

time-consuming tests of hypotheses and experimental caveats, trade-offs, and options. Taught in a case-study approach, teams consist of students with engineering, biology, computational sciences, and chemical backgrounds. Teams generate an interdisciplinary chemical genomic research project. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor. Cross-listed with BIEN 220. **Schultz**

CMDB 230. Molecular Plant-Microbial Interactions (3) Lecture, 2 hours; discussion, 1 hour. Prerequisite(s): BCH 100, BIOL 120/MCBL 120/PLPA 120, or equivalents. A study of the physiology of host-pathogen interactions with emphasis on the metabolism of diseased plants, nature of pathogenicity, and defense mechanisms in plants. Cross-listed with BPSC 230, GEN 230, and PLPA 230. **Eulgem, Jin**

CMDB 250. Special Topics in Cell, Molecular, and Developmental Biology (1-2) F, W, S Seminar, 1-2 hours. Prerequisite(s): graduate standing. Oral presentations and intensive small-group discussion of selected topics in the area of special competence of each participant. Content emphasizes recent advances in the topic area and varies accordingly. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CMDB 257. Seminar in Cell, Molecular, and Developmental Biology (1) F Seminar, 1 hour. Prerequisite(s): graduate standing. Lectures by visiting scholars on current research in cell, molecular, and developmental biology. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CMDB 258. Graduate Student Seminar in Cell, Molecular, and Developmental Biology (1) S one 1-day seminar. Prerequisite(s): graduate standing in Cell, Molecular, and Developmental Biology. An interdisciplinary seminar consisting of student presentations of original research and discussion of current research topics in cell, molecular, and developmental biology. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CMDB 281 (E-Z). Seminar in Cell Development, Structure, and Function (2) F, W, S Seminar, 2 hours. Prerequisite(s): graduate standing; consent of instructor. Lectures, discussions, and demonstrations by students, faculty, and invited scholars on selected subjects concerned with the principles of cell development, structure, and function. E. Cell Biology; F. Molecular Biology; G. Developmental Biology. Segments are repeatable. Cross-listed with BIOL 281 (E-Z).

CMDB 290. Directed Studies (1-6) Individual study, 3-18 hours. Prerequisite(s): graduate standing; consent of instructor and graduate advisor. Individual study, directed by a faculty member, of specially selected topics in cell, molecular, and developmental biology. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CMDB 292. Concurrent Analytical Studies in Cell, Molecular, and Developmental Biology (2-4) Outside research, 6-12 hours. Prerequisite(s): graduate standing. Elected concurrently with an appropriate undergraduate course, but on an individual basis. Students are required to submit one or more graduate papers based on research or criticism related to the course. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CMDB 297. Directed Research (1-6) Outside research, 3-18 hours. Prerequisite(s): graduate standing. Research and experimental studies conducted under the supervision of a faculty member on specially

selected topics in cell, molecular, and developmental biology. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CMDB 299. Research for the Thesis or Dissertation (1-12) Outside research, 3-36 hours. Prerequisite(s): graduate standing. Original research in an area selected for the advanced degree. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

Professional Course

CMDB 301. Teaching of Cell, Molecular, and Developmental Biology at the College Level (1) Seminar, 1 hour. Prerequisite(s): graduate standing. A program of weekly meetings and individual formative evaluations required of new teaching assistants. Covers instructional methods and classroom/section activities most suitable for teaching Biology. Conducted by the Teaching Assistant Development Program. Graded Satisfactory (S) or No Credit (NC).

CHASS F1RST

Subject abbreviation: CHFY
College of Humanities, Arts, and Social Sciences

Geoff Cohen Ph.D., Academic Coordinator
1609 Humanities and Social Sciences
(951) 827-7831; Chassf1rst.ucr.edu

Committee in Charge

Steven Brint, Ph.D. (Sociology)
Tracy Fisher, Ph.D (Women's Studies)
Michael Jayme, M.F.A. (Creative Writing)
Vorris Nunly, Ph.D. (English)
Georgia Warnke, Ph.D. (Philosophy)

CHASS F1RST provides first-year students with courses designed to help with the transition to UCR, a major research university setting, which involves high academic standards and rigorous course work. The courses offer students the resources and tools necessary to excel in the first year and beyond. They take place within a "learning-communities" framework so that students can successfully integrate into campus life.

Lower-Division Courses

CHFY 001 (E-Z). CHASS F1RST Humanities Course (5) Lecture, 3 hours; assignment of the remaining hours varies from segment to segment. Prerequisite(s): first-year freshman standing in the College of Humanities, Arts, and Social Sciences. A College of Humanities, Arts, and Social Sciences course designed to introduce students to the humanities and to academic life. Segments of CHFY 001 (E-Z), CHFY 002 (E-Z), and/or CHFY 003 (E-Z) may be thematically and pedagogically linked.

CHFY 002 (E-Z). CHASS F1RST Fine Arts Course (5) Lecture, 3 hours; assignment of the remaining hours varies from segment to segment. Prerequisite(s): first-year freshman standing in the College of Humanities, Arts, and Social Sciences. A College of Humanities, Arts, and Social Sciences course designed to introduce students to the fine arts and to academic life. Segments of CHFY 001 (E-Z), CHFY 002 (E-Z), and/or CHFY 003 (E-Z) may be thematically and pedagogically linked.

CHFY 003 (E-Z). CHASS F1RST Social Science Course (5) Lecture, 3 hours; assignment of the remaining hours varies from segment to segment. Prerequisite(s): first-year freshman standing in the College of Humanities, Arts, and Social Sciences. A College of Humanities, Arts, and Social Sciences course designed to introduce students to the social sciences and to academic life. Segments of CHFY 001 (E-Z), CHFY 002 (E-Z), and/or CHFY 003 (E-Z) may be thematically and pedagogically linked.

CHFY 010. CHASS Gateway Lecture Course (5) Lecture, 3 hours; discussion, 1 hour; workshop, 1 hour. Prerequisite(s): first-year freshman standing in the College of Humanities, Arts, and Social Sciences. A College of Humanities, Arts, and Social Sciences course designed to introduce freshmen to the College's annual theme.

Chemical and Environmental Engineering

Subject abbreviations: CEE, CHE, ENVE
The Marlan and Rosemary Bourns
College of Engineering

Yushan Yan, Ph.D., Chair
Department Office, A242 Bourns Hall
(951) 827-2859; www.cee.ucr.edu

Professors

Wilfred Chen, Ph.D., *President's Chair*
Robert Haddon, Ph.D. (Chemistry/Chemical and Environmental Engineering)
Mark R. Matsumoto, Ph.D.
Ashok K. Mulchandani, Ph.D.
Joseph M. Norbeck, Ph.D. *W. Ruel Johnson Professor*
Jianzhong Wu, Ph.D.
Charles Wyman, Ph.D., *Ford Motor Company Chair in Environmental Engineering*
Yushan Yan, Ph.D.

Associate Professors

David R. Cocker, Ph.D.
Nosang Myung, Ph.D.

Assistant Professors

Akua A. Asa-Awuku, Ph.D.
David Cwiertrny, Ph.D.
David Kisailus, Ph.D.
Sharon Walker, Ph.D., *John Babbage Chair in Environmental Engineering*
**

Adjunct Professors

Marc A. Deshusses, Ph.D.
Rex Hjelm, Ph.D.
Ashutosh Sharma, Ph.D.
Wayne Miller, Ph.D.

Cooperating Faculty

Christopher Amrhein, Ph.D. (Environmental Sciences)
Matthew J. Barth, Ph.D. (Electrical Engineering)
John Y.-J. Shyy, Ph.D. (Biomedical Sciences)
Paul J. Ziemann, Ph.D. (Environmental Sciences)

150 / Programs and Courses

Majors

The Department of Chemical and Environmental Engineering offers B.S. degrees in Chemical Engineering and in Environmental Engineering, and M.S. and Ph.D. degrees in Chemical and Environmental Engineering. For more details, see www.cee.ucr.edu.

Chemical Engineering focuses on transforming raw materials into useful everyday products. Chemical engineers turn the discoveries of chemists and physicists into commercial realities. They find work in a variety of fields including pharmaceuticals, materials, chemical, fuels, pollution control, medicine, and nuclear and electronic industries. At UCR, the B.S. degree in Chemical Engineering offers students three options: Biochemical Engineering, focusing on biochemical processes; Bioengineering, focusing on the biomedical industry; or Chemical Engineering, emphasizing traditional chemical engineering issues.

The program's educational objectives are to produce graduates who demonstrate in their careers and professional pursuits the following:

- An ability to apply mathematics, engineering principles, computer skills, and natural sciences to chemical engineering practice
- Application of fundamental chemical engineering principles at an advanced level, and competence in synthesizing knowledge from multiple disciplines to develop and evaluate design solutions.
- Engagement in chemical engineering careers in diverse areas including bioengineering, nanotechnology, petrochemicals, alternative energy, and semiconductor manufacturing.
- Pursuit of graduate education and research in chemical engineering at major research universities.
- Exercise professional responsibility and sensitivity to a broad range of societal concerns, such as ethical, environmental, economic, regulatory, and global issues
- Effective performance in a team environment, outstanding communication, and involvement in personal and professional growth activities.

The Chemical Engineering B.S. degree at UCR is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; (410) 347-7700.

Environmental Engineering deals with design and construction of processes and equipment intended to lessen the impact of man's activities on the environment. With the growing importance of environmental quality, the environmental engineer plays a pivotal role in modern industrial activity. Environmental engineers are involved in a wide range of activities including the design of alternative fueled vehicles, the development of renewable energy sources, the design of equipment for solid waste collection and disposal, municipal and industrial wastewater treatment, air pollution control systems,

and hazardous waste management. At UCR, the B.S. degree in Environmental Engineering allows students to concentrate on air and/or water quality.

The program's educational objectives are to produce graduates who demonstrate in their careers and professional pursuits the following:

- An ability to apply mathematics, engineering principles, computer skills, and natural sciences to environmental engineering practice
- Application of fundamental environmental engineering principles at an advanced level, and competence in synthesizing knowledge from multiple disciplines to develop and evaluate design solutions.
- Engagement in environmental engineering careers in diverse areas including sustainability, air quality and pollution control, water quality engineering, bioremediation, and green engineering.
- Pursuit of graduate education and research in environmental engineering at major research universities
- Exercise professional responsibility and sensitivity to a broad range of societal concerns, such as ethical, environmental, economic, regulatory, and global issues
- Effective performance in a team environment, outstanding communication, and involvement in personal and professional growth activities.

The Environmental Engineering B.S. degree at UCR is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; (410) 347-7700.

All undergraduates in the College of Engineering must see an advisor at least annually. Visit student.engr.ucr.edu for details.

University Requirements

See Undergraduate Studies section.

College Requirements

See The Marlan and Rosemary Bourns College of Engineering, Colleges and Programs section.

The Chemical Engineering major and the Environmental Engineering major use the following major requirements to satisfy the college's Natural Sciences and Mathematics breadth requirement.

1. BIOL 005A, BIOL 05LA
2. CHEM 001A, CHEM 001B, CHEM 001C, CHEM 01LA, CHEM 01LB, CHEM 01LC
3. MATH 008B or MATH 009A

Major Requirements

Chemical Engineering

Students must choose either a Biochemical Engineering, Chemical Engineering, Bioengineering or Nanotechnology option.

1. Lower-division requirements (62 units)
 - a) BIOL 005A, BIOL 05LA
 - b) CHEM 001A, CHEM 001B, CHEM 001C, CHEM 01LA, CHEM 01LB, CHEM 01LC
 - c) CS 010
 - d) MATH 008B or MATH 009A, MATH 009B, MATH 009C, MATH 010A, MATH 010B, MATH 046
 - e) PHYS 040A, PHYS 040B, PHYS 040C
2. Upper-division requirements (76 units)
 - a) CEE 158
 - b) CHEM 112A, CHEM 112B, CHEM 112C
 - c) CHE 100, CHE 110A, CHE 110B, CHE 114, CHE 116, CHE 117, CHE 118, CHE 120, CHE 122, CHE 160B, CHE 160C, CHE 175A, CHE 175B
 - d) CHE 130/ENVE 130, CHE 160A/ENVE 160A
 - e) ENGR 118
3. Option requirements: choose one option
 - a) Biochemical Engineering option (20 units)
 - (1) BCH 110A
 - (2) BIOL 121/MCBL 121
 - (3) CEE 010
 - (4) CHE 124, CHE 124L
 - (5) Four (4) units of technical electives chosen from CEE 132, CEE 135, CHE 140, CHE 150, CHE 171, ENVE 121
 - b) Chemical Engineering option (18 units)
 - (1) CEE 010, CEE 125
 - (2) Twelve (12) units of technical electives chosen from CEE 132, CEE 135, CHE 102, CHE 136, CHE 171, ENVE 120, ENVE 133, ENVE 134, ENVE 138
 - c) Bioengineering option (24–26 units)
 - (1) BCH 110A, BCH 110B
 - (2) BIOL 005B, BIOL 005C
 - (3) CEE 011
 - (4) Six to eight (6–8) units of technical electives chosen from BIEN 140A/CEE 140A, BIEN 140B/CEE 140B, BIOL 107A, BIOL 107B, BIOL 115, BIOL 121/MCBL 121, BIOL 128/CBNS 128, CEE 147, CEE 159/BIEN 159, CHE 124, CHE 140, CHE 150
 - d) Nanotechnology option (21 units)
 - (1) CEE 010
 - (2) CHE 105
 - (3) CHE 161
 - (4) CEE 135
 - (5) Eight (8) units of technical electives chosen from CHE 102, CHE 131, ENVE 133, ME 114, MSE 160, MSE 161

Visit the Student Affairs Office in the College of Engineering or student.engr.ucr.edu for a sample program.

Environmental Engineering

Students must choose either an Air Pollution Control Technology or a Water Pollution Control Technology option.

1. Lower-division requirements (68 units)
 - a) BIOL 005A, BIOL 05LA
 - b) CEE 010
 - c) CHEM 001A, CHEM 001B, CHEM 001C, CHEM 01LA, CHEM 01LB, CHEM 01LC
 - d) CS 010
 - e) MATH 008B or MATH 009A, MATH 009B, MATH 009C, MATH 010A, MATH 010B, MATH 046
 - f) ME 010
 - g) PHYS 040A, PHYS 040B, PHYS 040C
2. Upper-division requirements (78 units)
 - a) CEE 158
 - b) CHEM 112A, CHEM 112B
 - c) CHE 100, CHE 114, CHE 120
 - d) ENGR 118
 - e) ENSC 100/SWSC 100
 - f) ENVE 120, ENVE 133, ENVE 135, ENVE 142, ENVE 146, ENVE 160B, ENVE 160C, ENVE 171, ENVE 175A, ENVE 175B
 - g) ENVE 130/CHE 130, ENVE 160A/CHE 160A
3. Option requirements: choose one option (12 units)
 - a) Air Pollution Control Technology option
 - (1) CHE 116
 - (2) ENVE 134
 - (3) Choose one from CEE 125, CEE 132, CHE 102, ENSC 135/CHEM 135/ENTX 135, ENVE 144/ENSC 144, ENVE 138, ENVE 145
 - b) Water Pollution Control Technology option
 - (1) CHE 124 or ENVE 121
 - (2) Choose one from CEE 125, CHE 116, ENSC 136, ENSC 163
 - (3) Choose one from CEE 132, ENSC 155, ENVE 144/ENSC 144, ENVE 145

Visit the Student Affairs Office in the College of Engineering or student.engr.ucr.edu for a sample program.

Graduate Program

The Graduate Program in Chemical and Environmental Engineering offers training leading to the degrees of M.S. and Ph.D. in Chemical and Environmental Engineering. Fields of specialization include biochemical engineering and bioengineering, environmental biotechnology,

air quality systems engineering, water quality systems engineering, thermodynamics, advanced materials, and nanotechnology.

Combined B.S. + M.S. Five-Year Program The college offers combined B.S.+ M.S. programs in both Chemical Engineering and Environmental Engineering designed to lead to a Bachelor of Science degree as well as a Master of Science degree in five years. Applicants for this program must have a high school GPA above 3.6, a combined SAT Reasoning score above 1950 (or ACT plus Writing equivalent), complete the Entry Level Writing Requirement before matriculation, and have sufficient mathematics preparation to enroll in calculus in their first quarter as freshmen.

Interested students who are entering their junior year should check with their academic advisor for information on eligibility and other details.

Admission Applicants should have a degree in chemical and environmental engineering or closely related fields, have a satisfactory overall GPA from their undergraduate studies, good letters of recommendation, and high scores on the GRE General Test. Normally, students admitted to regular standing have satisfied all prerequisite course work. Under special circumstances, students who have not completed all undergraduate requirements may be admitted provided that the deficiencies are corrected to the satisfaction of the student's advisory committee within the first year of graduate study. Courses taken for this purpose do not count towards an advanced degree. International students, permanent residents, and even U.S. citizens whose native language is not English and who do not have a bachelor's or postgraduate degree from an institution where English is the exclusive language of instruction must complete the Test of English as a Foreign Language (TOEFL) with a minimum score of 550 (paper-based test), 213 (computer-based), or 80 (internet-based).

Language Requirement All students whose native language is not English must achieve a "clear pass" on the TAST or SPEAK test before the completion of their first year or they will be asked to leave the program. However, for those who receive a "conditional pass," a departmental committee will evaluate their English proficiency before a final decision is made.

Course Work To ensure that advanced degree recipients in the graduate program have advanced knowledge in mathematics and chemical engineering principles that form the foundation for chemical and environmental engineering, a core course program has been implemented. All M.S. and Ph.D. students must participate in the core course program. Students who have completed these (or equivalent) courses elsewhere may petition to have the core course requirement waived or some of their units transferred (see the Graduate Division policy for transferring course units).

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Competency in these areas will be tested as part of the comprehensive exam for M.S. students and in the written preliminary examination for Ph.D. students. The current core courses are as follows:

- CEE 200 (Advanced Engineering Computations)
- CEE 202 (Transport Phenomena)
- CEE 204 (Advanced Kinetics and Reaction Engineering)
- CEE 206 (Advanced Chemical Engineering Thermodynamics)

Incoming students without a B.S. degree in chemical or environmental engineering must demonstrate competency in these areas either by taking the appropriate undergraduate courses and/or by passing the written preliminary exam. At UCR, the required courses are CHE 100, CHE 110A, CHE 110B, ENVE 171, CHE 114, CHE 116, CHE 120, CHE 130, and ENGR 118. Students may also be required to take some of the above courses to satisfy the prerequisites of the core graduate courses.

Each quarter, all M.S. and Ph.D. students in residence must enroll in CEE 286 (Colloquium in Chemical and Environmental Engineering). In addition, all M.S. and Ph.D. students must participate each year in the CEE Graduate Student Symposium, usually held just before the beginning of the fall quarter.

Master's Degree

The Department of Chemical and Environmental Engineering offers the M.S. degree in Chemical and Environmental Engineering.

Plan I (Thesis) requires completion of a minimum of 36 units of approved course work including the core courses and submission of an acceptable M.S. thesis. At least 24 of these units must be in regular lecture graduate courses (200 series courses). No more than 4 units of CEE 290 or CEE 297 combined and 6 units of CEE 286 or special topics courses (CEE 250 or CEE 260 series) may apply towards the 36 units.

Plan II (Comprehensive Examination) requires completion of a minimum of 36 units of approved course work including the core courses and successful passage of a comprehensive examination. At least 28 of these units must be in regular lecture graduate courses (200-series courses), and none may be in courses numbered CEE 286, CEE 290, CEE 297, CEE 299, or CEE 302. Typically, the examination is a six-hour written, closed-book examination emphasizing fundamental knowledge and breadth of the study area rather than specifics covered in individual courses. An oral follow-up session may be requested by the examination committee following its evaluation of the written exam. No more than two attempts to pass the exam are allowed. Students who fail the exam once and then want to switch to the thesis plan should contact the graduate advisor. Students who fail the exam twice may not switch to the thesis plan.

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For the M.S. degree, students must complete a minimum of three quarters in residence in the UC with a GPA of 3.00 or better in all 100- and 200-level course work related to the degree.

Thesis Committee The committee consists of three members. The student and advisor nominate the committee before the end of the first year with the concurrence of the graduate committee. After review of the nominations, the dean of the Graduate Division appoints the committee on behalf of the Graduate Council. The committee, once approved by the graduate dean, rather than the department, becomes responsible for the student's academic guidance and evaluation. The chairman of the committee is the director of the candidate's research and is normally a faculty member of the CEE department or a cooperating faculty member. A member may be appointed who is a researcher on campus, from off-campus, or a visiting lecturer within the department; however, a memo indicating the academic degree and affiliation of the nominated member, as well as a curriculum vitae, must accompany such a request. (Memos need not accompany the nomination of an adjunct faculty member.) After the committee is formed, the committee must approve the subject of the thesis. A joint meeting of the committee members and the student should be held before work on the thesis is begun to ensure the topic is clear and acceptable to all. Once the thesis is completed, all three members of the committee must approve the thesis and sign the title page. Students must give a departmental seminar presentation of their thesis work to the department and members of the academic community before completing the thesis.

Normative Time to Degree 6 quarters

Doctoral Degree

The Department of Chemical and Environmental Engineering offers the Ph.D. degree in Chemical and Environmental Engineering. Satisfying the requirements for the degree consists of four parts:

1. Successful completion of an approved program of course work
2. Passing a written preliminary examination
3. Approval of a dissertation proposal
4. Defense and approval of the dissertation

Course Work Upon choosing a faculty advisor, each Ph.D. student is appointed a Ph.D. advisory committee consisting of two CEE faculty members and the faculty advisor. This advisory committee is responsible for guiding the students in formulating their research activities and preparing for the preliminary and qualifying exams.

The program of course work is formulated by each student and a faculty advisor in the first or second quarter after admission to the program and must be approved by the student's advisor and advisory committee. Every student must complete a program of study that includes:

1. A major area of study intended to increase the student's depth of knowledge in an engineering research specialty and
2. A minor area of study intended to support and increase the student's breadth of knowledge in the major area

The CEE graduate program requires a coherent program of

1. Sixteen (16) units of core courses and
2. Eight (8) units of graduate and/or upper-division work approved by the advisory committee

None of these credits may be in courses numbered between CEE 250 and CEE 270, CEE 286, CEE 290, CEE 297, CEE 299, or CEE 302.

Preliminary Examination The preliminary examination tests students' understanding of the fundamental principles of chemical and environmental engineering at the undergraduate level. This comprehensive examination consists of three written tests in three different areas selected from the following five subjects:

1. Thermodynamics
2. Kinetics
3. Transport (heat and mass transfer, fluid dynamics)
4. Air pollution control and engineering
5. Water quality engineering

The three subjects selected should be closely connected to the student's undergraduate training and approved by the student's advisory committee. Students who fail any portion of the exam are granted a final attempt to pass a makeup written examination that includes an oral defense of their answers in front of a faculty committee. Students who fail one or two subjects after the retest must enroll in remedial undergraduate courses and pass with a grade of "B+" or better. Credits from these remedial courses do not count toward the Ph.D. course work requirement. Students who fail all three subjects after the retest must leave the Ph.D. program.

Teaching Requirement All students must be employed as teaching assistants for at least one quarter. All TAs must take CEE 302 (Teaching Practicum) to help them learn effective teaching methods such as handling discussion sections; preparing and handling laboratory sections; preparing and grading homework, examinations, and lab reports; and student relations.

Oral Qualifying Examination Selection of the Qualifying Committee is as follows: 2 members are selected by the Graduate Committee, 2 members are selected by the student, and the student's advisor will chair the committee. All members of the qualifying committee are expected to have the appropriate expertise to guide and evaluate a candidate's research. No more than 1 member can be a non-academic senate member. After review of the nominations, the dean of the Graduate Division

appoints the committee on behalf of the Graduate Council. This committee becomes responsible for the student's academic guidance and evaluation until advancement to candidacy and administers the qualifying examination.

Dissertation Proposal After successful completion of the written preliminary examination, each student, with advisement from an advisor, prepares a dissertation proposal. Typically, students submit a dissertation proposal to their qualifying committee within one year after successfully completing the written preliminary examination. The proposal should clearly demonstrate the student's adequate preparation for the completion of the thesis research, which includes but is not limited to a thorough review of the pertinent literature, a presentation and discussion of the candidate's own research, and a detailed research plan with sufficient breadth and depth for the completion of the thesis. The qualifying committee chair schedules an oral defense normally within one month of the written proposal submission. The presentation is given only to the dissertation committee members.

The oral presentation/defense of the proposal focuses on the dissertation problem. Students should demonstrate considerable depth of knowledge in the student's area of specialization and a clear understanding of the research methods that are needed for successful completion of the dissertation research. The oral presentation/defense begins with a presentation by students on their dissertation topic and is followed by questions and suggestions from the qualifying committee.

On the basis of the written proposal and oral defense, the qualifying committee decides whether the student should be advanced to candidacy, asked to modify and enhance the proposal, or requested to withdraw from the program.

Dissertation and Final Oral Examination Following advancement to candidacy, students formally focus on their dissertation research. The progress of the dissertation is monitored by the student's dissertation committee. Candidates should interact frequently with members of their dissertation committee to insure that dissertation progress is acceptable.

The graduate committee nominates and approves the dissertation committee after consideration of the suggestions made by the student and thesis advisor. The dissertation committee consists of a minimum of three UCR Academic Senate members. The chair and majority of members must be from Chemical and Environmental Engineering. All committee members should be in a position to offer guidance and be able to judge the scholarship of the dissertation work. Upon recommendation of the graduate advisor, doctoral dissertation committees are appointed by the dean of the Graduate Division.

After completing the dissertation research, students must submit a written copy of the dissertation for approval for defense by the student's dissertation committee. Once a draft has been approved, an oral defense of the dissertation is scheduled. This defense consists of a seminar open to the entire academic community, followed by a question-and-answer period conducted by the dissertation committee.

Students must complete at least six quarters in residence in the UC with a GPA of 3.00 or better in all 100- and 200-level course work related to the degree.

Normative Time to Degree Three years for students with a UCR M.S. degree in Chemical and Environmental Engineering (five years for those without an M.S. degree in Chemical and Environmental Engineering)

Lower-Division Courses

CEE 010. Introduction to Chemical and Environmental Engineering (2) Discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): none. An introduction to chemical and environmental engineering for engineering majors and nonengineering majors. Aims to enrich students' appreciation of chemical, biochemical, and environmental engineering. Discusses typical careers, key applications, latest developments in the field, and the need to engage in lifelong learning. Provides hands-on experiences and includes a field trip. Graded Satisfactory (S) or No Credit (NC).

CEE 011. Introduction to Bioengineering (2) Lecture, 1 hour; laboratory, 3 hours. An introduction to bioengineering for engineering and nonengineering majors. Discusses the application of concepts and methods of the physical sciences and mathematics to problems in the life sciences. Covers typical careers, key applications, latest developments in the field, and the need to engage in lifelong learning. Provides hands-on experiences and includes a field trip. Graded Satisfactory (S) or No Credit (NC).

Upper-Division Courses

CEE 125. Analytical Methods for Chemical and Environmental Engineers (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): CHEM 001C, CHEM 01LC. Topics include chromatographic separations, mass spectrometry, atomic absorption, and electrophoresis. Presents total carbon analysis as an introduction to analytical methods and their use in the chemical and environmental engineering fields.

CEE 132. Green Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): senior standing or consent of instructor. An introduction to the design, commercialization, and use of feasible and economical processes and products that minimize risks to human health and the environment. Topics covered include environmental risk assessment, regulations, chemical process flow-sheet analysis for pollution prevention, product life-cycle assessment, and industrial ecology. Credit is awarded for only one of CEE 132 or CEE 232.

CEE 135. Chemistry of Materials (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 112A, MATH 009B. Introduction to the synthesis, structure, properties, and performance of modern materials. Topics include the science of materials, bonding and structure, the strength of materials, electrons in materials, semiconductors, superconductors, and optical properties of materials.

CEE 140A. Biomaterials (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BCH 100, CHEM 112C, MATH 010B, PHYS 040B. Covers the principles of materials science and engineering, with attention to topics in bioengineering. Explores atomic structures, hard treatment, fundamentals of corrosion, manufacturing processes, and characterization of materials. Cross-listed with BIEN 140A.

CEE 140B. Biomaterials (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BIEN 140A/CEE 140A. Covers the structure-property relations of metals, ceramics, polymers, and composites, as well as hard and soft tissues such as bone, teeth, cartilage, ligament, skin, muscle, and vasculature. Focuses on behavior of materials in the physiological environment. Cross-listed with BIEN 140B.

CEE 147. Bio-Microelectromechanical Systems (BioMEMS) (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BIOL 005C, CEE 011, CHEM 112C, MATH 046, PHYS 040C; or consent of instructor. An introduction to bio-microelectromechanical systems with applications in bioengineering. Topics include biocompatible materials, device fabrication techniques, and principles of practical biomedical devices. Exposes students to the biotech industry and possible career paths in bioengineering.

CEE 158. Professional Development for Engineers (3) Lecture, 3 hours. Prerequisite(s): upper-division standing. A review of various topics relevant to the professional development of chemical engineers. Includes career paths; interview strategies; professional registration and preparation for certification examinations; ethics; risk management and environmental health and safety; regulatory issues; and lifelong learning.

CEE 159. Dynamics of Biological Systems (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BCH 100 or BCH 110A. Covers engineering principles for the analysis and modeling of biological phenomena. Topics include molecular diffusion and transport, membranes, ligand-bioreceptor interactions, enzyme kinetics, and dynamics of metabolic pathways and the application of these principles to the design of bioreactors, bioassays, drug delivery systems, and artificial organs. Cross-listed with BIEN 159. Credit is awarded for only one of BIEN 159/CEE 159 or BIEN 264/CEE 264.

CEE 197. Research for Undergraduates (1-4) Outside research, 3-12 hours. Prerequisite(s): consent of instructor and Chemical and Environmental Engineering undergraduate program advisor. Directed research on a topic relevant to chemical and environmental engineering. Requires a final written report. Course is repeatable to a maximum of 8 units.

Chemical Engineering

Upper-Division Courses

CHE 100. Engineering Thermodynamics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 001C, MATH 010A, PHYS 040B; or consent of instructor. An introduction to engineering thermodynamics with emphasis on chemical and environmental engineering systems. Topics include concepts of equilibrium, temperature, and reversibility; the first law and concept of energy; and the second law and concept of entropy. Also examines equations of state, thermodynamic properties, and engineering applications used in the analysis and design of closed and open systems. Credit is awarded for only one of CHE 100 or ME 100A.

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CHE 102. Catalytic Reaction Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 122 or consent of instructor. Principles of surface reactions and heterogeneous catalysis. Catalyzed reaction kinetics, heterogeneous reactions, diffusion and heterogeneous catalysis, analysis and design of heterogeneous reactors.

CHE 105. Introduction to Nanoscale Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 001C, MATH 010A, PHYS 040C; or consent of instructor. An introduction to nanotechnology engineering and its various applications. Includes electromagnetic waves and quantum mechanics; synthesis of nanostructures; assembly of nanostructures; traditional and nontraditional methods of nanolithography and interactions between electronic and optical properties. Also covers the forefront topics such as organic heterostructures, nanotubes, and quantum computing.

CHE 110A. Chemical Process Analysis (3) Lecture, 2 hours; discussion, 1 hour. Prerequisite(s): CHEM 001C, MATH 009C, PHYS 040B; or consent of instructor. Introduces the principles of conservation of mass in chemical process systems. Topics include the development of steady-state mass balances, and application of mass balances to existing industrial processes.

CHE 110B. Chemical Process Analysis (3) Lecture, 2 hours; discussion, 1 hour. Prerequisite(s): CHE 110A or consent of instructor. Applies principles of conservation of energy to chemical process systems. Topics include the development of steady-state and unsteady-state energy balances, and combined mass and energy balances in industrial processes.

CHE 114. Applied Fluid Mechanics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): MATH 010A, MATH 046; or consent of instructor. An introduction to fluid statics, fluid flow, flow of compressible and incompressible fluids in conduits and open-channel flow, flow past immersed bodies, transportation and metering of fluids, and agitation and mixing of liquids. Credit is awarded for only one of CHE 114 or ME 113.

CHE 116. Heat Transfer (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 100, CHE 114; or consent of instructor. An analysis of heat transfer for Chemical Engineering and Environmental Engineering majors. Topics include steady- and unsteady-state heat conduction, forced convection, basic radiation heat transfer, and design of heat exchangers. Credit is awarded for only one of CHE 116 or ME 116A.

CHE 117. Separation Processes (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 130/ENVE 130 (may be taken concurrently), CHE 116, CHE 120; or consent of instructor. Fundamental concepts and practical techniques for designing equipment based on equilibrium stage processes such as gas-liquid absorption, distillation, liquid-liquid extraction, solid-liquid extraction, humidification, drying, and membrane processes.

CHE 118. Process Dynamics and Control (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 117, CHE 122, ENGR 118; or consent of instructor. Fundamentals of process control. Feedback and feed-forward control of dynamic processes. Frequency response analysis. Introduction to multivariable control.

CHE 120. Mass Transfer (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 114, ENGR 118, and either CHE 110A or ENVE 171; or consent of instructor. Introduction to analysis of mass transfer in systems of interest to chemical and environmental engineering practice. Transport of matter by diffusion, free and forced convection.

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CHE 122. Chemical Engineering Kinetics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 001C, MATH 010A, MATH 046, PHYS 040B; or consent of instructor. Introduction to homogeneous and heterogeneous kinetics and reactor design for chemical and biochemical processes.

CHE 124. Biochemical Engineering Principles (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BCH 110A, BIOL 121/MCBL 121 (BIOL 121/MCBL 121 may be taken concurrently), CHE 120, CHE 122; or consent of instructor. Examines the principles of biochemical engineering. Topics include kinetics of enzymatic reactions and microbial growth, batch and continuous culture reactors, product formulation, and nutrient utilization. Also studies oxygen transfer, bioreactor scale-up, air and media sterilization, fundamentals of bioreactor design, and bioseparations.

CHE 124L. Biochemical Engineering Laboratory (2) Laboratory, 6 hours. Prerequisite(s): CHE 124 or consent of instructor. Laboratory practices in biochemical engineering. Determination of microbial kinetics and biologically mediated reactions, oxygen transfer coefficients. Batch and continuous culturing, air and media sterilization, bioseparations.

CHE 130. Advanced Engineering Thermodynamics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 100, MATH 010B (MATH 010B may be taken concurrently); or consent of instructor. Advanced study of chemical thermodynamics and their applications to chemical and environmental engineering processes. Principles for the thermodynamic behavior of pure solutions and mixtures, phases, and chemical equilibria for homogeneous and heterogeneous systems are applied to a variety of processes common to chemical and environmental engineering. Cross-listed with ENVE 130.

CHE 131. Electrochemical Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 116, CHE 122, CHE 130; or consent of instructor. Explores role of thermodynamics, charge transfer kinetics, and mass transfer on behavior of electrochemical systems. Includes cell thermodynamics, faradaic and non-faradaic rate processes, ionic transport, nucleation and growth theories. Shows applications to chemical sensors, batteries, corrosion, and thin film deposition. Provides in-class demonstrations to illustrate concepts.

CHE 136. Advanced Topics in Heat Transfer (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 116, CHE 120. Advanced study of the computational and theoretical methods associated with heat transfer, fluid flow, and other related processes. Topics include phenomena of heat conduction, convection, and the calculation of flow fields.

CHE 140. Cell Engineering (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CHE 124 or consent of instructor. Introduction to genetic and environmental manipulation of cells for production of proteins and for enhanced biocatalytic and synthetic activities. Cloning and gene expression in different host systems, posttranslational processing, metabolic controls and kinetics, *in vivo* NMR spectroscopy, cell modeling, and sensitivity analysis.

CHE 150. Biosensors (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): BCH 184 or CHE 124 or consent of instructor. Introduces the fundamentals and applications of biosensors. Topics on enzyme-, whole cell-, tissue-, and antibody/antigen-based electrochemical, optical, and piezoelectric biosensors for applications in bioprocess monitoring and control, environmental monitoring, and health care are covered.

CHE 160A. Chemical and Environmental Engineering Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): CHE 114, CHE 120. Involves laboratory exercises in chemical and environmental engineering. Experiments cover physical measurements, fluid mechanics, and mass transfer. Emphasizes experimental design, analysis of results, and preparation of engineering reports. Cross-listed with ENVE 160A.

CHE 160B. Chemical Engineering Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): CHE 116, CHE 122. Consists of laboratory exercises in chemical engineering. Includes experiments in physical measurements, heat transfer, reactor analysis, and chemical kinetics. Emphasis is on experimental design, analysis of results, and preparation of engineering reports.

CHE 160C. Chemical Engineering Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): CHE 117, CHE 118 (CHE 117 and CHE 118 may be taken concurrently), CHE 122. Consists of laboratory exercises in chemical engineering. Includes experiments and simulations in separation processes and in process control. Emphasis is on experimental design, analysis of results, and preparation of engineering reports.

CHE 161. Nanotechnology Processing Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): CHE 100 or consent of instructor. An introduction to growth and characterization techniques that involve nanomaterials and devices. Includes preparing thin films; synthesizing Au and CdS nanoparticles; synthesizing carbon nanotubes; synthesizing alumina nanotemplate; synthesizing gold and nickel nanowires; and assembling of nanowires. Also includes imaging samples with optical, scanning electron microscope, scanning tunneling microscope, and atomic force microscope.

CHE 171. Pollution Control for Chemical Engineers (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CHE 117 or consent of instructor. Principles of industrial pollution control in chemical engineering plants. Regulations, criteria, measurements, and pollution control systems associated with air, wastewater, and solid waste management.

CHE 175A. Chemical Process Design (4) Lecture, 1 hour; laboratory, 6 hours; consultation, 1 hour. Prerequisite(s): senior standing in Chemical Engineering. Introduction to chemical process plant design procedures through economic analysis and actual design of chemical processes. Topics address practical applications to current chemical and biochemical processes and economic constraints. Concentrates mainly on general design considerations and economic principles. Graded In Progress (IP) until CHE 175A and CHE 175B are completed, at which time a final, letter grade is assigned.

CHE 175B. Chemical Process Design (4) Lecture, 1 hour; laboratory, 6 hours; consultation, 1 hour. Prerequisite(s): CHE 175A; senior standing in Chemical Engineering. Introduction to chemical process plant design procedures through economic analysis and actual design of chemical processes. Topics address practical applications to current chemical and biochemical processes and economic constraints. Students complete a detailed analysis and process design of the projects begun in CHE 175A. A final report and oral presentation are required. Satisfactory (S) or No Credit (NC) grading is not available.

CHE 190. Special Studies (1-5) Individual study, 3-15 hours. Prerequisite(s): upper-division standing; consent of instructor and department chair. Individual study to meet special curricular needs. Course is repeatable to a maximum of 9 units.

Environmental Engineering

Upper-Division Courses

ENVE 120. Unit Operations and Processes in Environmental Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ENVE 133, ENVE 142; or consent of instructor. Fundamentals of physicochemical unit processes used in environmental engineering. Coagulation and flocculation, sedimentation, filtration, adsorption, redox processes, and heat and mass transfer processes.

ENVE 121. Biological Unit Processes (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ENVE 120 (may be taken concurrently), ENVE 142. An introduction to the theory and design of biological unit processes used in environmental engineering. Suspended growth processes, attached growth processes, digestion processes, and nutrient removal systems are covered.

ENVE 130. Advanced Engineering Thermodynamics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 100, MATH 010B (MATH 010B may be taken concurrently); or consent of instructor. Advanced study of chemical thermodynamics and their applications to chemical and environmental engineering processes. Principles for the thermodynamic behavior of pure solutions and mixtures, phases, and chemical equilibria for homogeneous and heterogeneous systems are applied to a variety of processes common to chemical and environmental engineering. Cross-listed with CHE 130.

ENVE 133. Fundamentals of Air Pollution Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 114, CHEM 112B, ENVE 171; or consent of instructor. Principles, modeling, and design of systems for atmospheric emission control of pollutants such as photochemical smog and by-products of combustion. Effects of air pollution on health.

ENVE 134. Technology of Air Pollution Control (4) Lecture, 4 hours. Prerequisite(s): ENVE 133. Processes and design of control technologies for gaseous and particulate pollutants. Methods and design of ambient air quality measurements and air pollution source sampling for both gaseous and particulate pollutants.

ENVE 135. Fate and Transport of Environmental Contaminants (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 112B, ENVE 120; or consent of instructor. Fate and transport of contaminants in the air, water, and soil environments. Description and modeling of advection, dispersion, phase transfer, and chemical transformation mechanisms.

ENVE 138. Combustion Engineering (4) Lecture, 4 hours. Prerequisite(s): CHE 114, ENVE 133. Covers the fundamental development of the engineering and design principles underlying combustion engines and turbines and the associated emission control technology. Includes aspects of fuels, lubricants, instrumentation, chemistry of combustion, and kinetics related to the understanding of engineering processes, engine design, and emission control.

ENVE 142. Water Quality Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 114, ENVE 171; or consent of instructor. An introduction to the engineering aspects of water quality management. Water quality characterization and modeling techniques for natural and engineered systems. Application of chemical equilibrium and kinetic models to water quality is discussed.

ENVE 144. Solid Waste Management (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): BIOL 002 or both BIOL 005A and BIOL 051A; both CHEM 001C and CHEM 011C or both CHEM 01HC and CHEM 11HC; either both ENSC 001 (or ENSC 001H) and ENSC 002 (or ENSC 002H) or ENVE 171; MATH 009B (or MATH 09HB) or MATH 022; or consent of instructor. A study of the characterization, collection, transportation, processing, disposal, recycling, and composting of municipal solid waste. Emphasizes accepted management strategies and design procedures for recovering or disposing solid wastes while protecting public and environmental well-being. Cross-listed with ENSC 144.

ENVE 145. Hazardous Waste Management (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ENVE 120 and ENVE 142. Advanced course in the study of physio-chemical, thermal, and biological treatment of hazardous waste. Emphasis is placed on the technical understanding and design of physical, biological, and thermal treatment methods; transportation of hazardous waste; and hazardous waste characterization and site assessment.

ENVE 146. Water Quality Systems Design (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 114, ENVE 142 (ENVE 142 may be taken concurrently); or consent of instructor. An introduction to methods of analysis and hydraulic design of water quality systems. Application of the basic theories of fluid flow to the design of water distribution networks, wastewater and storm water collection systems, structures for flow measurement and control, and pumps and pump stations. Emphasis is given to design projects aimed at developing design process skills, including problem specification, modeling, and analysis.

ENVE 160A. Chemical and Environmental Engineering Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): CHE 114, CHE 120. Involves laboratory exercises in chemical and environmental engineering. Experiments cover physical measurements, fluid mechanics, and mass transfer. Emphasizes experimental design, analysis of results, and preparation of engineering reports. Cross-listed with CHE 160A.

ENVE 160B. Environmental Engineering Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): ENVE 133. Consists of laboratory exercises in environmental engineering. Includes experiments in physical measurements, reaction kinetics, reactor analysis, and air pollution engineering. Emphasis is on experimental design, analysis of results, and preparation of engineering reports.

ENVE 160C. Environmental Engineering Laboratory (3) Laboratory, 6 hours; written work, 3 hours. Prerequisite(s): ENVE 120, ENVE 142. Consists of laboratory exercises in environmental engineering. Includes experiments in physical measurements, water quality, and unit operations and processes. Emphasis is on experimental design, analysis of results, and preparation of engineering reports.

ENVE 171. Introduction to Environmental Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHEM 001C, MATH 009C, PHYS 040B; or consent of instructor. Introduction to mass and energy balances. Overview of contaminants and

their effects of human health and the environment. Provides a basic understanding of contaminants, their sources, and their movement and fate in the environment.

ENVE 175A. Senior Design Project (4) Lecture, 1 hour; laboratory, 6 hours; consultation, 1 hour. Prerequisite(s): senior standing in Environmental Engineering. Under the direction of a faculty member, students (individually or in small teams with shared responsibilities) propose, design, build, and test environmental engineering devices or systems. A written report, giving details of the project and test results, and an oral presentation of the design aspects are required. Graded In Progress (IP) until ENVE 175A and ENVE 175B are completed, at which time a final, letter grade is assigned.

ENVE 175B. Senior Design Project (4) Lecture, 1 hour; laboratory, 6 hours; consultation, 1 hour. Prerequisite(s): senior standing in Environmental Engineering; ENVE 175A. Under the direction of a faculty member, students (individually or in small teams with shared responsibilities) propose, design, build, and test environmental engineering devices or systems. A written report, giving details of the project and test results, and an oral presentation of the design aspects are required. Satisfactory (S) or No Credit (NC) grading is not available.

ENVE 190. Special Studies (1-5) Individual study, 3-15 hours. Prerequisite(s): upper-division standing; consent of instructor and department chair. Individual study to meet special curricular needs. Course is repeatable to a maximum of 9 units.

Graduate Courses

CEE 200. Advanced Engineering Computation (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ENGR 118 or consent of instructor. Problem-solving techniques for basic engineering systems including heat and mass transfer, coupled reactions, fluid flow potential, and control.

CEE 202. Transport Phenomena (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 114, CHE 116, CHE 120, ENGR 118; or consent of instructor. Topics include transport phenomena, potential flow, and boundary layer theories with applications to simultaneous heat, momentum, and mass transfer. Introduces numerical techniques used to solve advanced transport phenomena problems.

CEE 204. Advanced Kinetics and Reaction Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 102 or CHE 120 or consent of instructor. Emphasizes kinetics and mechanisms of heterogeneous reactions in different types of reactors. Specific topics include gas-solid noncatalytic reactions; catalytic surfaces and catalyst characterization; and adsorption, diffusion, reaction, and heat transfer in porous catalysts.

CEE 206. Advanced Chemical Engineering Thermodynamics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 130/ENVE 130 or consent of instructor. Application of the laws of thermodynamics to phase and chemical reaction equilibrium. Introduction to statistical thermodynamics, molecular simulations, and the evaluation of thermodynamic properties from molecular simulations.

CEE 210. Cell Engineering (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CHE 124 or consent of instructor. Introduction to genetic and environmental manipulation of cells for production of proteins and for enhanced biocatalytic and synthetic activities. Topics include cloning and gene expression in differ-

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ent host systems, posttranslational processing, metabolic controls and kinetics, in vivo nuclear magnetic resonance spectroscopy, cell modeling, and sensitivity analysis.

CEE 212. Bioseparations and Bioprocess Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 124 or consent of instructor. Examines fundamentals of separation processes used to isolate and purify biochemical products such as whole cells, enzymes, food additives, and pharmaceuticals. Covers selected aspects of biochemical engineering such as microbial interactions, economics, and mathematical modeling of bioprocesses.

CEE 220. Modeling Chemical, Biochemical, and Environmental Processes (4) Lecture, 2 hours; discussion, 2 hours. Prerequisite(s): graduate standing in Chemical and Environmental Engineering or consent of instructor. Introduces simulation softwares and the use of numerical simulation to solve dynamic chemical, biochemical, and environmental problems. Topics include model formulation and development, model sensitivity studies, and application of simulations to chemical, biochemical, and environmental processes.

CEE 221. Introduction to Microfluidics (4) Lecture, 4 hours. Prerequisite(s): CHE 160A/ENVE 160A or consent of instructor. Provides a theoretical and practical introduction to microfluidic devices. Covers traditional and new methods for making microfluidic devices and assembly of components into systems. Emphasizes the considerations underlying the design or operation of devices based on pressure-driven or electrokinetic flow. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

CEE 225. Physical and Chemical Separation Processes (4) Lecture, 4 hours. Prerequisite(s): graduate standing in Chemical and Environmental Engineering or consent of instructor. Covers the fundamental and applied concepts of physical and chemical processes relevant to engineered and natural environmental systems. Topics include basic colloid chemistry and an introduction to DLVO theory, coagulation and flocculation, mechanisms of particle removal in filters and transport in porous media, absorption, disinfection, control of disinfection by-products, and advanced treatment processes such as membranes.

CEE 230. Biosensors (4) Lecture, 2 hours; laboratory, 6 hours. Prerequisite(s): BCH 110A, BCH 110B, BIOL 121/MCBL 121, CHE 124; or consent of instructor. Introduces the fundamentals and applications of biosensors. Covers enzyme-, whole cell-, tissue-, and antibody- or antigen-based electrochemical, optical, and piezoelectric biosensors. Applies such knowledge to bioprocess monitoring and control, environmental monitoring, and health care.

CEE 231. Scattering and Reflectometry for Environmental, Material, and Biological Applications (4) Lecture, 3 hours; discussion, 5 hours per quarter; laboratory, 15 hours per quarter. Prerequisite(s): CEE 206 or equivalent. Covers experimental and theoretical aspects of conventional static and dynamic light scattering, small-angle X-ray scattering, small-angle neutron scattering, X-ray and neutron reflectivity for colloids and biological solutions, surfaces, and interfaces. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

CEE 232. Green Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 120 or consent of instructor. A study of the design, commercialization, and use of feasible and economical processes and products that minimize risks to human health and the

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environment. Topics include environmental issues, risk assessment, and regulations; flow of chemical and manufacturing unit processes and flow-sheet analysis for pollution prevention; product life-cycle assessment; and industrial ecology. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor. Credit is awarded for only one of CEE 132 or CEE 232.

CEE 233. Advanced Air Pollution Control and Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CEE 202, CEE 206, CHEM 112A, CHEM 112B, ENVE 133, ENVE 134; or consent of instructor. Covers principles necessary to understand the atmospheric behavior of air pollutants. Topics include gas- and aerosol-phase chemistry, atmospheric diffusion, removal processes and residence times, and the formation and fate of gas and aerosol pollutants.

CEE 234. Vehicle Emissions Control Technology, Measurement Procedures, and Alternative Fuels (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): graduate standing or consent of instructor. Covers the nature of gaseous and particulate emissions and the technical aspects of energy efficiency from mobile sources. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

CEE 241. Water Quality (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): ENVE 142 or consent of instructor. Topics include assessment of surface water and groundwater quality for beneficial uses, fate and transport of waterborne pollutants, and water quality modeling in natural and engineered systems.

CEE 242. Pilot Plant Laboratory (4) Lecture, 1 hour; laboratory, 9 hours. Prerequisite(s): ENVE 120, ENVE 121; or consent of instructor. Laboratory investigations of physical, chemical, and biological processes for water treatment, wastewater treatment, and soil remediation.

CEE 245. Advanced Hydraulic Engineering (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 114, ENVE 142 (ENVE 142 may be taken concurrently); or consent of instructor. An introduction to the basic methods of hydraulic engineering for water quality control. Topics include design and analysis of basic flow and water containment structures, sanitary and storm sewers, pumps and valves, and pipe networks. Emphasis is given to design projects aimed at developing skills in problem specification, modeling, and analysis. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

CEE 246. Surface and Interface Phenomena (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CHE 100 or ME 100A or consent of instructor. An introduction to colloid systems, capillarity, surface tension and contact angle, and micelles and microemulsions. Also covers adsorption and desorption at the solid-liquid interface, electrostatic forces, and colloid stability.

CEE 247. Molecular Thermodynamics of Complex Fluids (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): CEE 200, CEE 206, or consent of instructor. Introduces recent developments in applied thermodynamics and molecular simulations, with emphasis on current concerns in chemical and environmental engineering such as colloids, polymers, biomacromolecules, and fluids under inhomogeneous conditions.

CEE 249. Integration of Computational and Experimental Biology (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): BIOL 005B; MATH 009B or MATH 09HB; graduate standing. Multidisciplinary introduction to the mathematical concepts of design of experiments, information content, causation versus

correlation, and statistical analysis with respect to hypothesis testing, model development, and parameter estimation. Covers state-of-the-art experimental techniques in proteomics, transcriptomics, metabolomics, and genetics. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor. Cross-listed with BIEN 249.

CEE 250. Special Topics in Chemical and Environmental Engineering (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Seminar in selected topics in chemical and environmental engineering presented by graduate students, staff, faculty, and invited speakers. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 251. Microbial Engineering and Environmental Biotechnology (1 or 2) Seminar, 1-2 hours. Discusses the recent development of novel biocatalysts and biological materials for degrading toxic pollutants or synthesizing environmentally friendly chemicals. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 253. Biodegradation and Bioremediation (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Reviews current research. Special emphasis is placed on biological techniques for air pollution control, bioremediation of methyl tert-butyl ether, and molecular techniques for microorganism monitoring. Normally graded Satisfactory (S) or No Credit (NC), but students may petition the instructor for a letter grade on the basis of assigned extra work or examination. Course is repeatable.

CEE 254. Organic Electronic Materials (2) Seminar, 2 hours. Prerequisite(s): graduate standing or consent of instructor. A study of design, synthesis, purification, manufacture, and application of carbon-based electronic materials. Students who present a seminar or submit a term paper receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable. Cross-listed with CHEM 267.

CEE 255. Special Topics in Water Quality Engineering (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Involves reports and discussion by students, faculty, and visiting scholars on current research topics in water quality engineering. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 256. Special Topics in Particulate Measurement and Air Quality (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Topics include atmospheric chemistry, aerosol chemistry and physics, and measurement techniques used for source and ambient sampling of gases and aerosols. Normally graded Satisfactory (S) or No Credit (NC), but students may petition the instructor for a letter grade on the basis of assigned extra work or examination. Course is repeatable.

CEE 257. Special Topics of Bio-Nanotechnology (1-2) Seminar, 1 hour; consultation, 0-1 hour. Prerequisite(s): graduate standing or consent of instructor. Focuses on the application of nanotechnology for further developments in bioengineering and medicine. Students complete presentations on the latest developments in nanotechnology. Students who submit a term paper receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 258. Biosensing and Biotransformation (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Involves oral presentations and intensive small-group discussions of current literature on biological detoxification of hazardous chemicals and biological-based sensors for environmental, clinical, food quality, and process monitoring. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CEE 259. Special Topics in Materials Electrochemistry (1) Seminar, 1 hour. Prerequisite(s): graduate standing. Topics include nanoelectrochemical systems, electrochemistry, bioelectrochemistry, magnetic materials, spintronics, microelectromechanical systems/nanoelectromechanical systems (MEMS/NEMS), nanosensor arrays, nanoelectronics, corrosion, fuel cells, batteries, thermoelectric materials, electroenzymology, electrodeposition, electroless deposition, and synthesis of nanowires and nanotubes. Normally graded Satisfactory (S) or No Credit (NC), but students may petition the instructor for a letter grade on the basis of assigned extra work or examination. Course is repeatable as topics change.

CEE 260. Structural Ordering in Colloidal Dispersions (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Introduces recent advances in understanding intercolloid forces and self-assembly of colloidal particles for the fabrication of new materials. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 261. Special Topics in Zeolites, Fuel Cells, and Nanostructured Materials (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Covers design, synthesis, and engineering of zeolite thin films for applications in semiconductors and in aerospace; development of fuel cell membranes and electrode catalysts and production of hydrogen; and synthesis and manipulation of nanomaterials. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 262. Special Topics in Systems Biology (1 or 2) Seminar, 1-2 hours. Prerequisite(s): graduate standing. Consists of oral presentations and intense small-group discussions of the current literature and research on computational and experimental aspects of systems biology. Explores high-throughput experiments, experimental design, numerical methods, model development, written and oral presentation skills, ethics, and laboratory techniques. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable.

CEE 263. Membrane Separations (2) Seminar, 2 hours. Prerequisite(s): graduate standing in Chemical and Environmental Engineering or consent of instructor. Covers theoretical and applied concepts of membrane separation processes. Topics may include basic membrane transport theory, membrane materials and formation processes, advanced colloid and surface chemistry, Derjaguin-Landau-Verwey-Overbeek (DLVO) theory on colloid stability, colloidal hydrodynamics, and transport in porous media. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CEE 264. Dynamics of Biological Systems (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): graduate standing or consent of instructor. Covers engineering principles for the analysis and modeling of biological phenomena. Topics include molecular diffusion and transport, membranes, ligand-bioreceptor interactions, enzyme kinetics, and dynamics of metabolic pathways

and the application of these principles to the design of bioreactors, bioassays, drug delivery systems, and artificial organs. Normally graded Satisfactory (S) or No Credit (NC), but students may petition the instructor for a letter grade on the basis of assigned extra work or examination. Cross-listed with BIEN 264. Credit is awarded for only one of BIEN 159/CEE 159 or BIEN 264/CEE 264.

CEE 265. Special Topics in Microbial Fate and Transport in Aquatic Environments (1 or 2) Seminar, 1 hour; individual study, 0-3 hours. Prerequisite(s): graduate standing or consent of instructor. Explores the theoretical and applied research currently being conducted in the area of microbial pathogen transport in natural and engineered aquatic systems. Topics include the theory of colloid transport and filtration, quantification and analysis of microbial adhesion or deposition kinetics, and whole-cell and molecular-scale microbial analysis techniques. Students who give class presentations receive credit for 2 units; other students receive credit for 1 unit. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CEE 266. Special Topics in Biological Conversion of Biomass (1 or 2) Seminar, 1 hour; individual study, 0-3 hours. Prerequisite(s): graduate standing. Consists of oral presentations and small group discussions of current and historic literature on biological conversion of biomass to fuels and chemicals. Students who make presentations receive credit for 2 units; other students receive credit for 1 unit. Graded Satisfactory (S) or No Credit (NC). Course is repeatable as topics change.

CEE 267. Special Topics in Bionanotechnology (2) Seminar, 2 hours. Prerequisite(s): graduate standing. Introduces recent advances in biomimetics, biomaterialization, and bio-inspired materials for nanostructures, as well as for energy storage and conversion applications. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable to a maximum of 18 units.

CEE 268. Special Topics in Environmental Chemistry (2) Seminar, 2 hours. Prerequisite(s): graduate standing. Addresses the key role that environmental chemical processes play in water quality, pollutant fate, and the development of strategies for the treatment and reuse of contaminated natural resources. Students who present a seminar receive a letter grade; other students receive a Satisfactory (S) or No Credit (NC) grade. Course is repeatable to a maximum of 18 units.

CEE 286. Colloquium in Chemical and Environmental Engineering (1) Colloquium, 1 hour. Prerequisite(s): graduate standing. Lectures on a current research topic in chemical engineering, environmental engineering, and other related fields presented by faculty members and visiting scientists. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

CEE 290. Directed Studies (1-6) Individual study, 3-18 hours. Prerequisite(s): graduate standing; consent of instructor and graduate advisor. Individual study, directed by a faculty member, of selected topics in chemical and environmental engineering. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 9 units.

CEE 292. Concurrent Studies in Chemical and Environmental Engineering (1-4) Outside research, 3-12 hours. Prerequisite(s): consent of instructor. To be taken concurrently with a 100-series course but on an individual basis. Devoted to specific additional projects related to the 100-series course. Faculty

provide guidance and evaluation throughout the quarter. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 8 units.

CEE 297. Directed Research (1-6) Outside research, 3-18 hours. Prerequisite(s): graduate standing; consent of instructor. Research conducted under the supervision of a faculty member on selected problems in chemical and environmental engineering. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 9 units.

CEE 298-I. Individual Internship (1-12) Written work, 1-12 hours; internship, 2-24 hours. Prerequisite(s): graduate standing; consent of instructor. Individual apprenticeship in chemical and environmental engineering with an approved professional individual or organization, and a faculty member. A written report is required. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 16 units.

CEE 299. Research for the Thesis or Dissertation (1-12) Outside research, 3-36 hours. Prerequisite(s): graduate standing; consent of instructor. Research in chemical and environmental engineering for the M.S. thesis or Ph.D. dissertation. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

Professional Course

CEE 302. Teaching Practicum (1-4) Seminar, 1-4 hours. Prerequisite(s): appointment as a teaching assistant or associate in Chemical and Environmental Engineering. Topics include effective teaching methods such as those involved in leading discussion sections, preparing and grading examinations, and student-instructor relations in lower- and upper-division Chemical Engineering and Environmental Engineering courses. Required each quarter of teaching assistants and associates in Chemical and Environmental Engineering. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 12 units.

Chemistry

Subject abbreviation: CHEM
College of Natural and Agricultural Sciences

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Leonard Mueller, Ph.D., Vice Chair
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Professors

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Cynthia K. Larive, Ph.D.
Thomas H. Morton, Ph.D.
Michael Pirrung, Ph.D. *UC Presidential Chair in Chemistry*
Dallas L. Rabenstein, Ph.D.
Christopher A. Reed, Ph.D.
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Catharine Larsen, Ph.D.
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**

Cooperating Faculty

Roger Atkinson, Ph.D. (Environmental Sciences)
Sean Cutler, Ph.D. (Botany and Plant Sciences)
Richard Debus, Ph.D. (Biochemistry)
Russ Hille, Ph.D. (Biochemistry)
Jocelyn G. Millar, Ph.D. (Entomology)
Ashok Mulchandani, Ph.D. (Chemical Engineering)
Jerome S. Schultz, Ph.D. (Bioengineering)
Paul J. Ziemann, Ph.D. (Environmental Sciences)

Major

The Department of Chemistry offers a B.S. and B.A. degree in Chemistry and a B.S. in Chemistry with a Chemical Physics option or an Environmental Chemistry option.

The B.S. program is certified by the American Chemical Society and is designed for students interested in a professionally oriented major leading most often to a career or advanced study in chemistry.

The B.A. program is designed for students who wish to obtain a broad educational background with less intensive emphasis on chemistry. In this program, students have increased ease in meeting requirements for such areas as pre-medical, pre-dental, or prepharmaceutical science; education; and administration. Check www.careers.ucr.edu.

A **Chemical Physics** option is available for students who wish to prepare for admission to a graduate program in chemical physics.

The **Environmental Chemistry** option is available for students who wish to become familiar with environmental processes and problems related to air, water, and soil, and to apply their chemical knowledge working in environmental-related areas. This option also prepares students for admission to a graduate program emphasizing environmental chemistry.

Pre-Health Science Chemistry majors in either the B.S. or B.A. programs can prepare for admission to medical, pharmacy, or dental schools by care-