9	9
	Electives	18	18	18
		45	45	45

### Fourth Year

Ph 77 abc	Advanced Physics Laboratory	9	9	-
Ph 70	Oral and Written Communication	-	6	-
	Advanced Physics Electives	18	18	18
	Electives	9	6	18
	HSS and/or PE Electives	9	9	9
		45	48	45

### Social Science Option

The social science program is designed to provide undergraduates with multidisciplinary training in social science. The program focuses on the processes of social, political, and economic change and the analytical methods used by social scientists to describe and predict them. The program is designed to be sufficiently flexible to provide an excellent preparation for students intending to attend graduate school in any social science discipline, or in law or business.

### Option Requirements

1. Ec 11, PS 12, Ec 121 a, Ma 112 a, Ec 122, PS/Ec 172, BEM/Ec/SS 20.
2. One of the following: An 22, An 23, or Psy 15.
3. 45 additional units of science, mathematics, and engineering courses. The requirement cannot be satisfied by courses listed as satisfying the introductory laboratory requirement or by any course with a number less than 10.
4. 54 additional units of social science courses, which include any course listed under the following headings: anthropology, business economics and management (except BEM 101), economics, law, political science, psychology, and social science. (Courses that are used to fulfill the Institute's advanced social science requirement [courses numbered 100 and above] will also count toward the 54 additional units required under the economics and social science options.)
5. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

## Typical Course Schedule

		<i>Units per term</i>		
		<i>1st</i>	<i>2nd</i>	<i>3rd</i>
<i>Second Year</i>				
Ec 11	Introduction to Economics	9	-	-
PS 12	Introduction to Political Science	-	-	9
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
	Menu Course	-	-	9
	Electives	18	27	27
		45	45	45
<i>Third Year</i>				
Ma 112 a	Statistics	9	-	-
Ec/SS 20	Oral Presentation	-	3	-
Ec 121 a	Theory of Value	-	9	-
Ec 122	Econometrics	-	9	-
PS/Ec 172	Noncooperative Games in Social Science	-	9	-
An 22 or An 23 or Psy 15	Introduction to the Anthropology of Development			
	Introduction to Physical Anthropology			
	Social Psychology	-	9	-
	Electives	36	9	45
		45	48	45
<i>Fourth Year</i>				
BEM/Ec/SS 20	Scientific Writing	-	6	-
	Electives <sup>1</sup>	45	39	45
		45	45	45

<sup>1</sup> Students may concentrate on research by taking 54 units of supervised research in their senior year.