Information for Undergraduate Students

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 or ACT, and one SAT science subject test and the SAT mathematics level 2 test; teacher and counselor evaluations; personal characteristics; a demonstrated interest in math, science, or engineering; and information provided on the application.

Applying
Information on the application process can be found on the admissions office website at http://www.admissions.caltech.edu. Students are encouraged to apply online through the Common Application. For further information on admission, please call (626) 395-6341 or e-mail ugadmissions@caltech.edu. To be considered for admission, applications to the freshman class must be submitted online or postmarked by January 3.

Early Action
The Early Action application process requires that the completed application be postmarked or submitted online 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)

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 Decision consideration:

SAT or ACT
SAT mathematics level 2
One of the following SAT subject tests: 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; or 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. 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 Decision 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
Biology majors who have passed Bi 8 and Bi 9 are considered to have met the core requirement of Bi 1.

Chemistry
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 qualifications for advanced placement in chemistry will only be determined by the performance on a placement examination to be administered in the summer prior to registration. Similarly, qualified students, with the instructor's consent, are allowed to substitute either Ch 8 or Ch/ChE 9 for the "core" chemistry laboratory requirement (Ch 3 a).

English/Writing
All incoming students (freshmen and transfers) must submit a placement essay to determine whether they are adequately prepared for the substantial writing component that is part of all freshman humanities courses. Most new students participate in a web-based version of this assessment, which is usually conducted in early June. A makeup assessment is held just before fall classes begin. Based on results of this writing assessment, students may be required to take En 1 a or En 2 before enrolling in a freshman humanities class. (En 1 ab and En 2 count for general Institute credit only.) During the first week of classes, students will be required to produce an in-class writing sample to confirm the initial placement.

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 or 3 x
Biology 1, 1 x, 8, or 9
Humanities and Social Science electives
Menu science class (see page 182; 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 course work 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. Information on the application process can be found on the admissions office website at http://www.admissions.caltech.edu. Students are encouraged to apply online through the Common Application. For further information on admission, please call (626) 395-6341 or e-mail ugadmissions@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)
Bryn Mawr (PA)
Grinnell College (IA)
Haverford College (PA)
Mt. Holyoke College (MA)
Oberlin College (OH)
Occidental College (CA)
Ohio Wesleyan University (OH)
Pomona College (CA)
Reed College (OR)
Spelman College (GA)
Wesleyan University (CT)
Whitman College (WA)

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. The 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 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.

Visiting Student Program

A limited number of students from other institutions of collegiate rank may enroll at Caltech to take classes for up to one year. These students are classified as visiting students and will not receive Caltech degrees. Applicants should have an excellent academic record and be recommended by their home institutions. Visiting

students are responsible for all costs, including Caltech's tuition and fees. Accommodations in Institute housing depends on availability. Decisions on admission are made by the dean of students office, and prospective visiting students should contact this office by April 1 to apply for fall enrollment.

STUDY ABROAD

Study abroad allows students to gain a firsthand experience of life in countries abroad, while also gaining a broader exposure to the sciences, engineering, economics/management, the social sciences, and humanities. Students who study abroad develop an international viewpoint that transfers to their education at Caltech and to their graduate study and future career regardless of the field they pursue professionally.

Please see the Financial Aid section of this catalog for details on applying for and eligibility for financial aid related to study abroad. Note that supplemental charges and travel should be listed by the student in his or her financial aid budget so that these amounts can be considered when funding is calculated.

Additional information, including application procedures and exact deadline dates, is available from the Fellowships Advising and Study Abroad Office at http://www.fasa.caltech.edu.

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 program. The participating colleges are Corpus Christi, Pembroke, St. Catharine's, and St. John's. Students pay Caltech room, board, tuition, and other standard Caltech fees for the term. There may be a small supplemental charge for room and tuition. The supplement varies yearly depending on prices and the exchange rate.

Students are admitted into one Cambridge department in the biological sciences, physical sciences, computer sciences, mathematics, engineering, or economics to take classes within the tripos, i.e., subject, offered by that department. Students may only take courses in one tripos unless special permission is granted, and this is usually granted by Cambridge if a student needs a course to fulfill a Caltech option requirement. Students will find more information on the tripos structure and Cambridge University in the Fellowships Advising and Study Abroad Office or at http://www.cam.ac.uk.

During the term at Cambridge, students take the equivalent of at least 36 Caltech units, usually four Cambridge courses, but may take five in most cases. The exact number of courses depends on

Cambridge departmental requirements. For their classes, students receive a minimum of 36 Caltech units that can be used for general or option credit or to fulfill other Institute course requirements. 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 should apply by the January deadline for the next academic year. Further information, including application procedures, more about Cambridge University, and exact deadline date, is available from the Fellowships Advising and Study Abroad Office at http://www.fasa.caltech.edu.

Please see the Financial Aid section for details on applying for and eligibility for financial aid related to study abroad. Note that supplemental charges and travel should be listed by the student in his or her financial aid budget so that these amounts can be considered when funding is calculated.

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 as well as the sciences, e.g., chemistry, physics, and math.

Students live in a modern kollegiet (dormitory) with Danish students. There is a supplemental charge for the room because the Copenhagen semester is 15 weeks long plus one week of fall vacation. The supplement varies yearly depending on prices and the exchange rate.

There is no board plan, but each kollegiet has a well-equipped kitchen, and students may cook for themselves or with the other students on the hall. Aside from the supplemental room charge, all students pay standard board and tuition, but should budget additional funds for food due to the length of the semester. Note that while students pay Caltech board fees, the board fee is used to spend on food while in Copenhagen. Students can cook in their kollegiet or eat out. Caltech fees are due by the normal fall due date.

Both KU and DTU are on a semester system, and Caltech students attend from around August 25 to mid-December. Students have a one-week vacation in mid-October, and many use this vacation week to travel in Denmark or Europe. DTU students attend a one-week orientation the last week of August, and students going to KU have an advising and orientation period the last week of August.

Students take two to four courses in their Caltech option or a closely related subject and a course in the Danish language. Students attending Copenhagen University are required to take the course in Danish culture but may substitute or take in addition a course taught in English on subjects such as the Danish monarchy, Danish architecture, Danish film, or the Vikings, depending on what is offered that fall. Students who will be studying primarily at DTU are required to take the Danish-language course and may audit or take for credit a course in Danish culture or take one of the courses noted above. The Danish-culture course, in addition to weekly lectures, offers field trips to interesting cultural and historical sites in the city and surrounding area. All upper-level undergraduate or beginning graduate-level courses at KU and DTU can be taught in English. More information can be found at http://www.dtu.dk or http://www.ku.dk.

For this work, students receive a minimum of 36 Caltech units that can be used for general or option credit or to fulfill other Institute course requirements. 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.

Students can enroll in an optional three-week-long Danish-language course in August. There is no charge for this course. This course is not required, but all students are required to take Danish language during the fall semester for credit.

A minimum 3.0 GPA is required to apply. Eligible sophomores and juniors should apply by the January deadline for the fall semester at KU or DTU. Further information, including application procedures and exact deadline dates, is available from the Fellowships Advising and Study Abroad Office: http://www.fasa.caltech.edu.

Please see the Financial Aid section for details on applying for and elibility for financial aid related to study abroad. Note that supplemental charges and travel should be listed by the student in his or her financial aid budget so that these amounts can be considered when funding is calculated.

École Polytechnique Scholars Program

The École Polytechnique Scholars Program offers qualified juniors and seniors the opportunity to spend the fall, winter, or spring term at the École Polytechnique, which is located outside of Paris in the town of Palaiseau, about 40 minutes by train from Paris. Note that the winter and spring terms can only be attended in years that do not overlap with Caltech term dates and only with the permission of École Polytechnique and Caltech. In addition, seniors may not attend the spring term if they plan to graduate in June.

The École Polytechnique (the "Polytechnic School"), often referred to by the nickname "X," is the foremost French *grande école* of engineering (according to French and international rank-

ings). Founded in 1794 and initially located in the Latin Quarter in central Paris, it was moved to Palaiseau in 1976. It is one of the oldest and most prestigious engineering schools in the world, with a very selective entrance exam. As one of the world's foremost establishments in science education, the École Polytechnique trains graduates who become outstanding scientists, engineers, researchers, managers, and politicians.

At École Polytechnique, students can take courses in engineering or the applied sciences as well as the sciences, e.g., chemistry, physics, and math, as these are also taught. Students can also take classes in the social sciences and humanities. Two classes must be in the student's Caltech option in science, engineering, or economics and two classes can be taken in other subjects or in the student's option.

All classes are taught in French, and all discussions, assignments, and exams are in French. *Students must have very good ability in speaking, reading, and writing French* ***before*** *applying for this program.* Students will continue to take French at their level while at École Polytechnique.

École Polytechnique has different academic schedules depending on the year of study. Caltech students who study at École Polytechnique for a term (usually the fall) during their junior or senior year can only select classes from the third year of the École Polytechnique curriculum, and all classes must be selected from this year's curriculum. Note that the second-year classes are not allowed, as this year goes from the fall through January and then has a second semester versus two terms. The third-year specialized curriculum has a schedule that corresponds closely to Caltech's three-term system, and students must take all classes from the third-year curriculum. These classes are equivalent to 100-level classes at Caltech. For further information, go to this URL and scroll down to the third-year specialized education section: http://www.polytechnique.edu/page.php?MID=216.

A minimum 3.3 GPA is required to apply. Eligible sophomores and juniors apply to study during their junior or senior year by the Caltech internal deadline, which is usually in January.

Note that students must be nominated by Caltech in order to apply and cannot apply without going through the internal Caltech nomination process, which is run by the Fellowships Advising and Study Abroad Office. Only this office can provide the required nomination. Each year application specifics will be provided to sophomores and juniors in the fall. Students will be required to complete both Caltech Study Abroad Proposal and Forms and complete the École Polytechnique application forms as well as undergoing a formal assessment of French skills by Caltech's French instructor.

Please see the Financial Aid section for details on applying for and elibility for financial aid related to study abroad. Note that

supplemental charges and travel should be listed by the student in his or her financial aid budget so that these amounts can be considered when funding is calculated.

Edinburgh Scholars Program

The Caltech 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 mid-September to mid-December. All students are required to attend a weeklong orientation held the week before classes start. All students live in university dormitories or flats, which are within walking distance from the George Square (humanities and social sciences) and the King's Buildings (the science and engineering campus). The university operates a free shuttle bus from the George Square campus to the King's Buildings campus.

Students pay Caltech room, board, tuition, and other standard Caltech fees for the term. There is a supplemental charge 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 because that is in the College of Humanities and Social Sciences, but they can take 20 credits in that department. Students whose option is BEM or economics may be allowed in an urgent situation to take 40 credits in economics in order to fulfill BEM or economics option requirements.

Students take a minimum of 60 Edinburgh credits per semester and a maximum of 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 the College of Humanities and Social Sciences. Note that 60 credits is the standard courseload, but most Caltech students take 70 to 80 credits. Note that at least 36 Caltech units must be taken.

A minimum 3.0 GPA is required to apply. Eligible sophomores and juniors should apply by the January deadline for the fall semester at Edinburgh. Further information, including application procedures and exact deadline dates, is available from the Fellowships Advising and Study Abroad Office: http://www.fasa.caltech.edu.

Please see the Financial Aid section for details on applying for and elibility for financial aid related to study abroad. Note that supplemental charges and travel should be listed by the student in his or her financial aid budget so that these amounts can be considered when funding is calculated.

London Scholars Program

The Caltech London Scholars Programs offers qualified juniors and seniors the opportunity to spend the fall at University College London, which is located in the lovely Bloomsbury area of

London. University College London (UCL) is on a semester system, and Caltech students attend UCL's autumn semester from about the third week of September to mid-December. All students are required to attend an orientation (Wednesday evening through Friday/Saturday) the week before the semester begins. All students live in a UCL dormitory, which is located a short walk or short bus ride from the academic buildings of the UCL campus. Students pay Caltech room, board, tuition, and other standard Caltech fees for the term. There is a supplemental charge for housing/board 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 and must take two UCL/30 ECTS (European Credit Transfer System) credits. Students are required by UCL to take at least 50 percent of their classes in their Admitting Department. Usually the Admitting Department is in a subject area that most closely corresponds to the student's Caltech option, but there is some leeway in this provided the student has the background to be admitted to the department in question. Note that students can be admitted to two departments in the life, physical, and engineering courses and take at least 25 percent of their classes in each. However, dual admission is only available if there is a compelling reason, e.g., double-option students who need to fulfill a course requirement.

The remaining 50 percent of classes can either be taken in the Admitting Department, another department in the sciences or engineering, or the humanities and social sciences with the exception of the English literature department, which does not admit visiting students, even those with majors in English literature. Note that there are ample opportunities to take literature courses from a number of departments that offer literature classes, e.g., Slavonic and East European studies, Classics, Scandinavian studies, European cultural studies, Hebrew and Jewish studies, French, etc. Note that these departments offer classes taught in translation and in the foreign language.

A typical UCL semester class is 7.5 ECTS or 5 ECTS credits in the sciences or life sciences. In engineering subjects, a one-semester class is typically 2.5 UCL/3.75 ECTS credits. Caltech students must take 30 ECTS credits/2 UCL units during their semester at UCL. This would be equivalent to 36 to 45 Caltech units. UCL classes can be used for general or option credit or for humanities or social science 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.

Note that students can be admitted into the economics department as a secondary department. Such students must take at least 50 percent of their classes in their primary department in the physical, life, or engineering sciences and at least 25 percent of classes

in economics. Only students with a secondary admission to economics may take upper-level economics classes. Note that students can take up to two first- or second-year courses in the economics department without a formal dual admission.

A minimum 3.0 GPA is required to apply. Eligible sophomores and juniors apply by the January deadline for the fall semester at UCL. Further information, including application procedures and exact deadline dates, is available from the Fellowships Advising and Study Abroad Office.

Please see the financial aid section for details on applying for and eligibility for financial aid related to study abroad. Note that supplemental charges and travel should be listed by the student in his or her financial aid budget so that they can be considered when funding is calculated.

Melbourne Scholars Program

The Caltech Melbourne Scholars Programs offers qualified juniors and seniors the opportunity to spend the summer/fall at the University of Melbourne, which is located in the exciting city of Melbourne, Australia. Melbourne is on a semester system, and Caltech students attend Melbourne's second semester from the second week of July to the end of November. Since Melbourne is in the Southern Hemisphere, the university's first semester starts in July and crosses over both the Caltech winter and spring terms. Therefore, students attend Melbourne's second semester, which corresponds better to Caltech's fall semester. All students are required to attend an orientation that takes place at the University of Melbourne the week before the semester begins.

Students live in a residence hall, which is located a short walk from the academic buildings of the campus. The hall of residence, RMIT Village, has a suite setup and offers amenities such as a 15-meter outdoor swimming pool and lounge area, barbecue area, workout gym (with plasma TV, cross trainers, free weights, treadmills, exercise bikes, etc.), café, lounge, and laundry. There is also a new e-library that offers computers and printers as well as group and individual study rooms.

Students share a suite with another student (bedroom, bathroom/shower, kitchenette, living room). Students pay Caltech room, board, tuition, and other standard Caltech fees for the term. There is a supplemental charge for housing/board due to the longer length of the Melbourne semester. In some years there could be a supplemental tuition charge. The supplement varies yearly depending on prices and the exchange rate.

Students take four classes at Melbourne. Each class is worth 12.5 Melbourne credit points. Of the four classes, students must take two classes related to their option at Caltech and may take up to two outside of their subject, including the humanities and social sciences. Students are eligible to take one class as a research class in an area related to their option.

The Melbourne credit load would be equivalent to 36 to 45 Caltech units. Melbourne classes can be used for general or option credit or for humanities or social science 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 by the fall deadline for the second semester starting in July. Further information, including application procedures and exact deadline dates, is available from the Fellowships Advising and Study Abroad Office.

Please see the financial aid section for details on applying for and eligibility for financial aid related to study abroad. Note that supplemental charges and travel should be listed by the student in his or her financial aid budget so that they can be considered when funding is calculated.

ROTC

Air Force Reserve Officer Training Corps (AFROTC) offers 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 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 scholarships valued at up to 100 percent of annual tuition, along with a nontaxable monthly stipend. By agreement through the Air Force, Caltech students enroll in Air Force ROTC classes at the University of Southern California, California State University San Bernardino, Loyola Marymount University, or the 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 afrotcdet060@rotc.usc.edu or call (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 the 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*
- are current with the Bursar's Office. All undergraduate students with an outstanding Bursar's bill balance of $300 or more and graduate students with a Bursar's bill balance of $1,500 or more will have a hold placed on their registration for the subsequent quarter the day before online registration opens. The hold will be released once students have paid their bill or worked out a satisfactory payment plan with the Bursar's Office.

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.

Humanities Drop Policy
Students who do not attend the first class of the term will be automatically dropped from the class. Students who notify the instructor in advance of their inability to attend the first class may remain enrolled in the class at the instructor's discretion.

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 educational 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, although special circumstances can be considered, 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 recommended by the senior director of health and counseling services. Return from a leave for medical reasons also requires the recommendation of the senior director of health and 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 recommendation from the senior director of health and 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).

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 entered by 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 official transcript, 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 the withdrawal occurs after Add Day of any term, a W (standing for "withdrawn") will be recorded on the student's transcript for all courses in which the student is enrolled. A grade of W is not included in the computation of the student's grade-point average. 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 the first day of classes of the term in which registration is sought. Undergraduates who register for programs that make it appear that 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 and 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 official transcript shall show the ineligibility and a rein-

statement. 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.

Undergraduate students may request to add an approved minor to their program of study. The request for a minor must be approved by the option representatives of the student's option and proposed minor. A plan must be presented which meets the minimum requirements for both the option and the minor, but the option representatives may impose additional requirements as well. The approved request must be submitted to the registrar before the start of the senior year.

Undergraduate students 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. 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 or option 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. Classroom and laboratory courses are to be limited to 45 units for freshmen and the remaining six units should be used for frontier ("pizza") courses, PE, PA, or research. 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 for freshmen, sophomores, and juniors must be approved by the dean or associate dean. Seniors may take an underload by presenting for the registrar's approval a senior underload petition and a course plan for graduation the following June, provided that the plan does not require an overload in any term.

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 credit based on Caltech placement exams upon admission, credit will not be granted for Caltech courses in which the student is not officially enrolled, 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

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For freshmen and transfer students applying for admission, there is a $65 application fee. This fee is nonrefundable.

Housing contracts must be submitted to the assistant director of housing-occupancy by the date specified in the instructions accompanying the contract.

Expense Summary 2011–12

General:

General deposit	$ 100.00[1]
Orientation fee	500.00[1]
Tuition	36,387.00
	$ 36,987.00

[1] *This charge is made only once during residence at the Institute.*

Other:

Student fees	$ 1,317.00
Room (contract price)	6,570.00[2]
Board (5 days/week)	5,106.00
Additional meal allowance (est.)	1,413.00
Books and supplies (est.)	1,323.00
Personal expenses (est.)	1,974.00

[2] *The housing/room rate is calculated based on the weighted average of all available undergraduate on-campus housing options.*

The tuition and fees charge for all students is payable in full before the first day of classes unless the student enrolls in the Direct Cost Three Payment Plan through the Bursar's Office. The fee to enroll in the plan is $25.00 per term. Enrollment in the Direct Cost Three Payment Plan must be completed by August 10, 2012. Fees are subject to change at the discretion of the Institute.

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 from the Institute before the end of the sixth week of the term. 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 has spent in academic attendance. If the amount of aid disbursed to the student is greater than the amount the student has earned, unearned funds must be returned. If the amount the student was disbursed is less than the amount the student earned, the student will be eligible to receive a postwithdrawal disbursement.

Determining the Student's Last Date of Attendance or Withdrawal Date: The Office of the Registrar is responsible for obtaining requests for withdrawal from the 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;
- the date the student otherwise provided official notification to the registrar (written or oral) of his or her intent to withdraw;
- the midpoint of the academic term if no official notification is provided;
- 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 from the Institute prior to the first day of classes for the period of enrollment, Caltech will return 100 percent of the student's federal financial aid in accordance with federal procedures, as well as Caltech and/or state grants or 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 percent of the period, he or she earned 100 percent of the aid for the period. If the student completed 60 percent 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, 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: When a student, for whatever reason, withdraws 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 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 154.

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 applied to the student's outstanding balance or refunded if there is no unpaid balance.

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 ab) 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 following term. All undergraduate students with an outstanding bursar's bill balance of $300 or more will have a hold placed on their registration for the subsequent term the day before online registration opens. The hold will be released once students have paid their bill at the Bursar's Office. Official transcripts and diplomas will not be released until the bursar account is paid in full.

Caltech ID Card Charges
If an undergraduate student owes more than $300 at the end of the term, the student's ID card will be deactivated on the seventh day of the following term and he or she will be unable to charge any new purchases. Cards will be reactivated once students have paid their bill at 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, student fees, room and board, an allowance for meals not covered in the board contract, books and supplies, and personal expenses. For U.S. citizens or eligible noncitizens who reside in the United States, Canada, Mexico, or Guam, costs

include a travel allowance designed to (partially) offset the cost of two round-trips from a student's home during the academic year, and a travel allowance based on airfare for two round-trips. 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. With the exception of international students, 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 171–180.)

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

The Financial Aid Office 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 20-90, Pasadena, CA 91125; call (626) 395-6280; or visit the Caltech Financial Aid Office website 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 priority due dates for prospective and continuing students 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 following materials are needed to apply for all financial aid funds administered by the Caltech Financial Aid Office. We realize that you may not have access to your completed 2011 federal income tax information by the priority due dates and ask that you complete the application based on the best estimates available.

CSS/Financial Aid PROFILE Application:
Register for the 2012–13 CSS/Financial Aid PROFILE after October 1, 2011. Designate "California Institute of Technology" as one of the recipients by using Caltech's CSS Code, 4034. Due dates: Applicants must register for the CSS/Financial Aid PROFILE by December 15, 2011. Regular Decision applicants must submit the completed PROFILE application by January 15, 2012. Note: Early Action applicants must register for the CSS/Financial Aid PROFILE by October 15, 2011, and must submit the completed PROFILE application by November 15, 2011.

Free Application for Federal Student Aid (FAFSA):
The 2012–13 FAFSA will be available on January 1, 2012, at www.fafsa.ed.gov. File the FAFSA and designate "California Institute of Technology" as the recipient by using Caltech's Undergraduate Federal Code Number, 001131. Due date: February 1, 2012.

Parents' and Students' Federal Income Tax Return:

Parents and students must submit 2011 Federal Income Tax Returns (including all schedules and W-2s) before eligibility for financial aid can be determined. Applicants will be sent an e-mail from the College Board with instructions on how to submit their tax returns using the Institutional Documentation Service (IDOC). Log in to the IDOC site at https://idoc.collegeboard.com/idoc/index.jsp, download and complete the IDOC cover sheet, and submit your 2011 federal income tax return, all schedules, all W-2 forms, and all other required documents directly to the College Board. If you or your parents own corporations, partnerships, or trusts, please include copies of those tax returns (Forms 1041, 1065, 1120, 1120S, K-1). If you or your parent(s) did not and will not file a federal income tax return, please complete the Parent or Student Certification of Nonfiling. Please attach copies of W-2 or 1099 forms (if applicable) to the Parent or Student Certification of Nonfiling. Use the IDOC Cover Sheet to submit this form and all other required documents directly to the College Board along with your IDOC cover sheet. Due date: March 2, 2012.

Verification Worksheet:
All students and parents must complete and sign the 2012–13 Verification Worksheet, available at www.finaid.caltech.edu/forms. Use the IDOC cover sheet to submit the appropriate worksheet directly to the College Board. Due date: March 2, 2012.

Caltech Supplemental Application:
All students must complete the 2012–13 Caltech Supplemental Application, available at www.finaid.caltech.edu/forms. Use the IDOC cover sheet to submit this form directly to the College Board. Due date: March 2, 2012.

CSS Noncustodial PROFILE Application:
If your parents are divorced, separated, or never married, your noncustodial parent will need to complete the 2012–13 CSS Noncustodial PROFILE Application. After your CSS/Financial Aid PROFILE application is processed, you will receive an e-mail from the College Board with instructions on how to submit this information. Once you have your login information, your noncustodial parent can access the application at https://ncprofile.collegeboard.com/ncpWeb/pageflows/Main/Ncp MainController.jpf. Due date: March 2, 2012.

CSS Business/Farm Supplement:
If you or either of your parents is self-employed or owns a business or farm, you will need to submit the 2012–13 CSS Business/Farm Supplement, available at the Caltech Financial Aid Office website. You will receive an e-mail from the College Board with instructions on how to submit this form and other required tax documents using the Institutional Documentation Service (IDOC). Log in to the IDOC site to get your IDOC cover sheet. Use the IDOC cover sheet to submit this form and all other required documents directly to the College Board. Due date: March 2, 2012.

Caltech Scholarship Data Form:
Complete the 2012–13 Caltech Scholarship Data Form to be considered for named and endowed scholarships. Entering students will not be issued a Caltech ID number—required for the form—until sometime in June 2012. Due date: July 15, 2012.

International Applicants
If you are applying for admission as a freshman for the fall of 2012 and are not a citizen or permanent resident of the United States at the time of your application for admission, you will need to refer to the Caltech Financial Aid Office website at http://www.finaid.caltech.edu for instructions for applying for financial aid. 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 need-based financial aid for any other academic period while they are undergraduates at the Institute (with the exception of citizens of Canada and Mexico). Those with financial aid offers will be eligible to apply for assistance in subsequent years. All eligible students must reapply for aid each year.

International students are required to complete the CSS/Financial Aid profile. This online application has been modified to collect family income and asset information from international students. Students will need to register for the PROFILE service online at www.collegeboard.com by December 15, 2011, and indicate the college(s) to which they will be applying. (Students can also visit EducationUSA Advising Centers, which are located around the world, to register online.) Students will then

receive a personalized PROFILE application at www.collegeboard.com that should be completed and submitted by February 1, 2012. Please refer to the complete application instructions provided on the Caltech Financial Aid Office website at http://www.finaid.caltech.edu.

Types of Aid Available

There are three basic categories of financial aid that may be awarded.

1. Grants and scholarships represent "gift aid," which does not need to be repaid. In general, a Caltech scholarship is awarded based on financial need. Caltech named and/or endowed scholarships are considered to be based on need and merit. If you qualify for a state or federal grant, this grant would be included in your financial aid package.
2. Federal Work-Study or Caltech Work-Study represents student employment funds that have been allocated for you to earn during the academic year. Summer Caltech Work-Study represents funds that have been allocated for you to earn during the summer. While a work-study award is not a guarantee of employment, Caltech generally has more opportunities for student employment than it has students interested in working.
3. Low-interest educational loans: Students are generally offered Federal Perkins Loans or Caltech/Institute loans. Students may be awarded Federal Direct Stafford Loans if they request them.

Caltech Scholarships

Awarded to students with demonstrated financial need. Recipients are expected to be enrolled full-time. The named and/or endowed scholarships are also need-based, but many have a merit component. Recipients of named and/or endowed scholarships are often selected after their initial financial aid offer based on scholarship-specific eligibility. These scholarships are almost always used to replace some or all of the recipient's Caltech scholarship. The Financial Aid Office makes every attempt to renew these scholarships, contingent upon the recipients continuing to meet the specific eligibility criteria.

Federal Grants

Federal Pell Grant
Awarded to exceptionally needy undergraduate students who are seeking their first bachelor's degree. Amounts are set by the federal government based on need and enrollment status. In 2011–12,

awards ranged from $555 to $5,550 for full-time students; awards for part-time students are set in proportion to their enrollment, i.e., three-quarter time, half-time, less than half-time. Recipients must be in good academic standing.

Federal Supplemental Educational Opportunity Grant
Awarded to undergraduates with demonstrated need who are seeking their first bachelor's degree. Priority goes to full-time Pell Grant recipients. Recipients must be in good academic standing. Awards cannot exceed $4,000 per year.

State Grants

Cal Grant A
Provides tuition and fee assistance to undergraduate California residents seeking their first bachelor's degree. Awarded on the basis of cumulative grade-point average and financial need. Qualifying students can receive up to $9,708, renewable for up to four years. Continuing Cal Grant recipients must maintain good academic standing in addition to financial need. They are not required to resubmit verification of their grade-point average for renewal.

Cal Grant B
Provides a living-allowance stipend and tuition/fee assistance to undergraduate California residents seeking their first bachelor's degree. Awards are based on cumulative grade-point average and high financial need. Recipients are generally from disadvantaged economic or educational backgrounds. Awards for first-year students provide up to $1,551 for books and living expenses. When renewed or applied beyond the first year, awards also include tuition and fee assistance of up to $9,708. Continuing Cal Grant recipients must maintain good academic standing in addition to financial need. They are not required to resubmit verification of their grade-point averages for renewal.

Other State Grants
Other states, such as Pennsylvania, Vermont, and Rhode Island, may offer grant assistance to their residents who plan to attend Caltech. Students are encouraged to contact their respective state post-secondary agencies for specific eligibility and renewal criteria.

Educational Loans

An educational loan is a serious financial obligation and must be repaid. You should carefully consider the repayment obligation before you accept educational loans. Loans can be an invaluable resource for many students and their families in financing a college education. Students can postpone paying a portion of their educa-

tional costs until they complete their education or leave school. The repayment period on most loans can extend up to 10 years after graduation or leaving school.

Graduating with educational debt is a fairly common experience for students. At Caltech, however, the average educational indebtedness at graduation is significantly lower than the national average for students attending four-year private and public colleges. Over the last several years, the average for Caltech graduates has been among the lowest in the nation for four-year colleges.

Federal Perkins Loans
Awarded to students based on financial need. The maximum amount an eligible student may borrow is $5,500 per award year if he or she has not successfully completed a program of undergraduate education ($8,000 per year for graduate students). The maximum aggregate amount that may be borrowed is $11,000 for any student who has not yet completed two years of undergraduate work; $27,500 for an undergraduate student who has completed two years of undergraduate work and is pursuing an undergraduate degree; and $60,000 for a graduate student, including loans borrowed as an undergraduate. The aggregate loan limits include only the unpaid principal. Perkins Loans carry an annual interest rate of 5 percent. Interest does not accrue while the borrower is enrolled in school at least half-time, during the grace period (the time before which the borrower must begin or resume repaying a loan), or during authorized deferments. The borrower is responsible for paying the interest that accrues on the loan during repayment or forbearance (a temporary postponement of payments). Loans are repayable over a period of up to 10 years and have a nine-month initial grace period.

Your monthly payment amount will depend on the size of your debt and the length of your repayment period. The minimum monthly payment is $40.

The William D. Ford Federal Direct Loan Program
This program offers eligible students and parents the opportunity to borrow money directly from the federal government to help pay the cost of attendance at Caltech. The U.S. Department of Education makes loans, through Caltech, directly to students and/or parents. The Institute will use the loan(s) to pay your tuition/fees and other direct charges such as room and board, and give the student any remaining money for indirect costs. Students and/or parents make their repayments directly to the federal government.
Direct loans include

1. The Federal Direct Stafford Loan Program;
2. The Federal Direct Parent PLUS Loan Program;
3. The Federal Direct Graduate PLUS Loan Program; and
4. The Federal Direct Consolidation Loan Program.

Federal Direct Stafford Loan

There are two types of Federal Direct Stafford Loans: subsidized and unsubsidized. The federal government pays the interest on subsidized loans while the borrower is enrolled at least half-time and during authorized periods of deferment. The interest on unsubsidized loans begins to accrue immediately upon disbursement and is generally capitalized (added to the amount borrowed) when the borrower is no longer enrolled at least half-time.

Eligibility for subsidized Stafford Loans is based on financial need as demonstrated by the FAFSA. Students who do not demonstrate sufficient need or whose need is met may borrow unsubsidized Stafford Loans provided their total financial aid, including the Stafford Loan, does not exceed the total estimated cost of attendance.

Dependent undergraduate students (excluding students whose parents cannot borrow Parent PLUS loans) may borrow Stafford Loan amounts not to exceed an annual total of

- $5,500 for first-year students, with no more than $3,500 in subsidized Stafford;
- $6,500 for second-year students, with no more than $4,500 in subsidized Stafford; and
- $7,500 for third- and fourth-year students, with no more than $5,500 in subsidized Stafford.

Independent undergraduate students and dependent undergraduate students whose parents are unable to borrow Parent PLUS loans may borrow additional unsubsidized Stafford Loan amounts not to exceed an annual total of

- $9,500 for first-year students, with no more than $3,500 in subsidized Stafford;
- $10,500 for second-year students, with no more than $4,500 in subsidized Stafford; and
- $12,500 for third- and fourth-year students, with no more than $5,500 in subsidized Stafford.

Graduate students may borrow Stafford Loan amounts not to exceed an annual total of $20,500, with no more than $8,500 in subsidized Stafford.

The maximum outstanding total subsidized and unsubsidized Stafford Loan debt is

- $31,000 for dependent undergraduate students, with no more than $23,000 in subsidized Stafford;
- $57,500 for independent undergraduate students (or for dependent undergraduate students whose parents do not qualify for PLUS loans), with no more than $23,000 of this aggregate amount in the form of subsidized loans; and
- $138,500 for graduate students (including loans for undergraduate study), with no more than $65,500 of this aggregate in the form of subsidized loans.

Stafford Loan interest rates:

- The interest rate on subsidized Stafford Loans disbursed for enrollment periods that begin after July 1, 2011, and before June 30, 2012, is fixed at 3.4% for undergraduate students.
- The interest rate on subsidized Stafford Loans disbursed for enrollment periods that began after July 1, 2010, and before June 30, 2011, is fixed at 4.5% for undergraduate students.
- The interest rate on subsidized Stafford Loans disbursed for enrollment periods that began after July 1, 2009, and before June 30, 2010, is fixed at 5.6% for undergraduate students.
- The interest rate on subsidized Stafford Loans disbursed for enrollment periods that began after July 1, 2008, is fixed at 6.0% for undergraduate students.
- The interest rate on unsubsidized Stafford Loans disbursed for enrollment periods that began after July 1, 2006, is fixed at 6.8% for both undergraduate and graduate students.
- The interest rate for subsidized and unsubsidized Stafford Loans disbursed for enrollment periods that began before July 1, 2006, is variable and will be adjusted each year on July 1, though it will never exceed 8.25% for both undergraduate and graduate students.[1]

To offset the federal government's cost of the program, the borrower must pay an up-front origination fee of the principal amount of the loan. From July 1, 2010, to June 30, 2011, the origination fee for Stafford Loans was 1%. The maximum repayment period under this program is 10 years, not including authorized periods of deferment. Direct Stafford Loans have a six-month grace period that starts the day after the borrower graduates, leaves school, or drops below half-time enrollment. Repayment begins when the grace period ends. Deferments are available for new borrowers during at least half-time enrollment at an eligible institution; during periods of academic study in approved graduate fellowship or rehabilitation programs; and for periods of unemployment and economic hardship.

Applications for Federal Direct Stafford Loans are available on the Caltech Financial Aid Office website. Complete information on Stafford Loan deferments and repayment options is also available from the Financial Aid Office.

Federal Parent PLUS Loan

Parent PLUS loans are available to the parents or stepparents of dependent undergraduate students. These credit-based loans are not based on federal need or subsidized by the government, but students must file a FAFSA in order for their parents to qualify for

[1] *Interest rates for enrollment periods that begin on or after July 1, 2011, can be found at http://studentaid.ed.gov/PORTALSWebApp/students/english/FFEL_DL_InterestRates.jsp.*

a Parent PLUS loan. The interest rate on Parent PLUS loans disbursed for enrollment periods that began after July 1, 2006, is fixed at 7.9 percent. Interest is charged on Direct Parent PLUS loans during all periods, beginning on the date of the loan's first disbursement. There is no annual limit to the amount that can be borrowed through the Parent PLUS loan program. In general, parents may borrow the difference between the cost of the student's education and any other financial aid received. PLUS loans may also be used to pay for all or part of the expected family contribution. In addition to the interest, parents pay a loan fee of 4 percent of the principal amount of each Direct Parent PLUS loan received. For Parent PLUS loans that are first disbursed on or after July 1, 2008, parent borrowers have the option of deferring repayment based on the enrollment status of the dependent student on whose behalf a Direct PLUS loan was obtained.

Specifically, Parent PLUS loan borrowers may defer repayment

- while the dependent student on whose behalf the loan was obtained is enrolled on at least a half-time basis, and
- during the six-month period after the dependent student on whose behalf the loan was obtained ceases to be enrolled on at least a half-time basis.

If a Parent PLUS loan borrower does not request a deferment, the first payment on the loan will be due within 60 days after the loan is fully disbursed.

Applications for Federal Direct Parent PLUS loans are available on the Caltech Financial Aid Office website. Applications must be submitted to the Financial Aid Office for eligibility certification. Complete information on Parent PLUS loan deferments and repayment options is also available from the Financial Aid Office.

Federal Student Aid Ombudsman

The Federal Student Aid 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 Stafford 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; or visit the website at http://www.ombudsman.ed.gov.

Caltech Loans
Awarded to students who are not eligible for or who may have used their eligibility for Federal Perkins Loans. Generally, no interest is charged and no repayment of principal is required while a student maintains a continuous course of study at Caltech. Like the Federal Perkins Loan program, repayment on Caltech loans begins nine months after graduation, leaving school, or less than half-time enrollment. Caltech loans carry an annual interest rate of 5 percent. More specific information is provided on the promissory note and the disclosure statement provided to students prior to disbursement of the loan.

Cecil L. Kilgore Student Loans are available to members of all undergraduate 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.

Student Employment

Work programs provide students with a double incentive—to earn money to help with college expenses while gaining valuable job experience.

Student employment opportunities are generally available to all Caltech students, even those who have not applied for financial aid or qualified for need-based aid. Students should go to http://www.career.caltech.edu/joblistings/index.shtml to register on NACElink to see relevant job listings. Note that students are discouraged from working more than 16 hours per week and must seek the approval of the dean of students to do so. First-year students may not work during fall term.

Students can expect to earn at least the California state minimum wage of $8 per hour. Compensation rates will vary based on the position, a student's skills, and previous work experience. Please note that undergraduate students who serve as teaching assistants may only have one assignment per term of up to 12 hours per week.

Federal Work-Study
Awarded to domestic students who have demonstrated financial need through their submission of the FAFSA, this federally funded program provides part-time employment to eligible students.

Most Caltech students are awarded $2,000 in Federal Work-Study (FWS). Some students may be awarded less. Since entering students are not permitted to work on-campus in the fall term and can only work in the winter and spring terms, student employment awards for entering students are limited to $1,350 in their first year. Employment awards will increase to the standard student employment amount offered to continuing students after the first year. The maximum amount of FWS wages that a student may earn is determined by his or her financial need. Students have the option to move all or a portion of their loan or student employment from one program to the other at any time during the academic year until April 27, 2012.

Please go to the work-study page on the Caltech Financial Aid Office website (http://www.finaid.caltech.edu/workstudy) for additional information about student employment at Caltech.

Caltech Work-Study
The Caltech Work-Study Program is funded by the Institute and is designed to provide part-time employment for international students who have demonstrated financial need, and other students who do not qualify for the Federal Work-Study Program. The Caltech Work-Study Program is limited to on-campus employment or student employment positions at the Jet Propulsion Laboratory. The program's regulations parallel the Federal Work-Study Program's regulations.

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, Caltech Edinburgh Scholars Program, École Polytechnique Scholars Program, Caltech London Scholars Program, or Melbourne 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 study-abroad programs, 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, École Polytechnique, Melbourne, 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 page 136.)

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; financial aid recipients may be offered interest-free Institute loans to cover study-abroad travel expenses. Students will have their expected family contribution and financial package calculated in the same manner as other students. Students studying abroad are subject to the standard Caltech policy of a maximum of 12 terms of eligibility for financial aid. Cambridge, Copenhagen, University College London, École Polytechnique, University of Edinburgh, and Melbourne University 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, École Polytechnique, University of Edinburgh, and University of Melbourne scholars will continue to be considered for available federal, state, 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 website. Such scholarships can also often be found with the help of a search service. We recommend FastWeb (www.fastweb.com); BrokeScholar (www.brokescholar.com); and College Answer (www.collegeanswer.com). (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. Caltech's policy is to use outside scholarships to replace the student employment and/or loan components of the financial aid package. For entering students, we generally replace student employment first. For continuing students, loans are generally replaced first. Only if the total outside scholarships exceeds the student employment and/or loan that would have been included in

your financial aid package will it be necessary to reduce Caltech scholarship. In general, a student's total financial aid, including outside assistance, cannot exceed his or her demonstrated financial need. Under no circumstances can a student's total financial aid, including Caltech merit scholarships, exceed their estimated cost of attendance.

Financial Aid Disbursement

Most financial aid funds are credited directly to your student account and are applied first to institutional charges for the current term. Funds are credited no earlier than 10 days prior to the first day of the term. Aid that can be credited directly to your account will be credited when you have

- completed and returned your award letter;
- provided all required documents for the aid programs you have been awarded;
- made satisfactory academic progress;
- enrolled in at least the minimum number of credits for the financial aid programs you have been awarded;
- completed all necessary loan documents and, for first-time Direct Stafford Loan borrowers, completed the online Entrance Interview.

If the disbursement of your aid results in a credit balance, any aid awarded in excess of institutional charges will be paid to the student as a refund. Refunds must be requested by the account holder. Requests may be made by e-mail, telephone, or in person at the Bursar's Office. Prior to receiving funds, it may be necessary to fill out and sign a refund form. Refunds can be obtained in cash or by check. A maximum refund of $500 cash per day can be received from the Bursar's Office cashier. Refund checks are requested by the Bursar's Office and issued by Accounts Payable. This usually takes five working days from the day of request.

Outside scholarships are usually disbursed in the form of a check and must be handled according to the sponsor's specifications. If the funds are sent to the Financial Aid Office or the Bursar's Office, they will be credited to your account. Again, if the crediting of any outside scholarship results in a credit balance on your account, you may request that the credit balance be refunded to you. Federal regulations allow Caltech to credit financial aid funds to your account for payment of tuition, fees, and room and board charges. You must give the Bursar's Office written authorization to keep a credit balance on your account from one term to the next term during the academic year. Federal guidelines prohibit keeping a credit balance from one academic year to the next. If you complete your financial aid file late in the term, resulting in the late disbursement of your financial aid funds, you may be subject to late fees assessed by the Bursar's Office.

Cal Grant B stipend payments will be credited to your tuition account unless you contact the Financial Aid Office in person within the first three weeks of the term to make alternate arrangements. Again, if the crediting of any financial aid results in a credit balance on your account, you may request that the credit balance be refunded to you.

In general, loans are disbursed in three installments, one at the beginning each term. For most Caltech students who are enrolled for the full academic year, this means that one-third of their loan(s) will be disbursed at the beginning of the fall term, another at the beginning of the winter term, and the final third at the beginning of the spring term. Students whose loan periods are for one term receive their entire disbursement at the beginning of that term. If you work through either the Federal Work-Study or the Caltech Work-Study program, you will be paid by check through the biweekly Caltech payroll system. Checks are normally distributed at your actual work site.

Since financial aid is generally awarded on the assumption of full-time enrollment, it is possible that some or all of your aid will need to be adjusted if your enrollment status results in a reduction in your tuition for a term. If you withdraw or drop below half-time enrollment after the last day for adding classes for a term, you may be required to repay all or a portion of the aid that has already been credited to your account. You must inform the Financial Aid Office if you take a leave of absence or change your enrollment subsequent to receiving your financial aid. Cal Grant recipients who take a leave of absence are advised to contact the California Student Aid Commission (www.csac.ca.gov) and submit a form to remain eligible for the program.

You have the right to cancel your loan(s) anytime before disbursement and up to 14 days after disbursement.

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 in the *Caltech Catalog*. 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 in the *Caltech Catalog*) 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 financial aid purposes, undergraduate students are classified according to the number of units earned and the number of terms

in 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.

Classification	*Minimum Units Earned*	*Minimum Terms in Residence*
Sophomore	108	3
Junior	216	6
Senior	324	9

Part-Time Enrollment (Underloads)
Underloads (undergraduate students taking less than 36 units in a term) must be approved by the registrar or the Undergraduate Academic Standards and Honors Committee. All students planning to carry an underload should contact the Financial Aid Office prior to taking less than a full-time course load.

PRIZES

Tom Apostol Award for Excellence in Teaching in Mathematics
In 2010, the mathematics option set up the Apostol Teaching Award named in honor of Tom Apostol, who was a great teacher at Caltech for over 50 years. The three to five awards are given each year to recognize excellence in teaching by mathematics graduate and undergraduate teaching assistants.

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 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. This prize is given at commencement.

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.

Amasa Bishop Summer Study Abroad Prize
This prize is awarded to one or more freshmen, sophomores, or juniors to fund summer study abroad in an organized program with the aim of gaining exposure to foreign language and international issues or cultures, including global issues in the sciences and engineering.

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 Student Life and Master's Award
Two or more awards, selected by the deans, the assistant vice president for student 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 $1,500 to a junior in the upper five percent of his or her class who shows outstanding promise for a creative professional career. The student is selected by the deans and 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 $1,500 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 deans and 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. This award is given at commencement.

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.

The George W. Housner Prize for Academic Excellence and Original Research
The George W. Housner prize is given annually to a senior in the upper 20 percent of his or her class who has demonstrated excellence in scholarship and in the preparation of an outstanding piece of original scientific research. The student is selected by the deans and the Undergraduate Academic Standards and Honors Committee. At the discretion of the dean, more than one award may be made in any year. The prize, presented at commencement, consists of a cash award and a certificate. This prize is made possible by a gift from George W. Housner, Carl F Braun Professor of Engineering, Emeritus.

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 $2,000 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.

Harry Leiter Memorial Mechanical Engineering Prize
Awarded to a candidate for the degree of Bachelor of Science in mechanical engineering who has demonstrated extraordinary creativity as judged by a faculty committee appointed each year by the executive officer for mechanical engineering. The prize consists of a citation and a cash award. This prize is made possible by a gift from Dr. Symme Leiter.

Lemelson-MIT Caltech Student Prize
The Lemelson-MIT Caltech Student Prize is awarded to a Caltech senior or graduate student who has created or improved a product or process, applied a technology in a new way, redesigned a system, or in other ways demonstrated remarkable inventiveness. Students gain invaluable exposure to the science, business, and investment communities through participation in this competition.

Library Friends' Senior Thesis Prize
This prize was established in 2010 to recognize senior theses that exemplify research and the effective use of library resources. An honorarium of $1,200 accompanies the citation. The thesis is an extensive, independent written work produced during the senior year, usually within a senior thesis course series. The university librarian and Library Friends oversee evaluation and make recommendations to the Undergraduate Academic Standards and Honors Committee for final selection. An oral presentation may be requested. At the discretion of the Library Friends, more than one award, or none, may be made in any year. This award is given at commencement.

Mari Peterson Ligocki (B.S.'81) Memorial Fund
This award is made to one student who, through his or her personal character, has improved the quality of student life at Caltech. It recognizes the student who provides quiet support and kind encouragement to peers. This fund was established by Mr. José F. Helú Jr. (B.S. '79) to honor the memory of Mari Peterson Ligocki, who possessed these qualities. The award consists of dinner for two at the recipient's choice of a fine restaurant, and a grant toward any project or cause of the recipient's choosing. It may be seed money for a project in any field, whether science-related or not.

Gordon McClure Memorial Communications Prize
This prize is awarded to undergraduate students for excellence in written and oral communication skills. Awards will be given in the following fields: English, history, and philosophy.

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 $1,000; second prize, $600; third prize, $400.

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.

San Pietro Travel Prize
This prize is awarded to one or more sophomores, juniors, or seniors to fund an adventurous and challenging summer experience that expands the recipient's cultural horizons and knowledge of the world.

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.

Renuka D. Sharma Prize and Award in Chemistry
This prize was established in 2009 by Prof. Brahama D. Sharma, in memory of his daughter Renuka D. Sharma, to be given to the sophomore who has demonstrated outstanding performance in chemistry during his or her freshman year. The prize, consisting of a cash award of $1,000, was donated to encourage scholastic achievement early in a student's career and is administered by the Division of Chemistry and Chemical Engineering.

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.

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."

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; must complete a minimum of 486 units (515 units for chemical engineering); and must achieve a grade-point aver-

age 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 core and option requirements for the B.S. degree are the ones stated in the catalog published in the first year of a student's continuous enrollment at Caltech, under normal circumstances. Changes to these requirements can occur due to actions and decisions made by the student's option, the registrar, the Curriculum Committee, or the Faculty Board. Students must complete the core requirements listed in the catalog published in the first year of a student's enrollment and cannot elect to fulfill the core requirements from a different later year. However, a student may elect to satisfy the option requirements stated in a catalog from a different later year 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 of this catalog.

Core Institute Requirements, All Options

A Caltech education requires not just the depth of an option, but also considerable breadth in basic science, humanities, and social science. Caltech's core curriculum prepares students for the interdisciplinary nature of contemporary research in science and technology. This encourages a culture of problem solving, collaboration, and communication while providing valuable experience in all fields of science. Significant study in the humanities and social sciences is an important component of Caltech's core curriculum, giving alumni the ability to navigate the societal, political, and economic factors that influence, and are influenced by, their work.

The following requirements are applicable to incoming freshmen for 2011–12 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.

Course	*Units*
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[1])	18
5. Freshman Chemistry (Ch 1 ab)	15
6. Freshman Biology (Bi 1 or Bi 1 x)[2]	9

7. Menu Class (currently Ay 1, Ch/APh 2, ESE 1, Ge 1, IST 1, or IST 4) 9
8. Freshman Chemistry Laboratory (Ch 3 a)[3] 6
9. Additional Introductory Laboratory 6
10. Scientific Writing[4] 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

[1] *Students taking Ph 12 a but not Ph 12 c must take one term in statistical physics or thermodynamics from the list: Ph 2 b, APh 17 a, Ch 21 c, Ch 24 b, or ME 18 a.*
[2] *Bi 8 or Bi 9 are acceptable alternatives to Bi 1 or Bi 1 x for students with a strong background in biology. Students who earned a 5 on the AP Biology exam may also petition the biology option representative to take a higher-level biology course of nine or more units to fulfill the biology core requirement.*
[3] *This requirement can also be met by completing Ch 3 x, Ch 4 a, Ch 8, or Ch/ChE 9.*
[4] *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.*

Menu Classes

Menu classes are specifically designed for breadth. The intent of the menu class requirement is to introduce students to a subject that they did not plan to study. In many cases, it is the only class in that subject that they ever take; in other cases, they may decide to take more classes in that subject as a result. Students cannot take a menu class in a subject that they have already taken classes in or in their current option. This requirement must be completed by the end of sophomore year.

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) or Ch 3 x (6 units) shall be taken during the freshman year. The additional 6 units must be chosen from one of the following: APh/EE 9 ab (6 units), APh 24 (6 units), Bi 10 (6 units), Ch 4 ab (9 units), Ch 8 (9 units), Ch/ChE 9 (9units), Ge 116 (6 units), Ph 3 (6 units), Ph 5 (9 units), Ph 8 bc (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, film, history, history and philosophy of science, humanities, music, and philosophy) and 36 in the social sciences (anthropology, business economics and management, 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. They may *not* include read-

ing 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 20 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 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. Other humanities courses numbered 30 or greater are open only to students who have fulfilled the freshman humanities requirement.

To encourage breadth, students will have to take their two freshman humanities classes in different disciplines, the disciplines 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 90 or above in art history, English, film, history, history and philosophy of science, humanities, music, and philosophy. Courses used to fulfill the advanced humanities requirement must be taken for grades. Courses taken on a pass/fail basis will not fulfill the requirement. While beginning, intermediate, and advanced language courses do not count toward the 36-unit humanities requirement, every term receives credit toward the final 36 units of the 108-unit requirement in HSS, except for courses in a student's native language.

Since writing is a crucial skill, all humanities courses, with the exception of some foreign languages and courses numbered between 29 and 90, 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 or En 2 before entering either freshman or advanced humanities classes.

Students are required to take two introductory social science courses and 18 units of related advanced undergraduate social science courses. Courses used to fulfill the advanced social science requirement must be taken for grades. Courses taken on a pass/fail basis will not fulfill the requirement. 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, Psy 16, 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 on the next page.

Introductory Course	*Following Course*
An 22 or 23	advanced anthropology
Ec 11	advanced economics or BEM (except BEM 101)
Law 33	advanced law
PS 12	advanced political science
Psy 15, 16, or 20	advanced psychology
SS 13	advanced economics or political science, or BEM (except BEM 101)

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 course work. 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.

Options	*Requirements*	
	Oral	*Written*
ACM, APh, BE, CS, EE, EAS, ME	E 10	E 11
Ay	Ay 30	Ay 31
Bi	Bi 24	same or CNS/Bi/Ph 107

BEM, Ec, PS	BEM/Ec/SS 20	same
ChE	ChE 126	Ch/ChE 91
Ch	Ch 90	Ch/ChE 91
CNS	E 10	E 11 or CNS/Bi/Ph 107
En, H, HPS, Pl	En 84	same
GPS	Ge 109	Ge 13
Ma	Ma 10	Ma 11
Ph	Ph 70	same or CNS/Bi/Ph 107

Typical First-Year Course Schedule, All Options

Differentiation into the various options begins in the second year.

		Units per term		
		1st	*2nd*	*3rd*
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	Principles of Biology	0	0	9
Ch 3 a	Fundamental Techniques of Experimenal Chemistry[1]	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[2]	x	x	x
	Menu course[3] or additional electives	x	x	x
PE	Physical education[4]	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. First- and second-term freshmen will be limited to 45 units of classroom and laboratory courses. 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.

[1] *This course is offered in each of the three terms. Students may also take Ch 3 x.*

[2] *The additional 6 units must be chosen from one of the following: APh/EE 9 ab (6 units), APh 24 (6 units), Bi 10 (6 units), Ch 4 ab (9 units), Ch 8 (9 units), Ch/ChE 9 (9 units), Ge 116 (6 units), Ph 3 (6 units), Ph 5 (9 units), Ph 8 bc (6 units) or a more advanced laboratory course.*

[3] *Students must take a menu course 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. Menu courses currently include Ay 1, Ch/APh 2, ESE 1, Ge 1, IST 1 or IST 4.*

[4] *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.*

Other First-Year Courses

In addition to the required core classes described on the previous pages, freshmen are encouraged to participate in freshman seminar classes, frontier classes, research tutorials and other research opportunities.

Starting in the 2011–12 academic year, Caltech will be offering a series of freshman seminars in which 10 to 15 freshmen and a faculty member explore in depth an exciting topic in the lab, around a table, or in the field. There will be nine offerings on a wide range of topics, including biomechanics, the Large Hadron Collider, and the physics of music. These courses can be found on page 469.

Caltech also offers a series of "frontier courses" that involve a weekly presentation by a faculty member on a topic of current research. These courses often meet at lunch time and serve pizza; hence, students often refer to the courses as "pizza courses." The frontier courses are an opportunity for students to meet the Caltech faculty and to hear about state-of-the-art research projects for the summer or academic year. There are a total of 10 frontier courses offered for freshmen in biology, chemistry, physics, geology and planetary sciences, engineering, computer science, applied and computational mathematics, chemical engineering, bioengineering, and electrical engineering.

Currently there are three "research tutorials" for freshmen: one in physics, one in biology, and one in chemistry. These tutorials have many of the same features as the freshman seminars. In physics, the research tutorial includes approximately seven freshmen and extends over three academic terms plus the summer. The purpose is to demonstrate how research opportunities arise, are evaluated, and are tested, and how the ideas that survive develop in larger projects. In biology and chemistry, the tutorials are offered in the winter and spring quarters and involve small group discussions on special areas or problems in biology, biotechnology, and chemistry.

More than 80 percent of Caltech students participate in research at some point in their academic career. Students may embark on research activities by registering for research credits with a faculty member, by working in a laboratory for pay during the summer or academic year, by completing a senior thesis, or by participating in Caltech's Summer Undergraduate Research Fellowship (SURF) program. The SURF program is described on page 28.

Aerospace Minor

The aerospace 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 aerospace or aeronautical engineering. Students completing the aerospace minor requirements will have the phrase "minor in aerospace engineering" added to their transcripts.

Ae Minor Requirements

1. Complete Ae 105 abc.
2. Complete a second three-term 100-level Ae class, chosen from Ae 101 abc, 102 abc, 103 abc, 104 abc, 121 abc, Ae/Ge/ME 160 ab, or 27 units of selected Ae courses approved by the minor adviser. All Ae courses to be applied to fulfill the aerospace minor requirements must be taken for grades, and students must obtain a grade of B or higher. Courses that are used to satisfy the aerospace minor cannot be used to satisfy course requirements in the major options. Courses taken as part of the aerospace minor are counted toward the total 486-unit Institute graduation requirements. A typical course sequence would be to take Ae 105 abc and the second Ae course in the senior year.

Applied and Computational Mathematics Option

The undergraduate option in applied and computational mathematics within the Computing & Mathematical Sciences department is for those students who want to combine their basic studies in mathematics with considerable involvement in applications. This program is designed to give students a thorough training in fundamental computational and applied mathematics and to develop their research ability in a specific application field. The fields of application include a wide range of areas such as fluid mechanics, materials science, and mathematical biology, engineering applications, image processing, and mathematical finance. The training essential for future careers in applied mathematics in academia, national laboratories, or in industry is provided, especially when combined with graduate work, by successful completion of the requirements for an undergraduate degree in applied and computational mathematics. 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 108 ab, ACM 104, ACM 95 abc, ACM 106 abc, and E 10.

2. An approved sequence of three one-quarter courses to be selected from the following: ACM 101, ACM 105, ACM 113, ACM 114, ACM 116, ACM/ESE 118, ACM 126 ab, ACM 201 ab, ACM 210 ab, ACM 216, ACM 217, Ae/ACM/ME 232 abc, ACM 270.
3. A three-term sequence from the following (or an option representative-approved three-term combination totaling at least 27 units): Ma 5 abc, Ma/CS 6 abc, Ma 109 abc, Ma 110 abc, Ma 120 abc, Ma 121 abc, EE/Ma 126 ab, EE/Ma/CS 127, CS/EE/Ma 129 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 486 units, including the courses listed above.

Typical Course Schedule

		Units per term		
Second Year		*1st*	*2nd*	*3rd*
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
ACM 11	Intro. to Matlab and Mathematica	6	-	-
	HSS electives	9	9	9
	Electives	-	9	27
		45	48	48
Third Year		*1st*	*2nd*	*3rd*
Ma 108 ab	Classical Analysis	9	9	
ACM 104	Linear Algebra and Applied Operator Theory	9		
ACM 106 abc	Intro. Methods of Comput. Math.	9	9	9
	HSS electives	9	9	9
	Electives[1]	9	18	27
		45	45	45
Fourth Year		*1st*	*2nd*	*3rd*
	HSS electives	9	9	9
	Electives[1]	36	27	27
		45	36	36

[1] *See items 2, 3, and 4 under option requirements.*

Applied Physics Option

The applied physics option is designed to extend knowledge of the principles of pure physics to applications pertinent to applied physics or engineering. Research in applied physics typically centers on problems of technological concern. 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. The interdisciplinary nature of this 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 the dynamics of pure electron plasmas. Transport in fluids spans processes at low and high Reynolds numbers, including micro/nanofluidic, optofluidic, or biofluidic devices, optical trapping in fluids, dissipation behavior in cantilever arrays, pattern formation and phase separation in thin-films or bulk layers, cellular, pulmonary, ocular, or cardiovascular flows, thin-film patterned growth by chemical vapor deposition and etching, convection-diffusive problems, aeronautical flows, combustion, etc.

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.

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

1. E 10 and E 11. E 11 can be satisfied by three units of additional work associated with the senior thesis (APh 78 or 79), or by taking En 84 or Ph 70.
2. Any three of the following: APh/EE 9 b, APh 24, Ph 3, Ph 5, Ph 6, or Ph 7.
3. APh 17 abc, Ph 106 abc, and Ph 125 ab or Ch 125 ab.
4. ACM 95 abc.
5. Either APh 78 abc, or one term of APh 77 and one term of any of the following: APh 77, Ph 77, EE 91, Ch 6, Ae/APh 104 bc, and MS 90. Any substitutions or additions require prior approval of the option representative.
6. One additional three-term sequence of APh courses numbered over 100, which must include one of the following complete sequences: APh 101 abc, 105 abc, 114 abc, APh/Ph 115 and

APh/Ph/Ae 116, APh/EE 130, 131, and 132, APh 156 abc, 161, 162 plus additional one-term course, APh/EE 183, or APh 190 abc. Note that APh 100 and APh 200 do not satisfy this requirement. Any substitutions or additions require prior approval of the option representative.

7. Passing grades must be earned in a total of 486 units, including the courses listed above. No course in fulfillment of option requirements may be taken on a pass/fail basis.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ph 2 ab	Sophomore Physics	9	9	0
Ma 2 ab	Sophomore Mathematics	9	9	0
	HSS electives	9	9	9
	Laboratory electives[1]	6	6	6
APh 17 abc	Thermodynamics	9	9	9
	Other electives	9	9	27
		51	51	51
Third Year				
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[2]	18	18	27
		50	50	50
Fourth Year				
APh 78 abc	Senior Thesis, Experimental[3]	9	9	9
or				
APh 77	Laboratory in Applied Physics[3]	-	9	9
Ph 106 abc	Topics in Classical Physics	9	9	9
	Electives[2]	9	9	9
	HSS electives	9	9	9
	Other electives	18	9	9
		54	54	54

[1] *See item 2, option requirements.*
[2] *See item 6, option requirements.*
[3] *See item 5, option requirements.*

Suggested Electives

Students are encouraged to obtain a well-rounded course of study pursuant to the B.S. degree in applied physics. The option representative and/or undergraduate adviser will gladly assist students in choosing appropriate elective courses. Students ultimately interested in pursuing an advanced degree in applied physics or related fields are encouraged to complete a senior thesis project through APh 78 or 79.

Astrophysics Option

With the goal of understanding the physical processes that govern the universe, its constituents, and their origins and evolution, astronomy uses the apparatus and methodology of physics to gather and interpret data. Theoretical work and technology development round out astrophysics. In what follows, we use the terms "astronomy" and "astrophysics" interchangeably.

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

1. Ay 20, 21, 101, 102, 30 or 141, 31, Ph 125 ab, and Ph 106 abc.
2. 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.
3. 63 additional units of Ay or Ph courses.
4. 27 additional units of science or engineering electives, of which 18 must be outside the Division of Physics, Mathematics and Astronomy. Core classes (see pages 181–182) or other introductory-level courses such as CS 1 do not count toward fulfillment of this requirement.
5. Passing grades must be earned in a total of 486 units, including the courses listed above. Courses satisfying requirements 1, 2, and 3 must be taken for grades unless they are pass/fail only.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ph 12 abc	Sophomore Physics	9	9	9
or				
Ph 2 ab and Ph lab				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ay 20	Basic Astronomy and the Galaxy	10	-	-
Ay 21	Galaxies and Cosmology	-	9	-
Ay 30	Intro. to Modern Research	-	3	-
	Physics Laboratory	-	-	9
ACM 95 abc	Intro. Methods of App. Math.	12	12	12
	HSS electives	9	9	9
		49	51	36

Third Year				
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	-	-	10
	HSS electives	9	9	9
	Astronomy, physics, or APh electives	9–12	9–15	9–15
		47–50	36–42	46–52
Fourth Year				
Ay 31	Written Communication	-	-	3
Ay 102	Physics of the Interstellar Medium	-	9	-
	Astronomy, physics, or APh electives	9	9	9
Ay 78	Senior Thesis	9	9	9
	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, Ay 117, Ay 190, ACM 106, or equivalent classes.

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 104, Ay 105, Ay 117, Ay 121–127, Ay 190, Ch 125, EE 45, EE 91, EE/Ae 157, Ge/Ay 11 c, Ge 103, Ge/Ch 128, Ge 131, Ge/Ay 132, 133, 137, Ma 4, Ma 112, ME 18 ab, ME 19 ab, Ph 20–22, Ph 77, 101, 127, 129, 136, 199 (this is not necessarily a complete list).

Bioengineering Option

The undergraduate bioengineering option provides a foundation for graduate studies in the application of engineering principles to the design, analysis, construction, and manipulation of biological systems, and in the discovery and application of new engineering principles inspired by the properties of biological systems. Course work emphasizes the fundamentals of biological circuit design at the molecular, cellular, and multicellular levels, addressing both the physical and information-processing aspects of biological circuits. Undergraduate research is encouraged both during the academic year and through participation in summer research programs.

Students should present a plan for satisfying all degree requirements to their academic adviser by the end of the third term of the second year. Students with a grade-point average lower than 1.9 will not be allowed to continue in the option except with special permission from the option representative.

Option Requirements

1. BE 1; BE 159; BE/APh 161; ChE/BE 163; BE/CS/CNS/Bi 191 a.
2. Experimental methods: Bi 1 x; BE/EE 189 a; ChE 130.
3. Biology and chemistry: Bi 8; Bi 9; Ch 25; Ch 41 a; Bi/Ch 110. One advanced biology course selected from Bi/Ch 111, Bi/Ch 113, Bi 114, Bi 117, Bi 122, Bi 145 ab, Bi/CNS 150, Bi 250 c. Students may pass out of Bi 8 and Bi 9 via placement exams administered by the biology option.
4. Mathematical and computational methods: ACM 95 abc; CDS 110 a or ChE 105; 9 units selected from CS 1, CS 2, CS 3.
5. 36 units of BE electives (selected from the elective lists below or approved by the student's academic adviser).
6. Communication: E 10; E 11.
7. Courses satisfying option requirements must be taken for grades (except when courses are only available P/F) and passed with a grade of C– or higher. Passing grades must be earned in a total of 486 units.

BE Electives

BE 98, BE 141, BE/Bi 152, BE 153, BE 157, BE/APh 162, Bi/CNS 162, Bi/BE 177, Bi 180, BE/APh/Ph 181, BE/EE 189 b, BE/CS/CNS/Bi 191 b, EE/BE 166, EE/BE 185, Bi/BE 227, Ae/BE 242, BE/Ae 243.

Other Relevant BE-Approved Electives

Biodevices: EE 112, EE 113, EE 114 ab, APh/EE 9 ab, EE 45, EE 111, EE 151

Biomechanics: ME 19 ab, ME 35 abc, ME 71, Ae/APh/CE/ME 101 abc, Ae/APh/CE/ME 102 abc, Ae/APh 104 abc

Synthetic biology: BE 150, CS 21, Ch 24, ChE/Ch 148, ChE/Ch 164, ChE/Ch 165

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
First Year				
Ma 1 abc	Freshman Mathematics	9	9	9
Ph 1 abc	Freshman Physics	9	9	9
Ch 1 ab	General Chemistry	6	9	-
Ch 3 a	Fundamental Techniques of Experimental Chemistry	6	-	-

Bi 1 x	The Great Ideas of Biology: An Introduction Through Experimentation	-	-	9
BE 1	Frontiers in Bioengineering	-	1	-
	Introductory HSS courses	9	9	9
	Physical education	-	-	3
		30	37	39

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
Ch 41 a	Organic Chemistry	9	-	-
Ch 25	Introduction to Biophysical Chemistry	-	-	9
Bi 8	Introduction to Molecular Biology	-	9	-
Bi 9	Cell Biology	-	-	9
	Menu course	-	-	9
	General and BE electives	x	x	x
	HSS electives	x	x	x
	Physical education	x	x	x
		42–45	42–45	42–45

		Units per term		
		1st	*2nd*	*3rd*
Third Year				
ACM 95 abc	Introductory Methods of Applied Mathematics	12	12	12
Bi/Ch 110	Introduction to Biochemistry	12	-	-
ChE/BE 163	Introduction to Biomolecular Engineering	9	-	-
	Computational methods requirement	x	x	x
	General and BE electives	x	x	x
E 10	Technical seminar presentations	x	x	x
	HSS electives	x	x	x
	Physical education	x	x	x
ChE 130	Biomolecular Engineering Laboratory	-	-	9
		42–45	42–45	42–45

		Units per term		
		1st	*2nd*	*3rd*
Fourth Year				
CDS 110 a *or* ChE 105	Introductory Control Theory *or* Dynamics and Control of Chemical Systems	x	-	x
BE/APh 161	Physical Biology of the Cell	-	12	-
BE/EE 189 a	Design and Construction of Biodevices	12	-	-
BE/CS/-CNS/Bi 191 a	Biomolecular Computation	-	9	-

BE 159	Signal Transduction and Biomechanics in Eukaryotic Cell Morphogenesis	-	-	9
	General and BE Electives	x	x	x
	Advanced biology and biology lab requirements	x	x	x
E11	Written Technical Communication in Engineering and Applied Science	x	x	x
	HSS electives	x	x	x
	Physical education	x	x	x
		42–45	42–45	42–45

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 at the Career Development Center or Professor David Chan in the Division of Biology.

Option Requirements

1. Bi 8, Bi 9, Bi 117, Bi 122, Bi/CNS 150, and Ch 41 abc.
2. One advanced laboratory course chosen from Bi 123, Bi/CNS 162, Bi 180, Bi 227, or at least 12 units of independent research such as Bi 22.
3. Two courses chosen from Bi/Ch 110, 111, 113, and/or Bi/Ch 132.
4. Scientific writing requirement met by taking Bi 24 (six units), or by taking any other writing course such as En 84 or Ge 13 (three units) plus oral presentation at SURF Seminar Day or equivalent, with option representative approval.
5. None of the courses satisfying requirements 1–4 may be taken pass/fail, except Bi 22 and Bi 180.
6. A total of 146 units of biology must be taken and passed (Bi 1, Bi 2, and Bi 10 cannot be counted toward this total), including at least 6 additional bio classes which satisfy the following:
   a. Distribution requirement: These additional courses must be drawn from at least two of the following course "tracks" defined below.
   b. At least four of these additional courses (including courses drawn from at least two tracks) must be taken for letter grades.
   c. At least two of these additional graded courses (from different tracks) must be for at least nine units.
7. Passing grades must be earned in a total of 486 units, including the courses listed above.

Biology Tracks

Individual classes may be relevant to more than one track, but classes cannot be double-counted toward the distribution requirement. Courses included in the general option requirements that provide logical background for these tracks are indicated in parentheses; however, these cannot be counted toward the distribution requirement.

a. Biochemistry and molecular biology
   (Bi 8, Bi 9)
   Bi/Ch 110, 111, 113, 132 (if not taken to satisfy item 3; no double-counting)
   Bi 129, BMB/Bi/Ch 170 abc, Bi 189, Bi/Ch 206, Bi/Ch 211
   Note: Ch 24 and Ch 7 or Ch 145 are also recommended for students interested in this track.
b. Genetics
   (Bi 8, Bi 115, Bi 122)
   Bi 123, 129, 180, 188, 190, 206

Microbial biology subtrack: ESE/Bi 166, ESE/Bi 168 with Bi 180

c. Developmental biology and evolution
(Bi 117, Bi 122)
Bi 123, Bi/CNS 157, Bi/CNS 158, Bi 182, 188, 190, 204, 214

d. Neurobiology
(Bi/CNS/Psy 150)
Bi 152, 156, 157, 162, 186, 202, 216, 217, 218, Bi/CNS 184, Bi/CNS 220, CNS/Bi 176, Ph/Bi 103 b
Behavior/psychology subcluster: CNS/SS/Psy/Bi 102 ab, CNS/Bi/Psy 120, 131, Bi/CNS 220, Bi 152, Bi 156, 176, 216, 217, CNS/Bi 256

e. Computational and systems biology
(Bi/CNS/Psy 150)
Ay/Bi 199, Bi/CNS 184, Bi/CNS 220, CNS/Bi/SS/Psy 176, CNS/Bi/EE/CS 186, CNS/Bi/Ph/CS 187, BE/CS/CNS/Bi 191 ab, CNS/Bi 221, CNS/Bi 247, CNS/Bi 256
CS programming courses are highly recommended for those interested in this track.

f. Organismal
Bi 114, 115, 129, 145 ab, 146, 157, 158, 188, 202, 214, 215

g. Cell biology
(Bi 9)
Bi 113 if not taken to satisfy requirement item 3, 115, 129
Bi 145 ab, 189, 215

h. Interdisciplinary, technology approaches
BE/CS/CNS/Bi 191, Bi 177, 206, 227

Planning the Biology Course Schedule

Course requirements for biology are designed to be met by students taking Bi 8 and Bi 9 starting in their second year. However, many students interested in biology elect to take these courses in their first year.

Students may place out of the option requirement to take Bi 8 or Bi 9 by passing an exam and then earning a passing grade in Bi/Ch 111 or Bi/Ch 113, respectively, instead. The exam for placing out of Bi 8 and Bi 9 is given in the fall term of freshman year and is open to students who have scored a 5 on the advanced placement exam in biology, or who have an unusually strong background in biology, e.g., substantial research experience.

Bi 10 is not required for the biology option but is commonly taken by biology students to meet the Institute introductory laboratory requirement.

Bi 123 is not required but is recommended for students planning to take any additional courses in genetics.

Prerequisites listed for individual biology courses are advisory, not compulsory. They indicate the kind of background that is assumed for the work level of the course. In general they may be waived with the instructor's permission.

Ch 24 and Ch 25 are 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.

Additional courses of potential interest to biology majors include Ge 11 b, BE/APh 161, BE 163, and advanced geobiology courses.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
	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	-	9	-
Bi 9	Cell Biology	-	-	9
Bi 10	Cell Biology Laboratory	-	-	6
	Electives	9–15	0–6	9–18
		45–51	45–51	42–51
Third Year				
	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	-	12	-
Ch 24, 25	Introduction to Biophysical Chemistry	-	9	9
	Electives	15–21	15–21	27–33
		45–51	54–60	45–51
Fourth Year				
	HSS electives	9	9	9
Bi 24	Technical Communication	6	-	-
Bi/CNS 150	Neurobiology	10	-	-
	Electives	23–26	36–42	36–42
		48–51	45–51	45–51

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. For more information, go to http://www.hss.caltech.edu/ss.

Option Requirements

1. Ec 11, PS/Ec 172, BEM/Ec/SS 20 (or a similar writing/oral presentation course), BEM 101, Law 33.
2. BEM 103, BEM 104, and BEM 105.
3. ACM/ESE 118 or Ec 122.
4. Five courses, to be chosen from the menu (may be taken pass/fail): BEM courses (excluding the ones listed under [1] and [2] above), Ec 105, 106, 116, 121 ab, 122, 123, 129, 130, 132, 135, 145, 155, Ec/PS 160 abc, PS 12, PS/Ec 173, Psy 20, ACM 113, ACM 116, Ma 112 a, Law 133, 134, 135. Other courses with permission of BEM option representative.
5. 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 (may be taken pass/fail).
6. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
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	-	-
PS/Ec 172	Noncooperative Games	-	-	9
	Electives[1]	-	27	27
		45	45	45
Third Year				
BEM 103	Introduction to Finance	9	-	-
BEM 104		-	9	-
BEM 105	Options	-	9	-
ACM/ ESE 118	Methods in Applied Statistics and Data Analysis	9	-	-
	Electives[1]	27	27	45
		45	45	45
Fourth Year				
BEM/Ec/SS 20	Scientific Writing	-	6	-
	Electives[1]	45	39	45
		45	45	45

[1] *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. This is accomplished by providing 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 an understanding of the importance of continuing intellectual growth.

Chemical engineering involves applications of chemistry, physics, mathematics, and, increasingly, biology and biochemistry. In addition to these disciplines, 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, pharmaceuticals, hydrocarbon fuels, and petrochemicals); in other process industries; or in the biotechnology, pharmaceutical, 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 such as biofuels, fuel cells, and solar energy conversion technologies. Air and water pollution control and abatement and the study of climate change, its impacts, and its mitigation 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.

Key educational objectives of our chemical engineering curriculum are to prepare students for professional practice at the forefront of chemical engineering or for graduate school, and to become leaders in engineering, science, academia, business, and public service in a continually changing world. To do this, the curriculum focuses on developing an ability to synthesize and apply knowledge from the many subjects studied to the design of systems, components, processes, or experiments, subject to technical, economic, environmental, and/or social constraints. Problems

illustrating the design process are integrated into the core courses. The senior laboratories integrate design with the construction and experimental evaluation of a system, process, or component.

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 take the sophomore chemistry labs (Ch 3 a [or Ch 3 x] and Ch/ChE 9). They also take the second-year organic chemistry course (Ch 41 abc) and the basic chemical engineering courses (ChE 62 and ChE 63 ab), and applied and computational mathematics (ACM 95 abc). It is strongly recommended that they also take a course in computer programming (e.g., CS 1, CS 11, or ACM 11).

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 junior and senior years, students diversify into one of four tracks (biomolecular, environmental, materials, or process systems), where they pursue concentrated study in their chosen area of chemical engineering. An optional senior thesis provides an opportunity to pursue independent research and design in lieu of one of the senior laboratories.

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

1. Ch/ChE 9, Ch 21 a[1], Ch 21 b[1] (or Ch 24)[1], Ch 41 abc, ChE 62, ChE 63 ab, Ch/ChE 91 (or En 84), ACM 95 abc, ChE 101, ChE 103 abc, ChE 105, ChE 126, three science/engineering electives (two if ChE 90 ab is selected), and one of Ec 11, BEM 101, or BEM 103[2].
2. Completion of a track (biomolecular, environmental, process systems, or materials), each consisting of eight science or engineering courses (72 units). Students should inform the executive officer of their track choice by the beginning of the spring quarter of the sophomore year by providing a planned schedule for completion of all degree requirements. Requirements for the tracks are as follows.

   a. Biomolecular track: ChE/BE 163, Bi/Ch 110, [ChE 130 or ChE 90 ab], and five additional bioengineering or biochemical engineering electives (45 units). ChE 118 and/or ChE 120 may be elected provided the design project undertaken contains a significant biological component.

   b. Environmental track: two of the core ESE courses [ESE 101, 102, and 103], [ChE 128 or ChE 90 ab], five additional ESE or

related courses (45 units). ChE 118 and/or ChE 120 may be elected provided the design project undertaken contains a significant environmental component.

c. Process systems track: ChE 118, ChE 120, [ChE 128 or ChE 90 ab], five engineering electives (45 units).

d. Materials track: ChE 128 or ChE 90 ab; one course on materials synthesis or processing selected from Ch/ChE 147[3], ChE 115[3], or MS 133; at least one course on the physical basis of structure and properties selected from Ch 120, ChE/Ch 148[3], MS 115 ab, MS/APh 120, MS/APh 122, or MS 131; and five additional chemical engineering or materials science elective courses (45 units) selected from ChE 118, ChE 120, ChE/Ch 155[3], ChE/Ch 164, ChE/Ch 165, or any MS course.

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.
4. Passing grades must be earned in a total of 515 units, including courses listed above.

[1] May be taken in junior or senior year.
[2] These 9 units partially satisfy the Institute requirements in humanities and social sciences.
[3] Given in alternate years.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
Ch/ChE 9	Chemical Synthesis and Characterization for Chemical Engineering	-	-	9
Ch 41 abc	Organic Chemistry	9	9	9
ChE 62	Separation Processes	9	-	-
ChE 63 ab	Chemical Engineering Thermodynamics	-	9	9
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	HSS electives	-	-	9
		48	48	48
Third Year				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
ChE 103 abc	Transport Phenomena	9	9	9
ChE 101	Chemical Reaction Engineering	-	9	-
ChE 105	Dynamics and Control of Chemical Systems	-	-	9
Ch/ChE 91	Scientific Writing	-	-	3
	ChE, Ch, track courses, and electives[1]	18	9	-
Ec 11, BEM 101, or BEM 103		9	-	-
	HSS electives	9	9	18
		45	39	45

Fourth Year

ChE 126	Chemical Engineering Lab	9	-	-
	ChE, Ch, track courses, and electives[1]	36	36	18
Ch 21 ab[2]	Physical Chemistry	9	9	-
	Electives	-	9	18
		45	45	36

[1] See option requirements.
[2] Ch 24 a can be substituted for Ch 21 b.

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. To satisfy the Institute chemistry requirement, students may substitute at least two terms from Ch 21 ab or Ch 24 or Ch 41 ab for Ch 1 ab only after passing the chemistry placement exam. Exceptions will be granted only by petition to the chemistry curriculum and undergraduate studies committee. Students who did not pass the placement exam may take Ch 1 and Ch 41 simultaneously, but Ch 1 ab must be passed to satisfy the Institute chemistry requirement. 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 4 a, Ch 8, or Ch/ChE 9 for the core requirement of Ch 3 a. Freshmen intending to major in chemistry are encouraged to take Ch 10 abc, which provides an introduction to research activities and opportunities in chemistry for undergraduates.

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 Chemistry Curriculum and Undergraduate Studies Committee. The chemistry option representative should be consulted for the future scheduling of courses not offered during the current academic year.

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, Ch 24, and Ch 41 ab.

Senior Thesis

Students attempting a senior thesis in the chemistry option must complete the following requirements.

1. Three terms (27 units) of Ch 82 are to be completed during the junior and/or senior year of study; continued work from research experiences prior to the commencement of the senior thesis is encouraged.
2. At the time of registering for the first term of Ch 82, the candidate will submit a short (five-page) proposal delineating his/her project for approval by the research mentor and the Chemistry Curriculum and Undergraduate Studies Committee (CUSC).
3. The candidate will present a short progress report (maximum of five pages) at the end of each of the first two terms of Ch 82, describing the current status of the research work and any results obtained. Upon evidence of satisfactory effort, the student will be allowed to continue his/her senior thesis.
4. A thesis of approximately 20 pages (excluding figures and references) will be presented to the mentor and the CUSC at the end of the third term of Ch 82. An oral thesis defense will be arranged by the CUSC. The thesis must be approved by both the research mentor and the CUSC.
5. Upon approval by the research mentor and the CUSC, the Ch 91 requirement for graduation may be satisfied by the written thesis and the progress reports from the first two quarters of Ch 82. If the thesis is being completed during the spring quarter of the senior year, a draft of the thesis is to be submitted by Add Day.

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

1. Ch 14 (or ESE 142), Ch 21 abc (or Ch 21 a, Ch 24, and Ch 25), Ch 41 abc, Ch 90.
2. 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.
3. A minimum of five terms of advanced chemistry electives (which must total at least 45 units) taken for a letter grade from chemistry course offerings at the 100 and 200 level, including cross-listed offerings, but excluding Ch 180 and Ch 280.
4. 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.
5. Passing grades must be earned in a total of 486 units, including courses listed above.[1]

[1] *No more than 27 units of Ch 80 will count toward the 486-unit requirement.*

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
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	9
Ch 14	Chemical Equilibrium and Analysis	-	-	6
	Electives	18-21	9–12	21-24
		45–48	45–48	45–48
Third Year				
Ch 5 a or	Advanced Techniques of Synthesis and Analysis	-	12	-
Ch 5 b		9	-	-
Ch 15	Chemical Equilibrium and Analysis Laboratory	10	-	-
Ch 21 abc or	Physical Chemistry	9	9	9
Ch 21 a, Ch 24, Ch 25				
Ch 90	Oral Presentation	-	3	-
Ch/ChE 91	Scientific Writing	-	-	3
	Electives	17-29	21-36	33-36
		45–48	45–48	45–48
Fourth Year				
Ch 6 a or	Physical and Biophys. Chemistry Lab	-	10	-
Ch 6 b or		-	-	10

Ch 7	Advanced Experim. Methods in Bioorganic Chemistry	-	-	9
	Electives	45–48	35–48	26–48
		45–48	45–48	45–48

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

	Second Year	*Third Year*	*Fourth Year*
Inorganic Chemistry	Ch 4 ab, Ch 5 a, Ch 41 abc, Ch 102, Ma 2 ab, Ph 2 ab, HSS elective, other elective	Ch 5 b, Ch 14, Ch 21 abc, Ch elective(s), Ch laboratory, Ch 80, Ch 90, Ch/ChE 91, HSS elective	Ch 6 a or 6 b, Ch electives, Ch 80, HSS elective
Chemical Physics	Ch 4 ab, Ch 21 abc, Ch 6 ab, Ch 14, Ma 2 ab, Ph 2 ab, HSS elective	Ch laboratory, Ch 41 abc, Ch elective(s), Ch 80, Ch 90, ACM 95 abc, Ch/ChE 91, HSS elective	Ch 125 abc, Ch electives, Ch 80, HSS elective
Organic Chemistry	Ch 4 ab, 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), Ch laboratory, Ch 80, Ch 90, Ch/ChE 91, HSS elective	Ch 6 a or Ch 6 b, Ch electives, Ch 80, HSS elective
Biochemistry	Ch 4 ab, Bi 10, Ch 41 abc, Bi 9, Ma 2 ab, Ph 2 ab, HSS elective	Ch laboratory, Ch 7, Ch 14, Ch 21 a, Ch 24, Ch 25 (or Ch 21 bc), Ch 80 (or Bi 22), Ch 90, Ch/ChE 91, Bi/Ch 110, Bi/Ch 111, Bi/Ch 113, Bi 10, HSS elective	Ch 6 a or 6 b, Ch (Bi) electives, Ch 80 (or Bi 22), HSS elective

Computer Science Option

Study in the computer science option within the Computing & Mathematical Sciences department emphasizes rigor and creativity, and is good preparation either for graduate study followed by a research career, or for a variety of professional or entrepreneurial occupations.

The option introduces students to the mathematical and engineering foundations of the discipline. It 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 may be helpful for this purpose).

Any student in 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; CS 4; 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. An undergraduate thesis (CS 80 abc) supervised by a CS faculty member.
   b. A project in computer science, mentored by the student's academic adviser or a sponsoring faculty member. The sequence must extend at least two quarters and total at least 18 units of CS 81 abc.
   c. Any of the following three-quarter sequences involving a large project in their last quarter. Each of the sequences is expected to be available yearly, with the exception of sequence vi.
      i. Databases: CS 121, CS 122, CS 123.
      ii. VLSI: Either of the three-term sequences CS/EE 181 abc or CS 185 abc.
      iii. Networking & Distributed Systems: Either CS 141 c or CS/EE 145 combined with two courses chosen from CS 141 ab, CS/EE 143, and CS/EE 144.
      iv. Learning & Vision: At least three courses chosen from EE/CNS/CS 148 ab, CS/CNS/EE 154, 155, 156 ab, 159, CNS/Bi/EE/CS 186, CNS/Bi/Ph/CS 187, including at least one of 156 b, 148 b, and 159.
      v. Graphics: CS/CNS 174 and two other CS 17 x courses.
      vi. Information & Complexity: CS/EE/Ma 129 abc.
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 EAS or Ma; and 9 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

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
CS 1	Intro. to Computer Programming[1]	9	-	-
CS 2	Intro. to Programming Methods[1]	-	9	-
CS 4	Fundamentals of Computer Program.	-	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
	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
	EAS/Ma courses	9	9	9
	Other electives	9	9	-
		45	45	39
Fourth Year				
	CS courses	9	-	-
	HSS electives	9	18	9
	EAS/Ma courses	9	9	9
	Other electives	18	9	18
		45	36	36

[1] *Commonly taken during the freshman year.*

Control and Dynamical Systems Minor

Control and dynamical systems (CDS) may be pursued as a minor concentration by undergraduates who are taking degrees in science, mathematics, or engineering. The CDS minor is intended to supplement one of Caltech's normal 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 minor requirements below in CDS will have the phrase "minor in control and dynamical systems" added to their transcripts and their graduating degree materials.

CDS Minor Requirements

1. Complete CDS 110 a and CDS 140 a.
2. Complete nine additional units in CDS courses, chosen from CDS 110 b, 140 b, or 150.
3. Complete a three-term senior thesis approved by the CDS faculty.

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. The senior thesis requirement may be satisfied by completing a three-term senior thesis in the student's major option but on CDS subject matter, with the 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 EAS options where this 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 units needed for Institute graduation requirements.

A typical course sequence would be to take either CDS 110 a or CDS 140 a in the junior year, followed by the remaining courses 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, law, or economics.

The option is sufficiently flexible that students can combine their pursuit of economics with studies in engineering, mathematics, or science. The core of the option consists of an economic theory component, a data analysis component, an applied microeconomic component, and a macroeconomic/growth component. Students are strongly encouraged to supplement this core with additional electives in economics, political science, and mathematics.

Option Requirements

1. Ec 11 and BEM/Ec/SS 20.
2. Theory: Ec 121 ab and PS/Ec 172.
3. Data analysis: one of Ma 112 a or ACM/ESE 118, followed by Ec 122.
4. Applied microeconomics: one of Ec 105, BEM/Ec 118, or 145.

5. Macroeconomics and growth: one of Ec 123, Ec/SS 129, 130, or Ec 140.
6. 45 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 this requirement.) 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. Students who take both Ma 112 a and ACM 118 may count one of them under requirement 3 and the other one for this requirement.
7. 45 additional units of advanced science, social science, mathematics, and engineering courses. The requirement cannot be satisfied by any course with a number less than 100.
8. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
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[1]	18	27	27
		45	45	45
Third Year				
Ec 105	Industrial Organization	-	9	-
Ec 121 ab	Theory of Value	9	9	-
PS/Ec 172	Game Theory	-	-	9
Ec 122	Econometrics	9	-	-
Ec 123	Macroeconomics	-	-	9
Ma 112 a	Statistics	9	-	-
	Electives[1]	18	27	27
		45	45	45
Fourth Year				
BEM/Ec/SS 20	Scientific Writing	-	6	-
	Electives[1]	45	39	45
		45	45	45

[1] *See option requirements 5 and 6.*

Electrical Engineering Option

The main objective of the electrical engineering (EE) program is to prepare its students for either graduate study or research and development work in government or industrial laboratories. This

objective is consistent with the Institute's mission since 1921 (as quoted on page 10). It accomplishes this by building on the core curriculum to provide a broad and rigorous exposure to the fundamentals (e.g., math, science, and engineering) of electrical engineering. EE's other program objectives are multiple. The program strives to maintain a balance between classroom lectures and laboratory and design experience, and it emphasizes the problem-formulation, system-design, and solving skills that are essential to any engineering discipline. The program also strives to develop in each student self-reliance, creativity, teamwork ability, professional ethics, communication skills, and an appreciation of the importance of contemporary issues and lifelong intellectual growth.

Students electing this option will normally choose to take APh/EE 9 ab as a freshman-year elective and the introductory seminar EE 1. The formal study of electrical engineering begins in the sophomore year with circuits and systems, EE 44; digital electronics, EE/CS 51, 52; semiconductor sensors and actuators, EE 40; the theory and laboratory practice of analog circuits, EE 45; and then a course on feedback control systems, EE 113 or CDS 110 a. The junior year features the fundamentals of signals and systems and digital signal processing, EE 111; probability and random processes, ACM/EE 116; an introduction to analog and digital communications, EE 160; electromagnetic engineering, EE 151; and an analog electronics laboratory, EE 90. In the senior year, the student will be asked to demonstrate his or her ability to formulate and carry out a design project through independent research or either a senior thesis, EE 80 abc, or two courses selected from the senior project design laboratory, EE 91 ab, EE/CS 53, and CS/EE/ME 75 c. 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 214.)

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.

Double Majors

The electrical engineering option allows interested students to declare electrical engineering as one of the majors in a double major pursuit. To enroll in the program, the student should meet and discuss his/her plans with the option representative. In general, approval is contingent on good acadamic performance by the stu-

dent and demonstrated ability for handling the heavier course load. For students simultaneously pursuing a degree in a second option, courses taken as required courses for that option can also be counted as EE electives where appropriate. However, courses that count toward the electives requirement in the other option cannot be simultaneously counted toward satisfying the elective requirement in EE. To qualify for an EE degree, the student would need to complete all option requirements.

Option Requirements

1. EE 1, APh/EE 9 ab, E 10, E 11, EE 40, 44, 45, EE/CS 51, 52, EE 90, 111, 151, and 160.
2. ACM 95 ab, ACM/EE 116.
3. EE 113 or CDS 110 a.
4. One term of EE 91.
5. EE 80 abc, or a sequence consisting of CS/EE 143, 144, 145, or a sequence consisting of BE/EE 189 ab, or one course selected from an additional term of EE 91, EE/CS 53, EE 119 c, and CS/EE/ME 75 c (note that CS/EE/ME 75 ab does not satisfy this requirement).
6. 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.
7. Passing grades must be earned in a total of 486 units, including courses listed above.

Typical Course Schedule[1]

		Units per term		
		1st	*2nd*	*3rd*
Second Year – Schedule 1				
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives[1]	9	9	9
EE 40	Introduction to Semiconductors and Sensors	-	-	9
EE 44	Circuits and Systems	9	-	-
EE 45	Electronics Laboratory	-	12	-
EE 113	Feedback and Control Systems	-	-	12
EE/CS 51	Principles of Microprocessor Systems	12	-	-
EE/CS 52	Microprocessor Systems Laboratory	-	12	-
	Electives	-	-	9
		48	51	39
Second Year – Schedule 2				
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives	9	9	9
EE 40	Introduction to Semiconductors and Sensors	-	-	9
EE 44	Circuits and Systems	9	-	-
EE 45	Electronics Laboratory	-	12	-

EE 113	Feedback and Control Circuits	-	-	12
ACM 95 ab	Intro. Methods of Applied Math.	12	12	-
	Electives	-	-	9
		48	51	39

Third Year – Schedule 1

E 10	Technical Seminar Presentations	3	-	-
E 11	Written Technical Communication	-	3	-
ACM 95 ab	Intro. Methods of Applied Math.	12	12	-
	HSS electives[1]	9	9	9
ACM/EE 116	Intro. to Stochastic Processes	9	-	-
EE 151	Electromagnetic Engineering	-	9	-
EE 111	Signals, Systems, and Transforms	9	-	-
EE 90	Analog Electronics Project Lab	-	-	9
EE 160	Communication-System Fundamentals	-	9	-
	Electives	-	-	18
		42	42	36

Third Year – Schedule 2

E 10	Technical Seminar Presentation	3	-	-
E 11	Written Technical Communication	-	3	-
EE/CS 51	Principles of Microprocessor Systems	12	-	-
EE/CS 52	Microprocessor Systems Laboratory	-	12	-
	HSS electives	9	9	9
ACM/EE 116	Intro. to Stochastic Processes	9	-	-
EE 151	Electromagnetic Engineering	-	9	-
EE 111	Signals, Systems, and Transforms	9	-	-
EE 90	Analog Electronics Project Lab	-	-	9
EE 160	Communication-System Fundamentals	-	9	-
	Electives	-	-	18
		42	42	36

Fourth Year (for project)

	HSS electives[1]	9	9	9
EE 91 ab[2]	Experimental Projects in Electronic Circuits	12	-	-
	EE electives	9	9	9
	Electives	9	18	18
		39	36	36

Fourth Year (for thesis)

	HSS electives[1]	9	9	9
EE 91 ab[2]	Experimental Projects in Electronic Circuits	12	-	-
EE 80	Senior Thesis	9	9	9
	EE electives	9	9	9
	Electives	3	9	9
		42	36	36

[1] *See Institute requirements for specific rules regarding humanities and social sciences.*
[2] *See option requirements 4 and 5.*

Suggested Electives
First-year students interested in electrical engineering should take 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.

Bioengineering
Second Year: Bi 9, Bi 10, APh 17 abc.
Third and Fourth Year: Bi/Ch 110, Bi/Ch 113, BE 141, EE/BE 166, EE/BE 185, CNS/Bi/EE/CS 186, CNS/CS/EE 188, BE/EE 189 ab.

Communications and Signal Processing
Second Year: Selected from APh 17 abc, APh 23, APh 24, EE/CS 53.
Third and Fourth Year: EE 112, EE/Ma 126 ab, 127 ab, EE 128 ab, 161, 163 ab, 164, 167, EE/APh 131, APh/EE 130, 132, Ma 112 a.

Control
Second Year: APh 17 abc.
Third and Fourth Year: CDS 110 ab, and selections from EE 112, EE 128 ab, EE 164.

Electronic Circuits
Second Year: EE 113, CDS 101, APh/EE 183.
Third and Fourth Year: EE 114 ab, 124, 125, 153, EE 119 abc, CS/EE 181 abc, and selections from EE 112, CS 185 abc, EE/APh 180, EE 119, EE 160, EE 128 ab.

Microwave and Radio Engineering
Second Year: APh 23, APh 24, APh 17 abc.
Third and Fourth Year: EE 153, EE/Ae 157 ab, EE 114 ab, EE/APh 131, APh/EE 130, 132, APh/EE 183.

Optoelectronics
Second Year: APh 23, APh 24, APh 17 abc.
Third and Fourth Year: APh/EE 130, 132, APh 105 abc, APh 114 abc, APh/EE 183, APh 190 abc, EE/APh 131, EE 153.

Solid-State Electronics and Devices
Second Year: APh 17 abc.
Third and Fourth Year: APh/EE 183, and selections from APh 105 abc, APh 114 ab, EE 153, EE/BE 185, EE 187.

Engineering and Applied Science Option

The engineering and applied science (EAS) option offers students the opportunity for study in a wide variety of challenging areas of science and technology and includes concentrations in computation and neural systems, environmental science and engineering,

and materials science. In addition, the EAS 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 EAS 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, culminating in a capstone 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 EAS option are assigned advisers as close to their expressed field of interest as possible, and together with their advisers they develop programs of study for the next three years. Beyond the Institute-wide requirements of physics, mathematics, and humanities, the EAS 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 EAS 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 EAS option.

Option Requirements

Students who have elected the EAS 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 EAS 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 EAS 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 EAS 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/CNS 171, 173, and 174, EE 45, EE/CS 52, 53, 54, EE 90, EE 91 ab, ESE 159, MS 90, MS 125, ME 72 ab, ME 90 bc, ME 96;

and

b. 9 units of additional laboratory courses either from the list in 3 a or from EAS 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: computation and neural systems, environmental science and engineering, and materials science,

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 capstone design project, such as, but not restricted to, EE 80 abc, 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 EAS 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 EAS 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 EAS option listed on their transcript.)

7. At least 117 units of EAS courses not including those used to satisfy requirements 3, 4, and 5 above. Concentrations marked with a dagger (†) in the list below include sufficient EAS 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 EAS courses to bring the total to 117 units. Courses in ChE count toward this requirement.
8. All concentrations and the customized schedule of requirements described in 6 b shall include a major design experience.
9. Passing grades must be earned in at least 486 units, including those listed in requirements 1–8 above.

Discipline Concentration Requirements (to satisfy requirements 6 a and 8 above)

*Computation and Neural Systems**
CNS 100, Bi/CNS 150, CNS/Bi/Ph/CS 187, CNS/Bi/EE/CS 186, CNS/CS/EE 188 (or IST 4), EE 111, CDS 101, Bi 8 (or Bi 9). CS 2 is required in addition to CS 1 for the CNS concentration. In addition, the laboratory course Bi/CNS 162 is required. The project for CNS/Bi/EE/CS 186 shall be organized as a design project drawing on the ensemble of CNS disciplines.

Environmental Science and Engineering†
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 101, ESE 102, 130–138, ESE/Ge 139, or ChE/ESE 158), and environmental biology (ESE 103, ESE/Bi 166, or ESE/Bi 168); ESE 90 (senior thesis), 18 units.
ESE 159 satisfies requirement 8. Substitution of courses may be approved at the discretion of the concentration representative, provided they meet the overall EAS requirements.

Materials Science†
APh 17 ab or ChE 63 ab or ME 18 ab, MS 115 ab, MS 90, and three terms of MS 78 (senior thesis, which includes a major design experience). 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, APh/EE 183, Ch 120 ab, Ch 121 ab, Ch 125 abc, Ch/ChE 147, ChE/Ch 148, CS 11, Ge 114 ab, MS 105, MS/APh 120, 122, MS 125, 131, 133, 142, Ph 125 abc. Substitution of courses may be approved at the discretion of the concentration representative, provided they meet the overall EAS requirements.

Typical Course Schedules

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
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
Third Year				
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

Fourth Year				
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.

Computation and Neural Systems

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

[1] *Offered biannually.*

Environmental Science and Engineering

	First Term	*Second Term*	*Third Term*
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

	First Term	*Second Term*	*Third Term*
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/APh 120	MS 78 b E 10	MS 78 c MS 133

English Option and Minor

The option in English provides students with a broad education in English and American literatures, their historical contexts, and different approaches to their study. 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. This paper provides the most important means for evaluating a major's progress in the rigorous study of English. The English option provides excellent preparation for students seeking careers in law, business, administration, and medicine. The emphasis on writing critical essays helps scientists and engineers develop the communication skills necessary for success in their fields.

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. All courses to be counted toward the option in English must be taken for grades except for a freshman humanities course in English when taken in the first two quarters of the freshman year.

Option Requirements

1. En 99 ab.
2. 81 additional units of English courses numbered 99 and above. 27 of these units must include one course in British literature, one course in American literature, and one course in literature before 1850 (En 114, 116, 122, 125, 129). Courses cannot be counted twice in meeting these distribution requirements. Up to nine units of Hum/En 5, Hum/En 6, or Hum/En 7 and/or up to nine units of En 98 may be substituted for up to 18 of the remaining 54 English units. Students may also substitute courses in foreign literature (in the original or in translation) and/or, with authorization of the adviser, related humanities courses numbered above 99, for up to 18 of the remaining 54 English 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. Passing grades must be earned in a total of 486 units, including the courses listed above.

English Minor Requirements

The English minor is designed for students who want to pursue concentrated study in English and/or American literature, without the extensive course work and the senior thesis required by the English option.

English minors must take 72 units of English courses. These units may include one freshman humanities course; they may also include one directed reading course (En 98). Students wishing to do a minor in English must declare a minor with the English option representative. All courses to be counted toward the option in English must be taken for grades except for a freshman humanities course in English when taken in the first two quarters of the freshman year. Students completing the English minor requirements will have the phrase "minor in English" added to their transcripts.

1. 72 units of English courses numbered 99 or above.
2. Nine units of Hum/En 5, Hum/En 6, or Hum/En 7 may be substituted for any nine of the 72 units required for the minor.
3. Nine units of En 98 may be substituted for any nine of the 72 units required for the minor.

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 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 important 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 the biology or the GPS division. 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 geochemistry, geophysics, and planetary science options within two years, but there are benefits from starting with the Ge 11 sequence in the sophomore year. Because Ge 120 ab may not be offered every year, students in the geology option may also need to take Ge 106 and Ge 120 a in spring term of their sophomore year in order to prepare for Ge 120 b the following summer.

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.

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 Ge electives where appropriate. However, courses that count toward the electives requirement in the other option cannot simultaneously be counted toward satisfying the elective requirement in GPS.

Option Requirements

Geology Option Requirements

1. Ge 11 ab, Ge/Ay 11 c or Ge 11 d, Ge 13, 109.
2. ACM 95 abc or a full-year chemistry sequence (Ch 41 abc or Ch 21 abc) and either Ge 108 or ACM/ESE 118.
3. Ge 106, 112, 114 ab, 115 abc, 120 ab.
4. Ge 116 and 111 ab; or Ge 125 and Ge 11 d[1].
5. 15 units of elective courses in Ge or cross-listed with Ge.

[1] If Ge 11 d is used to satisfy requirement 4, students must take Ge/Ay 11 c to satisfy requirement 1.

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ge 11 abc	Intro. to Earth and Planetary Sciences	9	9	9
Ge 13	Scientific Writing	-	-	3
Ge 109	Oral Presentation	-	-	3
Ge 106	Intro. to Structural Geology	-	-	9
Ge 120 a	Field Geology Intro.[1]	-	-	6

Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives	9	9	9
		36	36	39
Summer				
Ge 120 b	Field Geology Camp[1]	-	-	18
Third Year				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
Ge 112	Sedimentology and Stratigraphy	12	-	-
Ge 114 ab	Mineralogy	12	-	-
Ge 115 abc	Petrology and Petrography	-	6	12
Option 1:				
Ge 111 ab	Applied Geophysics	-	6	9
and Ge 116	Analytical Techniques	-	6	-
	HSS electives	9	9	9
		45	39–27	42–33
Fourth Year				
Option 2:				
Ge 125	Geomorphology	12	-	-
and Ge 11d	Geophysics	-	9	-
	Geology electives	9	-	6
	HSS electives	9	9	9
		18–30	9–18	15

[1] *Ge 120 ab is taught in alternate years. Some cohorts of students will take this course in their third year and the summer following.*

Geobiology Option Requirements

1. Ge 11 ab, Ge/Ay 11 c, Ge 13, 109.
2. Ch 41 abc and Bi/Ch 110.
3. Bi 8–10, 117, 122, ESE/Bi 166, Ge 114 a, Ge/ESE 170, Ge 112.
4. 9 units of geobiology electives from the following list: Bi 123, 180, Ch 4 ab, 5 ab, 15, Ge 121 ab.
5. 27 units of geobiology electives in geology, biology, chemistry, and/or environmental engineering to be chosen in consultation with adviser from the list in 4 (above) or from the following list: Ge 11 d, 40, 41 abc, 100 abc, 106, 114 b, 115 abc, 116, 120 ab, 121 ab, 124 ab, 140, 142, Ge/ESE 149, Ge/Bi 244, 246, BMB/Bi/Ch 170, Bi 22, 24, 90 abc, Bi/Ch 111, 113, Bi 115, 123, Bi/CNS 150, Bi 152, Bi/CNS 158, Bi 180, 182, 188, 190, 204, Bi/CNS 216, ESE 142, ESE 101–103, 152, ESE/Ge/Ch 171, 172, 175, Ch 4 ab, 5 ab, 7, 14, 15, 21 abc, 24, 25, 112, 145, 146, 154 ab, 212; Occidental College Ge 365.

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ge 11 abc	Intro. to Earth and Planetary Sci.	9	9	9
Ge 13	Scientific Writing	-	-	3
Ge 109	Oral Presentation	-	-	3

Bi 8	Introduction to Molecular Biology	-	9	-
Bi 9	Cell Biology	-	-	9
Bi 10	Cell Biology Laboratory	-	-	6
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives	9	9	9
		36	45	39
Third Year				
ESE/Bi 166	Microbial Physiology	9	-	-
Ge 114 a	Mineralogy	9	-	-
Ch 41 abc	Organic Chemistry	9	9	9
Ge/ESE 170	Microbial Ecology	-	-	9
	HSS electives	9	9	9
	Geobiology electives	9	9	9
		45	27	36
Fourth Year				
Bi/Ch 110	Intro. to Biochemistry	12	-	-
Bi 117	Developmental Biology	-	9	-
Bi 122	Genetics	9	-	-
Ge 112	Sedimentology and Stratigraphy	12	-	-
	HSS electives	9	9	9
	Geobiology electives	-	9	18
		42	27	27

Geochemistry Option Requirements

1. Ge 11 ab and either Ge/Ay 11 c or Ge 11 d, Ge 13, Ge 109.
2. ACM 95 abc or (Ch 41 abc and ACM/ESE 118) or (Ch 21 abc and ACM/ESE 118).
3. Geochemistry students must take a total of 105 units from the core geochemistry list and the geochemistry elective list, including at least three courses from the core geochemistry list[1]. Core geochemistry: Ge 114 ab[2], 140, Ch 41 a, 21 a, ESE/Ge/Ch 171, Ge/ESE 149, Ge 116. Geochemistry electives: Ch 41 bc, 21 bc, 4 ab, 6 ab, 8, 14, 15, 102, Ch/ChE 9, ChE 63 ab, ESE 142, Ge/ESE 143, ESE 103, Ge/ESE 154, ESE 159, ESE/Ge/Ch 172, 175, Ge 106, 115 abc, 120 ab, 127, 128, 132, 191, 212, 214, 215, 232, 236, Ge/Ay 133, APh 17 abc, MS 105, 115 ab, 125, 130–133.

[1] Any units from either Ch 41 or Ch 21 that are used to satisfy requirement 2 may not be used to satisfy requirement 3.
[2] Students must take both Ge 114 a and Ge 114 b to count as one core geochemistry course.

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ge 11 abc	Intro. to Earth and Planetary Sci.	9	9	9
Ge 13	Scientific Writing	-	-	3
Ge 109	Oral Presentation	-	-	3

	Geochemistry core or electives	9	9	9
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives	9	9	9
		45	45	33
Third Year				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	HSS electives	9	9	9
	Geochemistry core or electives	18	18	18
		39	39	39
Fourth Year				
	HSS electives	9	9	9
	Geochemistry electives	9	9	9
		18	18	18

Geophysics Option Requirements

1. Ge 11 ab, Ge/Ay 11 c, Ge 13, 109.
2. ACM 95 abc.
3. Ge 111 ab, Ge 11 d.
4. 27 units of physics or mechanics electives: any non-GPS course numbered 100 or greater, relevant to the option and approved by the option representative, including ME 65, 66, AM 125 abc, Ae/Ge/ME 160, Ph 106 abc.
5. 36 units of geophysics electives (selected in consultation with adviser): Ge 161–168, Ge 211, 200-level courses.

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ge 11 abc	Intro. to Earth and Planetary Sciences	9	9	9
Ge 13	Scientific Writing	-	-	3
Ge 109	Oral Presentation	-	-	3
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives	9	9	9
		36	36	24
Third Year				
	Physics or mechanics electives	9	9	9
	HSS electives	9	9	9
Ge 111 ab	Applied Geophysics Seminar	-	6	9
Ge 11 d	Geophysics	-	9	-
		18	33	27
Fourth Year				
	Geophysics electives	18	18	9
	HSS electives	9	9	9
		27	27	18

Planetary Science Option Requirements

1. Ge 11 ab, Ge/Ay 11 c, Ge 13, 109.
2. ACM 95 abc.
3. 27 units of advanced science courses selected from Ae/APh/CE/ME 101 abc, Ae/Ge/ME 160 ab, Ch 21 abc, Ph 101, 106 abc, 125 abc, which must include two consecutive terms of one of the multiterm courses.
4. 63 units selected from Ge 11 d, 102, Ge/Ch 128, Ge 131, Ge/Ay 132, Ge/Ay 133, ESE 101–103, Ge 150, 151, ESE 130, ESE/Ge 139.
5. 27 units of additional science and engineering courses (selected in consultation with adviser and planetary science option representative), appropriate Ge courses, any of the courses listed above, or any of the following: ACM 101, ACM/ESE 118, ME 35 abc, APh 17 abc, Ay 20, 21, 101, 102, ChE 63 ab, Ch 6 ab, CS 1–3, Ma 112 ab, ME 18 ab, 19 ab, 65, 66, AM 125 abc.

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ge 11 abc	Intro. to Earth and Planetary Sci.	9	9	9
Ge 13	Scientific Writing	-	-	3
Ge 109	Oral Presentation	-	-	3
Ph 2 ab	Sophomore Physics	9	9	-
Ma 2 ab	Sophomore Mathematics	9	9	-
	HSS electives	9	9	9
		36	36	24
Third Year				
ACM 95 abc	Intro. Methods of Applied Math.	12	12	12
	HSS electives	9	9	9
	Advanced science	9	9	9
	Planetary science	18	9	9
		48	39	39
Fourth Year				
	HSS electives	9	9	9
	Planetary science	9	9	9
	Additional science and engineering	9	9	9
		27	27	27

GPS Minor Requirements

The GPS minor is intended for non-GPS undergraduates to supplement a major degree with knowledge of earth and planetary science. Students completing the GPS minor will have the phrase "minor in Geological and Planetary Sciences" added to their transcript. Any student interested in a minor in GPS is urged to contact any option representative in the division.

1. Ge 11 a and Ge 11 b.
2. One of Ge 11 c or Ge 11 d.
3. 27 units of 100-level or higher GPS courses, excluding Ge 108 and Ge 109.

History Option and Minor

The history option allows students to study past societies and their development in more depth than can be done within the limits of the Institute humanities requirements. With the guidance of a faculty member in history, students taking the option explore the range of human experience, in the realms of politics, culture, religion, and economics, that lies outside the realm of science and technology. They also learn the critical reading and thinking skills, and the facility in writing, that are central to the historical enterprise. The history option thus provides students with an important supplement to the scientific training and technical skills they acquire in other courses and options. In addition, it offers excellent preparation for careers in business, administration, law, journalism, or public affairs, as well as a solid foundation for graduate work in history.

History majors must take at least 99 units of history courses (including freshman humanities) during their four years as undergraduates. Of these, 27 must be in the senior tutorial (H 99 abc). All courses to be counted toward the history option must be taken for grades except for a freshman humanities course in history when taken in the first two quarters of the freshman year.

Each history major will choose an area of concentration in consultation with his or her adviser and the history option representative. These areas might include, but are not restricted to, fields such as ancient history, medieval Europe, early-modern Europe, modern Europe, Russian history, American history pre-1865, American history post-1865, early-modern history of science, modern history of science, or economic history. He or she must take 63 units of courses in this area; 27 of these units must be in the senior tutorial H 99 abc. The senior tutorial will culminate in a research paper.

Each student must take the remaining 36 units of history required by the option in areas other than the area of concentration, again defined in consultation with his or her adviser and the history option representative. These areas may include not only fields within the discipline of history proper, but also useful cognate fields such as economics, political science, anthropology, law, English, or a foreign language.

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, 3, or 4. 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, 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. At the beginning of the senior year, a history major will enroll in H 99 abc with a faculty member in his or her area of concentration. The first term of this course will be devoted to preparation, the second to research, and the third to the writing of a substantial research paper.

Option Requirements

1. H 99 abc.
2. 72 additional units of history courses numbered 99 or above. Up to nine units of Hum/H 1, 2, 3, or 4 and/or up to nine units of H 98 may be substituted for up to 18 of these units.
3. 63 of the total history units, including H 99 abc, must be in an area of concentration, as defined in consultation with the student's adviser and the history option representative.
4. 36 of the total history units must be in an area or areas other than the area of concentration, as defined in consultation with the student's adviser and the history option representative. H 99 abc may not be used to fulfill this requirement.
5. 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 menu courses.
6. Three units of oral communication. En 84 satisfies this requirement, as do oral communication courses offered by other options.
7. Passing grades must be earned in a total of 486 units, including the courses listed above.

History Minor Requirements

The history minor is designed for students who want to pursue concentrated study in history without the extensive course work and the senior thesis required by the history option.

History minors must take 72 units of history courses. These units may include one freshman humanities course; they may also include one directed reading course (H 98). All courses to be counted toward the history minor must be taken for grades except for a freshman humanities course in history when taken in the first two quarters of the freshman year. Students wishing to do a minor in history must declare a minor with the history option representative. Students completing the history minor requirements will have the phrase "minor in history" added to their transcripts.

1. 72 units of history courses numbered 99 or above.
2. Nine units of Hum/H 1, 2, 3, or 4 may be substituted for any nine of the 72 units required for the minor.
3. Nine units of H 98 may be substituted for any nine of the 72 units required for the minor.

History and Philosophy of Science Option and Minor

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 the 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/Pl 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 98 or higher (see note 2).
3. Three advanced courses in philosophy of science, chosen from HPS/Pl offerings with a course number of 98 or higher (see note 2).
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. 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. No more than nine units of HPS 98 may be counted toward the HPS major.

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/Pl 120 as early as possible in that year.

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
Ma 2 ab	Sophomore Mathematics	9	9	-
Ph 2 ab	Sophomore Physics	9	9	-
HPS 10[1]	Introduction to History of Science	9	-	-
HPS/Pl 120[1]	Introduction to Philosophy of Science	-	9	-
	Advanced HPS/history	-	-	9
HPS 103	Public Lecture Series	1	1	1
	Menu course	-	-	9
Ec 11	Introductory Social Science			
or PS 12		9	-	-
	Other electives	9	18	27
		46	46	46
Third Year				
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[2]	9	-	-
	Other electives	18	18	18
		46	46	46
Fourth Year				
HPS 103	Public Lecture Series	1	1	1
HPS 102 ab[3]	Senior Research Seminar	-	12	12
	Advanced social science[2]	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.*

[1] *If not taken in first year; otherwise one additional HPS or elective.*

[2] *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).*

[3] *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.*

History and Philosophy of Science Minor Requirements

The minor in history and philosophy of science (HPS) is designed for students who want to pursue concentrated study in HPS

without the extensive course work and the senior thesis required by the HPS option.

HPS minors must complete 72 units of HPS courses. These may include Hum/H/HPS 10 and up to nine units of advanced reading in HPS (HPS 98). Freshman humanities courses other than Hum/H/HPS 10 may not be counted toward an HPS minor. Students wishing to do a minor in HPS must declare a minor with the HPS option representative. Those completing the HPS minor requirements will have the phrase "minor in history and philosophy of science" added to their transcripts.

1. 72 units of HPS courses numbered 99 or above.
2. Nine units of HPS 98 may be substituted for any nine of the 72 units required for the minor.
3. Nine units of Hum/H/HPS 10 may be substituted for any nine of the 72 units required for the minor.

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. Passing grades must be earned in a total of 486 units.
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 very well in mathematics courses in their freshman and sophomore years, they should not contemplate specializing 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, statistics, 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 to become 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. Unlike courses satisfying requirements 4 and 5, which may be taken pass/fail, none of the courses satisfying requirements 1–3 may be taken on a pass/fail basis.
7. 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*
Second Year				
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[1]	9	9	27
		45	45	45
Third Year				
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[1]	18	27	18
		48	45	45
Fourth Year				
Ma 109 abc	Introduction to Geometry and Topology	9	9	9
	HSS electives	9	9	9
	Electives[1]	27	27	27
		45	45	45

[1] *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 objective of the undergraduate program in mechanical engineering at Caltech is to prepare and inspire students for careers that lead to top positions in academia, industry, and government in areas related to fluid, solid, thermal, and mechanical systems. Specifically, the objective is to prepare students for graduate school and for professional practice in an era of rapidly advancing interdisciplinary technology.

To attain these objectives, the program builds on Caltech's 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 problem-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. For interested students, there are opportunities to conduct research with a faculty member.

The outcomes of the undergraduate program are to prepare the student to build on a fundamental education in physics, mathematics, chemistry, and biology and to apply those principles to the solution of open-ended engineering problems; to design, analyze, measure, and evaluate fluid, thermal, and mechanical systems; to work effectively as part of a team; to communicate effectively; to apply ethical considerations; and to understand the broader implications of engineering developments, including societal, cultural, and environmental impacts.

The mechanical engineering option is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202–4012, (410) 347-7700.

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.
3. 9 units from ACM 11, CS 1, CS 2, CS 11, EE/CS 51, Ph 20–22.
4. ME 35 abc, 18 ab, 19 ab, 71, 170, ME 65 or MS 115 b, and CDS 110 a.
5. 9 units of ME 96 and 9 units of additional engineering laboratory[1] (such as CS/EE/ME 75 abc, MS 90, ME 72 b), 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/CE 151 ab, CS/EE/ME 75 abc, CDS 110 b, CDS 140, EE/BE 185, E/ME 103, E/ME 105, EST/EE/ME 109 ab, ME 20, 66, 72 a (only if ME 72 b is completed), 90 abc, 91 abc, 115 ab, 118, 119 ab, MS 115 a, 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 ab, 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.
8. Units fulfilling requirements 5, 6, and 7 need not be unique. For example, E/ME 105 fulfills requirement 7 *and* counts as 9 units towards requirement 6, and ME 72 ab fulfills requirement 7 *and* counts as 9 units towards each of requirements 5 and 6.
9. None of the courses satisfying requirements 1 through 7 may be taken pass/fail, unless they are only offered pass/fail.
10. Passing grades must be earned in a total of 486 units, including courses listed above.

[1] *Excluding courses for which freshman laboratory credit is allowed.*

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
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
		36	45	45

Third Year				
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
E 10	Technical Seminar Presentation	3	-	-
E 11	Written Technical Communication	3	-	-
		36	39	39
Fourth Year				
ME 65	Mechanics of Materials	9	-	-
CDS 110 a	Introductory Control Theory	12	-	-
ME 96	Mechanical Engineering Lab	-	-	9
	HSS electives	9	9	9
	ME electives	9	9	-
	Electives	9	18	18
		48	36	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 and Minor

The philosophy option provides students with a broad education in philosophy. The courses in the philosophy option concentrate in four major areas: philosophy of science; philosophy of mind, brain, and behavior; history of philosophy; and moral and political philosophy. The option is designed to complement the scientific curriculum at Caltech, to provide students with new perspectives on the material they learn in their science courses, and to enable them to bring their technical skills and scientific learning to traditional problems in philosophy. In addition, the philosophy option focuses on the development of rigor in argument, as well as clarity in written and oral communication.The philosophy curriculum will provide interested students with a solid foundation for graduate work in philosophy. In addition, the analytical and communication skills learned in the philosophy option provide an excellent foundation for careers in law, business, medicine, and scientific research.

Philosophy majors must take at least 99 units of philosophy courses during their four years as undergraduates. These must include 18 units of Pl 90 ab, to be taken in any two consecutive terms in the senior year. The 99 units may include nine units of

either Hum/Pl 8 or Hum/Pl 9, nine units of Pl 98, and up to 18 units of study in related disciplines.

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/Pl 8 or Hum/Pl 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 Pl 90 ab in the senior year. Students in Pl 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. Pl 90 ab.
2. 63 units of advanced philosophy courses, numbered 99 or above. (Up to nine units of Hum/Pl 8 or Hum/Pl 9 and/or up to nine units of Pl 98 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 toward 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. Passing grades must be earned in a total of 486 units, including the courses listed above.

Philosophy Minor Requirements
The minor in philosophy is designed for students who want to pursue concentrated study in philosophy without the extensive course work and the senior thesis required by the philosophy option.

Philosophy minors must complete 72 units of philosophy courses. These units may include nine units of Hum/Pl 8 or Hum/Pl 9 and/or nine units of reading in philosophy (Pl 98). Students wishing to do a minor in philosophy must declare a minor with the philosophy option representative. Students completing the philosophy minor requirements will have the phrase "minor in philosophy" added to their transcripts.

1. 72 units of philosophy courses numbered 99 or above.
2. Nine units of Pl 98 may be substituted for any nine units of the 72 required for the minor.
3. Nine units of either Hum/Pl 8 or Hum/Pl 9 (not both) may be substituted for any nine units of the 72 required for the minor.

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[1] or APh 24.
3. Ph 7.

4. 27 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.[2]
6. Ph 106.
7. Ph 125.

[1] *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.*
[2] *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, Ma 5, Ma 108, up to 12 units of Ph 20–22, or up to 10 units of Ay 20–21. Nine 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. Nine 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

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
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	-	-	9
		45	48	48
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

Political Science Option

The political science option provides students with training in the substance and methods of modern political science, including the analysis of representative democracy, electoral institutions, the allocation of public goods, and regulatory behavior. The option emphasizes formal tools like game theory, social choice theory, and formal political theory along with quantitative methodologies to test those theories. In addition, the option encourages original research. The design of the political science option ensures that students will be well suited to pursue careers in government or the private sector, as well as to pursue graduate work in political science.

Option Requirements

1. PS 12, PS 132, Ec 122.
2. Four political science courses from the list: PS 120, 123, 126, 130, 135, PS/SS 139, PS 141, Law/PS/H 148 ab, PS/Ec 172.
3. PS 99 ab.
4. 36 additional units in advanced political science, economics, law, social science, psychology, or history.
5. 36 additional units in advanced social science, science, engineering, or mathematics.
6. Passing grades must be earned in a total of 486 units, including all courses used to satisfy the above requirements.

Typical Course Schedule

		Units per term		
		1st	*2nd*	*3rd*
Second Year				
PS 12	Introduction to Political Science	9	-	-
PS 132	Formal Theories in Political Science	-	9	-
Ec 122	Econometrics	-	9	-
	Electives	36	27	45
		45	45	45
Third Year				
	Political science electives[1]	18	18	18
	Electives	27	27	27
		45	45	45

Fourth Year				
PS 99 ab	Research in Political Science	-	9	9
	Political science electives[1]	18	18	18
	Electives	27	18	18
		45	45	45

[1] *See option requirements 2, 4, 5.*

Structural Mechanics Minor

This 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, especially for those who wish to join the structural engineering profession after graduation or pursue a graduate degree in structural mechanics or structural engineering. Students completing the structural mechanics minor requirements will have the phrase "minor in structural mechanics" added to their academic transcripts.

Minor Requirements

The student must complete 54 units of classes selected from Ae/AM/CE 102 abc, AM/CE 151 ab, and CE 160 ab, and obtain a grade of B– or higher. Courses taken as part of the structural mechanics minor are counted toward the total 486-unit Institute graduation requirement.