NanoEngineering (NANO)

PROFESSORS

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Sadik C. Esener, Ph.D., *NanoEngineering and Electrical and Computer Engineering*
Eric Fullerton, Ph.D., *Electrical and Computer Engineering and NanoEngineering*
Michael J. Heller, Ph.D., *NanoEngineering and BioEngineering*
Sungho Jin, Ph.D., *Mechanical and Aerospace Engineering and NanoEngineering*
Marc A. Meyers, Ph.D., *Mechanical and Aerospace Engineering and NanoEngineering*
Jan B. Talbot, Ph.D., *NanoEngineering*
Joseph Wang, Ph.D., *NanoEngineering*
Kenneth S. Vecchio, Ph.D., Chair, *NanoEngineering*

ASSOCIATE PROFESSOR

Richard K. Herz, Ph.D., *NanoEngineering*

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Donald J. Sirbuly, Ph.D., *NanoEngineering*
Andrea R. Tao, Ph.D., *NanoEngineering*
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Prab Bandaru, Ph.D., *Associate Professor, Mechanical and Aerospace Engineering*
Karen Christman, Ph.D., *Assistant Professor, Bioengineering*
Seth M. Cohen, Ph.D., *Associate Professor, Chemistry and Biochemistry*
Marye Anne Fox, Ph.D., *Chancellor, Professor, Chemistry and Biochemistry*
Andrew C. Kummel, Ph.D., *Professor, Chemistry and Biochemistry*
Yu-Hwa Lo, Ph.D., *Professor, Electrical and Computer Engineering*
Michael J. Sailor, Ph.D., *Professor, Chemistry and Biochemistry*
Gabriel A. Silva, Ph.D., *Assistant Professor, Bioengineering*
Shankar Subramanian, Ph.D., *Professor, Bioengineering*
William R. Trogler, Ph.D., *Professor, Chemistry and Biochemistry*
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James K. Whitesell, Ph.D., *Professor, Chemistry and Biochemistry*
Paul Yu, Ph.D., *Professor, Electrical and Computer Engineering*

PROFESSIONAL RESEARCH STAFF

Min-Chieh Chuang
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CHEMICAL ENGINEERING PROGRAM (CENG)

Student Affairs: 2802 Atkinson Hall, Warren College

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David A. Gough, Ph.D., *Bioengineering*
Miroslav Krstic, Ph.D., *MAE*
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BUSINESS AFFAIRS:
2803 Atkinson Hall, Warren College

STUDENT AFFAIRS:
2802 Atkinson Hall, Warren College

http://nanoengineering.ucsd.edu

DEPARTMENTAL FOCUS

The Department of NanoEngineering focuses on nanoscale science, engineering, and technology that have the potential to make valuable advances in different areas that include, to name a few, new materials, biology and medicine, energy conversion, sensors, and environmental remediation. Nanoengineering is a highly diversified and multidisciplinary field. The graduate research programs cover a broad range of topics, but focus particularly on biomedical nanotechnology, nanotechnologies for energy conversion and storage, computational nanotechnology, and molecular and nanomaterials. Undergraduate degree programs focus on integrating the various science and engineering disciplines necessary for successful careers in the evolving nanotechnology industry.

DEGREE AND PROGRAM OPTIONS

The Department of NanoEngineering offers undergraduate programs leading to the **B.S. degrees** in **NanoEngineering** and **Chemical Engineering**. The Chemical Engineering Program is accredited by the Engineering Accreditation Commission of the Accreditation Board of Engineering and Technology (ABET/EAC). The Nanoengineering Program is newly introduced, but the program is designed using ABET accreditation criteria; the department will apply for accreditation once there are graduates to measure the program outcomes. These two degree programs have very different requirements and are described in separate sections.

NANOENGINEERING PROGRAM (NANO)

PROGRAM MISSION AND OBJECTIVES

The mission of the Nanoengineering Program is to provide a multidisciplinary education in nanoscale science and technology. The primary goals are

- Prepare students for a career in nanotechnology by providing them with a sound grounding in multidisciplinary areas of nanoscale science and engineering.
- Increase students' understanding of materials and their properties at the atomic and nanometer scales, including an understanding of the intimate relationship between the scale and the properties of materials. This is referred to as the third dimension in the periodic table, where elements, and combinations thereof, have properties and functions that depend on the material dimension, spanning from the nanoscale to macroscale.
- Prepare graduates who, while skilled in nanoscale science and engineering, will be qualified for jobs in traditional science-based industries and government laboratories and, as nanotechnologies mature, well positioned for jobs in this applied area. This program will be anticipating trends and providing students with integrated, cross-disciplinary scientific knowledge and professional skills.
- Educate a new generation of engineers who can participate in, and indeed seed, new high-technology companies that will be the key to maintaining jobs, wealth, and educational infrastructures as nanotechnology results in a new industrial revolution.
- Enable students to develop a range of professional, scientific, and computational skills that will enhance employment opportunities in a wide range of industrial and governmental institutions.
- Prepare students for the workplace through developing their ability to have effective communication skills, modern science and engineering skills, and contribute constructively

to multidisciplinary teams.

- Form strong multidisciplinary educational links through joint team projects that cross the traditional areas of science and engineering.

THE UNDERGRADUATE PROGRAM

The B.S. program in NanoEngineering is tailored to provide breadth and flexibility by taking advantage of the strength of basic sciences and other engineering disciplines at UC San Diego. The intention is to graduate nanoengineers who are multidisciplinary and can work in a broad spectrum of industries.

All NANO courses are taught only once per year, and courses are scheduled to be consistent with the curriculum as shown in the tables below. Under normal circumstance, students must follow the prescribed curriculum. Unavoidable deviation from the curriculum, for example, to participate in the Education Abroad Program, must be approved by the Undergraduate Affairs Committee prior to taking alternative courses elsewhere. Approvals are also needed for engineering courses not listed under the current selections for different engineering focus areas. Courses such as NANO 195, 197, and 198 are not allowed as a NanoEngineering elective in meeting the upper-division major requirements. NANO 199 can be used as a technical elective only under restrictive conditions. Policy regarding these conditions may be obtained from the department's Student Affairs Office. All students are encouraged to visit the Student Affairs Office or visit the Department of NanoEngineering Web site for any clarification and updated information. To graduate, students must maintain an overall GPA of at least 2.0, and the department requires at least a C– grade in each course required for the major.

GENERAL-EDUCATION/COLLEGE REQUIREMENTS

For graduation each student must satisfy general-education course requirements determined by the student's college as well as the major requirements determined by the department. The six colleges at UCSD require widely different general-education courses, and the number of such courses differs from one college to another. Each student should choose his or her college carefully, considering the special nature of the college and the breadth of general education.

The NANO curriculum allows for forty-eight units of humanities and social science (HSS) courses, which are sufficient to fulfill most but not all college requirements. Regardless the specific college, students must develop a program that includes a total of at least forty-eight units in the arts, humanities, and social sciences, not including subjects such as accounting, industrial management, finance, or personnel administration. Students must consult with their college to determine which HSS courses to take.

MAJOR REQUIREMENTS

To receive a B.S. in NanoEngineering, students must complete 192 units. The specific breakdown is as follows:

Humanities and social sciences (forty-eight units): This requirement is intended to fulfill the general-education requirements (GER) from respective colleges.

Basic sciences and mathematics (fifty-nine units): This lower-division requirement includes twenty-four units of mathematics (Math. 20A–F), sixteen units of physics (Phys. 2A–D), fifteen units of chemistry (Chem. 6A–C, 6BL), and four units of biology (BILD 1).

Engineering preparation (sixteen units): This requirement covers basics in computer programming, circuit analysis and circuits lab (ECE 15, 35, 45, 65).

Nanoengineering core (thirty-seven units): This requirement is constituted of a one-unit seminar (NANO 1) and nine core courses (NANO 101 to 104, 110 to 112, and 120A-B).

Nanoengineering electives (eight units): This requirement must be chosen from among the upper-division NANO courses offered by the department.

Engineering focus (twenty-four units): Students are recommended to select all six engineering electives from within one single major to constitute an engineering focus. However, to allow for unforeseen class scheduling conflicts and to comply with the prerequisites of some Bioengineering courses, students are required to take only four of the six courses in one major, with the other two outside their chosen engineering focus. Preapproved accepted courses of each of the four focuses are listed below.

- *Bioengineering:*
  BENG 100, 101, 103B*, 109, 110, 112A, 112B, 122A*, 130, 186A
  *BENG 103B requires CENG 101A and 122A requires MAE 140. Both prerequisites are accepted as part of the twenty-four-unit bioengineering focus.
- *Chemical engineering:*
  CENG 100, 101A, 101B, 101C, 102, 113, 120.
- *Electrical engineering:*
  ECE 103, 107, 109, 134, 135A, 135B, 136, 136L, 138L, 139, 183, 187.
- *Mechanical engineering:*
  MAE 20, 101A, 101B, 101C, 105, 113, 110A, 130A, 130B, 131A, 143A, 143B, 160, 161, 166, 168.
- *Materials science:*
  NANO 108, 140, 148, 150, 156, 158, 161, 164, 168.

All students follow the same basic science preparation and core set of classes in NanoEngineering during the first two years.

Fall	Winter	Spring
Freshman Year		
Math. 20A	Math. 20B	Math. 20C
Chem. 6A	Chem. 6B	Chem 6C
ECE 15	BILD 1	Phys. 2A
HSS	HSS	HSS
	NANO 1	
Sophomore Year		
Math. 20D	Math. 20F	Math. 20E
Phys. 2B	Phys. 2C	Phys. 2D
Chem. 6BL	NANO 101	ECE 25
HSS	HSS	HSS

After the sophomore year, students must choose an engineering focus. Sample programs of the five choices are shown below. Students must keep in mind that the NANO courses are only offered once a year.

Recommended Course Sequence— Bioengineering Focus

Fall	Winter	Spring
Junior Year		
NANO 102	NANO 103	NANO 104
CENG 101A	BENG 130	BENG 100
ECE 35	ECE 65	NE Elective
HSS	HSS	HSS
Senior Year		
NANO 110	NANO 111	NANO 112
BENG 101	BENG 109	BENG 103B
NE Elective	NANO 120A	NANO 120B
HSS	HSS	HSS

Recommended Course Sequence— Chemical Engineering Focus

Fall	Winter	Spring
Junior Year		
NANO 102	NANO 103	NANO 110
CENG 100	CENG 102	CENG 113
ECE 35	ECE 65	NE Elective
HSS	HSS	HSS
Senior Year		
NANO 110	NANO 111	NANO 112
CENG 101A	CENG 101B	CENG 101C
NE Elective	NANO 120A	NANO 120B
HSS	HSS	HSS

Recommended Course Sequence— Electrical Engineering Focus

Fall	Winter	Spring
Junior Year		
NANO 102	NANO 103	NANO 104
ECE 35	ECE 65	ECE 134
ECE 103	NE Elective	ECE 136
HSS	HSS	HSS
Senior Year		
NANO 110	NANO 111	NANO 112
ECE 135A	ECE 135B	ECE 139
NE Elective	NANO 120A	NANO 120B
HSS	HSS	HSS

Recommended Course Sequence— Mechanical Engineering Focus

Fall	Winter	Spring
Junior Year		
NANO 102	NANO 103	NANO 104
NANO 108	MAE 130A	MAE 131A
ECE 35	ECE 65	MAE 130B
HSS	HSS	HSS
Senior Year		
NANO 110	NANO 111	NANO 112
CENG 101A	NANO 120A	NANO 120B
MAE 105	NE Elective	NE Elective
HSS	HSS	HSS

Recommended Course Sequence— Materials Science Focus

Fall	Winter	Spring
Junior Year		
NANO 102	NANO 103	NANO 104

ECE 35	ECE 65	NANO 148
NANO 108	NE Elective	NANO 150
HSS	HSS	HSS
Senior Year		
NANO 110	NANO 111	NANO 112
NANO 158	NANO 120A	NANO 120B
NANO 161	NE Elective	NANO 168
HSS	HSS	HSS

POLICIES AND PROCEDURES FOR UNDERGRADUATE STUDENTS

[In this policy section, much is in common with the Chemical Engineering major. Duplicate sections will be consolidated in the final catalog edition.]

Application for Admission to the Major

Admission to the department as a NANO major or minor, or to fulfill a major in another department that requires NANO courses, is in accordance with the general requirements established by the Jacobs School of Engineering. The admission requirements and procedures are described in detail in the section on "Acceptance to Departmental Majors in the Jacobs School of Engineering" in this catalog. Applicants who have demonstrated excellent academic performance prior to being admitted to UC San Diego will be admitted directly to the engineering major of their choice. These directly admitted students and all students are expected to complete lower- and upper-division courses, as suggested in the curriculum tables, in a timely fashion in the sequences outlined.

Academic Advising

Upon admission to the major, students should consult the catalog or NanoEngineering Web site (http://nanoengineering.ucsd.edu) for their program of study or their undergraduate advisor if they have questions. The program plan may be revised in subsequent years, but revisions involving curricular requirements require approval by the undergraduate advisor or the Undergraduate Affairs Committee. Because some course and/or curricular changes may be made every year, it is imperative that students consult with the department's undergraduate advisor on an annual basis.

As aforementioned, NANO and CENG courses are offered only once a year and therefore should be taken in the recommended sequence. If courses are taken out of sequence, it may not always be possible to enroll in courses as desired or needed. If this occurs, students should seek immediate departmental advice. When a student deviates from the sequence of courses specified for each curriculum in this catalog, it may be impossible to complete the major within the nominal four-year period.

In addition to the advising available through the Student Affairs Office, programmatic or technical advice may be obtained from faculty members. A specific faculty mentor is assigned to each student. All students are required to meet with their faculty mentor at least once a quarter.

Program Alterations/Exceptions to Requirements

Variations from or exceptions to any program or course requirements are possible only if the Undergraduate Affairs Committee approves a petition before the courses in question are taken. Petition forms may be obtained from the Student Affairs Office and must be processed through this office.

Independent Study

Students may take NANO 199, Independent Study for Undergraduates, under the guidance of a NANO faculty member. This course is taken as an elective on a P/NP basis. Under very restrictive conditions, however, it may be used to satisfy upper-division technical elective course requirements for the major. Students interested in this alternative must identify a faculty member with whom they wish to work and propose a two-quarter research or study topic. After obtaining the faculty member's concurrence on the topic and scope of the study, the student must submit a Special Studies Course form (each quarter) and NANO 199 as Technical Elective Contract form to the Undergraduate Affairs Committee. These forms must be completed, approved, and processed prior to the add/drop deadline. Detailed policy in this regard and the requisite forms may be obtained from the Student Affairs Office.

Transfer Students

The undergraduate engineering curriculum is designed to integrate four years of college educational experience. It is not easy for transfer students to complete the major requirements in only two additional years beyond their junior college work. Students should consult their advisor for a transition program compatible with their junior college preparation.

Requirements for admission as a NANO major or into NANO courses are the same for transfer students as they are for continuing students (see section on "Acceptance to Departmental Majors in the Jacobs School of Engineering" in this catalog). Accordingly, when planning their program, transfer students should be mindful of lower-division prerequisite course requirements, as well as for meeting collegiate requirements.

Students who have taken equivalent courses elsewhere may request to have transfer credit apply toward the department's major requirements. To receive transfer credit, complete a Student Petition form and submit it to Student Affairs. For mathematics, chemistry, and physics, the respective department determines transfer equivalencies. An Undergraduate Student Petition must be submitted to each department from which you are requesting transfer credit.

The following courses are strongly recommended for all engineering transfer students for success in their major.

- Calculus I—for Science and Engineering (Math. 20A)
- Calculus II—for Science and Engineering (Math. 20B)
- Calculus and Analytic Geometry (Math. 20C)
- Differential Equations (Math. 20D)
- Linear Algebra (Math. 20F)
- Complete calculus-based physics series with lab experience (Physics 2A-B-C)
- Chemistry 6A (except computer science and computer engineering majors)
- Highest level of introductory computer programming language course offerings at the community college*
- Community college equivalent courses can be found at: http://www.assist.org

*Refer to the *UC San Diego General Catalog* to select major prerequisite recommendations for computer language courses.

GRADUATE PROGRAM

DEGREE AND PROGRAM OPTIONS

Plans are currently underway to develop graduate curricula leading to the **M.S. and Ph.D. degrees in nanoengineering by 2011.** Until NanoEngineering graduate programs are in place, students wishing to pursue nanoengineering as a graduate focus are encouraged to apply to related graduate programs in bioengineering, chemical engineering, and mechanical and aerospace engineering. Transfer to NanoEngineering will be considered upon approval of its degree programs.

The Chemical Engineering Program offers graduate instruction leading to the **M.S. and Ph.D. degrees in chemical engineering.** Effective fall 2009, Chemical Engineering will offer a concentration in nanotechnology within the graduate program, which also will bridge with the future graduate degree program in nanoengineering.

CHEMICAL ENGINEERING PROGRAM (CENG)

Student Affairs: 2802 Atkinson Hall, Warren College

PROGRAM OBJECTIVES

The Chemical Engineering Program has affiliated faculty from the Department of NanoEngineering, Department of Mechanical and Aerospace Engineering, Department of Chemistry and Biochemistry, and the Department of Bioengineering. The curricula at both the undergraduate and graduate levels are designed to support and foster chemical engineering as a profession that interfaces engineering and all aspects of basic sciences (physics, chemistry, and biology).

The primary educational objectives of the Chemical Engineering Program are

- To provide chemical engineering students with a strong technical education and communication skills that will enable them to have successful careers in a wide range of industrial and professional environments.
- To prepare chemical engineering students for rapidly changing technological environments with the core knowledge central to multidisciplinary development and personal improvement throughout their professional careers.
- To instill in chemical engineering students a strong sense of humanistic values and professionalism such that they can conduct ethically and knowledgeably regarding technological

impact in societal issues.

The curriculum is designed to prepare chemical engineering graduates for further education and personal development through their entire professional career. We strive to accomplish these goals by providing a rigorous and demanding curriculum that incorporates lectures, discussions, laboratory and project development experiences in basic sciences, mathematics, engineering sciences, and design as well as the humanities and social sciences.

B.S./M.S. Contiguous Program

A contiguous program leading to a bachelor of science and a master of science degree in chemical engineering is offered to a student with junior standing who has an upper-division GPA of 3.5 or better and a 3.0 overall UCSD GPA. During the last quarter of their junior year (more specifically, the fourth quarter prior to the receipt of the B.S. degree), students interested in obtaining the M.S. degree within one year following receipt of the B.S. degree may apply to the department for admission to the program.

The M.S. program is intended to extend and broaden an undergraduate background and/or equip practicing engineers with fundamental knowledge in their particular fields. The degree is offered under both the Thesis Plan I and the Comprehensive Examination Plan II.

Integrated B.S./M.S. Requirements

An integrated co-terminal program leading to a bachelor of science and a master of science degree in chemical engineering is offered to a student with junior standing who has an upper-division GPA of 3.5 or better and a 3.0 overall UCSD GPA. Details of the program are available from the Student Affairs Office.

Program Accreditation

The B.S. Program in chemical engineering is accredited by the Accreditation Board of Engineering and Technology (ABET/EAC).

GRADUATE PROGRAM

The Chemical Engineering Program offers graduate instruction leading to the M.S. and Ph.D. degrees in chemical engineering. The nanotechnology concentration signifies that four elective courses are chosen from the approved courses in this area.

Admission is in accordance with the general requirements of the graduate division, which requires at least a B.S. In some branch of engineering, sciences, or mathematics; an overall GPA of 3.0, and three letters of recommendation from individuals who can attest to the academic or professional competence and to the depth of their interest in pursuing graduate study.

In addition, all applicants are required to submit GRE General Test Scores. A minimum score of 550 on the Test of English as a Foreign Language (TOEFL) is required of all international applicants whose native language is not English. Students who score below 600 on the TOEFL are strongly encouraged to enroll in an English as a second language program before beginning graduate work. UC San Diego Extension offers an excellent English language program during the summers as well as the academic year.

Applicants are judged competitively. Based on the candidate's background, qualifications, and goals, admission to the program is in one of three categories: M.S. only, MS, or Ph.D. Admission to the M.S. only category is reserved for students for whom the M.S. degree is likely to be the terminal graduate degree. The M.S. designation is reserved for students currently interested in obtaining an M.S. degree but who at a later time may wish to continue in the doctoral degree program. Admission to the Ph.D. Program is reserved for qualified students whose final aim is a doctoral degree.

Non-matriculated students are welcome to seek enrollment in graduate-level courses via UC Extension's concurrent registration program, but an extension student's enrollment in a graduate course must be approved by the instructor.

MASTER'S DEGREE PROGRAM

The M.S. Program is intended to extend and broaden an undergraduate education with fundamental knowledge in different fields. The degree may be terminal, or obtained on the way to the Ph.D. The degree is offered under both the Thesis Plan I and the Comprehensive Examination Plan II.

M.S. Time Limit Policy: Full-time M.S. students are permitted seven quarters in which to complete all requirements. While there is no written time limit for part-time students, the department has the right to intervene and set individual deadlines if it becomes necessary.

Course requirements: All M.S. students must complete a total of forty-eight units, which include a core of five courses (twenty units) chosen among fluid dynamics (CENG 210A, MAE 210B), heat and mass transfer (CENG 221AB), kinetics (CENG 252), and mathematics. To maintain a certain balance in the core, no more than two mathematics courses should be chosen among the choices of applied mathematics (MAE 294AB or Math. 210AB) and numerical mathematics (MAE 290AB or Math. 270AB).

No more than three courses (twelve units) of upper-division courses may be applied toward the total course work requirement. No more than a total of eight units of CENG 296 and 298 may be applied toward the course work requirement. Units in seminars (CENG 259) may not be applied toward the degree requirement.

Thesis Plan I: Completion of the research thesis (CENG 299) fulfills twelve units toward the total graduation requirement. The balance is made up of the five core courses (twenty units) and additional four elective courses (sixteen units) subject to the restrictions described above. The nanotechnology concentration signifies that four elective courses are chosen from the approved courses in this area.

Comprehensive Examination Plan II: This plan involves course work only and culminates in an oral comprehensive examination based on topics selected from the core courses. In addition to the five core courses (twenty units), one must choose an additional seven electives (twenty-eight units) subject to the restrictions of CENG 259, 296, and 298 described above. Sample electives are listed in the table below. A student should consult his or her academic advisor to choose an appropriate course schedule, including alternatives in bioengineering, electrical and computer engineering, materials science, basic sciences, and mathematics. The nanotechnology concentration signifies that four elective courses are chosen from the approved courses in this area.

Fall	**Winter**	**Spring**
Core selections		
CENG 210A	CENG 221A	CENG 221B
MAE 290A or 294A	MAE 210B	CENG 252
	MAE 290B or 294B	
Suggested electives		
MS 201A	MS 201B	MS 201C
MAE 211	MAE 212	MAE 213
Math. 270A	Math. 270B	Math. 270C
Chem. 211	Chem. 212	Chem. 213
Nanotechnology concentration		
CENG 211	CENG 213	
CENG 212	CENG 214	CENG 215

Change of Degree: Upon completion of the requirements for the M.S. degree, students admitted as M.S. only or M.S. candidates are not automatically eligible for admission to the Ph.D. Program.

M.S. only and M.S. candidates who subsequently wish to pursue a doctorate must submit an application for a change in status to their examining committee. The application, if approved by the committee, must be signed by a faculty member who expects to serve as the student's Ph.D. advisor. The student must also submit a general petition for graduate students to effect the change of status. If the student elects the comprehensive examination plan for the M.S. degree, the examining committee may recommend that the comprehensive examination may replace the preliminary qualifying examination expected of Ph.D. students.

DOCTORAL DEGREE PROGRAM

The Ph.D. Program is intended to prepare students for a variety of careers in research and teaching. The emphasis is on research. In general, there are no formal course requirements. All students, in consultation with their advisors, develop appropriate course programs that will prepare them for the Preliminary Qualifying Examination and for their dissertation research. These programs must be planned to meet the time limits established to advance to candidacy and to complete the requirements of the degree.

All Ph.D. students are required to pass three examinations. The first is a Preliminary Qualifying Examination, which should be taken within three to four quarters of full-time graduate study. The second is the Ph.D. Qualifying Examination. The last is the Dissertation Defense.

Preliminary Qualifying Examination: The examination is intended to determine a candidate's basic understanding of engineering fundamentals and the candidate's ability to pursue successfully a research project at a level appropriate for the doctorate. The scope of the examination is based on topics selected from the core curriculum as listed under the M.S. degree program. A candidate is expected to demonstrate knowledge equivalent to these courses and formal enrollment record is not a prerequisite. The format is an oral examination administered by a committee of three faculty members in the Chemical

Engineering Program. The candidate should present to the committee, prior to the examination, the five core courses that will constitute the basis of the examination.

Depth Requirement: A candidate must have the ability to perform in-depth analysis in the dissertation topic. A candidate should consult with the thesis advisor to develop a proper course program if it is deemed necessary. Depending on an individual's background and the nature of the research problem, a candidate should either complete a set of a minimum of four courses or demonstrate to the thesis advisor the equivalent knowledge and ability.

Ph.D. Qualifying Examination: Prior to taking this examination, the candidate must have completed the departmental qualifying examination, obtained a faculty research advisor, and must have made initial progress on a chosen dissertation project. At the time of application for advancement to candidacy, a doctoral committee responsible for the remainder of the student's graduate program is appointed by the Graduate Council under the policy listed in the "Graduate Studies" section of the *UC San Diego General Catalog*. The committee conducts the Ph.D. Qualifying Examination, during which the student must demonstrate the ability to engage in thesis research. The process involves the presentation of a plan for the thesis research project. The committee may ask questions directly or indirectly related to the project and general questions that it determines to be relevant. Upon successful completion of the examination, subject to the UCSD time limit policy, the student is advanced to candidacy and is awarded the candidate in philosophy degree (see "Graduate Studies" section in this catalog).

Teaching Experience: Prior to the dissertation defense, the candidate must serve at least once as a teaching assistant with the responsibility to hold a problem-solving section one hour a week.

Dissertation Defense: This is the final Ph.D. examination. Upon completion of the dissertation research project, the candidate writes a dissertation that must be successfully defended in an oral examination and public presentation conducted by the doctoral committee. A complete copy of the student's dissertation must be submitted to each member of the doctoral committee four weeks before the defense. It is understood that this copy of the dissertation given to committee members will not be the final copy, and that the committee members may request changes in the text at the time of the defense. This examination may not be conducted earlier than three quarters after the date of advancement to doctoral candidacy. Acceptance of the dissertation by the Office of Graduate Studies and the University Librarian represents the final step in completion of all requirements for the Ph.D. degree.

Ph.D. Time Limit Policy: Pre-candidacy status is limited to four years. Doctoral students are eligible for university support for six years. The defense and submission of the doctoral dissertation must be within seven years.

Annual Evaluation: In the spring of each year, the faculty advisor evaluates each doctoral student's overall performance in course work, research, and prospects for financial support for future years. A written assessment is given to the student after the evaluation. If a student's work is found to be inadequate, the faculty may determine that the student cannot continue in the graduate department.

COURSES

For course descriptions not found in the UC San Diego General Catalog, 2010–11, please contact the department for more information.

COURSES IN CHEMICAL ENGINEERING (CENG)

All undergraduate students enrolled in CENG courses or admitted to the CENG program are expected to meet prerequisite and performance standards, i.e., students may not enroll in any CENG courses or courses in another department which are required for the major prior to having satisfied prerequisite courses with a C– or better. (The program does not consider D or F grades as adequate preparation for subsequent material.) Additional details are given under the program outline, course descriptions, and admission procedures for the Jacobs School of Engineering in this catalog.

LOWER-DIVISION

CENG 1. The Scope of Chemical Engineering (1)
Demonstrations and discussions of basic knowledge and the opportunities in chemical engineering for professional development. Introduction to campus library and computer resources. Use of personal software tools such as spread-sheeting and student edition of MATLAB. **Prerequisites:** none. (P/NP grading only.)

UPPER-DIVISION

CENG 100. Process Modeling and Computation in Chemical Engineering (4)
Introduction to elementary numerical methods with applications to chemical engineering problems using a variety of problem solving strategies. Error analysis. Concepts of mathematical modeling, material and energy balances, and probability and statistics with applications to design problems. **Prerequisites:** admission to the chemical engineering major only and grades of C– or better in MAE 9 or 10, and Chem. 6C or consent of instructor.

CENG 101A. Introductory Fluid Mechanics (4)
Kinematics and equation of motion; hydrostatics; Bernoulli's equation; viscous flows; turbulence, pipe flow; boundary layers and drag in external flows; applications to chemical, structural, and bioengineering. Students may not receive credit for both MAE 101A and CENG 101A. **Prerequisites:** admission to the major and grades of C– or better in Phys. 2A and Math. 21D or 20D, and 20E or consent of instructor.

CENG 101B. Heat Transfer (4)
Conduction, convection, radiation heat transfer; design of heat exchangers. Students may not receive credit for both MAE 101C and CENG 101B**. Prerequisites:** admission to the major and a grade of C– or better in CENG 101A.

CENG 101C. Mass Transfer (4)
Diffusive and convective mass transfer in solids, liquids, and gases; steady and unsteady state; mass transfer coefficients; applications to chemical engineering and bioengineering. **Prerequisites:** admission to the major and grade of C– or better in CENG 101A.

CENG 102. Chemical Engineering Thermodynamics (4)
Thermodynamic behavior of pure substances and mixtures. Properties of solutions, phase equilibria. Thermodynamic cycles. Chemical equilibria for homogeneous and heterogeneous systems. **Prerequisites:** CENG 100 and Math. 20D or consent of instructor.

CENG 113. Chemical Reaction Engineering (4)
Principles of chemical reactor analysis and design. Experimental determination of rate equations, design of batch and continuous reactors, optimization of selectivity in multiple reactions, consideration of thermal effects and residence time distribution. Introduction to multi-phase reactors. **Prerequisites:** grade of C– or better in CENG 100 or consent of instructor and Math. 20D.

CENG 120. Chemical Process Dynamics and Control (4)
Examination of dynamic linear and linearized models of chemical processes. Stability analysis. Design of PID controllers. Selection of control and manipulated variables. Root locus, Bode and Nyquist plots. Cascade, feed- forward and ratio controls. **Prerequisites:** admission to the major and grades of C– or better in Math. 21D or Math. 20D. (Students may not receive credit for both MAE 141A or MAE 143B and CENG 120.)

CENG 122. Separation Processes (4)
Principles of analysis and design of systems for separation of components from a mixture. Topics will include staged operations (distillation, liquid-liquid extraction), and continuous operations (gas absorption, membrane separation) under equilibrium and nonequilibrium conditions. **Prerequisites:** admission to the major and grades of C– or better in CENG 100, CENG 102, and CENG 101C.

CENG 124A. Chemical Plant and Process Design I (4)
Principles of chemical process design and economics. Process flow diagrams and cost estimation. Computer-aided design and analysis. Representation of the structure of complex, interconnected chemical processes with recycle streams. Ethics and professionalism. Health, safety, and the environmental issues. **Prerequisites:** admission to chemical engineering major and grades of C– or better in CENG 113 and CENG 122 or consent of instructor.

CENG 124B Chemical Plant and Process Design II (4)
Engineering and economic analysis of integrated chemical processes, equipment, and systems. Cost estimation, heat and mass transfer equipment design and costs. Comprehensive integrated plant design. Optimal design. Profitability. **Prerequisites:** admission to chemical engineering major and grade of C– or better in CENG 124A.

CENG 176A. Chemical Engineering Process Laboratory I (4)
Laboratory projects in the areas of applied chemical research and unit operations. Emphasis on applications of engineering concepts and fundamentals to solution of practical and research problems. **Prerequisites:** admission to the major and grades of C– or better in CENG 113, CENG 122, and MAE 170 or consent of instructor and departmental approval.

CENG 176B. Chemical Engineering Process Laboratory II (4)
Training in planning research projects, execution of experimental work**,** and articulation (both oral and written) of the research plan and results in the areas of applied chemical technology and engineering operations related to mass, momentum, and heat transfer. **Prerequisites:** admission to the major and grade of C– or better in CENG 176A.

CENG 192. Senior Seminar in Chemical Engineering (1)
The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in chemical engineering (at the upper division level). Topics will vary from quarter to quarter. Senior seminars may be taken for credit up to four times, with a change in topic, and permission of the department. Enrollment is limited to twenty students with preference given to seniors. **Prerequisite:** department stamp or consent of the instructor.

CENG 199. Independent Study for Undergraduates (4-4)
Independent reading or research on a problem by special arrangement with a faculty member. **Prerequisite:** consent of instructor. (P/NP only.)

CHEMICAL ENGINEERING GRADUATE COURSES

CENG 205. Graduate Seminar in Chemical Engineering (1)
Each graduate student in CENG is expected to attend one seminar per quarter, of his or her choice, dealing with current topics in chemical engineering. Topics will vary. **Prerequisites:** none.

CENG 207. Nanomedicine (4)
Introduction to nanomedicine; diffusion and drug dispersion; diffusion in biological systems; drug permeation through biological barriers; drug transport by fluid motion; pharmacokinetics of drug distribution; drug delivery systems; nanomedicine in practice: cancers, cardiovascular diseases, immune diseases, and skin diseases. Prerequisites: none.

CENG 208. Nanofabrication (4)
Basic engineering principles of nanofabrication. Topics include: photo-, electron beam and nanoimprint lithography, block copolymers and self-assembled monolayers, colloidal assembly, biological nanofabrication. Prerequisites: none.

CENG 210A. Fluid Mechanics I (4)
(Cross-listed with MAE 210A.) Basic conservation laws, flow kinematics. The Navier-Stokes equations and some of its exact solutions, non-dimensional parameters and different flow regimes, vorticity dynamics. **Prerequisites:** MAE 101A-B and MAE 110A or consent of instructor.

CENG 211. Introduction to Nanoengineering (4)
Understanding nanotechnology, broad implications; miniaturization: scaling laws; nanoscale physics; types and properties of nanomaterials; nanomechanical oscillators, nano(bio)electronics, nanoscale heat transfer; fluids at nanoscale; machinery cell; applications of nanobiotechnology and nanobiotechnology. Prerequisites: none.

CENG 212. Intermolecular and Surface Forces (4)
Development of quantitative understanding of the different intermolecular forces between atoms and molecules and how these forces give rise to interesting phenomena at the nanoscale, such as flocculation, wetting, and self-assembly in biological (natural) and synthetic systems. **Prerequisites**: none.

CENG 213. Nanoscale Synthesis and Characterization (4)
Examination of nanoscale synthesis—top-down and bottom-up; physical deposition; chemical vapor deposition; plasma processes; sol-gel processing; soft-lithography; self-assembly and layer-by-layer; molecular synthesis. Nanoscale characterization; microscopy (optical and electron: SEM, TEM); scanning probe microscopes (SEM, AFM); profilometry; reflectometry, and ellipsometry; x-ray diffraction; spectroscopies (EDX, SIMS, Mass spec, Raman, XPS); particle size analysis; electrical, optical, magnetic, mechanical, thermal. **Prerequisites:** none.

CENG 214. Nanoscale Physics and Modeling (4)
Expanded mathematical analysis of topics introduced in CENG 212. Introduction of both analytical and numerical methods through application to problems in nanoengineering. Nanoscale systems of interest include colloidal systems, block-copolymer based self-assembled materials, molecular motors made out of DNA, RNA, or proteins, etc. Nanoscale phenomena including self-assembly at the nanoscale, phase separation within confined spaces, diffusion through nanopores and nanoslits, etc. Modeling techniques include quantum mechanics, diffusion and kinetics theories, molecular dynamics, etc. **Prerequisite:** CENG 212 or consent of the instructor.

CENG 215. Nanosystems Integration (4)
Discussion of scaling issues and how to carry out the effective hierarchical assembly of diverse molecular and nanoscale components into higher order structures that retain the desired electronic/photonic, structural, mechanical, or catalytic properties at the microscale and macroscale levels. Novel ways to combine the best aspects of both top-down and bottom-up processes to create a totally unique paradigm change for the integration of heterogeneous molecules and nanocomponents into higher order structures. **Prerequisites:** none.

CENG 221A Heat Transfer (4)
(Cross-listed with MAE 221A.) Conduction, convection, and radiation heat transfer development of energy conservation equations. Analytical and numerical solutions to heat transport problems. Specific topics and applications vary. **Prerequisites:** MAE 101A-B-C or CENG 101A-B-C or consent of instructor.

CENG 221B Mass Transfer (4)
(Cross-listed with MAE 221B.) Fundamentals of diffusive and convective mass transfer and mass transfer with chemical reaction. Development of mass conservation equations. Analytical and numerical solutions to mass transport problems. Specific topics and applications will vary. **Prerequisites:** MAE 101A-B-C or CENG 101A-B-C or consent of instructor.

CENG 251. Thermodynamics (4)
Principles of thermodynamics of single and multi-component systems. Phase equilibria. Estimation, calculation, and correlation of properties of liquids and gases. **Prerequisite:** consent of instructor.

CENG 252. Chemical Reaction Engineering (4)
Analysis of chemical rate processes; complex kinetic systems. Chemical reactor properties in steady state and transient operations; optimal design policies. The interaction of chemical and physical transport processes in affecting reactor design and operating characteristics. Uniqueness/multiplicity and stability in reactor systems. Applications of the heterogeneous reactor systems. **Prerequisite:** consent of instructor.

CENG 253. Heterogeneous Catalysis (4)
Physics and chemistry of heterogeneous catalysis. Adsorption/desorption kinetics, chemical bonding, isotherms, kinetic models, selection of catalysts, poisoning, experimental techniques. **Prerequisite:** consent of instructor.

CENG 254. Biochemical Engineering Fundamentals (4)
Introduction to microbiology as relevant to the main topic, biological reactor analysis. Fermentation and enzyme technology. **Prerequisite:** consent of instructor.

CENG 255. Electrochemical Engineering (4)
Fundamentals of electrochemistry and electrochemical engineering. Structure of the double layer, cell potential and electrochemical thermodynamics, charge transfer kinetics, electrochemical transport phenomena, and introduction to colloidal chemistry. Applications such as corrosion prevention, electroplating, reactor design, batteries and fuel cells. **Prerequisite:** consent of instructor.

CENG 259. Seminar in Chemical Engineering (4)
Presentations on research progress by graduate students and by visitors from industrial and academic research laboratories. (May be repeated for credit. S/U grades only.) **Prerequisite:** consent of instructor.

CENG 296. Independent Study in Chemical Engineering (4)
Independent reading or research on a problem as arranged by a faculty member. Must be taken for a letter grade only. **Prerequisite:** consent of instructor.

CENG 299. Graduate Research in Chemical Engineering (1–12)
S/U grades only. **Prerequisite:** consent of instructor.

CENG 501. Teaching Experience (2)
Teaching experience in an appropriate CENG undergraduate course under the direction of the faculty member in charge of the course. Lecturing one hour per week in either a problem-solving section or regular lecture. (S/U grades only) **Prerequisites:** consent of instructor and departmental stamp.

COURSES IN NANOENGINEERING (NANO)

All students enrolled in NANO courses or admitted to the NANO major are expected to meet prerequisite and performance standards, i.e., students may not enroll in any NANO courses or courses in another department that are required for the major prior to having satisfied prerequisite courses with a C– or better. (The department does not consider D or F grades as adequate preparation for subsequent material.) Additional details are given under the program outline, course descriptions, and admission procedures for the Jacobs S chool of Engineering in this catalog.

LOWER-DIVISION

NANO 1. Nanoengineering Seminar (1)
Overview of nanoengineering. Presentations and discussions of basic knowledge and career opportunities in nanotechnology for professional development. Introduction to campus library resources. **Prerequisites***:* none. (P/NP grading only.)

NANO 87. Freshman Seminar (1)
The Freshman Seminar Program is designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small seminar setting. Freshman seminars are offered in all campus departments and undergraduate colleges, and topics vary from quarter to quarter. Enrollment is limited to fifteen to twenty students, with preference given to entering freshmen.

UPPER-DIVISION

NANO 101. Introduction to Nanoengineering (4)
Introduction to nanoengineering; nanoscale fabrication: nanolithography and self-assembly; characterization tools; nanomaterials and nanostructures: nanotubes, nanowires, nanoparticles, and nanocomposites; nanoscale and molecular electronics; nanotechnology in magnetic systems; nanotechnology in integrative systems; nanoscale optoelectronics; nanobiotechnology: biomimetic systems, nanomotors, nanofluidics, and nanomedicine. **Prerequisites***:* grade of C– or better in Chem. 6B, Phys. 2B, Math. 20C.

NANO 102. Foundations in Nanoengineering: Chemical Principles (4)
Chemical principles involved in synthesis, assembly, and performance of nanostructured materials and devices. Chemical interactions, classical and statistical thermodynamics of small systems, diffusion, carbon-based nanomaterials, supramolecular chemistry, liquid crystals, colloid and polymer chemistry, lipid vesicles, surface modification, surface functionalization, catalysis. **Prerequisites***:* grade of C– or better in Chem. 6C, Math. 20D, NANO 101, or at least concurrent enrollment.

NANO 103. Foundations in Nanoengineering: Biochemical Principles (4)
Principles of biochemistry tailored to nanotechnologies. The structure and function of biomolecules and their specific roles in molecular interactions and signal pathways. Nanoscale detection methods. **Prerequisites***:* grade of C– or better in BILD 1, Chem. 6C, NANO 101, or at least concurrent enrollment.

NANO 104. Foundations in Nanoengineering: Physical Principles (4)
Introduction to quantum mechanics and nanoelectronics. Wave mechanics, the Schroedinger equation, free and confined electrons, band theory of solids. Nanosolids in 0D, 1D, and 2D. Application to nanoelectronic devices. **Prerequisites**: Grade of C– or better in Phys. 2D or Chem. 133, Math. 20D, NANO 102 or at least concurrent enrollment.

NANO 110. Modeling of Nanoengineering Systems (4)
Engineering computation applied to nanotechnology including linear systems, nonlinear equations, optimization, solution of ordinary and partial differential equations, microfluidics simulation, quantum mechanical methods, Monte Carlo and molecular dynamics methods. Students will write programs and use open-source and commercial software. **Prerequisites***:* grade of C– or better in Math. 20F, ECE 15, NANO 101.

NANO 111. Characterization of Nanoengineering Systems (4)
Fundamentals and practice of methods to image, measure, and analyze materials and devices that are structured at the nanometer scale. Optical and electron microscopy; scanning probe methods; photon-, ion-, electron-probe methods, spectroscopic, magnetic, electrochemical, and thermal methods. **Prerequisites**: grade of C– or better in NANO 104.

NANO 112. Synthesis and Fabrication of Nanoengineering Systems (4)
Introduction to methods for fabricating materials and devices in nanoengineering. Nano-particle, -vesicle, -tube, and -wire synthesis. Top-down methods including chemical vapor deposition, conventional and advanced lithography, doping, and etching. Bottom-up methods including self-assembly. Integration of heterogeneous structures into functioning devices. Prerequisites*:* grade of C– or better in NANO 102 and 103.

NANO 120A. Nanoengineering System Design I (4)
Principles of product design and the design process. Application and integration of technologies in the design and production of nanoscale components. Engineering economics. Initiation of team design projects to be completed in NANO 120B. Prerequisites*:* grade of C– or better in NANO 110, 111, and 112.

NANO 120B. Nanoengineering System Design II (4)
Principles of product quality assurance in design and production. Professional ethics. Safety and design for the environment. Culmination of team design projects initiated in NANO 120A with a working prototype designed for a real engineering application. **Prerequisites***:* grade of C– or better in NANO 120A.

NANO 140. Introduction to Molecular Simulations (4)
Principles of molecular simulations. The students will gain hands-on experience with development of a molecular dynamics and Monte Carlo codes, performing simulations, and analyzing simulation results. The students will also learn to apply molecular simulation techniques for solving nanoengineering problems. Prerequisite*:* NANO 110.

NANO 143. Nanomedicine (4)
History of nanomedicine; length scale; main topics of nanomedicine: drug delivery, drugs and therapy, in vivo imaging, in vitro diagnosis, biomaterials, and active implants; nanomedicine in practice for disease treatment and diagnostics: cancers, cardiovascular diseases, immune diseases, and skin diseases. Prerequisites*:* NANO 101, 102, 103, 104, or consent of instructor.

NANO 145. Introduction to Nanomachines (4)
Understanding nanoscale motion, scaling laws, motion control at the nanoscale, biological nanomotors, molecular nanomachines, design of artificial nanomotors, propulsion mechanisms of artificial nanomotors, applications, and future opportunities and challenges. Prerequisites: NANO 101, 102, 103, 104, or consent of instructor.

NANO 146. Nanoscale Optical Microscopy and Spectroscopy (4)
Fundamentals in optical imaging and spectroscopy at the nanometer scale. Diffraction-limited techniques, near-field methods, multiphoton imaging and spectroscopy, Raman techniques, plasmon-enhanced methods, scan-probe techniques, novel sub-diffraction-limit imaging techniques, and energy transfer methods. Prerequisite*:* consent of instructor.

NANO 147. BioNanotechnology (4)
Introduction to biofabrication and bioengineering as applied to nanoscience and nanoengineering. Biological nanostructures, bioelectronics, and biophysics. Basic biochemistry, genetic engineering, and library screening techniques. Bioconjugation and characterization of biological systems on surfaces and nanoscale materials. Biological synthesis of inorganic nanocrystals. **Prerequisite**: NANO 101, 102, 103, 104, or consent of instructor.

NANO 148. Thermodynamics of Materials (4)
Fundamental laws of thermodynamics for simple substances; application to flow processes and to nonreacting mixtures; statistical thermodynamics of ideal gases and crystalline solids; chemical and materials thermodynamics; multiphase and multicomponent equilibria in reacting systems; electrochemistry. **Prerequisite**: NANO 20.

NANO 150. Mechanics of Nanomaterials (4)
Continuum, quantum and, statistical mechanics, interatomic forces and intermolecular interactions, nanomechanics of self-assembly, pattern formation, hierarchical ordering, defects, surfaces, and interfaces, plasticity, creep, fracture and fatigue, adhesion, friction and wear, nanorheology, nanotribology, composite materials, carbon nanomaterials, biological materials. **Prerequisite**: NANO 20.

NANO 156. Nanomaterials (4)
Basic principles of synthesis techniques, processing, microstructural control and unique physical properties of materials in nanodimensions. Nanowires, quantum dots, thin films, electrical transport, optical behavior, functional behavior, and technical applications of nanomaterial. **Prerequisite**: NANO 20.

NANO 158. Phase Transformations and Kinetics (4)
Materials and microstructures changes.Understanding of diffusion to venable changes in the chemical distribution and microstructure of materials, rates of diffusion. Phase transformations, effects of temperature and driving force on transformations and microstructure. **Prerequisite**: NANO 20.

NANO 161. Material Selection in Engineering Design (4)
Selection of materials for engineering systems, based on constitutive analyses of functional requirements and material properties. The role and implications of processing on material selection. Optimizing material selection in a quantitative methodology. **Prerequisite**: NANO 20.

NANO 162. Nanosensors: Principles, Design, and Applications (4)
Why nanosensors? Nanosensors based on different nanomaterials, fabrication of nanosensors, large-scale integration of nanosensor arrays, common recognition elements, surface chemistry and functionalization, signal transduction, practical applications. **Prerequisite**: consent of instructor.

NANO 164. Advanced Micro- and Nanomaterials for Energy Storage and Conversion (4)
Materials for energy storage and conversion in existing and future power systems, including fuel cells and batteries, photovoltaic cells, thermoelectric cells, and hybrids. **Prerequisite**: consent of instructor.

NANO 168. Electrical, Dielectric, and Magnetic Properties of Engineering Materials (4)
Introduction to physical principles of electrical, dielectric, and magnetic properties. Semiconductors, control of defects, thin film, and nanocrystal growth, electronic and optoelectronic devices. Processing-microstructure-property relations of dielectric materials, including piezoelectric, pyroelectric and ferroelectric, and magnetic materials. **Prerequisite**: NANO 20.

NANO 192. Senior Seminar in NanoEngineering (1)
The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in chemical engineering (at the upper-division level). Topics will vary from quarter to quarter. Senior seminars may be taken for credit up to four times, with a change in topic, and permission of the department. Enrollment is limited to twenty students with preference given to seniors. **Prerequisite**: department stamp or consent of the instructor.

NANO 195. Teaching (2–4)
Teaching and tutorial assistance in a NANO course under supervision of instructor. Not more than four units may be used to satisfy graduation requirements. **Prerequisites**: junior status with a B average in major and consent of instructor. (P/NP only.)

NANO 197. Engineering Internship (1–4)
Coordinated through the UCSD Academic Internship Program, this course provides work experience through industry, government offices, hospitals, and their practices. Students work in local industry or hospitals under faculty supervision. Units may not be applied toward major graduation requirements. Internship is unsalaried. **Prerequisites**: completion of ninety units with 2.5 GPA and consent of instructor.

NANO 198. Directed Group Study (1–4)
Directed group study on a topic or in a field not included in the regular department curriculum, by special arrangement with a faculty member. **Prerequisite**: consent of instructor. (P/NP only.)

NANO 199. Independent Study for Undergraduates (4)
Independent reading or research on a problem by special arrangement with a faculty member. **Prerequisite**: consent of instructor. (P/NP only.)