of materials are performed using the basic tools and techniques of experimental stress analysis.—II, III. (II, III.)

105. Thermodynamics (4)
Lecture—4 hours. Prerequisite: Mathematics 22B and Physics 9B. Open to Engineering majors only. Fundamentals of thermodynamics: heat energy and work, properties of pure substances, First and Second Law for closed and open systems, reversibility, entropy, thermodynamic temperature scales. Applications of thermodynamics to engineering systems.—I, II, III. (I, II, III.)

106. Engineering Economics (3)
Lecture—3 hours. Prerequisite: upper division standing in Engineering. The analysis of problems in engineering economy; the selection of alternatives; replacement decisions. Compounding, tax, origins and cost of capital, economic life, and risk and uncertainty are applied to methods of selecting most economic alternatives.—II. (II.) Hartsough, Slaughter

111. Electric Power Equipment (3)
Lecture—2 hours; laboratory—3 hours. Prerequisite: course 17. Principles of AC and DC electric motors and generators, their control systems and power sources. Selection of electric power equipment components based on their construction features and performance characteristics.—I. (II.) Delwiche Hartsough

121. Fluid Power Actuators and Systems (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: courses 100, 102, 104 and either 103 or Biological Systems Engineering 103. Hydraulic and pneumatic systems with emphasis on analysis and control of actuators. Design of hydraulic and pneumatic systems, specification and sizing of components, and selection of electro-hydraulics/electro-pneumatics, servo valves, and closed loop systems to solve basic control problems.—(II.) Rosa

122. Introduction to Mechanical Vibrations (4)
Lecture—4 hours. Prerequisite: course 102. Free and forced vibrations in lumped-parameter systems with and without damping; vibrations in coupled systems; electromechanical analogs; use of energy conservation principles.—I. (I.) Frank

160. Environmental Physics and Society (3)
Lecture—3 hours. Prerequisite: Physics 9D, 5C, or 10 or 1B and Mathematics 16B or the equivalent. Impact of humankind on the environment will be discussed from the point of view of the physical sciences. Calculations based on physical principles will be made, and the resulting policy implications will be considered. (In the College of Engineering, students may receive only one unit of credit towards the Technical Electives requirement.) (Same course as Physics 160.) GE credit: SciEng or SocSci.—I. (I.) Jungerman, Craig

180. Engineering Analysis (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 21D, 22B, and course 6 or Mechanical Engineering 5. Solutions of systems of linear and nonlinear algebraic equations; approximation methods; solutions of ordinary differential equations; initial and boundary value problems; solutions of partial differential equations of Elliptic, parabolic, and hyperbolic types; Eigen value problems.—I. (I.) Hafez

190. Professional Responsibilities of Engineers (3)
Lecture—3 hours; laboratory—1 hour. Prerequisite: upper division standing. Organization of the engineering profession; introduction to contracts, specifications, business law, patents, and liability; discussion of professional and ethical issues; oral presentations on the interactions between engineering and society.—II, III. (II, III.)

198. Directed Group Study (1-5)
May be repeated for credit up to 3 times. (P/NP grading only.)

Graduate Course

250. Technology Management (3)
Lecture—3 hours. Prerequisite: consent of instructor. Management of the engineering and technology activity. Functions of design, planning, production, marketing, sales, and maintenance. Technological product life cycle. Research and development activity. Project planning and organization. Manufacturing issues. Case studies.—I. (III.)

Engineering: Applied Science

(College of Engineering)

Ann E. Orel. Ph.D., Chairperson of the Department

Hector A. Baldis, Ph.D., Vice Chairperson of the Department

Department Office. Engineering III
(530) 752-0360; *http://www.das.ucdavis.edu*

Faculty

Hector A. Baldis, Ph.D., Professor
Stephen P. Cramer, Ph.D., Professor
Yong Duan, Ph.D., Associate Professor
Francois Gygi, Ph.D., Professor
David Q. Hwang, Ph.D., Professor
Niels G. Jensen, Ph.D., Professor
Brian H. Kolner, Ph.D., Professor *(Applied Science, Electrical and Computer Engineering)*
Denise M. Krol, Ph.D., Professor
Neville C. Luhmann, Jr., Ph.D., Professor *(Applied Science, Electrical and Computer Engineering)*
Nelson Max, Ph.D., Professor *(Applied Science, Computer Science)*
William McCurdy, Ph.D., Professor *(Applied Science, Chemistry)*
Greg Miller, Ph.D., Professor
Ann E. Orel, Ph.D., Professor
Atul N. Parikh, Ph.D., Associate Professor
David M. Rocke, Ph.D., Professor *(Applied Science, CIPIC)*
Garry Rodrigue, Ph.D., Professor
Rao Vemuri, Ph.D., Professor *(Applied Science, Computer Science)*
Yin Yeh, Ph.D., Professor

Emeriti Faculty

Berni J. Alder, Ph.D., Professor Emeritus
Meera M. Blattner, Ph.D., Professor Emeritus
Stewart D. Bloom, Ph.D., Professor Emeritus
Richard Christensen, Ph.D., Professor Emeritus
Paul P. Craig, Ph.D., Professor Emeritus
Richard R. Freeman, Ph.D., Professor Emeritus
John S. De Groot, Ph.D., Professor Emeritus
Jonathan P. Heritage, Ph.D., Professor *(Applied Science, Electrical and Computer Engineering)*
William G. Hoover, Ph.D., Professor Emeritus
John Killeen, Ph.D., Professor Emeritus
Richard F. Post, Ph.D., Professor Emeritus
Wilson K. Talley, Ph.D., Professor Emeritus

Affiliated Faculty

Rod Balhorn, Ph.D., Adjunct Professor
Andrew Canning, Ph.D., Adjunct Professor
James S. Felton, Ph.D., Adjunct Professor

The Major Program

The Department of Applied Science administers two programs: Optical Science and Engineering and Computational Applied Science.

Mission Statement. The mission of the Department of Applied Science is to foster the use of fundamental mathematical and scientific knowledge to improve the quality of life. We provide the profession and academia with outstanding Computational Applied Science and Optical Science and Engineering graduates who advance both engineering practice and fundamental knowledge.

We challenge students to develop attributes that lead to professional growth throughout their careers: a sense of community, ethical responsibility, an expectation for lifelong learning and continuing education, the ability to think independently and perform creatively and effectively in teams, and the ability to communicate effectively both orally and in written media.

Upon graduation, we challenge our students to understand the fundamentals and the application of mathematics and sciences, to have an ability to design, conduct, and understand experiments, as well as to analyze and interpret data; to have a proficiency in the design of components and systems to meet desired performance specifications; an ability to function effectively on multi-disciplinary teams; a proficiency in the use of techniques, skills, and modern engineering tools to identify, formulate, and solve scientific and engineering problems; an understanding of professional and ethical responsibility; a proficiency in oral and written communication; the broad education necessary to understand the impact of engineering solutions in a global and societal context; an ability to engage in graduate education and life-long learning; and a knowledge of contemporary issues that have an impact on society and the profession.

Computational Applied Science Major Program

The Computational Applied Science program is not accredited by the Engineering Accreditation Commission of Accreditation Board for Engineering and Technology, Inc.

Computational Applied Science (CAS) encompasses the interplay between the mathematics of models, arising from physical science and engineering, and the numerical techniques for their computational implementation and subsequent solution. With a comprehensive background in mathematics and physical sciences, the major has, as its specific objective, to enable students in the major to construct practical numerical solutions to problems in science and engineering. A strong component of the program is the development, analysis, and integration of numerical algorithms and an appreciation for the interaction between numerical simulation, theoretical models, and experiment. Students who complete the Computational Applied Science program will receive a Bachelor of Science degree in Computational Applied Science.

Objectives. The objective of the Computational Applied Science program is to provide a basic education in the fundamental principles of computational applied science combined with key courses in mathematics, engineering, and the sciences. This will enable an integrated understanding of all components leading to practical and efficient computational solutions to problems. The major prepares students for careers in computational applied science professions as well as for graduate study in related fields.

Lower Division Required Courses

	UNITS
Applied Science Engineering 2	4
Mathematics 21A-21B-21C-21D	16
Mathematics 22A-22AL-22B	7
Physics 9A-9B-9C-9D	19
Chemistry 2A	5
Engineering 17	4
Computer Science Engineering 30 and 40	8
Computer Science Engineering 20 or 50 or Electrical Engineering 70	4
English 3 or University Writing Program 1 or Comparative Literature 1, 2, 3, or 4, or Native American Studies 5	4
Communication 1 or 3	4
Civil Engineering 19	4
General Education electives	12
Minimum Lower Division Units	**91**

Upper Division Required Courses

Applied Science Engineering 115, 116, 117A, 117B, 117C, 118, 119	31

Statistics 131A or Civil Engineering 114 or Mathematics 131 ... 4
Physics 104A ... 4
Civil Engineering 119 ... 4
Computational Applied Science electives* ... 28
Engineering 190 ... 3
General Education electives ... 12
Unrestricted electives ... 3
Minimum Upper Division Units ... 89

Minimum Units Required for Major ... 180

* Computational Applied Science Electives must be chosen in consultation with a faculty adviser. You may receive CAS elective credit, up to a maximum of 4 units, for any combination of engineering courses numbered 190C, 192, 198, and 199. With the exception of the following courses, all upper-division courses in chemistry, engineering, mathematics, physics, and statistics may be taken as CAS electives. The courses that may not be used are Chemistry 194HA, 194HB, 194HC, 197, 198, 199; Electrical and Computer Engineering 101; Engineering 160 (restricted to one unit of CAS elective); Mathematics 192, 194, 197TC, 198, 199; Physics 160 (restricted to one unit of CAS elective), 194HA, 194HB, 195, 197T, 198, 199; Statistics 102

The Minor in Computational Applied Science

A minor in Computational Applied Science will follow a logical composition of courses requiring prerequisites of basic courses equivalent to Mathematics 21A-21B-21C-21D and 22A-22B, Physics 9A-9B-9C-9D, and Computer Science and Engineering 30. Students considering the possibility of earning a Computational Applied Science minor should consult a major adviser before beginning coursework.

Computational Applied Science ... 22

Applied Science Engineering 115, 116, 117A, 117B, 119 ... 22

Optical Science and Engineering

The Optical Science and Engineering program is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; (410) 347-7700.

Optical Science and Engineering encompasses the physical phenomena and technologies associated with the generation, transmission, manipulation, detection, and applications of light. The Optical Science and Engineering curriculum prepares students to design, analyze, and fabricate effective optical systems. Much of the nation's high-technology infrastructure is based upon optics and its applications, the most prominent being optical digital information transmission. Optical systems play a central role in nearly all aspects of modern life including health care and the life sciences, remote optical sensing, lighting, cameras, space, and national defense.

Students who complete the Optical Science and Engineering curriculum will receive a Bachelor of Science degree in Optical Science and Engineering.

Objectives. Our fundamental program objective is to educate students in the basics required for optical science and engineering: mathematics, sciences, and engineering. We educate students in the fundamentals of the science, analysis, and design of optical systems.

The Optical Science and Engineering Major Program

Lower Division Required Courses

UNITS

Applied Science Engineering 1 ... 4
Mathematics 21A-21B-21C-21D ... 16
Mathematics 22A-22B ... 6
Physics 9A-9B-9C-9D ... 19
Chemistry 2A ... 5
Civil Engineering 19 or Computer Science Engineering 30 ... 4
Engineering 17 ... 4
Engineering 45 ... 4
English 3 or University Writing Program 1 or Comparative Literature 1, 2, 3, or 4, or Native American Studies 5 ... 4
Communication 1 or 3 ... 4
General Education electives ... 16
Total Lower Division Units ... 86

Upper Division Required Courses

Applied Science Engineering 108A, 108B, 115, 161, 165, 166, and 167 ... 28
Electrical and Computer Engineering 130A, 130B, and 135 ... 11
Physics 104A ... 4
Physics 112 or Chemistry 110C ... 4
Chemistry 110A ... 4
Applied Science Engineering 137 or Engineering 190 ... 3
Optics electives ... 20
20 units from the following: Applied Science Engineering 116, 167, 170, 172; Biological Sciences 102; Chemistry 110B; Electrical and Computer Engineering 100, 106, 133, 136, 140A, 140B, 150A, 150B
Technical electives ... 12
General Education electives ... 8
Minimum Upper Division Units ... 94

Minimum Units Required for Major ... 180

Optics electives and technical electives should be chosen in consultation with a staff or faculty adviser.

The Graduate Program

M.S. and Ph.D. in Applied Science
Designated Ph.D. emphasis available in Biophotonics
http://www.das.ucdavis.edu
(530) 754-8858

Graduate students in Applied Science at UC Davis use mathematics and physics to discover new knowledge at the dynamic intersections of engineering, mathematical, physical and biological sciences. Our mission is to advance the leading edge of research and create tools to serve industry, government and society.

We offer unusually rich research opportunities, with a high level of support for graduate students and demonstrated excellence in career prospects following graduation. Nanotechnology and biophotonics are particular areas of interest.

A major strength of the department is its access to the scientists and facilities of the Lawrence Livermore National Laboratory where many of our faculty have joint appointments. Nearly all the students use the laboratory for their thesis research, while the laboratory's facilities are some of the nation's best in atomic and molecular physics, computational physics, fusion technology, laser physics and nonlinear optics, materials science and condensed matter physics, plasma physics and scientific computing.

Generous financial support is available in the form of research assistantships, teaching assistantships, fellowships and financial aid.

Research Highlights:

- Applied Biosciences & Biotechnology
- Atomic, Molecular and Laser Physics
- Optical Sciences
- Computational Science & Engineering
- Materials Science & Condensed Matter Physics
- Plasma Science & Fusion Engineering
- Computer Visualization and Communications

Research Facilities:

- Lawrence Livermore National Laboratory
- Lawrence Berkeley National Laboratory
- Los Alamos National Laboratory
- High-Power Microwave Source and Plasma Interaction Laboratory
- Far-Infrared and Millimeter Wave Magnetic Fusion Plasma Diagnostics
- Ultrafast Optics and Optoelectronics Facility
- Center for Biophotonics Science and Technology

Complete Information on departmental Web site.

Courses in Engineering: Applied Science—Davis (EAD)

Lower Division Courses

1. Optical Science and Engineering (4)

Lecture—3 hours; discussion—1 hour. Discussion and demonstrations of optical science and engineering principles and applications. Discussion of the opportunities and professional practice in the field including ethics and responsibilities.—I. (I.) Baldis, Cramer, Orel

2. Introduction to Applied Computational Science and Engineering (4)

Lecture—3 hours; laboratory—3 hours. Prerequisite: Mathematics 21C (may be taken concurrently), Physics 9A (may be taken concurrently), Computer Science Engineering 30. Role of mathematics in modeling physical, biological, and engineering phenomena. Pitfalls in computation. Limitations of models, numerical implementations, and quality assessment of computational data. Interactions among mathematics, algorithms, computer hardware and software, and selected scientific and engineering applications.—III. (III.)

90C. Research Group Conference for Lower Division Students (1)

Discussion—1 hour. Prerequisite: lower division standing; consent of instructor. May be repeated for credit. (P/NP grading only.)—I, II, III. (I, II, III.)

98. Directed Group Study (1-5)

Prerequisite: consent of instructor and lower division standing. (P/NP grading only.)

99. Special Study for Lower Division Students (1-5)

Prerequisite: consent of instructor. (P/NP grading only.)

Upper Division Courses

108A. Optics I (4)

Lecture—3 hours; laboratory—3 hours. Prerequisite: Physics 9C and Mathematics 21D. Optical properties of matter, the nature of light, reflection, refraction, and other properties of light. Basic optical components, reflecting systems, and dispersive components. Geometrical optics, ray tracing, and optical aberrations. Optical instruments. The color of light.—I. (I.) Baldis, Kolner

108B. Optics II (4)

Lecture—3 hours; laboratory—3 hours. Prerequisite: course 108A. Introduction to wave theory of optics, including Maxwell's equations and boundary condition, reflection and transmission coefficients, interference, diffraction, polarization, thin film and ultra thin film optics, and radiation from extended distributions of oscillating electric dipoles. Applications of wave optics. Not open for credit to students who have completed Physics 108 and 108L.—II. (II.) Baldis, Kolner

108L. Optics Laboratory (4)

Discussion—1 hour; laboratory—6 hours; extensive problem solving—3 hours. Prerequisite: courses 108A, 108B. Practical applications of principles of geometrical and physical optics. Optical properties of materials, imaging, lens fabrication, interferometry, polarization, photometry, polarization, diffraction and propagation. Small course fee for materials.—III. (III.) Kolner

115. Numerical Solution of Engineering and Scientific Problems (4)

Lecture—3 hours; discussion—1 hour. Prerequisite: Engineering 6 or Computer Science Engineering 30, and Mathematics 22B. Computer problem solving, including error analysis, roots of equations, systems of equations, interpolation and data fitting, integration; initial value, boundary value, and eigenvalue ordinary differential equations. Emphasis on robust methods to solve realistic problems.—I. II, III. (I, II, III.)

116. Computer Solution of Physical Problems (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 115. Application of computers to the solution of physical problems. Numerical solution of elliptic, parabolic, and hyperbolic partial differential equations. Eigenvalue problems. Monte Carlo methods.—III. Jensen, Cramer, Miller, Orel, Laub, McCurdy, Rodrigue

117A. Simulation and Modeling of Deterministic Dynamical Systems (5)
Lecture—3 hours; laboratory—3 hours; extensive problem solving—3 hours. Prerequisite: course 2, 116; Physics 104A. Numerical techniques for simulation and modeling of nonlinear deterministic systems. Examples from fluid, continuum, molecular mechanics, low dimensional nonlinear systems. Emphasis on error and stability through adaptive methods, evaluation of relationships between physical systems, the model equations, numerical implementation. Jensen, McCurdy, Miller, Orel, Rocke

117B. Simulation and Modeling of Statistical Systems (5)
Lecture—3 hours; laboratory—3 hours; extensive problem solving. Prerequisite: Statistics 131A or Civil and Environmental Engineering 114 or Mathematics 131 and course 117A. Simulation of stochastic systems, maps, and deterministic chaos. Stability and error control in stochastic modeling. Fluctuations and dissipation; dynamics of complex and disordered systems; Monte Carlo techniques, Brownian, Langevin, and molecular dynamics. Simulation of meaningful statistical sampling in stochastic and disordered systems.—II. (II.) Miller, Orel, Laub, McCurdy, Rodrique

117C. Topics in Simulation and Modeling (5)
Lecture—3 hours; laboratory—3 hours; extensive problem solving. Prerequisite: course 117B. Topics may include algorithms in electromagnetics, materials, biology, and economics. Fast multipole and resummation techniques, algorithms for integral transforms, mesh generation, combinatorics, encryption; data mining, handling, and compression of large data sets; optimization.—III. (III.) Miller, Orel, Laub, McCurdy, Rodrigue

118. High Performance Computing (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 117B (may be taken concurrently). Algorithms for efficient scientific computing on modern high-performance computers; influence on algorithms of distributed computing, memory management, networking, and information flow; managing relationships among computer architecture, software, and algorithms.—II. (II.) Miller, Orel, Laub, McCurdy, Rodrigue

119. Applied Computational Linear Algebra (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 115 and Physics 104A. Introduction to computational linear algebra with emphasis on applications in engineered systems; matrix factorizations; mathematical software for fundamental algorithms.—I. (I.) Jensen, Laub

161A. Optical Design (4)
Lecture—3 hours; lecture/laboratory—3 hours. Prerequisite: course 108A; senior level standing. Optical materials and design of optical systems. Computer assisted design of optical systems including construction and final system characterization. Knowledge and skills acquired in earlier course work are used for designing that include engineering standards and realistic constraints. (Deferred grading only, pending completion of sequence.)—II. (II.) Baldis

161B. Optical Design (4)
Lecture—3 hours; laboratory—1 hour. Prerequisite: courses 108A, 161A (completed during the previous quarter); senior level standing,. Design of a complete optical system, construction, testing, and calibration. The knowledge and skills acquired in earlier course work are used for designing that includes engineering standards and realistic constraints. Knowledge and skills acquired in 161A are essential. (Deferred grading only, pending completion of sequence.)—III. (III.) Baldis

165. Statistical and Quantum Optics (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: Chemistry 110A; Electrical and Computer Engineering 130B. Waves and photons; photon number and fluctuations; field and number correlations; atom-photon interactions; line broadening, Einstein coefficients; strong field interactions; photon bunching and anti-bunching; photoelectric counting distributions for chaotic and coherent light; squeezed states.—I. (I.) Yeh

166. Lasers and Nonlinear Optics (4)
Lecture—3 hours; laboratory—3 hours. Prerequisite: course 165. Optical gain and amplification, laser threshold conditions, laser pumping requirements and techniques, laser resonator optics, cavity design, specific laser systems, short pulse generation, Q-switching, mode-locking, principles of nonlinear optics, second harmonic generation. optical parametric amplification, electro-optic effect.—II. (II.) Krol, Yeh

167. Fourier Optics (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Physics 104A and Electrical and Computer Engineering 130B. Linear systems analysis of two-dimensional optical systems, 2D Fourier transforms, scalar diffraction theory, Fresnel and Fraunhofer diffraction, coherent and incoherent optical systems, spatial frequency analysis, analog optical information processing, spatial light modulators, film, holography, character recognition, and image restoration.—II. (II.) Kolner, Orel, Jensen

169. Optical Properties of Materials (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 108B, Engineering 45, and Chemistry 110A. Relation between structure, composition, and optical properties of laser materials, nonlinear optical materials, photorefractives, fiber optics, semiconductors, liquid crystals, and thin films.—III. (III.) Krol, Parikh

170. Optical Spectroscopy: Concepts and Instrumentation (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Chemistry 110A and course 166. Fundamentals of absorption and emission, spectrometers, interferometers, light sources and detectors, UV, Visible, and IR spectroscopy, fluorescence spectroscopy, Raman and Brillouin scattering, high-resolution laser spectroscopy.—III. (III.) Orel, Kolner, Yeh, Parikh

172. Optical Methods for Biological Research (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 108B, Biological Sciences 2A, and Chemistry 110A. Optical techniques for resolving significant research problems in biology. Examples include the sequence, structure, and movement of DNA; nuclear organization and DNA replication; channel transport; membrane receptor sites and cell fusion; protein-protein interactions and supramolecular organization.—III. (III.) Yeh

190C. Research Group Conference for Advanced Undergraduates (1)
Discussion—1 hour. Prerequisite: advanced standing; consent of instructor. Weekly conference on research problems, progress and techniques in applied science. May be repeated for credit. (P/NP grading only.)—I, II, III. (I, II, III.)

192. Internship (1-5)
Internship—3-36 hours. Prerequisite: consent of instructor; upper division standing; approval of project prior to the period of the internship. Supervised work experience in Optical Science Engineering or Computational Applied Science. May be repeated for credit. (P/NP grading only.)—I, II, III. (I, II, III.)

198. Group Study (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)

199. Special Study for Advanced Undergraduates (1-5)
Prerequisite: consent of instructor. (P/NP grading only.)

Graduate Courses

205A. Mathematical Methods (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Mathematics 22B or equivalent. Complex variables, theory of convergence, evaluation of definite integrals, factorial function (gamma function), solution of second-order ODEs, Fourier analysis.—I. (I.) Jensen, Miller, Orel, Rodrique

205B. Mathematical Methods (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 205A. Laplace transforms, Fourier transforms, Delta sequences, Direct solution of PDEs, Green's functions for PDEs.—II. (II.) Jensen, Miller, Orel, Rodrique

205C. Mathematical Methods (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Mathematics 22A and 22B or equivalent. Spherical harmonics, Bessel functions, special functions, finite and infinite vector spaces.—I. (I.) Jensen, Miller, Orel

209. Linear Modeling Techniques (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: Mathematics 167 or the equivalent strongly recommended. Matrix theory and linear algebra with emphasis on applications in engineered systems; geometric aspects of linear algebra; matrix factorizations; analysis and design techniques for discrete- and continuous-time lumped parameter models.—I. (I.) Laub

210A. Numerical Methods in Applied Science (4)
Lecture—3 hours; lecture/discussion—1 hour. Prerequisite: facility with a programming language; C or C++ strongly recommended. Numerical methods developed from an applied mathematics perspective: Analysis and control of numerical error, interpolation, integration, noniterative solution of linear systems, iterative methods for root finding and minimization.—II. (II.) Rodrigue, Miller, Jensen

210B. Numerical Methods in Applied Science (4)
Lecture—3 hours; lecture/discussion—1 hour. Prerequisite: facility with a programming language; C or C++ strongly recommended. Numerical methods developed from an applied mathematics perspective: Iterative methods for linear systems, numerical solutions for ODE initial and boundary value problems, numerical PDEs, eigenvalues and eigenvectors.—III. (III.) Rodrigue, Miller, Jensen

210C. Numerical Methods in Applied Science (3)
Lecture—3 hours. Prerequisite: course 210B. Computational methods in various fields including: fluid mechanics, kinetic theory, solid mechanics, quantum mechanics.—I. (I.) Rodrigue, Vemuri

211A. Numerical Solution of Partial Differential Equations I (3)
Lecture—3 hours. Prerequisite: course 210A, 210B. Fundamentals of parallel computers, grid generation, domain decomposition, Poisson's equation, elliptic PDEs, Galerkin methods, numerical linear algebra, iterative acceleration.—I. (I.) Rodrigue, Miller, Orel, Jensen

211B. Numerical Solution of Partial Differential Equations II (3)
Lecture—3 hours. Prerequisite: course 211A. Parabolic PDEs, stability, preconditioned time differencing, hyperbolic PDEs, modified differential equation, advection-diffusion equations, wave equation, Burgers' equation, reaction-diffusion equations.—II. (II.) Rodrigue, Miller, Orel, Jensen

211C. Numerical Solution of Partial Differential Equations III (3)
Lecture—3 hours. Prerequisite: course 211B. Conservation laws, fluid equations, turbulence, elasticity equations, electromagnetic equations, transport equations.—III. (III.) Rodrigue, Miller, Orel, Jensen

213A. Computer Graphics (3)
Lecture—3 hours. Prerequisite: consent of instructor. Development of algorithms for perspective line drawings of three-dimensional objects, as defined by polygons or bicubic patches.—(II.) Max

217A. Applied Computational Science (3)
Lecture—3 hours. Prerequisite: course 210A, Mathematics 229A or the equivalent (may be taken concurrently). Applied modular programming in low level language (c or fortran). Direct implementations and integrated applications of algorithms applied to computational science problems, which are exemplified through projects. Emphasis on the practical use and implementation of theory taught in course 210A.—I. Rodrique, Miller, Orel, Jensen

217B. Applied Computational Science (3)
Lecture—3 hours. Prerequisite: course 210B or the equivalent (may be taken concurrently). Applied modular programming in low level language (c or fortran). Direct implementations of the theory taught in course 210B and integrated applications of algorithms for computational science problems, exemplified through projects including partial differential equations; initial/boundary value problems.—II. Rodrique, Miller, Orel, Jensen

218. Signal Processing (3)
Lecture—3 hours. Prerequisite: Mathematics 121A, 121B or the equivalent. Discrete-time and continuous-time signal processing. Fourier transforms, Laplace transforms, sampling and reconstruction. LTI systems: convolution. Discrete-time transforms: DFT, FFT, and Discrete wavelet transforms. Filters and filter designs.—I. (I.) Dowla

219. Wavelets and Their Applications (3)
Lecture—3 hours. Prerequisite: Electrical and Computer Engineering 150A, Mathematics 167. Fourier transforms and digital filters; sampling theorem and analog-to-digital conversion, multirate signal processing; wavelet transforms and filter banks; fast algorithms: FFT, DWT, and pyramid; data compression with wavelets; spectral factorization; designing application-specific wavelets. Offered in alternate years.—(II.) Dowla

220A. Artificial Neural Nets–I (3)
Lecture—3 hours. Prerequisite: Mathematics 167; ability to use computers to solve problems using a traditional language or via tools like Matlab or Mathematica. Biological and Computational motivations. Models of neurons. Supervised and unsupervised learning. Correlation matrix memories. Discrete and continuous Hopfield nets. Self organization. Kohonen Net. Counter propagation. Perceptron. LMS methods. Back propagation. Offered in alternate years.—(I.) Vemuri

220B. Artificial Neural Nets–II (3)
Lecture—3 hours. Prerequisite: course 220A. Growing and pruning algorithms for multi-layer perceptrons, acceleration of convergence, conjugate gradient methods. RBF networks. Temporal processing. Modular networks. Reinforcement learning. Neurodynamics. Case studies. Offered in alternate years.—(II.) Vemuri

221. Genetic Algorithms and Optimization (3)
Lecture—3 hours. Prerequisite: Mathematics 145 or the equivalent; graduate standing; ability to program in one of the modern programming languages. Introduction to genetic algorithms. Fundamental theorem; schema processing; genetic operators; applications to function optimization, scheduling, VLSI circuit layout. Implementation on parallel computers; genetic programming; evolutionary algorithms.—(III.) Vemuri

225. Computational Structures for Signal and Image Processing and Graphics (3)
Lecture—3 hours. Prerequisite: Computer Science Engineering 40; course 210A. Tools for research in digital media. Relevant computer architectures, algorithms and languages for signal processing, image processing and graphics. Hardware and software issues in parallelism. Programming in SISAL. Parallel C and Parallel Fortran. Parallel algorithms using SISAL on parallel computers. Offered in alternate years.—(III.) Vemuri

226. Practical Data Communications in Digital Media (3)
Lecture—3 hours. Prerequisite: Computer Science Engineering 152. Tools for research in digital media. Communication protocols, algorithms and architectures suitable in modern networked environment. Transmission of digital data over voice-grade channels, telecommunications networks for data transport, Broadband multimedia communications, ATM, and Broadband ISDN. Offered in alternate years.—(II.) Vemuri

228A-228B-228C. Properties of Matter (3-3-3)
Lecture—3 hours. Prerequisite: Mathematics 22B and Physics 112B. Microscopic and macroscopic descriptions of matter; thermodynamics and kinetics; constitutive, electrical, mechanical and thermal properties.—I, II, III. (I, II, III.) Luhmann, Yeh, Baldis, McCurdy

229. Computational Molecular Modeling (4)
Lecture—3 hours; project. Prerequisite: course 210A and 228A or consent of instructor. Theory and hands-on implementation of algorithm in computational statistical mechanics. Temporal integrators, molecular dynamics, force fields, constrained dynamics, Monte Carlo techniques, fluctuation-dissipation theorem, and parallel vs. serial computing.—II. (II.) Jensen

230. Topics in Computational Fluid Dynamics (3)
Lecture—3 hours. Prerequisite: course 210A, 210B or consent of instructor. A hands-on approach to numerical methods for compressible fluid flow. Readings and discussions of solution strategies complemented with programming exercises and projects to give first hand experience with performance and accuracy of several computational methods; from upwind differencing to Godunov methods.—III. (III.) Miller

231A. Applied Quantum Mechanics (3)
Lecture—3 hours; discussion—1 hour. Prerequisite: courses 205ABC (may be taken concurrently). Classical properties of matter; introduction to quantum mechanics by the correspondence principle. Solvable bound state/continuum problems in 1-D: well, barrier, and harmonic oscillator. Solvable problems in 3-D: HO, well, and hydrogen atom. Matrix theory: Schroedinger, Heisenberg, and interaction pictures.—II. (II.) Orel, Krol, Yeh

231B. Applied Quantum Mechanics (4)
Lecture—3 hours; discussion—1 hour. Prerequisite: course 231A. Approximate methods in quantum mechanics, perturbation methods, variational methods, time dependent perturbation theory, scattering, and radiation.—III. (III.) Orel, Krol, Yeh

233A-233B-233C. Theory and Applications of Solid-State Physics (3-3-3)
Lecture—3 hours. Prerequisite: course 230C or the equivalent. Structure and properties of crystals; theory of dielectrics, metals and alloys; magnetism, superconductivity, and semiconductors. Applications to various solid-state devices.—I-II-III. (I-II-III.) Orel

234A. Applied Electromagnetics I (3)
Lecture—3 hours. Prerequisite: Electrical and Computer Engineering 130B or the equivalent. Electrostatics; Gauss's law, potentials, fields, boundary value problems, multiple pole expansions, dielectrics, polarization, capacitance, energy, torque, forces, eigenfunction expansions. Magnostatics; Biot-Savart law, Ampere's law, vector potential, gauge transformations, magnetization, inductance, constitutive relations.—II. (II.) Kolner, Hwang

234B. Applied Electromagnetics II (3)
Lecture—3 hours. Prerequisite: course 234A. Maxwell's Equations, wave equations for fields and potentials. Poynting's Theorem and power flow. Momentum and angular momentum in the electromagnetic field. Stress tensor. Polarization. Reflection/refraction. Dispersion, causality, and susceptibility. Circuit concepts, radiation.—III. (III.) Kolner, Hwang

234C. Applied Electromagnetics III (3)
Lecture—3 hours. Prerequisite: course 234B. Dynamics of relativistic particles; collisions between charged particles, energy loss, and scattering; radiation by moving particles; bremsstrahung, method of virtual quanta, radiative beta processes; multipole fields; radiation damping, self fields of a particle, scattering and absorption of radiation.—I. (I.) Kolner, Hwang

262A. Atomic and Molecular Interactions (3)
Lecture—3 hours. Prerequisite: Physics 215A-215B-215C or the equivalent. Atomic structure and spectra. Offered in alternate years.—(I.) Orel

262B. Atomic and Molecular Interactions (3)
Lecture—3 hours. Prerequisite: Physics 215A-215B-215C. Molecular structure and spectra. Offered in alternate years.—(II.) Orel

262C. Atomic and Molecular Interactions (3)
Lecture—3 hours. Prerequisite: course 262B. Classical and quantum mechanical collision theory of electron and heavy particle scattering. Offered in alternate years.—(III.) Orel

263A. Quantum Statistics of Light (3)
Lecture—3 hours. Prerequisite: Physics 200B-200C and Physics 215A-215B-215C or the equivalent. Classical susceptibilities, single quantization of light/matter interactions, resonance phenomena, second quantization of electromagnetic fields, number representation and operators.—II. (II.) Orel, McCurdy

263B. Quantum Theory of Optics (3)
Lecture—3 hours. Prerequisite: course 263A. Statistics of photon fluctuations. Quantum theory of radiation. Theory of lasers.—III. (III.) Orel

264A. Classical Optics I (3)
Lecture—3 hours. Prerequisite: course 108B and Electrical and Computer Engineering 130B or Physics 110B. Crystal optics; anisotropic wave propagation, dispersion relations, phase and group velocity surfaces. Polarization, Stokes parameters, Poincare sphere. Optical crystallography; interference figures, optical activity, crystal symmetry and point groups. Piezoelectricity, electro-optic, magneto-optic effects. Geometrical optics; eikonal equation, Lagrange's integral invariant, Fermat's principle.—I. (I.) Kolner

264B. Classical Optics II (3)
Lecture—3 hours. Prerequisite: course 264A. Dielectric waveguide theory; slab waveguides, integrated optics waveguides, optical fibers. Guided, radiation, and leaky-wave modes. Dispersion, compensation, and communications bit rates. Coupled-mode theory, waveguide perturbations, directional couplers, fiber gratings. Dielectric microcavities. Self- and cross-phase modulation. Solitons.—II. (II.) Kolner

264C. Classical Optics III (3)
Lecture—3 hours. Prerequisite: course 264B. Huygens-Fresnel principle, Kirchoff's diffraction theory. Fresnel and Fraunhofer diffraction. Phase and amplitude gratings, aperatures, lenses, two-dimensional linear systems. Spatial filtering. Holography. Coherence theory; spatial/temporal coherence, partial coherence, mutual intensity, degree of coherence, van Cittert-Zernike theorem, coherency matrix.—III. (III.) Kolner

265A. Laser Physics I (3)
Lecture—3 hours. Prerequisite: Physics 200C and Physics 215B-215C or the equivalent. Classical theory of lasers. Classical electron oscillator, atomic susceptibility, line broadening mechanisms, rate equations, stimulated transitions, radiative/nonradiative relaxations, multilevel systems, population inversion, saturation, oscillation, Schawlow-Townes limit, paraxial wave propagation, dispersion, pulse compression, resonators, modes, stability, Q-switching, modelocking.—I. (I.) Kolner

265B. Laser Physics II (3)
Lecture—3 hours. Prerequisite: course 265A. Beam propagation, resonators and laser dynamics. Threshold dynamics and cavity modes. Ray optics and matrices, wave optics and Gaussian beams. Resonator stability. Linear pulse propagation, dispersion and pulse compression. Spiking, relaxation, Q-switching, injection locking and modelocking.—II. (II.) Kolner

267. Nonlinear Optics (3)
Lecture—3 hours. Prerequisite: course 265A-265B. Theory of the nonlinear interaction of radiation and matter. Nonlinear optical properties of materials. Crystal optics, electro-optics, and acousto-optics. Parametric oscillation and amplification. Harmonic conversion. Stimulated Raman and Brillouin scattering, self-focusing, four-wave mixing, phase conjugation and spectroscopy.—III. (III.) Krol

270A-270B. Advanced Laser Plasma Physics (3)
Lecture—3 hours. Prerequisite: course 205A, 205B, 234. Laser-produced plasmas and advanced applications of high power lasers. Plasma formation with lasers, ponderomotive force, kinetic theory, waves in unmagnetized plasmas, non-linear effects, parametric instabilities, hydrodynamic instabilities, and radiation transport. Applications include ICF, X-ray lasers.—II-III. (II-III.) Baldis

271. Optical Methods in Biophysics (4)
Lecture—3 hours; discussion/laboratory—1 hour. Prerequisite: Biological Sciences 102 or the equivalent, course 108B or the equivalent, and Chemistry 110A or the equivalent. Principal optical techniques used to study biological structures and their related functions. Specific optical techniques useful in the studies of protein-nucleic acid, protein-membrane and protein-protein interactions. Biomedical applications of optical techniques. (Same course as Biophysics 271.)—III. (III.) Yeh, Parikh, Balhorn, Matthews

273. X-Ray Spectroscopy and Synchroton Radiation (4)
Lecture—3 hours; discussion—1 hour. Fundamentals of x-ray absorption, emission, and inelastic scattering; x-ray imaging and microscopy; synchroton radiation from bend magnets, wigglers, undulators, and free electron lasers; x-ray optics and storage ring design; visits to the synchroton radiation facilities SSRL and ALS; optional experiments. Offered in alternate years.—III. Cramer

280A-280B-280C. Plasma Physics and Controlled Fusion (3-3-3)
Lecture—3 hours. Prerequisite: course 234B or consent of instructor. Equilibrium plasma properties; single particle motion; fluid equations; waves and instabilities in a fluid plasma; plasma kinetic theory and transport coefficients; linear and nonlinear Vlasov theory; fluctuations, correlations and radiation; inertial and magnetic confinement systems in controlled fusion.—I, II, III. (I, II, III.) Luhmann, Hwang

285A. Physics and Technology of Microwave Vacuum Electron Beam Devices I (4)
Lecture—4 hours. Prerequisite: B.S. degree in physics or electrical engineering or the equivalent background. Physics and technology of electron beam emissions, flow and transport, electron gun design, space charge waves and klystrons. Offered in alternate years.—(III.) Luhmann

285B. Physics and Technology of Microwave Vacuum Electron Beam Devices II (4)
Lecture—4 hours. Prerequisite: 285A. Theory and experimental design of traveling wave tubes, backward wave oscillators, and extended interaction oscillators. Offered in alternate years.—(I.) Luhmann

285C. Physics and Technology of Microwave Vacuum Electron Beam Devices III (4)
Lecture—4 hours. Prerequisite: 285B. Physics and technology of gyrotrons, gyro-amplifiers, free electron lasers, magnetrons, crossfield amplifiers and relativistic devices. Offered in alternate years.—(II.) Luhmann

285D. Physics and Technology of Microwave Vacuum Electron Beam Devices IV (4)
Lecture—4 hours. Prerequisite: 285C. Computational models of vacuum electron beam devices. Offered in alternate years.—(III.) Luhmann

289A-K. Special Topics in Applied Science (1-5)
Lecture, laboratory, or combination. Prerequisite: consent of instructor. Special topics in the following areas: (A) Atomic and Molecular Physics; (B) Chemical Physics; (C) Computational Physics; (D) Digital Media; (E) Materials Science; (F) Imaging Science and Photonics; (G) Nonlinear Optics; (H) Plasma Physics; (I) Quantum Electronics; (J) Solid State; (K) Microwave and Millimeter Wave Technology. May be repeated for credit up to a total of 5 units per segment when topic differs.—I, II, III. (I, II, III.)

290. Seminar (1-2)
Seminar—1-2 hours. (S/U grading only.)

290C. Graduate Research Group Conference (1)
Discussion—1 hour. Prerequisite: consent of instructor. May be repeated for credit. (S/U grading only.)

298. Group Study (1-5)
(S/U grading only.)

299. Research (1-12)
(S/U grading only.)

Course in Biophotonics (BPT)

Graduate Course

290. Biophotonics Seminar (1)
Seminar—1 hour. Prerequisite: graduate standing or consent of instructor. Presentation of current research in the area of biophotonics by experts in the field, followed by group discussions. May be repeated up to three times for credit. (S/U grading only.)—I, II, III (I, II, III.) Yeh

Engineering: Biological and Agricultural

(College of Engineering)

Michael J. Delwiche, Ph.D., Chairperson of the Department

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Wesley E. Yates, M.S., Professor Emeritus

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Dennis R. Heldman, Ph.D., Adjunct Professor
Zhongli Pan, Ph.D., Adjunct Assistant Professor
Herbert B. Scher, Ph.D., Research Engineer
James F. Thompson, M.S., Extension Specialist

Mission. The Department of Biological and Agricultural Engineering is dedicated to the advancement of engineering for biological systems. Specifically, our goals are to advance the science, teach the principles and application, and disseminate the knowledge of engineering needed to efficiently produce, distribute, and process biological products, such as food, feed, and fiber, while conserving natural resources, preserving environmental quality, and ensuring the health and safety of people.

Objectives. We educate students in the fundamentals of mathematics, physical and biological sciences, and engineering, balanced with the application of principles to practical problems. We teach students to develop skills for solving engineering problems in biological systems through use of appropriate analysis, synthesis, and engineering design techniques. We prepare students for entry into engineering practice and graduate education, as well as engagement in life-long learning. We foster the ability of our students to collaborate and communicate effectively, and provide an awareness of the importance of economics, professional responsibility, and the environment.

The Biological Systems Engineering Major Program

Biological Systems Engineering is an engineering major that uses biology as its main scientific base. In the new age of biology and biotechnology, engineers are needed to work side by side with life scientists to bring laboratory developments into commercial production. Industries in plant and animal production, bioenergy, bioprocessing, biotechnology, food processing, aquaculture, agriculture, and forest production all need engineers with strong training in biology. Concern for the use and preservation of environmental resources creates many engineering opportunities as society strives to maintain a balance within the biosphere.

In the freshman and sophomore years, the Biological Systems Engineering major requires sequences of courses standard in all engineering programs, including mathematics, physics, chemistry, engineering science, and humanities. In addition, the Biological Systems Engineering major also requires courses in the biological sciences. In the junior and senior years, core courses are taken involving the integration of engineering with biology.

Biological Systems Engineering Program

The Biological Systems Engineering program is accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; (410) 347-7700.

Lower Division Required Courses

	UNITS
Mathematics 21A-21B-21C-21D	16
Mathematics 22A-(22AL*)-22B	6 or 7