UCSD 访学项目（语言）申请须知

一、学校报名

按照学校要求，提交材料，并获得学校相关院系、部门的批准。

二、申请材料

1. 申请表（按样表格式填写 A3、A4 页）

2. 护照信息页复印件（如无护照，须尽快申请，**护照的有效期应在项目结束日期的 6 个月之后**）

3. 学费来源证明（银行存款单，人民币存单须注明：equivalent $ XXX USD）

三、访学流程

第一阶段：提交所有材料（**PDF 格式扫描件**）交中国区负责人谭老师审核。

第二阶段：审核通过，材料将被正式提交到 UCSD Extension；审核不通过，需按照要求提交补充材料。

第三阶段：UCSD Extension 寄出邀请函、I-20 表等材料。

第四阶段：收到录取材料后，申请人在美国驻中国大使馆网站在线申请 F-1 学生签证。

第五阶段：获得签证后，申请人预定住宿、购买机票，做赴美准备。

第六阶段：提前一天到校，并在开学日下午 4 点之前完成注册，逾期需缴迟到金。

第七阶段：项目结束后，返回中国。

四、申请须知

1、***关于住宿***：住宿方式包括寄宿家庭和校外公寓。

* 校外公寓　通过 UCSD 官方合作的中介申请，拎包入住。每个房间含 2 卧 2 卫，4 人同住。距离学校 15 分钟车程，公交车直达。费用为$250 美元的中介费和$2195 美元/学期的住宿费（以官方网站为准）。如遇签证问题，可全额退款。

申请网站：www.ac-housing.com

申请邮箱：info@ac-housing.com

* 寄宿家庭　通过 UCSD 官方合作的中介申请，提供接机服务和早晚餐，距离学校略远。费用为$200 美元的中介费和$2475 美元/学期的住宿费。如遇签证问题，可全额退款。

申请网站：1、fahomestay.com　2、kamohousing.com　3、ushstudent.com/homestay

2、***关于费用***：学费见招生手册，食宿费约 1000 美元/月。

3、***关于缴费***：推荐使用信用卡缴费。注册费和快递费不可退。

UCSD 访学项目（学分）申请须知

一、学校报名

按照学校要求，提交材料，并获得学校相关院系、部门的批准。

二、申请材料

1. 申请表（按样表格式填写 A3、A4 和 A6 页）
2. 护照信息页复印件（如无护照，须尽快申请，**护照的有效期应在项目结束日期的 6 个月之后**）
3. 标准成绩单（英文，近 4 个学期）
4. 学费来源证明（银行存款单，人民币存款须注明：equivalent $ XXX USD）
5. 合格的雅思或托福成绩
6. Information Release Form
7. 一页纸的自述，解释为何选择参加 UCSD 学分项目
8. Course List Form（预选 12 门课程，选课系统： students.ucsd.edu）
9. UPS Acknowledgement form
10. Academic Verification Form **(绩点高于 3.8 分者（5 分制），不需提供此材料)**

三、访学流程

第一阶段：提交第 1-9 项材料（**PDF 格式扫描件**）交中国区负责人谭老师初审。

第二阶段：初审通过，材料将被正式提交到各学院；初审不通过，需按照要求提交补充材料。

第三阶段：学院录取后，寄出邀请函、I-20 表及其它材料。

第四阶段：收到录取材料后，申请人在美国驻中国大使馆网站在线申请 F-1 学生签证。

第五阶段：获得签证后，申请人付清学费、在当地的国际旅行卫生保健中心做肺结核体检、预定住宿、购买机票，做赴美准备。

第六阶段：提前一天到校，并在开学日下午 4 点之前完成注册，逾期需缴迟到金。

第七阶段：项目结束后，返回中国。凭成绩单兑换学分，完成访学。

四、申请须知

1、***关于住宿***：住宿分为校内住宿、寄宿家庭、校外公寓。

* 校内住宿　**仅适用于暑期 10 周课程的项目**。需全额付费留位，建议尽早申请，如遇签证问题，可全额退款。

申请邮箱：iphousing@ucsd.edu

* 寄宿家庭　通过 UCSD 官方合作的中介申请，提供接机服务和早晚餐，距离学校略远。费用为$200 美元的中介费和$2475 美元/学期的住宿费。如遇签证问题，可全额退款。

申请网站：

1、fahomestay.com　　2、kamohousing.com　　3、ushstudent.com/homestay

* 校外公寓　通过 UCSD 官方合作的中介申请，拎包入住。每个房间含 2 卧 2 卫，4 人同住。距离学校 15 分钟车程，公交车直达。费用为$250 美元的中介费和$2195 美元/学期的住宿费。如遇签证问题，可全额退款。

申请网站：www.ac-housing.com

申请邮箱：info@ac-housing.com

2、***关于费用***：学费为 7800 美元/学期，食宿费约 3675 美元/学期。

3、***关于缴费***：推荐使用信用卡缴费。注册费和快递费不可退。项目开始前 30 天，需付清学费、申请费、快递费、医疗保险费，并提交肺结核评估表（**注册时需提交原件**）。

4、***关于学分***：申请人所选课程应和本校专业课程方向基本一致，以便于回校后转换学分。学分转换规则各学院不尽相同，请务必行前咨询学院教务员或分管副院长。参加 Track1 和 Track2 的申请人选修的 Extension 课程是否可以兑换学分，需按照中方学校相关要求。

Bioengineering

Upper Division

BENG 100. Statistical Reasoning for Bioengineering Applications (4)
General introduction to probability and statistical analysis, applied to bioengineering design. Topics include preliminary data analysis, probabilistic models, experiment design, model fitting, goodness-of-fit analysis, and statistical inference/estimation. Written and software problems are provided for modeling and visualization. ***Prerequisites:*** BENG 1, Math 18 or Math 31AH, Phys 2A-B-C, or consent of department. (S)

BENG 102. Molecular Components of Living Systems (4)
Introduction to molecular structures. Macromolecules and assemblies-proteins, nucleic acids, and metabolites. Principles of design of simple and complex components of organelles, cells, and tissues. ***Prerequisites:*** BENG 120 or consent of department. (S)

BENG 103B. Bioengineering Mass Transfer (4)
Mass transfer in solids, liquids, and gases with application to biological systems. Free and facilitated diffusion. Convective mass transfer. Diffusion-reaction phenomena. Active transport. Biological mass transfer coefficients. Steady and unsteady state. Flux-force relationships. (Credit not allowed for both CENG 101C and BENG 103B.) ***Prerequisites:*** CENG 101A or MAE 101A or BENG 112A, or consent of department. (S)

BENG 110. Foundation of Biomechanics (4)
Introduction to mechanics: statics and dynamics, free body diagrams, and bodies in contact. Vectors and tensors; stresses, theory of deformation, and constitutive equations. Equations of motion. Biomechanics design examples. ***Prerequisites:*** Math 20D, Math 20E or Math 31CH, Math 20F or Math 31AH; Phys 2C, or consent of department. (F)

BENG 112A. Tissue Biomechanics (4)
Biomechanics of living tissues with emphasis on mechanical properties of major tissues and organs. Foundations of viscoelasticity. Field equations and stress analysis of living tissues. Bioengineering and medical design examples. ***Prerequisites:*** BENG 110 or consent of department. (W)

BENG 112B. Fluid and Cell Biomechanics (4)
Foundations of membrane mechanics. Micro- and nano-mechanics of cells and their constituent protein networks. Biomechanics of the circulation, properties of blood, non-Newtonian behavior, dimensionless flow analysis. Applications to cardiovascular diseases. Polymer and statistical mechanics. Engineering design and problem solving. ***Prerequisites:*** BENG 112A or consent of department. (S)

BENG 119A. Design Development in Biomechanics (3)
Development of design project in biomechanics. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 119B. Design Implementation in Biomechanics (3)
Implementation of design project in biomechanics. ***Prerequisites:*** concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 120. Organic Chemistry Structural and Design Principles (4)

Structural and design principles of carbon compounds. Structure and stereochemistry. Functional groups and chemical transformations. Structure and design principles of biomolecules. Molecules of life and their organization. ***Prerequisites:*** Chem 6A and 6B; majors only or consent of department. (W)

BENG 122A. Biosystems and Control (4)

Systems and control theory applied to bioengineering. Modeling, linearization, transfer functions, Laplace transforms, closed-loop systems, design and simulation of controllers. Dynamic behavior and controls of first and second order processes. PID controllers. Stability. Bode design. Features of biological controls systems. A simulation term project using Matlab and an oral presentation are required. ***Prerequisites:*** MAE 140 or consent of department. (F)

BENG 123. Dynamic Simulation in Bioengineering (4)

Dynamic simulation of biochemical reaction networks, including reconstruction of networks, mathematical description of kinetics of biochemical reactions, dynamic simulation of systems of biochemical reactions, and use of simulators for data interpretation and prediction in biology. Emphasis on a design project. ***Prerequisites:*** Math 18 or Math 31AH, Math 20D, BENG 120, or Chem 40B; majors only or consent of department. (W)

BENG 125. Modeling and Computation in Bioengineering (4)

Computational modeling of molecular bioengineering phenomena: excitable cells, regulatory networks, and transport. Application of ordinary, stochastic, and partial differential equations. Introduction to data analysis techniques: power spectra, wavelets, and nonlinear time series analysis. ***Prerequisites:*** BENG 122A or BENG 123 or consent of department. (S)

BENG 126A. Design Development in Bioinformatics Bioengineering (3)

Development of design project in bioinformatics bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 126B. Design Implementation in Bioinformatics Bioengineering (3)

Implementation of design project in bioinformatics bioengineering. ***Prerequisites:*** BENG 126A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 127A. Design Development in Molecular Systems Bioengineering (3)

Development of design project in molecular systems bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 127B. Design Implementation in Molecular Systems Bioengineering (3)

Implementation of design project in molecular systems bioengineering. ***Prerequisites:*** BENG 127A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 128A. Design Development in Genetic Circuits Bioengineering (3)

Development of design project in genetic circuits bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 128B. Design Implementation in Genetic Circuits Bioengineering (3)

Implementation of design project in genetic circuits bioengineering. ***Prerequisites:*** BENG 128A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 129A. Design Development in Cell Systems Bioengineering (3)

Development of design project in cell systems bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 129B. Design Implementation in Cell Systems Bioengineering (3)

Implementation of design project in cell systems bioengineering. ***Prerequisites:*** BENG 129A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 130. Biotechnology Thermodynamics and Kinetics (4)

An introduction to physical principles that govern biological matter and processes, with engineering examples. Thermodynamic principles, structural basis of life, molecular reactions and kinetics, and models to illustrate biological phenomena. ***Prerequisites:*** Chem 6B, Math 20A, 20B, 20D, Physics 2A, 2B, 2C; majors only or consent of department. (W)

BENG 133. Numerical Analysis and Computational Engineering (4)

Principles of digital computing, including number representation and arithmetic operations. Accuracy, stability, and convergence. Algorithms for solving linear systems of equations, interpolation, numerical differentiation, and integration and ordinary differential equations. ***Prerequisites:*** Math 20D and 20F or consent of department. (S)

BENG 134. Measurements, Statistics, and Probability (4)

A combined lecture and laboratory course that provides an introductory treatment of probability theory, including distribution functions, moments, and random variables. Practical applications include estimation of means and variances, hypothesis testing, sampling theory, and linear regression. ***Prerequisites:*** Math 20D and Math 18 or Math 31AH; BENG 100 or consent of department. (F)

BENG 135. Biomedical Signals and Systems (4)

Discrete systems: linearity, convolution, impulse, and step responses. Linear systems properties. Difference equations. Fourier Series. Continuous FS. Discrete FS. Periodic signals, filtering, and FT. Discrete FT examples. Frequency response of linear systems. Sampling. Relationship between FT, DFT. Laplace Transform. LT and inverse LT. ***Prerequisites:*** ECE 45 and BENG 133 or consent of department. (F) Not offered until fall 2016.

BENG 139A. Design Development in Molecular Bioengineering (3)

Development of design project in molecular bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 139B. Design Implementation in Molecular Bioengineering (3)

Implementation of design project in molecular bioengineering. ***Prerequisites:*** BENG 139A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 140A. Bioengineering Physiology (4)

Introductory mammalian physiology for bioengineering students, with emphasis on control mechanisms and engineering principles. Basic cell functions; biological control systems; muscle;

neural; endocrine, and circulatory systems. Not intended for premedical bioengineering students. Credit not allowed for both BIPN 100 and BENG 140A. ***Prerequisites:*** Chem 6A-B, Physics 2A-B-C, BILD 1, or BENG 102; majors only or consent of department. (W)

BENG 140B. Bioengineering Physiology (4)

Introductory mammalian physiology for bioengineering students, with emphasis on control mechanisms and engineering principles. Digestive, respiratory, renal, and reproductive systems; regulation of metabolism, and defense mechanisms. (Credit not allowed for both BIPN 102 and BENG 140B.) ***Prerequisites:*** BENG 140A; majors only or consent of instructor. (S)

BENG 141. Biomedical Optics and Imaging (4)

Introduction to optics. Light propagation in tissue. Propagation modeling. Optical components. Laser concepts. Optical coherence tomography. Microscopic scattering. Tissue optics. Microscopy. Confocal microscopy. Polarization in tissue. Absorption, diffuse reflection, light scattering spectroscopy. Raman, fluorescence lifetime imaging. Photo-acoustic imaging. ***Prerequisites:*** BENG 100 or consent of department. (F)

BENG 147A. Design Development in Neural Engineering (3)

Development of design project in neural engineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 147B. Design Implementation in Neural Engineering (3)

Implementation of design project in neural engineering. ***Prerequisites:*** BENG 147A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 148A. Design Development in Cardiac Bioengineering (3)

Development of design project in cardiac bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 148B. Design Implementation in Cardiac Bioengineering (3)

Implementation of design project in cardiac bioengineering. ***Prerequisites:*** BENG 148A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 149A. Design Development in Vascular Bioengineering (3)

Development of design project in vascular bioengineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 149B. Design Implementation in Vascular Bioengineering (3)

Implementation of design project in vascular bioengineering. ***Prerequisites:*** BENG 149A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 152. BioSystems Engineering Laboratory (4)

Experimental study of real and simulated systems and their controls (examples will include electrical, biological, and biomechanical systems). Projects consist of identification, input-output analysis, design, and implementation of analog controls. Laboratory examples will include electrical circuit design and analysis, analysis of living tissues such as bone, analysis and manipulation of cells (bacteria in chemostat). Program or materials fees may

apply. ***Prerequisites:*** BENG 102; Bioengineering: BioSystems majors only or consent of department. (W)

BENG 160. Chemical and Molecular Bioengineering Techniques (4)

Introductory laboratory course in current principles and techniques of chemistry and molecular biology applicable to bioengineering. Quantitation of proteins and nucleic acids by spectrophotometric, immunological, and enzymatic methods. Separations and purification by centrifugation, chromatographic, and electrophoretic methods. Course materials fees may apply. ***Prerequisites:*** BICD 100, BENG 100, MAE 170; majors only or consent of department. (S)

BENG 161A. Bioreactor Engineering (4)

Engineering, biochemical, and physiological considerations in the design of bioreactor processes: enzyme kinetics, mass transfer limitations, microbial growth, and product formation kinetics. Fermentation reactor selection, design, scale-up, control. Quantitative bioengineering analysis and design of biochemical processes and experiments on biomolecules. ***Prerequisites:*** BENG 123 and BENG 160 or consent of department. (F)

BENG 161B. Biochemical Engineering (4)

Commercial production of biochemical commodity products. Application of genetic control systems and mutant populations. Recombinant DNA and eucaryotic proteins in *E. coli* and other host organisms. Product recovery operations, including the design of bioseparation processes of filtration, adsorption, chromatography, and crystallization. Bioprocess economics. Human recombinant erythropoietin as an example, from genomic cloning to CHO cell expression, to bioreactor manufacturing and purification of medical products for clinical application. ***Prerequisites:*** BENG 161A or consent of department. (W)

BENG 162. Biotechnology Laboratory (4)

Laboratory practices and design principles for biotechnology. Culture of microorganisms and mammalian cells, recombinant DNA bioreactor design and operation. Design and implementation of biosensors. A team design-based term project and oral presentation required. Course materials fees may apply. ***Prerequisites:*** MAE 170 and BENG 160; majors only or consent of department . (F)

BENG 166A. Cell and Tissue Engineering (4)

Engineering analysis of physico-chemical rate processes that affect, limit, and govern the function of cells and tissues. Cell migration, mitosis, apoptosis, and differentiation. Dynamic and structural interactions between mesenchyme and parenchyme. The role of the tissue microenvironment including cell-cell interactions, extracellular matrix, and growth factor communication. The design of functional tissue substitutes including cell and material sourcing, scale-up and manufacturability, efficacy and safety, regulatory, and ethical topics. Clinical applications. ***Prerequisites:*** BENG 103B or BENG 112B; senior standing or consent of department. (F)

BENG 168. Biomolecular Engineering (4)

Basic molecular biology and recombinant DNA technologies. Structure and function of biomolecules that decode genomes and perform energy conversion, enzymatic catalysis, and active transport. Metabolism of macromolecules. Molecular diagnostics. Design, engineering, and manufacture of proteins, genomes, cells, and biomolecular therapies. ***Prerequisites:*** BILD 1 and BENG 100, or consent of department. (W)

BENG 169A. Design Development in Tissue Engineering (3)

Development of design project in tissue engineering. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 169B. Design Implementation in Tissue Engineering (3)

Implementation of design project in tissue engineering. ***Prerequisites:*** BENG 169A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG 172. Bioengineering Laboratory (4)

A laboratory course demonstrating basic concepts of biomechanics, bioengineering design, and experimental procedures involving animal tissue. Sources of error and experimental limitations. Computer data acquisition, modeling, statistical analysis. Experiments on artery, muscle and heart mechanics, action potentials, viscoelasticity, electrocardiography, hemorheology. Course materials fees may apply. ***Prerequisites:*** MAE 170; junior or senior standing in the major or consent of instructor. (S)

BENG 179A. Design Development in Bioinstrumentation (3)

Development of design project in bioinstrumentation. ***Prerequisites:*** concurrent enrollment in BENG 187B; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (F)

BENG 179B. Design Implementation in Bioinstrumentation (3)

Implementation of design project in bioinstrumentation. ***Prerequisites:*** BENG 179A; concurrent enrollment in BENG 187C; Bioengineering or Bioengineering: Biotechnology majors only or consent of instructor. (W)

BENG/BIMM/CSE 181. Molecular Sequence Analysis (4)

(Cross-listed as BIMM 181 and CSE 181.) This course covers the analysis of nucleic acid and protein sequences, with an emphasis on the application of algorithms to biological problems. Topics include sequence alignments, database searching, comparative genomics, and phylogenetic and clustering analyses. Pairwise alignment, multiple alignment, DNA sequencing, scoring functions, fast database search, comparative genomics, clustering, phylogenetic trees, gene finding/DNA statistics. ***Prerequisites:*** CSE 100; CSE 101; BIMM 100 or Chem 114C; Bioinformatics majors only. (W)

BENG/BIMM/CSE/Chem 182. Biological Databases (4)

(Cross-listed as BIMM 182, CSE 182, and Chem 182.) This course provides an introduction to the features of biological data, how those data are organized efficiently in databases, and how existing data resources can be utilized to solve a variety of biological problems. Object-oriented databases, data modeling, and data description. Survey of current biological database with respect to above; implementation of database focused on a biological topic. ***Prerequisites:***CSE 100; Bioinformatics majors only. (S)

BENG 183. Applied Genomic Technologies (4)

Principles and technologies for using genomic information for biomedical applications. Technologies will be introduced progressively, from DNA to RNA to protein to whole cell systems. The integration of biology, chemistry, engineering, and computation will be stressed. Topics include technology for the genome, DNA chips, RNA technologies, proteomic technologies, aphysiomic and phenomic technologies, and analysis of cell function. ***Prerequisites:*** BIMM 100 or Chem 114C and BICD 110, or consent of department. (F)

BENG/BIMM/CSE/Chem 184. Computational Molecular Biology (4)
(Cross-listed as BIMM 184, CSE 184, and Chem 184.) This advanced course covers the application of machine learning and modeling techniques to biological systems. Topics include gene structure, recognition of DNA and protein sequence patterns, classification, and protein structure prediction. Pattern discovery, hidden Markov models/support vector machines/neural network/profiles, protein structure prediction, functional characterization of proteins, functional genomics/proteomics, metabolic pathways/gene networks. ***Prerequisites:*** BENG 181 or BIMM 181 or CSE 181; BENG 182 or BIMM 182 or CSE 182 or Chem 182; Bioinformatics majors only. (S)

BENG 186A. Principles of Biomaterials Design (4)
Fundamentals of materials science as applied to bioengineering design. Natural and synthetic polymeric materials. Materials characterization and design. Wound repair, blood clotting, foreign body response, transplantation biology, biocompatibility of materials, tissue engineering. Artificial organs and medical devices. Government regulations. Patenting. Economic impact. Ethical issues. A term project and oral presentation are required. ***Prerequisites:*** BENG 112B or BENG 123, or consent of department. (S)

BENG 186B. Principles of Bioinstrumentation Design (4)
Biophysical phenomena, transducers, and electronics as related to the design of biomedical instrumentation. Potentiometric and amperometric signals and amplifiers. Biopotentials, membrane potentials, chemical sensors. Electrical safety. Mechanical transducers for displacement, force, and pressure. Temperature sensors. Flow sensors. Light-based instrumentation. ***Prerequisites:*** ECE 35 or MAE 140; ECE 45 or MAE 170; or consent of department. (W)

BENG 187A. Bioengineering Design Project: Planning (1)
General engineering design topics including project planning and design objectives, background research, engineering needs assessment, technical design specifications, engineering standards, and design requirements and constraints. Introduction to biomedical and biotechnology design projects. Career and professional advising. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. ***Prerequisites:*** BENG 112A or BENG 152 or BENG 168; Bioengineering, Bioengineering: Biotechnology, or Bioengineering: BioSystems majors only or consent of department. (S)

BENG 187B. Bioengineering Design Project: Development (1)
Development of an original bioengineering design for solution of a problem in biology or medicine. Analysis of economic issues, manufacturing and quality assurance, ethics, safety, design constraints, government regulations, and patent requirements. Oral presentation and formal engineering reports. Career and professional advising. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. ***Prerequisites:*** BENG 187A; concurrent enrollment in one of BENG 119A, BENG 126A, BENG 127A, BENG 128A, BENG 129A, BENG 139A, BENG 147A, BENG 148A, BENG 149A, BENG 169A, or BENG 179A; Bioengineering, Bioengineering: Biotechnology, or Bioengineering: BioSystems majors only or consent of instructor. (F)

BENG 187C. Bioengineering Design Project: Implementation (1)
Approaches to implementation of senior design project, including final report. Teams will report on construction of prototypes, conduct of testing, collection of data, and assessment of

reliability and failure. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. ***Prerequisites:*** BENG 187B; concurrent enrollment in one of the following lab sections: BENG 119B, BENG 126B, BENG 127B, BENG 128B, BENG 129B, BENG 139B, BENG 147B, BENG 148B, BENG 149B, BENG 169B, or BENG 179B; Bioengineering, Bioengineering: Biotechnology, or Bioengineering: BioSystems majors only or consent of instructor. (W)

BENG 187D. Bioengineering Design Project: Presentation (1)

Oral presentations of design projects, including design, development, and implementation strategies and results of prototype testing. Majors must enroll in the course for a letter grade in order to count the sequence toward the major. No exceptions will be approved. ***Prerequisites:*** BENG 187C; Bioengineering, Bioengineering: Biotechnology, or Bioengineering: BioSystems majors only or consent of instructor. (S)

BENG 189. Physiological Systems Engineering (4)

Quantitative description of physiological systems, e.g., electrical and mechanical properties of muscle (skeletal and cardiac). Modeling and simulation of properties. Kidney, transport, and models. Neural circuits and models. ***Prerequisites:*** BENG 133, 134, 135, 140A and 140B, or consent of department. (S) Not offered until spring 2017.

BENG 191/291. Senior Seminar I: Professional Issues in Bioengineering (2)

(Conjoined with BENG 291.) Instills skills for personal and organizational development during lifelong learning. Student prepares portfolio of personal attributes and experiences, prepares for career interviews plus oral report of interviewing organizational CEO. Graduate students will prepare a NIH small business research grant. ***Prerequisites:*** consent of instructor. (F)

BENG 193. Clinical Bioengineering (4)

Introduction on the integration of bioengineering and clinical medicine through lectures and rotations with clinical faculty. Students will work with clinical mentors and course faculty to identify areas where engineering can improve diagnostics, clinical practice, and/or treatment. ***Prerequisites:*** BENG 140A or BIPN 100; BENG 140B or BIPN 102; consent of instructor required. A GPA of 3.5 is requested as a requirement per the agreement with the School of Medicine to ensure that students who are participating in the program have a strong academic background to be in the clinic as an undergraduate. (F)

BENG 195. Teaching (2–4)

Teaching and tutorial assistance in a bioengineering course under supervision of instructor. Not more than four units may be used to satisfy graduation requirements. (P/NP grades only.) ***Prerequisites:*** 3.0 GPA in the major and departmental approval. (F,W,S)

BENG 196. Bioengineering Industrial Internship (1–4)

Under the joint supervision of a faculty adviser and industry mentor, the student will work at a bioengineering industrial site to gain practical bioengineering experience, summarized in a technical report. With departmental approval, four units of credit may substitute for a technical elective. (P/NP grades only.) Course may be taken for credit three times. ***Prerequisites:*** consent of department and completion of all lower-division course requirements, including general-science requirements; laboratory experience; completion of ninety units with a 2.5 GPA; and consent of a bioengineering faculty coordinator. (F,W,S,Su)

BENG 197. Engineering Internship (1–4)

An enrichment program, available to a limited number of undergraduate students, which provides work experience with industry, government offices, hospitals, and their practices. Subject to the availability of positions, students will work in a local industry or hospital (on a salaried or unsalaried basis) under the supervision of a faculty member and industrial, government, or hospital employee. Coordination of the Engineering Internship is conducted through UC San Diego's Academic Internship Program. Time and effort to be arranged. Units may not be applied toward major graduation requirements unless prior approval of a faculty adviser is obtained and internship is an unsalaried position. ***Prerequisites:*** completion of ninety units with a 2.5 GPA and consent of a bioengineering faculty coordinator. (F,W,S,Su)

BENG 198. Directed Group Study (1–4)

Directed group study, on a topic or in a field not included in the regular department curriculum, by arrangement with a bioengineering faculty member. (P/NP grades only.) ***Prerequisites:*** upper-division standing, completion of ninety units of UC San Diego undergraduate study, a minimum UC San Diego GPA of 2.5, consent of instructor, and a completed and approved Special Studies form. (F,W,S)

BENG 199. Independent Study for Undergraduates (4)

Independent reading or research by arrangement with a bioengineering faculty member. May be taken for credit three times. (P/NP grades only.) ***Prerequisites:***upper-division standing, completion of ninety units of UC San Diego undergraduate study, a minimum UC San Diego GPA of 2.5, consent of instructor, and a completed and approved Special Studies form. (F,W,S,Su)

Graduate

BENG 202/CSE 282. Bioinformatics II: Introduction to Bioinformatics Algorithms (4)
(Formerly BENG 202/CSE 257A.) Introduction to methods for sequence analysis. Application to genome and proteome sequences. Protein structure, sequence-structure analysis. ***Prerequisites:*** Pharm 201 or consent of instructor. (W)

BENG 203/CSE 283. Genomics, Proteomics, and Network Biology (4)
Annotating genomes, characterizing functional genes, profiling, reconstructing pathways. ***Prerequisites:*** Pharm 201, BENG 202/CSE 282, or consent of instructor. (S)

BENG 207. Topics in Bioengineering (4)
Course given at the discretion of the faculty on current topics of interest in bioengineering. (F,W,S)

BENG 208. Topics in Bioengineering with Lab (4)
Course given at the discretion of the faculty on topics of current interest in engineering science. This course is intended to be a lecture and lab companion topics course. ***Prerequisites:*** consent of instructor. (S)

BENG 211. Systems Biology and Bioengineering I: Biological Components (4)
Components of biological systems, their biochemical properties and function. The technology used for obtaining component lists. Relationship within and integration of component lists. Structured vocabularies and component ontologies. Algorithms for comparative approaches in deciphering and mining component lists. ***Prerequisites:*** BENG 230A or BIMM 100, or consent of instructor. (F)

BENG 212. Systems Biology and Bioengineering II: Network Reconstruction (4)
This course will cover the process of reconstructing complex biological reaction networks. Reconstruction of metabolic networks, regulatory networks and signaling networks. Bottom-up and top-down approaches. The use of collections of historical data. The principles underlying high-throughput experimental technologies and examples given on how this data is used for network reconstruction, consistency checking, and validation. ***Prerequisites:*** BENG 211 or consent of instructor. (W)

BENG 213. Systems Biology and Bioengineering III: Building and Simulating Large-Scale In Silico Models (4)
Mathematical models of reconstructed reaction networks and simulation of their emergent properties. Classical kinetic theory, stochastic simulation methods and constraints-based models. Methods that are scalable and integrate multiple cellular processes will be emphasized. Existing genome-scale models will be described and computations performed. Emphasis will be on studying the genotype-phenotype relationship in an in silico model driven fashion. Comparisons with phenotypic data will be emphasized. ***Prerequisites:*** BENG 212 or consent of instructor. (S)

BENG 221. Mathematical Methods for Bioengineering (4)
Introduction of the foundations of engineering by teaching the mathematical methods that describe the engineering principles. Analytical and numerical approaches to solving the equations. ***Prerequisites:*** graduate standing in bioengineering or consent of instructor. (F)

BENG 223. Thermodynamics, Statistical Mechanics, Interfacial Phenomena in Living Systems (4)
Thermodynamics, statistical mechanics, and interfacial phenomena that emphasize the chemical natures of living systems. Topics include intermolecular and surface forces, calculation

of energetic processes, computation of electrical forces and fields, and principles of physics in multiscale engineering and design. ***Prerequisites:*** graduate standing in bioengineering or consent of instructor. (W)

BENG 225. BioBusiness: Starting, Growing, and Harvesting a Biotech Company (4)

Biotech is a special breed of business, especially in start-up and early phases. Whether you are considering joining a biotech start-up or want to be successful in a life-science organization, it pays to understand this unique business model. In this course, you will study and analyze (1) start-up proposals, (2) the genesis of biotech industry, (3) biotech categories and growth strategies, (4) the process of spinning out viable product concepts from academia, (5) financing techniques, (6) business development, (7) acquisition/IPO valuation methods, and (8) potentially disruptive technologies. The format is highly interactive and learning is enhanced by means of exercises, team presentations, and case studies. ***Prerequisites:*** graduate standing in bioengineering or consent of instructor.

BENG 226. Foundations of Bioengineering I: Tissue and Cell Properties (4)

Modern development of biomechanics at an advanced mathematical level. Description of internal stresses and deformation in living tissues and fluids, thermodynamics. Mechanics of soft connective tissue, extracellular matrix, cells, membranes, and cytoskeleton. Mechanotransduction, migration, adhesion. Blood flow in microvessels. Biomechanical analysis of tissue injury. Students that have taken BENG 222 cannot take BENG 226 for credit. Recommended preparation: A previous background in biomechanics is strongly recommended prior to taking this course. ***Prerequisites:*** graduate standing or consent of instructor. (S)

BENG 227. Transport Phenomena in Living Systems (4)

This course describes the movement of heat and chemical mass in biological systems. Diffusion, convection and biochemical reactions in a variety of biological and engineering examples are analyzed and modeled. Students that have taken BENG 222 cannot take BENG 227 for credit. ***Prerequisites:*** BENG 221, graduate standing, or consent of instructor. (S)

BENG 230A. Biochemistry (4)

A graduate course in biochemistry especially tailored to the requirements and background of bioengineering graduate students. It will cover the important macro- and small molecules in cells that are the major constituents, or that function as signaling molecules or molecular machineries. The structures, pathways, interactions, methodologies, and molecular designs using recombinant DNA technology will be covered. ***Prerequisites:*** restricted to bioengineering graduate students with major code BE75. (F)

BENG 230B. Cell and Molecular Biology (4)

A general survey of structure-function relationships at the molecular and cellular levels. Emphasis on basic genetic mechanisms; control of gene expression; membrane structure, transport and traffic; cell signaling; cell adhesion; mechanics of cell division; and cytoskeleton. ***Prerequisites:*** BENG 230A; restricted to bioengineering graduate students with major code BE75. (W)

BENG 230C. Cardiovascular Physiology (4)

Physical concepts of behavior of heart, large blood vessels, vascular beds in major organs and the microcirculation. Physical and physiological principles of blood flow, blood pressure, cardiac work, electrophysiology of the heart. Special vascular beds, including their biological and

hemodynamic importance. Integration through nervous and humoral controls. ***Prerequisites:*** BENG 230B or consent of instructor.

BENG 230D. Respiratory and Renal Physiology (4)

Mechanics of breathing. Gas diffusion. Pulmonary blood flow. Stress distribution. Gas transport by blood. Kinetics of oxygen and carbon dioxide exchange. VA/Q relations. Control of ventilation. Glomerular and proximal tubule functions. Water metabolism. Control of sodium and potassium in the kidney. ***Prerequisites:*** BIPN 100, 102, and BENG 230C, or consent of instructor. (F,W,S)

BENG 232. Musculoskeletal Health, Injury, and Disease (4)

An overview of the musculoskeletal system from a bioengineering perspective. Health, injury, disease of bone, cartilage, tendon, ligament, meniscus, synovium, intervertebral disc, skeletal muscle, peripheral nerve. Mechanisms and models underlying current and future therapies. ***Prerequisites:*** graduate standing or consent of instructor. (S)

BENG 233. Neuromuscular Physiology and Biomechanics (4)

Mechanical properties of structures involved in movement (muscles, tendons, bones). Models of neuromuscular adaptation to chronic electrical stimulation, voluntary exercise, surgical overload, spinal cord injury, denervation, limb immobilization, exercise-induced injury and muscle regeneration. Stem cells in muscle function and plasticity. ***Prerequisites:*** graduate standing or consent of instructor.

BENG 234. Intro to Neurophysiology: Molecules to Systems (4)

Introduction to molecular and cellular neurobiology and their integration with systems neurophysiology. Homeostasis will be an organizing theme. The material will be presented both qualitatively and quantitatively, emphasizing the mathematical, physical, and chemical foundations and dynamics that underlie neurophysiological functions. ***Prerequisites:*** graduate standing or consent of instructor. (S)

BENG 235. Molecular Imaging and Quantitation in Living Cells (4)

This course will introduce quantitative fluorescence microscopy techniques for imaging, manipulating, and quantifying the spatiotemporal characteristics of molecular events in live cells. A laboratory component will be integrated with students organized into small teams for projects. Recommended preparation: basic optics at the level of ECE 181, introductory molecular and cellular biology at the level of BIMM 100 and BICD 110, respectively. ***Prerequisites:*** graduate standing or consent of instructor. (S)

BENG 238/MED 238. Molecular Biology of the Cardiovascular System (4)

An overview of heart, vascular development and associated diseases from a molecular biological perspective. Current approaches for generating mouse models of cardiovascular disease and recently developed technologies for physiological assessment in small animal models will be presented. (W)

BENG 241A. Tissue Engineering and Regenerative Medicine: Foundations (4)

Overview and foundations of tissue engineering and regenerative medicine. Tissue structure, function, and dynamics in health and disease. Cells, microenvironment, extracellular matrix, and biomaterials as components of engineered tissues and organs. Functional goals, design, testing, and evaluation of therapies. ***Prerequisites:*** graduate standing. (F)

BENG 241B. Tissue Engineering and Regenerative Medicine: Cell Microenvironment (4)

The role of the cellular microenvironment in directing cell behavior and function in health and disease. Cell adherence and deformation and cell-mediated matrix remodeling. Bioengineering of the microenvironment in tissue engineering and regenerative medicine. ***Prerequisites:*** BENG 241A, graduate standing, or consent of instructor.

BENG 241C. Tissue Engineering and Regenerative Medicine: Development and Growth (4)
Development, morphogenesis, growth, and remodeling of tissues and organs in health and disease. Integrative metabolism and biomechanics of cells and extracellular matrix at tissue, organ, and organism scales. Bioengineering restoration of tissues and organs. Industry applications and regulations. ***Prerequisites:*** BENG 241A, graduate standing, or consent of instructor.

BENG 242/MATS 257/NANO 257. Polymer Science and Engineering (4)
Quantitative basic understanding of different branches of polymer science varying from polymer chemistry, characterization, thermodynamics, rheological properties, smart materials, self-assembly in biopolymers (natural) and synthetic polymers, and applications of polymers ranging from medicine to structure. ***Prerequisites:*** graduate standing in bioengineering, nanoengineering, or materials science, or consent of instructor.

BENG 247A/ECE 247A/NANO 247A. Advanced Biophotonics (4)
Basic physics and chemistry of interaction of photons with matter; photonic radiation pressure; advanced optoelectronic detection systems, devices, methods, time-resolved fluorescent, chemiluminescent methods, fluorescent energy transfer techniques, quantum dots, near-field optical techniques, mechanisms of light sensitive biological systems including chloroplasts for photosynthetic energy conversion and basis of vision processes. ***Prerequisites:*** graduate standing. (F)

BENG 247B/ECE 247B/NANO 247B. Bioelectronics (4)
Topics include photolithographic techniques for high-density DNA microarray production, incorporation of CMOS control into electronic DNA microarrays, direct electronic detection technology, bio-fuel cells, highly integrated devices (lab-on-a-chip, in vivo biosensors, etc.). Form heterogeneous materials and components. ***Prerequisites:*** graduate standing. (W)

BENG 247C/ECE 247C/NANO 247C. Bionanotechnology (4)
Nanosensors, nanodevices for clinical diagnostics, biowarfare agent detection; nanostructures for drug delivery; nanoarrays, nanodevices; nanoanalytical devices and systems, methods for modification or functionalization of nanoparticles; nanostructures with biological molecules; nanostructural aspects of fuel cells, biofuel cells; potential use of DNA, other biomolecules. ***Prerequisites:*** graduate standing. (S)

BENG 260/BGGN 260/PHYS 279. Neurodynamics (4)
Introduction to the nonlinear dynamics of neurons and neural systems using bifurcation theory and chaotic motions, at different levels of abstraction, e.g., biophysical and “reduced” models for analysis of regularly spiking and bursting cells. Laboratory exercises will accompany the lectures. ***Prerequisites:***graduate standing or consent of instructor. (F)

BENG 267. Microcirculation in Health and Disease (4)
Structural and functional aspects of transport and blood-tissue exchange in key organs during circulatory shock, bacterial toxemia, hypertension. Physical and ultrastructural techniques used to analyze small-vessel dynamics. ***Prerequisites:*** consent of instructor. (S)

BENG 276/Chem 276/Math 276/Pharm 276. Numerical Analysis in Multiscale Biology (4)

Introduces mathematical tools to simulate biological processes at multiple scales. Numerical methods for ordinary and partial differential equations (deterministic and stochastic), and methods for parallel computing and visualization. Hands-on use of computers emphasized; students will apply numerical methods in individual projects. ***Prerequisites:*** consent of instructor. (W)

BENG 277/BIOM 287. Tissue Engineering Laboratory (4)

Students will learn to conduct tissue engineering and developmental biology experiments, microfabricate cell culture systems, engineer biopolymer materials, and develop and analyze quantitative models of transport, cell fate, and growth mechanics. The understanding and manipulation of multicellular processes that comprise development and growth involves specialized areas of biomechanics, developmental biology, biomaterials, and the tools of molecular biology, as well as the integration of theory and experiment. To fabricate functional tissues, it is important to establish underlying molecular and physical mechanisms and then control and integrate these. ***Prerequisites:*** consent of instructor. (W)

BENG 278/RAD 278. Magnetic Resonance Imaging (4)

This lab course provides hands-on experience with MR physics, data acquisition, image formation, and data analysis, using a human MRI scanner. It will cover basic principles of MRI and key applications, including scanner hardware, spin echoes, gradient echoes, echo-planar imaging, MR angiography, fMRI, and perfusion imaging. This will be accomplished through one hour of formal instruction and four hours of scanner time per week. Each week will cover one topic, and grading will be based on lab reports. The last two weeks are reserved for a final project, which can be student initiated. ***Prerequisites****:* BENG 280A or basic knowledge of linear systems and MRI, or consent of instructor. (W)

BENG 280A. Principles of Biomedical Imaging (4)

Fundamentals of Fourier transform and linear systems theory including convolution, sampling, noise, filtering, image reconstruction and visualization with an emphasis on applications to biomedical imaging. Examples from optical imaging, CT, MR, ultrasound, nuclear, PET, and radiography. ***Prerequisites:*** graduate standing. (F)

BENG 280B. Comparative Biomedical Imaging (4)

Application of biomedical imaging to the measurement of structure, function, and dynamics of organ systems from the microscopic to the organ level. Emphasis on detailed evaluation and comparison of specific imaging modalities. ***Prerequisites:*** consent of instructor. (W,S)

BENG 281. Seminar in Bioengineering (1)

Weekly seminars by faculty, visitors, postdoctoral research fellows, and graduate students concerning research topics in bioengineering and related subjects. May be repeated for credit. Course does not apply toward MS graduation requirements. (S/U grades only.) (F,W,S)

BENG 282. Seminar: Faculty Research (1)

Weekly seminars by bioengineering faculty presenting their research. May be repeated for credit. Course does not apply toward MS or PhD graduation requirements. (S/U grades only.) (F)

BENG 283/Chem 283/BIOM 283. Supramolecular Structure Determination Laboratory (4)

A laboratory course combining hands-on mass spectrometry and bioinformatics tools to explore the relationship between structure and function in macromolecules. Tools for peptide sequencing, analysis of post-translational modification, and fragmentation analysis by mass

spectrometry are examples of experiments students will run. ***Prerequisites:*** consent of instructor.

BENG 285/BNFO 285/ECE 204. Statistical Learning in Bioinformatics (4)

A hallmark of bioinformatics is the computational analysis of complex data. The combination of statistics and algorithms produces statistical learning methods that automate the analysis of complex data. Such machine learning methods are widely used in systems biology and bioinformatics. This course provides an introduction to statistical learning and assumes familiarity with key statistical methods. Students may not receive credit for BENG 285 and ECE 204 and BNFO 285. ***Prerequisites:*** ECE 271A or ECE 271B or Math 283; or consent of instructor.

BENG 291/191. Senior Seminar I: Professional Issues in Bioengineering (2)

(Conjoined with BENG 191.) Instills skills for personal and organizational development during lifelong learning. Student prepares portfolio of personal attributes and experiences, prepares for career interviews plus oral report of interviewing organizational CEO. Graduate students will prepare a NIH small business research grant. ***Prerequisites:*** consent of instructor. (F)

BENG 295. Bioengineering Design Project and Industrial Training (4)

Independent work by graduate students focused on design, applied research, and professional experience. ***Prerequisites:*** consent of instructor and departmental approval. (F,W,S)

BENG 296. Independent Study (4)

Prerequisites: consent of instructor. (F,W,S)

BENG 298. Directed Group Study (1–4)

Directed group study on a topic or in a field not included in regular department curriculum, by special arrangement with a faculty member. (S/U grades only.) ***Prerequisites:*** consent of instructor. (F,W,S)

BENG 298L. Laboratory Research Rotation (4)

Laboratory research rotation for first-year BENG PhD students. Students will write a final paper. (S/U grades only.) ***Prerequisites:*** PhD student in bioengineering. (F,W,S)

BENG 299. Graduate Research (1–12)

Independent work by graduate students engaged in research and writing theses. (S/U grades only.) ***Prerequisites:*** consent of instructor. (F,W,S)

BENG 500. Apprentice Teaching for Specialization in Multi-Scale Biology (2, 4)

Teaching experience in one of the six bioengineering lab courses designated as a part of the BENG PhD Specialization in Multi-Scale Biology. Student is under the direction of the faculty member in charge of the course. (S/U grades only.) **Prerequisites:** consent of instructor and departmental approval. (F,W,S)

BENG 501. Teaching Experience (2, 4)

Teaching experience in an appropriate bioengineering undergraduate course under direction of the faculty member in charge of the course. Lecturing one to two hours per week in either a problem-solving section or regular lecture. (S/U grades only.) ***Prerequisites:*** consent of instructor and departmental approval. (F,W,S)

Electrical and Computer Engineering (ECE)

Upper Division

ECE 100. Linear Electronic Systems (4)

Linear active circuit and system design. Topics include frequency response; use of Laplace transforms; design and stability of filters using operational amplifiers. Integrated lab and lecture involves analysis, design, simulation, and testing of circuits and systems. Program or materials fees may apply.***Prerequisites:*** ECE 45 and ECE 65. ECE 65 may be taken concurrently.

ECE 101. Linear Systems Fundamentals (4)

Complex variables. Singularities and residues. Signal and system analysis in continuous and discrete time. Fourier series and transforms. Laplace and z-transforms. Linear Time Invariant Systems. Impulse response, frequency response, and transfer functions. Poles and zeros. Stability. Convolution. Sampling. Aliasing. ***Prerequisites:*** ECE 45 with grade of C– or better.

ECE 102. Introduction to Active Circuit Design (4)

Nonlinear active circuits design. Nonlinear device models for diodes, bipolar and field-effect transistors. Linearization of device models and small-signal equivalent circuits. Circuit designs will be simulated by computer and tested in the laboratory. ***Prerequisites:*** ECE 65 and ECE 100. ECE 100 can be taken concurrently.

ECE 103. Fundamentals of Devices and Materials (4)

Introduction to semiconductor materials and devices. Semiconductor crystal structure, energy bands, doping, carrier statistics, drift and diffusion, p-n junctions, metal-semiconductor junctions. Bipolar junction transistors: current flow, amplification, switching, nonideal behavior. Metal-oxide-semiconductor structures, MOSFETs, device scaling. ***Prerequisites:*** ECE 65 and Phys 2D or Phys 4D and 4E.

ECE 107. Electromagnetism (4)

Electrostatics and magnetostatics; electrodynamics; Maxwell's equations; plane waves; skin effect. Electromagnetics of transmission lines: reflection and transmission at discontinuities, Smith chart, pulse propagation, dispersion. Rectangular waveguides. Dielectric and magnetic properties of materials. Electromagnetics of circuits. ***Prerequisites:*** Phys 2A–D or 4A–E and ECE 45 with grades of C– or better.

ECE 108. Digital Circuits (4)

A transistor-level view of digital integrated circuits. CMOS combinational logic, ratioed logic, noise margins, rise and fall delays, power dissipation, transmission gates. Short channel MOS model, effects on scaling. Sequential circuits, memory and array logic circuits. Three hours of lecture, one hour of discussion, three hours of laboratory. ***Prerequisites:*** ECE 25 or CSE 140, 45, and 65 and ECE 30 or CSE 30.

ECE 109. Engineering Probability and Statistics (4)

Axioms of probability, conditional probability, theorem of total probability, random variables, densities, expected values, characteristic functions, transformation of random variables, central limit theorem. Random number generation, engineering reliability, elements of estimation, random sampling, sampling distributions, tests for hypothesis. Students who completed MAE 108, Math 180A–B, Math 183, Math 186, Econ 120A, or Econ 120AH will not receive credit for ECE 109. ***Prerequisites:*** Math 20A-B-C, 20D, 20F, with grades of C– or better. ECE 101 recommended.

ECE 111. Advanced Digital Design Project (4)
Advanced topics in digital circuits and systems. Use of computers and design automation tools. Hazard elimination, synchronous/asynchronous FSM synthesis, synchronization and arbitration, pipelining and timing issues. Problem sets and design exercises. A large-scale design project. Simulation and/or rapid prototyping. ***Prerequisites:*** ECE 25 or CSE 140.

ECE 115. Fast Prototyping (4)
Lab-based course. Students will learn how to prototype a mechatronic solution. Topics include: cheap/accessible materials and parts; suppliers; fast prototyping techniques; useful electronic sketches and system integration shortcuts. Students will learn to materialize their electromechanical ideas and make design decisions to minimize cost, improve functionality/robustness. Labs will culminate toward a fully functional robot prototype for demonstration. ***Prerequisites:*** ECE 16 or consent of instructor.

ECE 118. Computer Interfacing (4)
Interfacing computers and embedded controllers to the real world: busses, interrupts, DMA, memory mapping, concurrency, digital I/O, standards for serial and parallel communications, A/D, D/A, sensors, signal conditioning, video, and closed loop control. Students design and construct an interfacing project. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 30 or CSE 30 and ECE 35, 45, 65.

ECE 120. Solar System Physics (4)
General introduction to planetary bodies, the overall structure of the solar system, and space plasma physics. Course emphasis will be on the solar atmosphere, how the solar wind is produced, and its interaction with both magnetized and unmagnetized planets (and comets). ***Prerequisites:*** Phys 2A–C or 4A–D, Math 20A–B, 20C with grades of C– or better.

ECE 121A. Power Systems Analysis and Fundamentals (4)
This course introduces concepts of large-scale power system analysis: electric power generation, distribution, steady-state analysis and economic operation. It provides the fundamentals for advanced courses and engineering practice on electric power systems, smart grid, and electricity economics. The course requires implementing some of the computational techniques in simulation software. ***Prerequisites:*** ECE 35.

ECE 121B. Energy Conversion (4)
Principles of electro-mechanical energy conversion, balanced three-phase systems, fundamental concepts of magnetic circuits, single-phase transformers, and the steady-state performance of DC and induction machines. Students may not receive credit for both ECE 121B and ECE 121. ***Prerequisites****:* ECE 121A.

ECE 123. Antenna Systems Engineering (4)
The electromagnetic and systems engineering of radio antennas for terrestrial wireless and satellite communications. Antenna impedance, beam pattern, gain, and polarization. Dipoles, monopoles, paraboloids, phased arrays. Power and noise budgets for communication links. Atmospheric propagation and multipath. ***Prerequisites:*** ECE 107 with a grade of C– or better.

ECE 125A. Introduction to Power Electronics I (4)
Power generation, system, and electronics. Topics include power semiconductor devices and characteristics, single-phase and three-phase half and full controlled AC-to-DC rectifiers, nonisolated/isolated DC-DC converters, power loss calculation, and thermal considerations, Snubber circuits. ***Prerequisites:*** ECE 121A.

ECE 125B. Introduction to Power Electronics II (4)
Design and control of DC-DC converters, PWM rectifiers, single-phase and three-phase inverters, power management, and power electronics applications in renewable energy systems, motion control, and lighting. ***Prerequisites:*** ECE 125A.

ECE 134. Electronic Materials Science of Integrated Circuits (4)
Electronic materials science with emphasis on topics pertinent to microelectronics and VLSI technology. Concept of the course is to use components in integrated circuits to discuss structure, thermodynamics, reaction kinetics, and electrical properties of materials. ***Prerequisites:*** Phys 2C–D with grades of C– or better.

ECE 135A. Semiconductor Physics (4)
Crystal structure and quantum theory of solids; electronic band structure; review of carrier statistics, drift and diffusion, p-n junctions; nonequilibrium carriers, imrefs, traps, recombination, etc; metal-semiconductor junctions and heterojunctions. ***Prerequisites:*** ECE 103 with a grade of C– or better.

ECE 135B. Electronic Devices (4)
Structure and operation of bipolar junction transistors, junction field-effect transistors, metal-oxide-semiconductor diodes and transistors. Analysis of dc and ac characteristics. Charge control model of dynamic behavior. ***Prerequisites:*** ECE 135A with a grade of C– or better.

ECE 136L. Microelectronics Laboratory (4)
Laboratory fabrication of diodes and field effect transistors covering photolithography, oxidation, diffusion, thin film deposition, etching and evaluation of devices. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 103.

ECE 138L. Microstructuring Processing Technology Laboratory (4)
A laboratory course covering the concept and practice of microstructuring science and technology in fabricating devices relevant to sensors, lab-chips and related devices. (Course materials and/or program fees may apply.) ***Prerequisites:*** upper-division standing for science and engineering students.

ECE 140A. The Art of Product Engineering I (4)
Building on a solid foundation of electrical and computer engineer skills, this course strives to broaden student skills in software, full-stack engineering, and concrete understanding of methods related to the realistic development of a commercial product. Students will research, design, and develop an IOT device to serve an emerging market. ***Prerequisites:*** CSE 8B or CSE 11 or ECE 15.

ECE 140B. The Art of Product Engineering II (4)
Building on a solid foundation of electrical and computer engineer skills, this course strives to broaden student skills in software, full-stack engineering, and concrete understanding of methods related to the realistic development of a commercial product. Students will research, design, and develop an IOT device to serve an emerging market. ***Prerequisites:*** ECE 140A.

ECE 143. Programming for Data Analysis (4)
This course covers the fundamentals of using the Python language effectively for data analysis. Students learn the underlying mechanics and implementation specifics of Python and how to effectively utilize the many built-in data structures and algorithms. The course introduces key modules for data analysis such as Numpy, Pandas, and Matplotlib. Participants learn to leverage

and navigate the vast Python ecosystem to find codes and communities of individual interest. ***Prerequisites:*** ECE 16.

ECE 144. LabVIEW Programming: Design and Applications (4)

Develop, debug, and test LabVIEW VIs, solve problems using LabVIEW, use data acquisition, and perform signal processing and instrument control in LabVIEW applications. Groups of students will build an elevator system from laser-cut and 3-D printed parts; integrate sensors, motors, and servos; and program using state-machine architecture in LabVIEW. Students will have the opportunity to take the National Instruments Certified LabVIEW Associate Developer (CLAD) exam at the end of the quarter. Program or materials fees may apply. ***Prerequisites:*** CSE 11 or CSE 8B or ECE 15.

ECE 145AL-BL-CL. Acoustics Laboratory (4-4-4)

Automated laboratory based on H-P GPIB controlled instruments. Software controlled data collection and analysis. Vibrations and waves in strings and bars of electromechanical systems and transducers. Transmissions, reflection, and scattering of sound waves in air and water. Aural and visual detection. ***Prerequisites:*** ECE 107 with a grade of C– or better or consent of instructor.

ECE 148. Introduction to Autonomous Vehicles (4)

Fundamentals of autonomous vehicles. Working in small teams, students will develop 1:8 scale autonomous cars that must perform on a simulated city track. Topics include: robotics system integration, computer vision, algorithms for navigation, on-vehicle vs. off-vehicle computation, computer learning systems such as neural networks, locomotion systems, vehicle steering, dead reckoning, odometry, sensor fusion, GPS auto-pilot limitations, wiring, and power distribution and management. Cross-listed with MAE 148. Students may not receive credit for ECE 148 and MAE 148. Program or materials fees may apply. ***Prerequisites:***ECE 15 or ECE 35 or MAE 2 or MAE 3, and consent of instructor.

ECE 153. Probability and Random Processes for Engineers (4)

Random processes. Stationary processes: correlation, power spectral density. Gaussian processes and linear transformation of Gaussian processes. Point processes. Random noise in linear systems. ***Prerequisites:*** ECE 109 with a grade of C– or better.

ECE 154A. Communications Systems I (4)

Study of analog modulation systems including AM, SSB, DSB, VSB, FM, and PM. Performance analysis of both coherent and noncoherent receivers, including threshold effects in FM. ***Prerequisites:*** ECE 101 and 153 with a grade of C– or better.

ECE 154B. Communications Systems II (4)

Design and performance analysis of digital modulation techniques, including probability of error results for PSK, DPSK, and FSK. Introduction to effects of intersymbol interference and fading. Detection and estimation theory, including optimal receiver design and maximum-likelihood parameter estimation. ***Prerequisites:*** ECE 154A with a grade of C– or better.

ECE 154C. Communications Systems III (4)

Introduction to information theory and coding, including entropy, average mutual information, channel capacity, block codes and convolutional codes. ***Prerequisites:*** ECE 154B with a grade of C– or better.

ECE 156. Sensor Networks (4)

Characteristics of chemical, biological, seismic, and other physical sensors; signal processing techniques supporting distributed detection of salient events; wireless communication and networking protocols supporting formation of robust sensor fabrics; current experience with low power, low cost sensor deployments. Undergraduate students must take a final exam; graduate students must write a term paper or complete a final project. Cross-listed with MAE 149 and SIO 238. ***Prerequisites:*** upper-division standing and consent of instructor, or graduate student in science and engineering.

ECE 157A. Communications Systems Laboratory I (4)

Experiments in the modulation and demodulation of baseband and passband signals. Statistical characterization of signals and impairments. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 154A with a grade of C+ or better.

ECE 157B. Communications Systems Laboratory II (4)

Advanced projects in communication systems. Students will plan and implement design projects in the laboratory, updating progress weekly and making plan/design adjustments based upon feedback. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 154A with a grade of C+ or better.

ECE 158A. Data Networks I (4)

Layered network architectures, data link control protocols and multiple-access systems, performance analysis. Flow control; prevention of deadlock and throughput degradation. Routing, centralized and decentralized schemes, static dynamic algorithms. Shortest path and minimum average delay algorithms. Comparisons. ***Prerequisites:*** ECE 109 with a grade of C– or better.

ECE 158B. Data Networks II (4)

Layered network architectures, data link control protocols and multiple-access systems, performance analysis. Flow control; prevention of deadlock and throughput degradation. Routing, centralized and decentralized schemes, static dynamic algorithms. Shortest path and minimum average delay algorithms. Comparisons. ***Prerequisites:*** ECE 158A with a grade of C– or better.

ECE 161A. Introduction to Digital Signal Processing (4)

Review of discrete-time systems and signals, Discrete-Time Fourier Transform and its properties, the Fast Fourier Transform, design of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, implementation of digital filters. ***Prerequisites:*** ECE 101.

ECE 161B. Digital Signal Processing I (4)

Sampling and quantization of baseband signals; A/D and D/A conversion, quantization noise, oversampling and noise shaping. Sampling of bandpass signals, undersampling downconversion, and Hilbert transforms. Coefficient quantization, roundoff noise, limit cycles and overflow oscillations. Insensitive filter structures, lattice and wave digital filters. Systems will be designed and tested with Matlab, implemented with DSP processors and tested in the laboratory. ***Prerequisites:*** ECE 161A with a grade of C– or better.

ECE 161C. Applications of Digital Signal Processing (4)

This course discusses several applications of DSP. Topics covered will include: speech analysis and coding; image and video compression and processing. A class project is required, algorithms simulated by Matlab. ***Prerequisites:*** ECE 161A.

ECE 163. Electronic Circuits and Systems (4)

Analysis and design of analog circuits and systems. Feedback systems with applications to operational amplifier circuits. Stability, sensitivity, bandwidth, compensation. Design of active filters. Switched capacitor circuits. Phase-locked loops. Analog-to-digital and digital-to-analog conversion. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 101 and 102 with grades of C– or better.

ECE 164. Analog Integrated Circuit Design (4)

Design of linear and nonlinear analog integrated circuits including operational amplifiers, voltage regulators, drivers, power stages, oscillators, and multipliers. Use of feedback and evaluation of noise performance. Parasitic effects of integrated circuit technology. Laboratory simulation and testing of circuits. ***Prerequisites:*** ECE 102 with a grade of C– or better. ECE 163 recommended.

ECE 165. Digital Integrated Circuit Design (4)

VLSI digital systems. Circuit characterization, performance estimation, and optimization. Circuits for alternative logic styles and clocking schemes. Subsystems include ALUs, memory, processor arrays, and PLAs. Techniques for gate arrays, standard cell, and custom design. Design and simulation using CAD tools. ***Prerequisites:*** ECE 102.

ECE 166. Microwave Systems and Circuits (4)

Waves, distributed circuits, and scattering matrix methods. Passive microwave elements. Impedance matching. Detection and frequency conversion using microwave diodes. Design of transistor amplifiers including noise performance. Circuits designs will be simulated by computer and tested in the laboratory. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 102 and 107 with grades of C– or better.

ECE 171A. Linear Control System Theory (4)

Stability of continuous- and discrete-time single-input/single-output linear time-invariant control systems emphasizing frequency domain methods. Transient and steady-state behavior. Stability analysis by root locus, Bode, Nyquist, and Nichols plots. Compensator design. ***Prerequisites:*** ECE 45 or MAE 140.

ECE 171B. Linear Control System Theory (4)

Time-domain, state-variable formulation of the control problem for both discrete-time and continuous-time linear systems. State-space realizations from transfer function system description. Internal and input-output stability, controllability/observability, minimal realizations, and pole-placement by full-state feedback. ***Prerequisites:*** ECE 171A with a grade of C– or better.

ECE 172A. Introduction to Intelligent Systems: Robotics and Machine Intelligence (4)

This course will introduce basic concepts in machine perception. Topics covered will include edge detection, segmentation, texture analysis, image registration, and compression. ***Prerequisites:*** ECE 101 with a grade of C– or better. ECE 109 recommended.

ECE 174. Introduction to Linear and Nonlinear Optimization with Applications (4)

The linear least squares problem, including constrained and unconstrained quadratic optimization and the relationship to the geometry of linear transformations. Introduction to nonlinear optimization. Applications to signal processing, system identification, robotics, and circuit design. Recommended preparation: ECE 100. ***Prerequisites:*** Math 20F or Math 18, ECE 15, and ECE 109 or consent of instructor.

ECE 175A. Elements of Machine Intelligence: Pattern Recognition and Machine Learning (4)

Introduction to pattern recognition and machine learning. Decision functions. Statistical pattern classifiers. Generative vs. discriminant methods for pattern classification. Feature selection. Regression. Unsupervised learning. Clustering. Applications of machine learning. ***Prerequisites:*** ECE 109 and ECE 174.

ECE 175B. Elements of Machine Intelligence: Probabilistic Reasoning and Graphical Models (4)

Bayes' rule as a probabilistic reasoning engine; graphical models as knowledge encoders; conditional independence and D-Separation; Markov random fields; inference in graphical models; sampling methods and Markov Chain Monte Carlo (MCMC); sequential data and the Viterbi and BCJR algorithms; The Baum-Welsh algorithm for Markov Chain parameter estimation. ***Prerequisites:*** ECE 175A.

ECE 180. Topics in Electrical and Computer Engineering (4)

Topics of special interest in electrical and computer engineering. Subject matter will not be repeated so it may be taken for credit more than once. ***Prerequisites:*** consent of instructor; department stamp.

ECE 181. Physical Optics and Fourier Optics (4)

Ray optics, wave optics, beam optics, Fourier optics, and electromagnetic optics. Ray transfer matrix, matrices of cascaded optics, numerical apertures of step and graded index fibers. Fresnel and Fraunhofer diffractions, interference of waves. Gaussian and Bessel beams, the ABCD law for transmissions through arbitrary optical systems. Spatial frequency, impulse response and transfer function of optical systems, Fourier transform and imaging properties of lenses, holography. Wave propagation in various (inhomogeneous, dispersive, anisotropic or nonlinear) media. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 103 and 107 with grades of C– or better.

ECE 182. Electromagnetic Optics, Guided-Wave, and Fiber Optics (4)

Polarization optics: crystal optics, birefringence. Guided-wave optics: modes, losses, dispersion, coupling, switching. Fiber optics: step and graded index, single and multimode operation, attenuation, dispersion, fiber optic communications. Resonator optics. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 103 and 107 with grades of C– or better.

ECE 183. Optical Electronics (4)

Quantum electronics, interaction of light and matter in atomic systems, semiconductors. Laser amplifiers and laser systems. Photodetection. Electrooptics and acoustooptics, photonic switching. Fiber optic communication systems. Labs: semiconductor lasers, semiconductor photodetectors. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 103 and 107 with grades of C– or better.

ECE 184. Optical Information Processing and Holography (4)

(Conjoined with ECE 241AL) Labs: optical holography, photorefractive effect, spatial filtering, computer generated holography. Students enrolled in ECE 184 will receive four units of credit; students enrolled in ECE 241AL will receive two units of credit. (Course materials and/or program fees may apply.) ***Prerequisites:***ECE 182 with a grade of C– or better.

ECE 185. Lasers and Modulators (4)

(Conjoined with ECE 241BL) Labs: CO_2 laser, HeNe laser, electrooptic modulation, acoustooptic modulation, spatial light modulators. Students enrolled in ECE 185 will receive four units of credit; students enrolled in ECE 241BL will receive two units of credit. (Course materials and/or program fees may apply.) ***Prerequisites:*** ECE 183 with a grade of C– or better.

ECE 187. Introduction to Biomedical Imaging and Sensing (4)
Image processing fundamentals: imaging theory, image processing, pattern recognition; digital radiography, computerized tomography, nuclear medicine imaging, nuclear magnetic resonance imaging, ultrasound imaging, microscopy imaging. ***Prerequisites:*** Math 20A-B-F, 20C or 21C, 20D or 21D, Phys 2A–D, ECE 101 (may be taken concurrently) with grades of C– or better.

ECE 188. Topics in Electrical and Computer Engineering with Laboratory (4)
Topics of special interest in electrical and computer engineering with laboratory. Subject matter will not be repeated so it may be taken for credit up to three times. ***Prerequisites:*** upper-division standing.

ECE 189. Technical Public Speaking (2)
Basics of technical public speaking, including speech organization, body language (eye contact, hand gestures, etc.), volume and rate, and design of technical slides. Students will practice technical public speaking, including speeches with PowerPoint slides and speaker introductions, and presenting impromptu speeches. Students may not receive credit for both ECE 189 and ENG 100E. ***Prerequisites:*** upper-division standing.

ECE 190. Engineering Design (4)
Students complete a project comprising at least 50 percent or more engineering design to satisfy the following features: student creativity, open-ended formulation of a problem statement/specifications, consideration of alternative solutions/realistic constraints. Written final report required. ***Prerequisites:***students enrolling in this course must have completed all of the breadth courses and one depth course. The department stamp is required to enroll in ECE 190. (Specifications and enrollment forms are available in the undergraduate office.)

ECE 191. Engineering Group Design Project (4)
Groups of students work to design, build, demonstrate, and document an engineering project. All students give weekly progress reports of their tasks and contribute a section to the final project report. ***Prerequisites:*** completion of all of the breadth courses and one depth course.

ECE 193H. Honors Project (4–8)
An advanced reading or research project performed under the direction of an ECE faculty member. Must contain enough design to satisfy the ECE program's four-unit design requirement. Must be taken for a letter grade. May extend over two quarters with a grade assigned at completion for both quarters. ***Prerequisites:*** admission to the ECE departmental honors program.

ECE 194. Viacar Design Project (4)
Students design, build, and race an autonomous car using principles in electrical engineering and computer science: circuit design, control theory, digital signal processing, embedded systems, microcontrollers, electromagnetism, and programming. ***Prerequisites:*** none.

ECE 195. Teaching (2 or 4)
Teaching and tutorial activities associated with courses and seminars. Not more than four units of ECE 195 may be used for satisfying graduation requirements. (P/NP grades only.) ***Prerequisites:*** consent of the department chair.

ECE 196. Engineering Hands-on Group Project (4)
Groups of students work to build and demonstrate at least three engineering projects at the beginning, intermediate, and advanced levels. The final project consists of either a new project

designed by the student team or extension of an existing project. The student teams also prepare a manual as part of their documentation of the final project. May be taken for credit two times. ***Prerequisites:*** upper-division standing.

ECE 197. Field Study in Electrical and Computer Engineering (4, 8, 12, or 16)

Directed study and research at laboratories and observatories away from the campus. (P/NP grades only.) ***Prerequisites:*** consent of instructor and approval of the department.

ECE 198. Directed Group Study (2 or 4)

Topics in electrical and computer engineering whose study involves reading and discussion by a small group of students under direction of a faculty member. (P/NP grades only.) ***Prerequisites:*** consent of instructor.

ECE 199. Independent Study for Undergraduates (2 or 4)

Independent reading or research by special arrangement with a faculty member. (P/NP grades only.) ***Prerequisites:*** consent of instructor.

Graduate

ECE 200. Research Conference (2)

Group discussion of research activities and progress of group members. (Consent of instructor is strongly recommended.) (S/U grades only.) ***Prerequisites:***graduate standing.

ECE 201. Introduction to Biophysics (4)

The class will cover fundamental physical principles of biological processes at the molecular, cellular, tissue and organ levels that are related to human physiology and diseases. Topics include energetics and dynamics of biological systems, physical factors of environment, and the kinetics of biological systems. ***Prerequisites:*** senior or graduate level standing.

ECE 202. Medical Devices and Interfaces (4)

This course will cover basic cellular and electrochemical processes, membrane potentials, ionic currents, nerve cell conductance, extracellular and intracellular stimulation, neural probe technology materials and devices, diagnostic and drug delivery devices, material/physiological considerations, biosensors, microfluids, optical, magnetic and electrical screening. ***Prerequisites:*** senior or graduate level standing.

ECE 203. Biomedical Integrated Circuits and Systems (4)

Integrated circuit analysis and design for medical devices. Introduction to subthreshold conduction in MOS transistor and its similarities to biomolecular transport. Design of instrumentation amplifiers, sensors, and electrical stimulation interfaces. Transcutaneous wireless power transfer and electromagnetic effects on tissue. Recommended preparation: ECE 164 or BENG 186B or equivalent. ***Prerequisites:*** senior or graduate level standing.

ECE 204. Statistical Learning in Bioinformatics (4)

A hallmark of bioinformatics is the computational analysis of complex data. The combination of statistics and algorithms produces statistical learning methods that automate the analysis of complex data. Such machine learning methods are widely used in systems biology and bioinformatics. This course provides an introduction to statistical learning and assumes familiarity with key statistical methods. Students may not receive credit for BNFO 285 and ECE 204 and BENG 285. Cross-listed with BNFO 285 and BENG 285. ***Prerequisites:*** ECE 271A or ECE 271B or Math 283; graduate standing.

ECE 207. Principles of Biomedical Imaging (4)

Fundamentals of Fourier transform and linear systems theory including convolution, sampling, noise, filtering, image reconstruction, and visualization with an emphasis on applications to biomedical imaging. Examples from optical imaging, CT, MR, ultrasound, nuclear, PET, and radiography. ***Prerequisites:*** graduate standing.

ECE 208. Computational Evolutionary Biology (4)

Evolutionary biology (e.g., the study of the tree of life) uses computational methods from statistics and machine learning. We cover methods of broad use in many fields and apply them to biology, focusing on scalability to big genomic data. Topics include dynamic programming, continuous time Markov models, hidden Markov models, statistical inference of phylogenies, sequence alignment, uncertainty (e.g., bootstrapping), and heterogeneity (e.g., phylogenetic mixture models). ***Prerequisites:*** graduate standing.

ECE 212AN. Principles of Nanoscience and Nanotechnology (4)

Introduction to and rigorous treatment of electronic, photonic, magnetic, and mechanical properties of materials at the nanoscale. Concepts from mathematical physics, quantum

mechanics, quantum optics, and electromagnetic theory will be introduced as appropriate. Students may not receive credit for both ECE 212A and ECE 212AN. ***Prerequisites:*** graduate standing.

ECE 212BN. Nanoelectronics (4)

Quantum states and quantum transport of electrons; single-electron devices; nanoelectronic devices and system concepts; introduction to molecular and organic electronics. Students may not receive credit for both ECE 212BN and ECE 212C. ***Prerequisites:*** ECE 212AN; graduate standing.

ECE 212CN. Nanophotonics (4)

Photonic properties of artificially engineered inhomogeneous nanoscale composite materials incorporating dielectrics, semiconductors, and/or metals. Near-field localization effects and applications. Device and component applications. Students may not receive credit for both ECE 212CN and 212B. ***Prerequisites:***ECE 212BN; graduate standing.

ECE 221. Magnetic Materials: Principles and Applications (4)

The basis of magnetism: classical and quantum mechanical points of view. Different kinds of magnetic materials. Magnetic phenomena including anisotropy, magnetostriction, domains, and magnetization dynamics. Current frontiers of nanomagnetics research including thin films and particles. Optical, data storage, and biomedical engineering applications of soft and hard magnetic materials. ***Prerequisites****:* graduate standing.

ECE 222A. Antennas and Their System Applications (4)

Antennas, waves, polarization. Friis transmission and Radar equations, dipoles, loops, slots, ground planes, traveling wave antennas, array theory, phased arrays, impedance, frequency independent antennas, microstrip antennas, cell phone antennas, system level implications such as MIMO, multi-beam and phased array systems. (Recommended prerequisites: ECE107 or an equivalent undergraduate course in electromagnetics.) ***Prerequisites:*** graduate standing.

ECE 222B. Applied Electromagnetic Theory—Electromagnetics (4)

Graduate-level introductory course on electromagnetic theory with applications. Topics covered include Maxwell's equations, plane waves in free space and in the presence of interfaces, polarization, fields in metallic and dielectric waveguides including surface waves; fields in metallic cavities, Green's functions, electromagnetic field radiation and scattering. ***Prerequisites:*** ECE 222A; graduate standing.

ECE 222C. Applied Electromagnetic Theory—Computational Methods for Electromagnetics (4)

Computational techniques for numerical analysis of electromagnetic fields, including the finite difference time domain (FDTD) method, finite difference frequency domain (FDFD) method, method of moments (MOM), and finite element method (FEM). Practice in writing numerical codes. Review of commercial electromagnetic simulators. ***Prerequisites:*** ECE 222B; graduate standing.

ECE 222D. Advanced Antenna Design (4)

Review of 222A–B. Fourier transform, waveguide antennas. Mutual coupling, active impedance, Floquet modes in arrays. Microstrip antennas, surface waves. Reflector and lens analysis: taper, spillover, aperture and physical optics methods. Impedance surfaces. Advanced concepts: Sub-wavelength propagation, etc. (chosen by instructor). (Recommended prerequisites: ECE 222A, ECE 222B, or equivalent.) ***Prerequisites:*** ECE 222C; graduate standing.

ECE 225A. Probability and Statistics for Data Science (4)

The course reinforces students' intuitive, theoretical, and computational understanding of probability and statistics, and builds on these foundations to introduce more advanced concepts useful in both data science research and practice. The following topics will be covered: basics, convergence, estimation, and hypothesis testing. Python programs, examples, and visualizations will be used throughout the course. ***Prerequisites:*** graduate standing.

ECE 225B. Universal Probability and Its Applications in Data Science (4)

In many data science problems, there is only limited information on statistical properties of the data. This course develops the concept of universal probability that can be used as a proxy for the unknown distribution of data and provides a unified framework for several data science problems, including compression, portfolio selection, prediction, and classification. ***Prerequisites:*** ECE 225A or ECE 250; graduate standing.

ECE 226. Optimization and Acceleration of Deep Learning on Various Hardware Platforms (4)

This course aims to present the mathematical and computational challenges for holistic content/algorithm/hardware codesign of an efficient deep learning framework. Participants will discuss selected topics including DNNs, CNNs, and RNNs in both supervised and unsupervised settings. Special emphasis will be on optimizing DL physical performance on different hardware platforms. The hardware platforms include CPU-CPU and CPU-GPU architectures. ***Prerequisites:*** ECE 250 or ECE 269 or ECE 271A; graduate standing.

ECE 227. Big Network Data (4)

A course on network science driven by data analysis. The class will focus on both theoretical and empirical analysis performed on real data, including technological networks, social networks, information networks, biological networks, economic networks, and financial networks. Students will be exposed to a number of state-of-the-art software libraries for network data analysis and visualization via the Python notebook environment. Previous Python programming experience recommended. ***Prerequisites:*** graduate standing.

ECE 228. Machine Learning for Physical Applications (4)

Machine learning has received enormous interest. To learn from data we use probability theory, which has been a mainstay of statistics and engineering for centuries. The class will focus on implementations for physical problems. Topics: Gaussian probabilities, linear models for regression, linear models for classification, neural networks, kernel methods, support vector machines, graphical models, mixture models, sampling methods, and sequential estimation. ***Prerequisites:*** graduate standing.

ECE 230A. Solid State Electronics I (4)

This course is designed to provide a general background in solid state electronic materials and devices. Course content emphasizes the fundamental and current issues of semiconductor physics related to the ECE solid state electronics sequences. (Recommended prerequisites: ECE 135A–B or equivalent.) ***Prerequisites:*** graduate standing.

ECE 230B. Solid State Electronics II (4)

Physics of solid-state electronic devices, including p-n diodes, Schottky diodes, field-effect transistors, bipolar transistors, pnpn structures. Computer simulation of devices, scaling characteristics, high frequency performance, and circuit models. ***Prerequisites:*** ECE 230A; graduate standing.

ECE 230C. Solid State Electronics III (4)

This course is designed to provide a treatise of semiconductor devices based on solid state phenomena. Band structures carrier scattering and recombination processes and their influence on transport properties will be emphasized. (Recommended prerequisites: ECE 230A or equivalent.) ***Prerequisites:*** ECE 230B; graduate standing.

ECE 235. Nanometer-Scale VLSI Devices (4)

This course covers modern research topics in sub-100 nm scale, state-of-the-art silicon VLSI devices. Starting with the fundamentals of CMOS scaling to nanometer dimensions, various advanced device and circuit concepts, including RF CMOS, low power CMOS, silicon memory, silicon-on-insulator, SiGe bipolar, strained silicon MOSFET's, etc. will be taught. The physics of nearballistic transport in an ultimately scaled 10 nm MOSFET will be discussed in light of the recently developed scattering theory. ***Prerequisites:*** graduate standing.

ECE 236A. III-V Compound Semiconductor Materials (4)

This course covers the growth, characterization, and heterojunction properties of III-V compound semiconductors and group-IV heterostructures for the subsequent courses on electronic and photonic device applications. Topics include epitaxial growth techniques, electrical properties of heterojunctions, transport and optical properties of quantum wells and superlattices. ***Prerequisites:*** ECE 230A; graduate standing.

ECE 236B. Optical Processes in Semiconductors (4)

Absorption and emission of radiation in semiconductors. Radiative transition and nonradiative recombination. Laser, modulators, and photodetector devices will be discussed. (Recommended prerequisites: ECE 230A and ECE 230C or equivalent.) ***Prerequisites:*** ECE 236A; graduate standing.

ECE 236C. Heterojunction Field Effect Transistors (4)

The physics and circuit applications of heterojunction field effect transistors (HFETs) and heterojunction bipolar transistors (HBTs). Operating principles of FETs and BJTs are reviewed, and opportunities for improving their performance with suitable material choices and bandgap engineering are highlighted. SiGe and III-V HBTs, III-V FETs, and current research areas are covered. Microwave characteristics, models and representative circuit applications. Students who have already completed ECE 236C and/or D should not enroll in this course. Recommended preparation: ECE 230B or equivalent course with emphasis on physics of solid-state electronic devices. ***Prerequisites:*** ECE 236B; graduate standing.

ECE 238A. Thermodynamics of Solids (4)

The thermodynamics and statistical mechanics of solids. Basic concepts, equilibrium properties of alloy systems, thermodynamic information from phase diagrams, surfaces and interfaces, crystalline defects. Cross-listed with Materials Science 201A and MAE 271A. ***Prerequisites:*** consent of instructor.

ECE 238B. Solid State Diffusion and Reaction Kinetics (4)

Thermally activated processes. Boltzman factor, homogeneous and heterogeneous reactions, solid state diffusion, Fick's law, diffusion mechanisms, Kirkendall effects, Boltzmann-Manato analysis, high diffusivity paths. Cross-listed with Materials Science 201B and MAE 271B. ***Prerequisites:*** ECE 238A.

ECE 240A. Lasers and Optics (4)

Fresnel and Fraunhofer diffraction theory. Optical resonators, interferometry. Gaussian beam propagation and transformation. Laser oscillation and amplification, Q-switching and mode

locking of lasers, some specific laser systems. (Recommended prerequisites: ECE 107 and ECE 182 or equivalent, introductory quantum mechanics or ECE 183.) ***Prerequisites:*** graduate standing.

ECE 240B. Optical Information Processing (4)

Space-bandwidth product, superresolution, space-variant optical system, partial coherence, image processing with coherent and incoherent light, processing with feedback, real-time light modulators for hybrid processing, nonlinear processing. Optical computing and other applications. (Recommended prerequisites:ECE 182 or equivalent.) ***Prerequisites:*** ECE 240A; graduate standing.

ECE 240C. Optical Modulation and Detection (4)

Propagation of waves and rays in anisotropic media. Electro-optical switching and modulation. Acousto-optical deflection and modulation. Detection theory. Heterodyne detection, incoherent and coherent detection. (Recommended prerequisites: ECE 181, ECE 183 or equivalent.) ***Prerequisites:*** ECE 240B; graduate standing.

ECE 241A. Nonlinear Optics (4)

Second harmonic generation (color conversion), parametric amplification and oscillation, photorefractive effects and four-wave mixing, optical bistability; applications. (Recommended prerequisites: ECE 240A, C.) ***Prerequisites:*** graduate standing.

ECE 241B. Integrated Photonics (4)

Integrated photonic devices and components made using silicon, compound semiconductors, thin-film crystals, and dielectric materials. Design, analysis, and applications of components (e.g., waveguides, micro-resonators, couplers, modulators, lasers, and detectors) for use in communications, sensing, metrology, and other areas. ***Prerequisites:*** ECE 241A; graduate standing.

ECE 241C. Holographic Optical Elements (4)

Fresnel, Fraunhofer, and Fourier holography. Analysis of thin and volume holograms, reflection and transmission holograms, color and polarization holograms. Optically recorded and computer-generated holography. Applications to information storage, optical interconnects, 2-D and 3-D display, pattern recognition, and image processing. (Recommended prerequisites: ECE 182 or equivalent.) ***Prerequisites:*** ECE 241B; graduate standing.

ECE 243B. Optical Fiber Communication (4)

Optical fibers, waveguides, laser communication system. Modulation and demodulation; detection processes and communication-receivers. (Recommended prerequisites: ECE 240A-B-C or equivalent.) ***Prerequisites:*** ECE 243A; graduate standing.

ECE 244A. Statistical Optics (4)

Introduction to statistical phenomena in optics including first order properties of light waves generated from various sources. Coherence of optical waves, high-order coherence. Partial coherence and its effects on imaging systems. Imaging in presence of randomly inhomogeneous medium. Limits in photoelectric detection of light. (Recommended prerequisites: ECE 240A–B.) ***Prerequisites:*** graduate standing.

ECE 247A. Advanced BioPhotonics (4)

Basic physics and chemistry for the interaction of photons with matter, including both biological and synthetic materials; use of photonic radiation pressure for manipulation of objects and materials; advanced optoelectronic detection systems, devices and methods, including time

resolved fluorescent and chemiluminescent methods, fluorescent energy transfer (FRET) techniques, quantum dots, and near-field optical techniques; underlying mechanisms of the light sensitive biological systems, including chloroplasts for photosynthetic energy conversion and the basis of vision processes. Cross-listed with BENG 247A and NANO 247A. ***Prerequisites:*** graduate standing.

ECE 247B. BioElectronics (4)

Topics to be covered will include photolithographic techniques for high-density DNA microarray production, incorporation of CMOS control into electronic DNA microarrays, direct electronic detection technology used in microarrays and biosensor devices, and focus on problems related to making highly integrated devices (lab-on-a-chip, in-vivo biosensors, etc.) from heterogeneous materials and components. Cross-listed with BENG 247B and NANO 247B. ***Prerequisites:*** graduate standing.

ECE 247C. BioNanotechnology (4)

Topics include: nanosensors and nanodevices for both clinical diagnostics and biowarfare (bioterror) agent detection; nanostructures for drug delivery; nanoarrays and nanodevices; use of nanoanalytical devices and systems; methods and techniques for modification or functionalization of nanoparticles and nanostructures with biological molecules; nanostructural aspects of fuel cells and bio-fuel cells; potential use of DNA and other biomolecules for computing and ultra-high-density data storage. Cross-listed with BENG 247C and NANO 247C. ***Prerequisites:*** graduate standing.

ECE 250. Random Processes (4)

Random variables, probability distributions and densities, characteristic functions. Convergence in probability and in quadratic mean, Stochastic processes, stationarity. Processes with orthogonal and independent increments. Power spectrum and power spectral density. Stochastic integrals and derivatives. Spectral representation of wide sense stationary processes, harmonizable processes, moving average representations. (Recommended prerequisites: ECE 153.) ***Prerequisites:*** graduate standing.

ECE 251A. Digital Signal Processing I (4)

Discrete random signals; conventional (FFT based) spectral estimation. Coherence and transfer function estimation; model-based spectral estimation; linear prediction and AR modeling. Levinson-Durbin algorithm and lattice filters, minimum variance spectrum estimation. Cross-listed with SIO 207B. SIO 207A is intended for graduate students who have not had an undergraduate course in DSP. (Recommended prerequisites: ECE 153 in addition to either ECE 161 or 161A and SIO 207A or equivalent background.) ***Prerequisites:*** graduate standing.

ECE 251B. Digital Signal Processing II (4)

Adaptive filter theory, estimation errors for recursive least squares and gradient algorithms, convergence and tracking analysis of LMD, RLS, and Kalman filtering algorithms, comparative performance of Weiner and adaptive filters, transversal and lattice filter implementations, performance analysis for equalization, noise cancelling, and linear prediction applications. Cross-listed with SIO 207C. ***Prerequisites:*** graduate standing; ECE 251A (for ECE 251B); SIO 207B (for SIO 207C).

ECE 251C. Filter Banks and Wavelets (4)

Fundamentals of multirate systems (Noble Identities, Polyphase representations), maximally decimated filter banks (QMF filters for 2-channels, M-channel perfect reconstruction systems),

Paraunitary perfect reconstruction filter banks, the wavelet transform (Multiresolution, discrete wavelet transform, filter banks and wavelet). (Recommended prerequisites: ECE 161 or equivalent.) ***Prerequisites:*** ECE 251B; graduate standing.

ECE 251D. Array Processing (4)

The coherent processing of data collected from sensors distributed in space for signal enhancement and noise rejection purposes or wavefield directionality estimation. Conventional and adaptive beamforming. Matched field processing. Sparse array design and processing techniques. Applications to acoustics, geophysics, and electromagnetics. Cross-listed with SIO 207D. (Recommended prerequisites: ECE 251A.) ***Prerequisites:*** graduate standing; ECE 251C (for ECE 251D); SIO 207C (for SIO 207D).

ECE 252A. Speech Compression (4)

Speech signals, production and perception, compression theory, high rate compression using waveform coding (PCM, DPCM, ADPCM, . . .), DSP tools for low rate coding, LPC vocoders, sinusoidal transform coding, multiband coding, medium rate coding using code excited linear prediction (CELP). (Recommended prerequisites: ECE 161A.) ***Prerequisites:*** graduate standing.

ECE 252B. Speech Recognition (4)

Signal analysis methods for recognition, dynamic time warping, isolated word recognition, hidden Markov models, connected word, and continuous speech recognition. ***Prerequisites:*** ECE 252A; graduate standing.

ECE 253. Fundamentals of Digital Image Processing (4)

Image quantization and sampling, image transforms, image enhancement, image compression. (Recommended prerequisites: ECE 109, 153, ECE 161, ECE 161A).

ECE 254. Detection Theory (4)

Hypothesis testing, detection of signals in white and colored Gaussian noise; estimation of signal parameters, maximum-likelihood detection; resolution of signals; detection and estimation of stochastic signals; applications to radar, sonar, and communications. (Recommended prerequisites: ECE 153.) ***Prerequisites:*** graduate standing.

ECE 255A. Information Theory (4)

Introduction to basic concepts, source coding theorems, capacity, noisy-channel coding theorem. (Recommended prerequisites: ECE 154A-B-C.) ***Prerequisites:*** graduate standing.

ECE 255B. Source Coding (4)

Theory and practice of lossy source coding, vector quantization, predictive and differential encoding, universal coding, source-channel coding, asymptotic theory, speech and image applications. Students that have taken 255BN cannot take 255B for credit. (Recommended prerequisites: ECE 250, and 259A or 259AN) ***Prerequisites:*** ECE 255A; graduate standing.

ECE 255C. Network Information Theory (4)

The course aims to provide a broad coverage of key results, techniques, and open problems in network information theory. Topics include background (information measures and typical sequences, point-to-point communication) and single-hop networks (multiple access channels, degraded broadcast channels, interference channels, channels with state, general broadcast channels, Gaussian vector channels, distributed lossless source coding, source coding with side information). ***Prerequisites:*** ECE 250; ECE 255B; graduate standing.

ECE 257A. Multiuser Communication Systems (4)

Congestion control, convex programming and dual controller, fair end-end rate allocation, max-min fair vs. proportional fairness. Markov Chains and recurrence, Lyapunov-Foster theorem, rate stable switch scheduling, stable (back-pressure) routing versus minimum delay routing versus shortest path routing. ***Prerequisites:*** graduate standing.

ECE 257B. Principles of Wireless Networks (4)

This course will focus on the principles, architectures, and analytical methodologies for design of multiuser wireless networks. Topics to be covered include cellular approaches, call processing, digital modulation, MIMO technology, broadband networks, ad-hoc networks, and wireless packet access. (Recommended prerequisites: ECE 159A and 154B, or equivalent.) ***Prerequisites:*** ECE 257A; graduate standing.

ECE 257C. Stochastic Wireless Networks Models (4)

Elements of spatial point processes. Spatial stochastic models of wireless networks. Topological structure, interference, stochastic dependencies. Elements of network information theory/statistical physics models of information flow. Role of signal propagation/random fading models. Decentralized operation, route discovery, architectural principles. Energy limitations/random failures. (Recommended prerequisites: previous exposure to stochastic processes and information theory.) ***Prerequisites:*** ECE 257B; graduate standing.

ECE 258A–B. Digital Communication (4-4)

Digital communication theory including performance of various modulation techniques, effects of inter-symbol interference, adaptive equalization, spread spectrum communication. ***Prerequisites:*** ECE 154A-B-C and ECE 254 or consent of instructor.

ECE 259A. Algebraic Coding (4)

Fundamentals of block codes, introduction to groups, rings and finite fields, nonbinary codes, cyclic codes such as BCH and RS codes, decoding algorithms, applications. Students who have taken ECE 259AN may not receive credit for ECE 259A. ***Prerequisites:*** graduate standing.

ECE 259B. Probabilistic Coding (4)

Convolutional codes, maximum-likelihood (ML) decoding, maximum a-posteriori (MAP) decoding, parallel and serial concatenation architectures, turbo codes, repeat-accumulate (RA) codes, the turbo principle, turbo decoding, graph-based codes, message-passing decoding, low-density parity check codes, threshold analysis, applications. Students who have taken ECE 259BN may not receive credit for ECE 259B. (Recommended prerequisites: ECE 154A-B-C.) ***Prerequisites:*** ECE 259A; graduate standing.

ECE 259C. Advanced Topics in Coding (4)

Advanced topics in coding theory. Course contents vary by instructor. Example course topics: Coded-modulation for bandwidth-efficient data transmission; advanced algebraic and combinatorial coding theory; space-time coding for wireless communications; constrained coding for digital recording. Students who have taken ECE 259CN may not receive credit for ECE 259C. ***Prerequisites:*** ECE 259A–B; graduate standing.

ECE 260A. VLSI Digital System Algorithms and Architectures (4)

Custom and semi-custom VLSI design from both the circuit and system designer's perspective. MOS transistor theory, circuit characterization, and performance estimation. CMOS logic design will be emphasized. Computer-aided design (CAD) tools for transistor level simulation, layout and verification will be introduced. Includes two hours of laboratory hours per week.

(Recommended preparation: undergraduate-level semiconductor electronics and digital system design, ECE 165 or equivalent.) ***Prerequisites:*** graduate standing.

ECE 260B. VLSI Integrated Circuits and Systems Design (4)

VLSI implementation methodology across block, circuit, and layout levels of abstraction. Circuit building blocks including embedded memory and clock distribution. Computer-aided design (synthesis, place-and-route, verification) and performance analyses, and small-group block implementation projects spanning RTL to tape-out using leading-edge EDA tools. Cross-listed with CSE 241A. (Recommended prerequisites: ECE 165.) ***Prerequisites:*** ECE 260A; graduate standing.

ECE 260C. VLSI Advanced Topics (4)

Advanced topics in design practices and methodologies for modern system-on-chip design. Different design alternatives are introduced and analyzed. Advanced design tools are used to design a hardware-software system. Class discussion, participation, and presentations of projects and special topics assignments are emphasized. ***Prerequisites:*** ECE 260B; graduate standing.

ECE 264A. CMOS Analog Integrated Circuits and Systems I (4)

Frequency response of the basic CMOS gain stage and current mirror configurations. Advanced feedback and stability analysis; compensation techniques. High-Performance CMOS operational amplifier topologies. Analysis of noise and distortion. (Recommended prerequisites: ECE 164 and ECE 153, or equivalent courses.) ***Prerequisites:*** graduate standing.

ECE 264B. CMOS Analog Integrated Circuits and Systems II (4)

Nonideal effects and their mitigation in high-performance operational amplifiers. Switched-capacitor circuit techniques: CMOS circuit topologies, analysis and mitigation of nonideal effects, and filter synthesis. Overview of CMOS samplers, data converters, and PLLs. (Recommended prerequisites: ECE 251A or ECE 251AN.) ***Prerequisites:*** ECE 264A; graduate standing.

ECE 264C. CMOS Analog Integrated Circuits and Systems III (4)

Integrated CMOS analog/digital systems: Analog to digital and digital to analog converters, Nyquist versus oversampling, linearity, jitter, randomization, calibration, speed versus resolution, pipeline, folding, interpolation, averaging. (Recommended prerequisites: ECE 163 and 164.) ***Prerequisites*:** ECE 264B; graduate standing.

ECE 264D. CMOS Analog Integrated Circuits and Systems IV (4)

PLL: Phase noise effect, VCO, phase detector, charge pump, integer/fractional-N frequency synthesizer, clock and data recovery, decision feedback. Filter: Continuous-time filter, I-Q complex filter, raised-cosine, Gaussian, delay, zero equalizers. (Recommended prerequisites: ECE 163 and 164.) ***Prerequisites****:* ECE 264C; graduate standing

ECE 265A. Communication Circuit Design I (4)

Introduction to noise and linearity concepts. System budgeting for optimum dynamic range. Frequency plan tradeoffs. Linearity analysis techniques. Down-conversion and up-conversion techniques. Modulation and demodulation. Microwave and RF system design communications. Current research topics in the field. ***Prerequisites:*** ECE 166 or consent of instructor.

ECE 265B. Communication Circuit Design II (4)

Radio frequency integrated circuits: low-noise amplifiers, AGCs, mixers, filters, voltage-controlled oscillators. BJT and CMOS technologies for radio frequency and microwave

applications. Device modeling for radio frequency applications. Design and device tradeoffs of linearity, noise, power dissipation, and dynamic range. Current research topics in the field. ***Prerequisites:*** ECE 166 and ECE 265A or consent of instructor.

ECE 265C. Power Amplifiers for Wireless Communications (4)

Design of power amplifiers for mobile terminals and base-stations, with emphasis on high linearity and efficiency. After a discussion of classical designs (Class A, AB, B, C, D, E, F, and S), linearization procedures are presented and composite architectures (envelope tracking, EER, and Doherty) are covered. Familiarity with basic microwave design and communication system architecture is assumed. (Recommended prerequisites: ECE 166.) ***Prerequisites:*** ECE 265A and B; consent of instructor.

ECE 267. Wireless Embedded and Networked Systems (4)

Study of wireless networked systems from a system design perspective, covering the protocol stack from physical to network layer with a focus on energy. Topics include digital communications, networking and programming, and a basic knowledge of these is recommended. ***Prerequisites:*** graduate standing.

ECE 268. Security of Hardware Embedded Systems (4)

The course gives an overview of areas of security and protection of modern hardware, embedded systems, and IoTs. Covers essential cryptographic methodologies and blocks required for building a secure system. Topics include low overhead security, physical and side-channel attacks, physical security primitives, physical security and proofs of presence, hardware-based secure program execution, scalable implementation of secure functions, emerging technologies, and rising threats. Recommended preparation: Programming in a standard programming language. Undergraduate level knowledge of the IC design flow and digital designs. ***Prerequisites:*** graduate standing.

ECE 269. Linear Algebra and Application (4)

This course will build mathematical foundations of linear algebraic techniques and justify their use in signal processing, communication, and machine learning. Topics include geometry of vector and Hilbert spaces, orthogonal projection, systems of linear equations and role of sparsity, eigenanalysis, Hermitian matrices and variational characterization, positive semidefinite matrices, singular value decomposition, and principal component analysis. ***Prerequisites****:* graduate standing.

ECE 271A. Statistical Learning I (4)

Bayesian decision theory; parameter estimation; maximum likelihood; the bias-variance trade-off; Bayesian estimation; the predictive distribution; conjugate and noninformative priors; dimensionality and dimensionality reduction; principal component analysis; Fisher's linear discriminant analysis; density estimation; parametric vs. kernel-based methods; expectation-maximization; applications. (Recommended prerequisites: ECE 109.) ***Prerequisites:*** graduate standing.

ECE 271B. Statistical Learning II (4)

Linear discriminants; the Perceptron; the margin and large margin classifiers; learning theory; empirical vs. structural risk minimization; the VC dimension; kernel functions; reproducing kernel Hilbert spaces; regularization theory; Lagrangian optimization; duality theory; the support vector machine; boosting; Gaussian processes; applications. (Recommended prerequisites: ECE 109.) ***Prerequisites:*** ECE 271A; graduate standing.

ECE 271C. Deep Learning and Applications (4)
Foundations of deep learning. Deep learning architectures and learning algorithms. Feedforward, convolutional, and recurrent networks. Regularization. Applications to vision, speech, or text processing. ***Prerequisites:*** ECE 271A-B; graduate standing.

ECE 272A. Stochastic Processes in Dynamic Systems I (4)
Diffusion equations, linear and nonlinear estimation and detection, random fields, optimization of stochastic dynamic systems, applications of stochastic optimization to problems. (Recommended prerequisites: ECE 250.) ***Prerequisites:*** graduate standing.

ECE 272B. Stochastic Processes in Dynamic Systems II (4)
Continuous and discrete random processes, Markov models and hidden Markov models, Martingales, linear and nonlinear estimation. Applications in mathematical finance and real options. ***Prerequisites:*** ECE 272A; graduate standing.

ECE 273. Convex Optimization and Applications (4)
This course covers some convex optimization theory and algorithms. It will mainly focus on recognizing and formulating convex problems, duality, and applications in a variety of fields (system design, pattern recognition, combinatorial optimization, financial engineering, etc.). (Recommended prerequisites: basic linear algebra.)

ECE 275A. Parameter Estimation I (4)
Linear least Squares (batch, recursive, total, sparse, pseudoinverse, QR, SVD); Statistical figures of merit (bias, consistency, Cramer-Rao lower-bound, efficiency); Maximum likelihood estimation (MLE); Sufficient statistics; Algorithms for computing the MLE including the Expectation Maximation (EM) algorithm. The problem of missing information; the problem of outliers. (Recommended prerequisites: ECE 109 and ECE 153.) ***Prerequisites:*** graduate standing.

ECE 275B. Parameter Estimation II (4)
The Bayesian statistical framework; Parameter and state estimation of Hidden Markov Models, including Kalman Filtering and the Viterbi and Baum-Welsh algorithms. A solid foundation is provided for follow-up courses in Bayesian machine learning theory. (Recommended prerequisites: ECE 153.) ***Prerequisites:***ECE 275A; graduate standing.

ECE 276A. Sensing and Estimation in Robotics (4)
This course covers the mathematical fundamentals of Bayesian filtering and their application to sensing and estimation in mobile robotics. Topics include maximum likelihood estimation (MLE), expectation maximization (EM), Gaussian and particle filters, simultaneous localization and mapping (SLAM), visual features and optical flow, and hidden Markov models (HMM). ***Prerequisites:*** graduate standing.

ECE 276B. Planning and Learning in Robotics (4)
This course covers optimal control and reinforcement learning fundamentals and their application to planning and decision-making in mobile robotics. Topics include Markov decision processes (MDP), Pontryagin's maximum principle, linear quadratic regulation (LQR), deterministic planning, value and policy iteration, and policy gradient methods. **Prerequisites:** ECE 276A; graduate standing.

ECE 276C. Robot Reinforcement Learning (4)
Course participants will explore new methods for robotics, particularly toward enabling robot manipulators in complex environments. This course is structured to rapidly consider the

previous techniques in robot manipulation to date and explore methods in reinforcement learning to solve open problems in robot manipulation. Topics will review kinematics, dynamics, low-level control and motion planning, and machine learning approaches. ***Prerequisites:*** ECE 276A; graduate standing.

ECE 278. Mathematical Topics for the Master's Comprehensive Exam (2)

Mathematical topics covered in the ECE master's comprehensive exam including calculus, linear algebra and linear systems, and statistics and probability theory. ***Prerequisites****:* graduate standing.

ECE 279. Special Seminar (2)

A seminar course in which topics of special interest for electrical and computer engineering students will be presented. S/U grades only. May be taken for credit three times. ***Prerequisites:*** graduate standing.

ECE 280. Special Topics in Electronic Devices and Materials/Applied Physics (4)

A course to be given at the discretion of the faculty at which topics of interest in electronic devices and materials or applied physics will be presented by visiting or resident faculty members. Subject matter will not be repeated, may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 281. Special Topics in Nanoscience/Nanotechnology (4)

A course to be given at the discretion of the faculty at which topics of interest in nanoscience and nanotechnology will be presented by visiting or resident faculty members. Subject matter will not be repeated, may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 282. Special Topics in Photonics/Applied Optics (4)

A course to be given at the discretion of the faculty at which topics of interest in photonics, optoelectronic materials, devices, systems, and applications will be presented by visiting or resident faculty members. Subject matter will not be repeated, may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 283. Special Topics in Electronic Circuits and Systems (4)

A course to be given at the discretion of the faculty at which topics of interest in electronic circuits and systems will be presented by visiting or resident faculty members. Subject matter will not be repeated, may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 284. Special Topics in Computer Engineering (4)

A course to be given at the discretion of the faculty at which topics of interest in computer engineering will be presented by visiting or resident faculty members. Subject matter will not be repeated, may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 285. Special Topics in Signal and Image Processing/Robotics and Control Systems (4)

A course to be given at the discretion of the faculty at which topics of interest in signal and image processing or robotics and control systems will be presented by visiting or resident faculty members. Subject matter will not be repeated, may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 286. State-of-the-Art Topics in Computational Statistics and Machine Learning (4)

Class discusses both fundamental and state-of-the-art research topics in computational statistics and machine learning. Topics vary based upon current research and have included:

nonparametric Bayesian models; sampling methods for inference in graphical models; Markov Chain Monte Carlo (MCMC) methods. ***Prerequisites:*** graduate standing.

ECE 287. Special Topics in Communication Theory and Systems (4)

A course to be given at the discretion of the faculty at which topics of interest in information science will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit more than once. ***Prerequisites:*** graduate standing.

ECE 289. Special Topics in Electrical and Computer Engineering (4)

A course to be given at the discretion of the faculty at which general topics of interest in electrical and computer engineering will be presented by visiting or resident faculty members. May be taken for credit six times provided each course is a different topic. ***Prerequisites:*** graduate standing.

ECE 290. Graduate Seminar on Current ECE Research (2)

Weekly discussion of current research conducted in the Department of Electrical and Computer Engineering by the faculty members involved in the research projects. (S/U grades only.) ***Prerequisites:*** graduate standing.

ECE 291. Industry Sponsored Engineering Design Project (4)

Design, build, and demonstrate an engineering project by groups. All students give weekly progress reports on tasks and write final report, with individual exams and presentations. Projects/sponsorships originate from the needs of local industry. (Recommended prerequisites: ECE 230 or ECE 240 or ECE 251 or ECE 253 or ECE 258 or equivalent.) ***Prerequisites:*** graduate standing.

ECE 293. Graduate Seminar in Communication Theory and Systems (2)

Weekly discussion of current research topics in communication theory and systems. (S/U grades only.) ***Prerequisites:*** graduate standing.

ECE 294. Graduate Seminar in Electronic Devices and Materials/Applied Physics (2)

Weekly discussion of current research topics in electronic devices and materials or applied solid state physics and quantum electronics. (S/U grades only.) ***Prerequisites:*** graduate standing.

ECE 295. Graduate Seminar in Signal and Image Processing/Robotics and Control Systems (2)

Weekly discussion of research topics in signal and image processing of robotics and control systems. (S/U grades only.) ***Prerequisites:*** graduate standing.

ECE 296. Graduate Seminar in Photonics/Applied Optics (2)

Weekly discussion of current research topics in photonics and applied optics, including imaging, photonic communications, sensing, energy and signal processing. (S/U grades only.) ***Prerequisites:*** graduate standing.

ECE 297. Graduate Seminar in Nanoscience/Nanotechnology (2)

Weekly discussion of current research topics in nanoscience and nanotechnology. (S/U grades only.) ***Prerequisites:*** graduate standing.

ECE 298. Independent Study (1–16)

Open to properly qualified graduate students who wish to pursue a problem through advanced study under the direction of a member of the staff. (S/U grades only.) ***Prerequisites:*** consent of instructor.

ECE 299. Research (1–16)

(S/U grades only.)

ECE 501. Teaching (1–4)

Teaching and tutorial activities associated with courses and seminars. Number of units for credit depends on number of hours devoted to class or section assistance. (S/U grades only.) ***Prerequisites:*** consent of department chair.

Mathematics

Upper Division

MATH 100A. Abstract Algebra I (4)
First course in a rigorous three-quarter introduction to the methods and basic structures of higher algebra. Topics include: groups, subgroups and factor groups, homomorphisms, rings, fields. (Students may not receive credit for both Math 100A and Math 103A.) ***Prerequisites:*** Math 31CH or Math 109 or consent of instructor.

MATH 100B. Abstract Algebra II (4)
Second course in a rigorous three-quarter introduction to the methods and basic structures of higher algebra. Topics include: rings (especially polynomial rings) and ideals, unique factorization, fields; linear algebra from perspective of linear transformations on vector spaces, including inner product spaces, determinants, diagonalization. (Students may not receive credit for both Math 100B and Math 103B.) ***Prerequisites:*** Math 100A or consent of instructor.

MATH 100C. Abstract Algebra III (4)
Third course in a rigorous three-quarter introduction to the methods and basic structures of higher algebra. Topics include: linear transformations, including Jordan canonical form and rational canonical form; Galois theory, including the insolvability of the quintic. ***Prerequisites:*** Math 100B or consent of instructor.

MATH 102. Applied Linear Algebra (4)
Second course in linear algebra from a computational yet geometric point of view. Elementary Hermitian matrices, Schur's theorem, normal matrices, and quadratic forms. Moore-Penrose generalized inverse and least square problems. Vector and matrix norms. Characteristic and singular values. Canonical forms. Determinants and multilinear algebra. ***Prerequisites:*** Math 18 or Math 20F or Math 31AH and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 103A. Modern Algebra I (4)
First course in a two-quarter introduction to abstract algebra with some applications. Emphasis on group theory. Topics include: definitions and basic properties of groups, properties of isomorphisms, subgroups. (Students may not receive credit for both Math 100A and Math 103A.) ***Prerequisites:*** Math 31CH or Math 109 or consent of instructor.

MATH 103B. Modern Algebra II (4)
Second course in a two-quarter introduction to abstract algebra with some applications. Emphasis on rings and fields. Topics include: definitions and basic properties of rings, fields, and ideals, homomorphisms, irreducibility of polynomials. (Students may not receive credit for both Math 100B and Math 103B.) ***Prerequisites:*** Math 103A or Math 100A or consent of instructor.

MATH 104A. Number Theory I (4)
Elementary number theory with applications. Topics include unique factorization, irrational numbers, residue systems, congruences, primitive roots, reciprocity laws, quadratic forms, arithmetic functions, partitions, Diophantine equations, distribution of primes. Applications include fast Fourier transform, signal processing, codes, cryptography. ***Prerequisites:*** Math 109 or Math 31CH, or consent of instructor.

MATH 104B. Number Theory II (4)

Topics in number theory such as finite fields, continued fractions, Diophantine equations, character sums, zeta and theta functions, prime number theorem, algebraic integers, quadratic and cyclotomic fields, prime ideal theory, class number, quadratic forms, units, Diophantine approximation, *p*-adic numbers, elliptic curves. ***Prerequisites:*** Math 104A or consent of instructor.

MATH 104C. Number Theory III (4)

Topics in algebraic and analytic number theory, with an advanced treatment of material listed for Math 104B. ***Prerequisites:*** Math 104B or consent of instructor.

MATH 109. Mathematical Reasoning (4)

This course uses a variety of topics in mathematics to introduce the students to rigorous mathematical proof, emphasizing quantifiers, induction, negation, proof by contradiction, naive set theory, equivalence relations and epsilon-delta proofs. Required of all departmental majors. ***Prerequisites:*** Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 110A. Introduction to Partial Differential Equations (4)

Fourier series, orthogonal expansions, and eigenvalue problems. Sturm-Liouville theory. Separation of variables for partial differential equations of mathematical physics, including topics on Bessel functions and Legendre polynomials. Formerly Math 110. (Students may not receive credit for Math 110A and Math 110.) ***Prerequisites:*** Math 20D and either Math 18 or Math 20F or Math 31AH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 110B. Elements of Partial Differential Equations and Integral Equations (4)

Basic concepts and classification of partial differential equations. First order equations, characteristics. Hamilton-Jacobi theory, Laplace's equation, wave equation, heat equation. Separation of variables, eigenfunction expansions, existence and uniqueness of solutions. (Formerly Math 132A. Students may not receive credit for Math 110B and Math 132A.) ***Prerequisites:*** Math 110A or consent of instructor.

MATH 111A. Mathematical Modeling I (4)

An introduction to mathematical modeling in the physical and social sciences. Topics vary, but have included mathematical models for epidemics, chemical reactions, political organizations, magnets, economic mobility, and geographical distributions of species. May be taken for credit two times when topics change. ***Prerequisites:*** Math 20D, Math 18 or Math 20F or Math 31AH, and Math 109 or Math 31CH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 111B. Mathematical Modeling II (4)

Continued study on mathematical modeling in the physical and social sciences, using advanced techniques that will expand upon the topics selected and further the mathematical theory presented in Math 111A. ***Prerequisites:*** Math 111A or consent of instructor.

MATH 120A. Elements of Complex Analysis (4)

Complex numbers and functions. Analytic functions, harmonic functions, elementary conformal mappings. Complex integration. Power series. Cauchy's theorem. Cauchy's formula. Residue theorem. ***Prerequisites:*** Math 20E or Math 31CH, or consent of instructor.

MATH 120B. Applied Complex Analysis (4)

Applications of the residue theorem. Conformal mapping and applications to potential theory, flows, and temperature distributions. Fourier transformations. Laplace transformations, and applications to integral and differential equations. Selected topics such as Poisson's formula, Dirichlet's problem, Neumann's problem, or special functions. ***Prerequisites:*** Math 120A or consent of instructor.

MATH 121A. Foundations of Teaching and Learning Mathematics I (4)

(Cross-listed with EDS 121A.) Develop teachers' knowledge base (knowledge of mathematics content, pedagogy, and student learning) in the context of advanced mathematics. This course builds on the previous courses where these components of knowledge were addressed exclusively in the context of high-school mathematics. ***Prerequisites:*** EDS 30/Math 95, Calculus 10C or 20C.

MATH 121B. Foundations of Teaching and Learning Math II (4)

(Cross-listed with EDS 121B.) Examine how learning theories can consolidate observations about conceptual development with the individual student as well as the development of knowledge in the history of mathematics. Examine how teaching theories explain the effect of teaching approaches addressed in the previous courses. ***Prerequisites:*** EDS 121A/Math 121A.

MATH 130A. Ordinary Differential Equations I (4)

Linear and nonlinear systems of differential equations. Stability theory, perturbation theory. Applications and introduction to numerical solutions. ***Prerequisites:***Math 20D and either Math 18 or Math 20F or Math 31AH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 130B. Ordinary Differential Equations II (4)

Existence and uniqueness of solutions to differential equations. Local and global theorems of continuity and differentiability. ***Prerequisites:*** Math 130A or consent of instructor.

MATH 140A. Foundations of Real Analysis I (4)

First course in a rigorous three-quarter sequence on real analysis. Topics include: the real number system, basic topology, numerical sequences and series, continuity. (Students may not receive credit for both Math 140A and Math 142A.) ***Prerequisites:*** Math 31CH or Math 109. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 140B. Foundations of Real Analysis II (4)

Second course in a rigorous three-quarter sequence on real analysis. Topics include: differentiation, the Riemann-Stieltjes integral, sequences and series of functions, power series, Fourier series, and special functions. (Students may not receive credit for both Math 140B and Math 142B.) ***Prerequisites:*** Math 140A or consent of instructor.

MATH 140C. Foundations of Real Analysis III (4)

Third course in a rigorous three-quarter sequence on real analysis. Topics include: differentiation of functions of several real variables, the implicit and inverse function theorems, the Lebesgue integral, infinite-dimensional normed spaces. ***Prerequisites:*** Math 140B or consent of instructor.

MATH 142A. Introduction to Analysis I (4)

First course in an introductory two-quarter sequence on analysis. Topics include: the real number system, numerical sequences and series, limits of functions, continuity. (Students may not receive credit for both Math 140A and Math 142A.) ***Prerequisites:*** Math 31CH or Math 109, or consent of instructor.

MATH 142B. Introduction to Analysis II (4)
Second course in an introductory two-quarter sequence on analysis. Topics include: differentiation, the Riemann integral, sequences and series of functions, uniform convergence, Taylor and Fourier series, special functions. (Students may not receive credit for both Math 140B and Math 142B.) ***Prerequisites:*** Math 142A or Math 140A, or consent of instructor.

MATH 150A. Differential Geometry (4)
Differential geometry of curves and surfaces. Gauss and mean curvatures, geodesics, parallel displacement, Gauss-Bonnet theorem. ***Prerequisites:*** Math 20E and either Math 18 or Math 20F or Math 31AH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 150B. Calculus on Manifolds (4)
Calculus of functions of several variables, inverse function theorem. Further topics may include exterior differential forms, Stokes' theorem, manifolds, Sard's theorem, elements of differential topology, singularities of maps, catastrophes, further topics in differential geometry, topics in geometry of physics. ***Prerequisites:*** Math 150A or consent of instructor.

MATH 152. Applicable Mathematics and Computing (4)
This course will give students experience in applying theory to real world applications such as Internet and wireless communication problems. The course will incorporate talks by experts from industry and students will be helped to carry out independent projects. Topics include graph visualization, labelling, and embeddings, random graphs and randomized algorithms. May be taken for credit three times. ***Prerequisites:*** Math 20D and either Math 18 or Math 20F or Math 31AH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 153. Geometry for Secondary Teachers (4)
Two- and three-dimensional Euclidean geometry is developed from one set of axioms. Pedagogical issues will emerge from the mathematics and be addressed using current research in teaching and learning geometry. This course is designed for prospective secondary school mathematics teachers. ***Prerequisites:***Math 109 or Math 31CH, or consent of instructor.

MATH 154. Discrete Mathematics and Graph Theory (4)
Basic concepts in graph theory. Combinatorial tools, structures in graphs (Hamiltonian cycles, perfect matching). Properties of graphics and applications in basic algorithmic problems (planarity, k-colorability, traveling salesman problem). ***Prerequisites:*** Math 109 or Math 31CH, or consent of instructor.

MATH 155A. Geometric Computer Graphics (4)
Bezier curves and control lines, de Casteljau construction for subdivision, elevation of degree, control points of Hermite curves, barycentric coordinates, rational curves. Programming knowledge recommended. (Students may not receive credit for both Math 155A and CSE 167.) ***Prerequisites:*** Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 155B. Topics in Computer Graphics (4)
Spline curves, NURBS, knot insertion, spline interpolation, illumination models, radiosity, and ray tracing. ***Prerequisites:*** Math 155A. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 157. Introduction to Mathematical Software (4)

A hands-on introduction to the use of a variety of open-source mathematical software packages, as applied to a diverse range of topics within pure and applied mathematics. Most of these packages are built on the Python programming language, but no prior experience with mathematical software or computer programming is expected. All software will be accessed using the CoCalc web platform (http://cocalc.com), which provides a uniform interface through any web browser. ***Prerequisites:*** Math 20D and Math 18 or Math 20F or Math 31AH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 160A. Elementary Mathematical Logic I (4)

An introduction to recursion theory, set theory, proof theory, model theory. Turing machines. Undecidability of arithmetic and predicate logic. Proof by induction and definition by recursion. Cardinal and ordinal numbers. Completeness and compactness theorems for propositional and predicate calculi. ***Prerequisites:***Math 100A, or Math 103A, or Math 140A, or consent of instructor.

MATH 160B. Elementary Mathematical Logic II (4)

A continuation of recursion theory, set theory, proof theory, model theory. Turing machines. Undecidability of arithmetic and predicate logic. Proof by induction and definition by recursion. Cardinal and ordinal numbers. Completeness and compactness theorems for propositional and predicate calculi. ***Prerequisites:***Math 160A or consent of instructor.

MATH 163. History of Mathematics (4)

Topics will vary from year to year in areas of mathematics and their development. Topics may include the evolution of mathematics from the Babylonian period to the eighteenth century using original sources, a history of the foundations of mathematics and the development of modern mathematics. ***Prerequisites:***Math 20B or consent of instructor.

MATH 168A. Topics in Applied Mathematics—Computer Science (4)

Topics to be chosen in areas of applied mathematics and mathematical aspects of computer science. May be taken for credit two times with different topics. ***Prerequisites:*** Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 170A. Introduction to Numerical Analysis: Linear Algebra (4)

Analysis of numerical methods for linear algebraic systems and least squares problems. Orthogonalization methods. Ill conditioned problems. Eigenvalue and singular value computations. Knowledge of programming recommended. ***Prerequisites:*** Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed the listed prerequisites may enroll with consent of instructor.

MATH 170B. Introduction to Numerical Analysis: Approximation and Nonlinear Equations (4)

Rounding and discretization errors. Calculation of roots of polynomials and nonlinear equations. Interpolation. Approximation of functions. Knowledge of programming recommended. ***Prerequisites:*** Math 170A.

MATH 170C. Introduction to Numerical Analysis: Ordinary Differential Equations (4)

Numerical differentiation and integration. Ordinary differential equations and their numerical solution. Basic existence and stability theory. Difference equations. Boundary value problems. ***Prerequisites:*** Math 20D or 21D and Math 170B, or consent of instructor.

MATH 171A. Introduction to Numerical Optimization: Linear Programming (4)

Linear optimization and applications. Linear programming, the simplex method, duality. Selected topics from integer programming, network flows, transportation problems, inventory problems, and other applications. Three lectures, one recitation. Knowledge of programming recommended. (Credit not allowed for both Math 171A and Econ 172A.) ***Prerequisites:*** Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 171B. Introduction to Numerical Optimization: Nonlinear Programming (4)

Convergence of sequences in Rn, multivariate Taylor series. Bisection and related methods for nonlinear equations in one variable. Newton's methods for nonlinear equations in one and many variables. Unconstrained optimization and Newton's method. Equality-constrained optimization, Kuhn-Tucker theorem. Inequality-constrained optimization. Three lectures, one recitation. Knowledge of programming recommended. (Credit not allowed for both Math 171B and Econ 172B.) ***Prerequisites:*** Math 171A or consent of instructor.

MATH 173A. Optimization Methods for Data Science I (4)

Introduction to convexity: convex sets, convex functions; geometry of hyperplanes; support functions for convex sets; hyperplanes and support vector machines. Linear and quadratic programming: optimality conditions; duality; primal and dual forms of linear support vector machines; active-set methods; interior methods. ***Prerequisites:*** Math 20C or Math 31BH and Math 20F or 31AH. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 173B. Optimization Methods for Data Science II (4)

Unconstrained optimization: linear least squares; randomized linear least squares; method(s) of steepest descent; line-search methods; conjugate-gradient method; comparing the efficiency of methods; randomized/stochastic methods; nonlinear least squares; norm minimization methods. Convex constrained optimization: optimality conditions; convex programming; Lagrangian relaxation; the method of multipliers; the alternating direction method of multipliers; minimizing combinations of norms. ***Prerequisites:*** Math 173A. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 174. Numerical Methods for Physical Modeling (4)

(Conjoined with Math 274.) Floating point arithmetic, direct and iterative solution of linear equations, iterative solution of nonlinear equations, optimization, approximation theory, interpolation, quadrature, numerical methods for initial and boundary value problems in ordinary differential equations. (Students may not receive credit for both Math 174 and PHYS 105, AMES 153 or 154. Students may not receive credit for Math 174 if Math 170A, B, or C has already been taken.) Graduate students will do an extra assignment/exam. ***Prerequisites:*** Math 20D or Math 21D, and either Math 20F or Math 31AH, or consent of instructor.

MATH 175. Numerical Methods for Partial Differential Equations (4)

(Conjoined with Math 275.) Mathematical background for working with partial differential equations. Survey of finite difference, finite element, and other numerical methods for the solution of elliptic, parabolic, and hyperbolic partial differential equations. (Formerly Math 172. Students may not receive credit for Math 175/275 and Math 172.) Graduate students do an extra paper, project, or presentation, per instructor. ***Prerequisites:*** Math 174 or Math 274, or consent of instructor.

MATH 179. Projects in Computational and Applied Mathematics (4)

(Conjoined with Math 279.) Mathematical models of physical systems arising in science and engineering, good models and well-posedness, numerical and other approximation techniques, solution algorithms for linear and nonlinear approximation problems, scientific visualizations, scientific software design and engineering, project-oriented. Graduate students will do an extra paper, project, or presentation per instructor. ***Prerequisites:*** Math 174 or Math 274 or consent of instructor.

MATH 180A. Introduction to Probability (4)

Probability spaces, random variables, independence, conditional probability, distribution, expectation, variance, joint distributions, central limit theorem. (Two units of credit offered for Math 180A if Econ 120A previously, no credit offered if Econ 120A concurrently. Two units of credit offered for Math 180A if Math 183 or 186 taken previously or concurrently.) Prior or concurrent enrollment in Math 109 is highly recommended. ***Prerequisites:*** Math 20C or Math 31BH, or consent of instructor.

MATH 180B. Introduction to Stochastic Processes I (4)

Random vectors, multivariate densities, covariance matrix, multivariate normal distribution. Random walk, Poisson process. Other topics if time permits. ***Prerequisites:*** Math 20D and either Math 18 or Math 20F or Math 31AH, and Math 109, and Math 180A. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 180C. Introduction to Stochastic Processes II (4)

Markov chains in discrete and continuous time, random walk, recurrent events. If time permits, topics chosen from stationary normal processes, branching processes, queuing theory. ***Prerequisites:*** Math 180B or consent of instructor.

MATH 181A. Introduction to Mathematical Statistics I (4)

Multivariate distribution, functions of random variables, distributions related to normal. Parameter estimation, method of moments, maximum likelihood. Estimator accuracy and confidence intervals. Hypothesis testing, type I and type II errors, power, one-sample t-test. Prior or concurrent enrollment in Math 109 is highly recommended. ***Prerequisites:*** Math 180A, and Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 181B. Introduction to Mathematical Statistics II (4)

Hypothesis testing. Linear models, regression, and analysis of variance. Goodness of fit tests. Nonparametric statistics. Two units of credit offered for Math 181B if Econ 120B previously; no credit offered if Econ 120B concurrently. Prior enrollment in Math 109 is highly recommended. ***Prerequisites:*** Math 181A or consent of instructor.

MATH 181C. Mathematical Statistics—Nonparametric Statistics (4)

Topics covered may include the following: classical rank test, rank correlations, permutation tests, distribution free testing, efficiency, confidence intervals, nonparametric regression and density estimation, resampling techniques (bootstrap, jackknife, etc.) and cross validations. Prior enrollment in Math 109 is highly recommended. ***Prerequisites:*** Math 181B or consent of instructor.

MATH 181E. Mathematical Statistics—Time Series (4)

Analysis of trends and seasonal effects, autoregressive and moving averages models, forecasting, informal introduction to spectral analysis. ***Prerequisites:***Math 181B or consent of instructor.

MATH 183. Statistical Methods (4)
Introduction to probability. Discrete and continuous random variables–binomial, Poisson and Gaussian distributions. Central limit theorem. Data analysis and inferential statistics: graphical techniques, confidence intervals, hypothesis tests, curve fitting. (Credit not offered for Math 183 if Econ 120A, ECE 109, MAE 108, Math 181A, or Math 186 previously or concurrently taken. Two units of credit offered for Math 183 if Math 180A taken previously or concurrently.) ***Prerequisites:*** Math 20C or Math 31BH, or consent of instructor.

MATH 184A. Combinatorics (4)
Introduction to the theory and applications of combinatorics. Enumeration of combinatorial structures. Ranking and unranking. Graph theory with applications and algorithms. Recursive algorithms. Inclusion-exclusion. Generating functions. Polya theory. ***Prerequisites:*** Math 31CH or Math 109 with a grade of C– or better. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 185. Introduction to Computational Statistics (4)
Statistical analysis of data by means of package programs. Regression, analysis of variance, discriminant analysis, principal components, Monte Carlo simulation, and graphical methods. Emphasis will be on understanding the connections between statistical theory, numerical results, and analysis of real data. Recommended preparation: exposure to computer programming (such as CSE 5A, CSE 7, or ECE 15) highly recommended. ***Prerequisites:*** Math 11, or Math 181A, or Math 183, or Math 186, or MAE 108, or ECE 109, or Econ 120A, and either Math 18 or Math 20F or Math 31AH, and Math 20C. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 186. Probability and Statistics for Bioinformatics (4)
This course will cover discrete and random variables, data analysis and inferential statistics, likelihood estimators and scoring matrices with applications to biological problems. Introduction to Binomial, Poisson, and Gaussian distributions, central limit theorem, applications to sequence and functional analysis of genomes and genetic epidemiology. (Credit not offered for Math 186 if Econ 120A, ECE 109, MAE 108, Math 181A, or Math 183 previously or concurrently. Two units of credit offered for Math 186 if Math 180A taken previously or concurrently.) ***Prerequisites:*** Math 20C or Math 31BH, or consent of instructor.

MATH 187A. Introduction to Cryptography (4)
An introduction to the basic concepts and techniques of modern cryptography. Classical cryptanalysis. Probabilistic models of plaintext. Monalphabetic and polyalphabetic substitution. The one-time system. Caesar-Vigenere-Playfair-Hill substitutions. The Enigma. Modern-day developments. The Data Encryption Standard. Public key systems. Security aspects of computer networks. Data protection. Electronic mail. Recommended preparation: programming experience. Renumbered from Math 187. Students may not receive credit for both Math 187A and 187. ***Prerequisites:*** none.

MATH 187B. Mathematics of Modern Cryptography (4)
The object of this course is to study modern public key cryptographic systems and cryptanalysis (e.g., RSA, Diffie-Hellman, elliptic curve cryptography, lattice-based cryptography, homomorphic encryption) and the mathematics behind them. We also explore other applications of these computational techniques (e.g., integer factorization and attacks on RSA). Recommended preparation: Familiarity with Python and/or mathematical software (especially

SAGE) would be helpful, but it is not required. ***Prerequisites:*** Math 187 or Math 187A and Math 18 or Math 31AH or Math 20F. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 189. Exploratory Data Analysis and Inference (4)

An introduction to various quantitative methods and statistical techniques for analyzing data—in particular big data. Quick review of probability continuing to topics of how to process, analyze, and visualize data using statistical language R. Further topics include basic inference, sampling, hypothesis testing, bootstrap methods, and regression and diagnostics. Offers conceptual explanation of techniques, along with opportunities to examine, implement, and practice them in real and simulated data. ***Prerequisites:*** Math 18 or Math 20F or Math 31AH, and Math 20C and one of BENG 134, CSE 103, ECE 109, Econ 120A, MAE 108, Math 180A, Math 183, Math 186, or SE 125. Students who have not completed listed prerequisites may enroll with consent of instructor.

MATH 190. Introduction to Topology (4)

Topological spaces, subspaces, products, sums and quotient spaces. Compactness, connectedness, separation axioms. ***Prerequisites:*** Math 31CH or Math 140A. Students who have not completed prerequisites may enroll with consent of instructor.

MATH 191. Topics in Topology (4)

Topics to be chosen by the instructor from the fields of differential algebraic, geometric, and general topology. ***Prerequisites:*** Math 190 or consent of instructor.

MATH 193A. Actuarial Mathematics I (4)

Probabilistic Foundations of Insurance. Short-term risk models. Survival distributions and life tables. Introduction to life insurance. ***Prerequisites:*** Math 180A or Math 183, or consent of instructor.

MATH 193B. Actuarial Mathematics II (4)

Life Insurance and Annuities. Analysis of premiums and premium reserves. Introduction to multiple life functions and decrement models as time permits. ***Prerequisites:*** Math 193A or consent of instructor.

MATH 194. The Mathematics of Finance (4)

Introduction to the mathematics of financial models. Basic probabilistic models and associated mathematical machinery will be discussed, with emphasis on discrete time models. Concepts covered will include conditional expectation, martingales, optimal stopping, arbitrage pricing, hedging, European and American options. ***Prerequisites:*** Math 20D, and either Math 18 or Math 20F or Math 31AH, and Math 180A. Students who have not completed listed prerequisites may enroll with consent of instructor. Students completing Econ 120A instead of Math 180A must obtain consent of instructor to enroll.

MATH 195. Introduction to Teaching in Mathematics (4)

Students will be responsible for and teach a class section of a lower-division mathematics course. They will also attend a weekly meeting on teaching methods. (Does not count toward a minor or major.) ***Prerequisites:*** consent of instructor.

MATH 196. Student Colloquium (1)

A variety of topics and current research results in mathematics will be presented by guest lecturers and students under faculty direction. May be taken for P/NP grade only. ***Prerequisites:*** upper-division status.

MATH 197. Mathematics Internship (2 or 4)
An enrichment program which provides work experience with public/private sector employers. Subject to the availability of positions, students will work in a local company under the supervision of a faculty member and site supervisor. Units may not be applied toward major graduation requirements. ***Prerequisites:***completion of ninety units, two upper-division mathematics courses, an overall 2.5 UC San Diego GPA, consent of mathematics faculty coordinator, and submission of written contract. Department stamp required.

MATH 199. Independent Study for Undergraduates (2 or 4)
Independent reading in advanced mathematics by individual students. Three periods. (P/NP grades only.) ***Prerequisites:*** permission of department.

MATH 199H. Honors Thesis Research for Undergraduates (2–4)
Honors thesis research for seniors participating in the Honors Program. Research is conducted under the supervision of a mathematics faculty member. ***Prerequisites:*** admission to the Honors Program in mathematics, department stamp.

Graduate

MATH 200A-B-C. Algebra (4-4-4)

Group actions, factor groups, polynomial rings, linear algebra, rational and Jordan canonical forms, unitary and Hermitian matrices, Sylow theorems, finitely generated abelian groups, unique factorization, Galois theory, solvability by radicals, Hilbert Basis Theorem, Hilbert Nullstellensatz, Jacobson radical, semisimple Artinian rings. ***Prerequisites:*** consent of instructor.

MATH 201A. Basic Topics in Algebra I (4)

Recommended for all students specializing in algebra. Basic topics include categorical algebra, commutative algebra, group representations, homological algebra, nonassociative algebra, ring theory. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** Math 200C. Students who have not taken Math 200C may enroll with consent of instructor.

MATH 202A. Applied Algebra I (4)

Introduction to algebra from a computational perspective. Groups, rings, linear algebra, rational and Jordan forms, unitary and Hermitian matrices, matrix decompositions, perturbation of eigenvalues, group representations, symmetric functions, fast Fourier transform, commutative algebra, Grobner basis, finite fields. ***Prerequisites:*** graduate standing or consent of instructor.

MATH 202B. Applied Algebra II (4)

Second course in algebra from a computational perspective. Groups, rings, linear algebra, rational and Jordan forms, unitary and Hermitian matrices, matrix decompositions, perturbation of eigenvalues, group representations, symmetric functions, fast Fourier transform, commutative algebra, Grobner basis, finite fields. ***Prerequisites:*** Math 202A or consent of instructor.

MATH 202C. Applied Algebra III (4)

Third course in algebra from a computational perspective. Groups, rings, linear algebra, rational and Jordan forms, unitary and Hermitian matrices, matrix decompositions, perturbation of eigenvalues, group representations, symmetric functions, fast Fourier transform, commutative algebra, Grobner basis, finite fields. ***Prerequisites:*** Math 202B or consent of instructor.

MATH 203A. Algebraic Geometry I (4)

Introduction to algebraic geometry. Topics chosen from: varieties and their properties, sheaves and schemes and their properties. May be taken for credit up to three times. ***Prerequisites:*** Math 200C. Students who have not taken Math 200C may enroll with consent of instructor.

MATH 203B. Algebraic Geometry II (4)

Second course in algebraic geometry. Continued exploration of varieties, sheaves and schemes, divisors and linear systems, differentials, cohomology. May be taken for credit up to three times. ***Prerequisites:*** Math 203A. Students who have not taken Math 203A may enroll with consent of instructor.

MATH 203C. Algebraic Geometry III (4)

Third course in algebraic geometry. Continued exploration of varieties, sheaves and schemes, divisors and linear systems, differentials, cohomology, curves, and surfaces. May be taken for credit up to three times. ***Prerequisites:*** Math 203B. Students who have not taken Math 203B may enroll with consent of instructor.

MATH 204A. Number Theory I (4)
First course in graduate-level number theory. Local fields: valuations and metrics on fields; discrete valuation rings and Dedekind domains; completions; ramification theory; main statements of local class field theory. ***Prerequisites:*** Math 200C. Students who have not taken Math 200C may enroll with consent of instructor.

MATH 204B. Number Theory II (4)
Second course in graduate-level number theory. Global fields: arithmetic properties and relation to local fields; ideal class groups; groups of units; ramification theory; adèles and idèles; main statements of global class field theory. ***Prerequisites:*** Math 204A. Students who have not taken Math 204A may enroll with consent of instructor.

MATH 204C. Number Theory III (4)
Third course in graduate-level number theory. Zeta and L-functions; Dedekind zeta functions; Artin L-functions; the class-number formula and generalizations; density theorems. ***Prerequisites:*** Math 204B. Students who have not taken Math 204B may enroll with consent of instructor.

MATH 205. Topics in Number Theory (4)
Topics in algebraic and analytic number theory, such as: L-functions, sieve methods, modular forms, class field theory, p-adic L-functions and Iwasawa theory, elliptic curves and higher dimensional abelian varieties, Galois representations and the Langlands program, p-adic cohomology theories, Berkovich spaces, etc. May be taken for credit nine times. ***Prerequisites:*** graduate standing.

MATH 206A. Topics in Algebraic Geometry (4)
Introduction to varied topics in algebraic geometry. Topics will be drawn from current research and may include Hodge theory, higher dimensional geometry, moduli of vector bundles, abelian varieties, deformation theory, intersection theory. Nongraduate students may enroll with consent of instructor. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing.

MATH 206B. Further Topics in Algebraic Geometry (4)
Continued development of a topic in algebraic geometry. Topics will be drawn from current research and may include Hodge theory, higher dimensional geometry, moduli of vector bundles, abelian varieties, deformation theory, intersection theory. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 206A. Students who have not completed Math 206A may enroll with consent of instructor.

MATH 207A. Topics in Algebra (4)
Introduction to varied topics in algebra. In recent years, topics have included number theory, commutative algebra, noncommutative rings, homological algebra, and Lie groups. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 208. Seminar in Algebraic Geometry (1)
Various topics in algebraic geometry. May be taken for credit nine times. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor. (S/U grade only.)

MATH 209. Seminar in Number Theory (1)

Various topics in number theory. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 210A. Mathematical Methods in Physics and Engineering (4)

Complex variables with applications. Analytic functions, Cauchy's theorem, Taylor and Laurent series, residue theorem and contour integration techniques, analytic continuation, argument principle, conformal mapping, potential theory, asymptotic expansions, method of steepest descent. ***Prerequisites:*** Math 20DEF,140A/142A or consent of instructor.

MATH 210B. Mathematical Methods in Physics and Engineering (4)

Linear algebra and functional analysis. Vector spaces, orthonormal bases, linear operators and matrices, eigenvalues and diagonalization, least squares approximation, infinite-dimensional spaces, completeness, integral equations, spectral theory, Green's functions, distributions, Fourier transform. ***Prerequisites:*** Math 210A or consent of instructor.

MATH 210C. Mathematical Methods in Physics and Engineering (4)

Calculus of variations: Euler-Lagrange equations, Noether's theorem. Fourier analysis of functions and distributions in several variables. Partial differential equations: Laplace, wave, and heat equations; fundamental solutions (Green's functions); well-posed problems. ***Prerequisites:*** Math 210B or consent of instructor. (S)

MATH 217. Topics in Applied Mathematics (4)

In recent years, topics have included applied complex analysis, special functions, and asymptotic methods. May be repeated for credit with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 218. Seminar in Mathematics of Biological Systems (1)

Various topics in the mathematics of biological systems. May be taken for credit nine times. ***Prerequisites:*** graduate standing. (S/U grades only.)

MATH 220A-B-C. Complex Analysis (4-4-4)

Complex numbers and functions. Cauchy theorem and its applications, calculus of residues, expansions of analytic functions, analytic continuation, conformal mapping and Riemann mapping theorem, harmonic functions. Dirichlet principle, Riemann surfaces. ***Prerequisites:*** Math 140A-B or consent of instructor.

MATH 221A. Topics in Several Complex Variables (4)

Introduction to varied topics in several complex variables. In recent years, topics have included formal and convergent power series, Weierstrass preparation theorem, Cartan-Ruckert theorem, analytic sets, mapping theorems, domains of holomorphy, proper holomorphic mappings, complex manifolds and modifications. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** Math 200A and 220C. Students who have not completed Math 200A and 220C may enroll with consent of instructor.

MATH 221B. Further Topics in Several Complex Variables (4)

Continued development of a topic in several complex variables. Topics include: formal and convergent power series, Weierstrass preparation theorem, Cartan-Ruckert theorem, analytic sets, mapping theorems, domains of holomorphy, proper holomorphic mappings, complex manifolds and modifications. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 221A. Students who have not completed Math 221A may enroll with consent of instructor.

MATH 231A-B-C. Partial Differential Equations (4-4-4)
Existence and uniqueness theorems. Cauchy-Kowalewski theorem, first order systems. Hamilton-Jacobi theory, initial value problems for hyperbolic and parabolic systems, boundary value problems for elliptic systems. Green's function, eigenvalue problems, perturbation theory. ***Prerequisites:*** Math 210A-B or 240A-B-C or consent of instructor.

MATH 237A. Topics in Differential Equations (4)
Introduction to varied topics in differential equations. In recent years, topics have included Riemannian geometry, Ricci flow, and geometric evolution. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 237B. Further Topics in Differential Equations (4)
Continued development of a topic in differential equations. Topics include: Riemannian geometry, Ricci flow, and geometric evolution. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 237A. Students who have not completed Math 237A may enroll with consent of instructor.

MATH 240A-B-C. Real Analysis (4-4-4)
Lebesgue integral and Lebesgue measure, Fubini theorems, functions of bounded variations, Stieltjes integral, derivatives and indefinite integrals, the spaces L and C, equi-continuous families, continuous linear functionals general measures and integrations. ***Prerequisites:*** Math 140A-B-C.

MATH 241A-B. Functional Analysis (4-4)
Metric spaces and contraction mapping theorem; closed graph theorem; uniform boundedness principle; Hahn-Banach theorem; representation of continuous linear functionals; conjugate space, weak topologies; extreme points; Krein-Milman theorem; fixed-point theorems; Riesz convexity theorem; Banach algebras. ***Prerequisites:*** Math 240A-B-C or consent of instructor.

MATH 242. Topics in Fourier Analysis (4)
In recent years, topics have included Fourier analysis in Euclidean spaces, groups, and symmetric spaces. May be repeated for credit with consent of adviser as topics vary. ***Prerequisites:*** Math 240C, students who have not completed Math 240C may enroll with consent of instructor.

MATH 243. Seminar in Functional Analysis (1)
Various topics in functional analysis. May be taken for credit nine times. **Prerequisites:** graduate standing or consent of instructor. (S/U grades only.)

MATH 245A. Convex Analysis and Optimization I (4)
Convex sets and functions, convex and affine hulls, relative interior, closure, and continuity, recession and existence of optimal solutions, saddle point and min-max theory, subgradients and subdifferentials. Recommended preparation: course work in linear algebra and real analysis. ***Prerequisites:*** graduate standing.

MATH 245B. Convex Analysis and Optimization II (4)
Optimality conditions, strong duality and the primal function, conjugate functions, Fenchel duality theorems, dual derivatives and subgradients, subgradient methods, cutting plane methods. ***Prerequisites:*** Math 245A or consent of instructor.

MATH 245C. Convex Analysis and Optimization III (4)

Convex optimization problems, linear matrix inequalities, second-order cone programming, semidefinite programming, sum of squares of polynomials, positive polynomials, distance geometry. ***Prerequisites:*** Math 245B or consent of instructor.

MATH 247A. Topics in Real Analysis (4)

Introduction to varied topics in real analysis. In recent years, topics have included Fourier analysis, distribution theory, martingale theory, operator theory. May be taken for credit six times with consent of adviser. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 247B. Further Topics in Real Analysis (4)

Continued development of a topic in real analysis. Topics include: Fourier analysis, distribution theory, martingale theory, operator theory. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 247A. Students who have not completed Math 247A may enroll with consent of instructor.

MATH 248. Seminar in Real Analysis (1)

Various topics in real analysis. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 250A-B-C. Differential Geometry (4-4-4)

Differential manifolds, Sard theorem, tensor bundles, Lie derivatives, DeRham theorem, connections, geodesics, Riemannian metrics, curvature tensor and sectional curvature, completeness, characteristic classes. Differential manifolds immersed in Euclidean space. ***Prerequisites:*** consent of instructor.

MATH 251A-B-C. Lie Groups (4-4-4)

Lie groups, Lie algebras, exponential map, subgroup subalgebra correspondence, adjoint group, universal enveloping algebra. Structure theory of semi-simple Lie groups, global decompositions, Weyl group. Geometry and analysis on symmetric spaces. ***Prerequisites:*** Math 200 and 250 or consent of instructor.

MATH 256. Seminar in Lie Groups and Lie Algebras (1)

Various topics in Lie groups and Lie algebras, including structure theory, representation theory, and applications. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 257A. Topics in Differential Geometry (4)

Introduction to varied topics in differential geometry. In recent years, topics have included Morse theory and general relativity. May be taken for credit six times with consent of adviser. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 257B. Further Topics in Differential Geometry (4)

Continued development of a topic in differential geometry. Topics include Morse theory and general relativity. May be taken for credit three times with consent of adviser. ***Prerequisites:*** Math 257A. Students who have not completed Math 257A may enroll with consent of instructor.

MATH 258. Seminar in Differential Geometry (1)

Various topics in differential geometry. May be taken for credit nine times. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 259A-B-C. Geometrical Physics (4-4-4)

Manifolds, differential forms, homology, deRham's theorem. Riemannian geometry, harmonic forms. Lie groups and algebras, connections in bundles, homotopy sequence of a bundle, Chern classes. Applications selected from Hamiltonian and continuum mechanics, electromagnetism, thermodynamics, special and general relativity, Yang-Mills fields. ***Prerequisites:*** graduate standing in mathematics, physics, or engineering, or consent of instructor.

MATH 260A. Mathematical Logic I (4)

Propositional calculus and first-order logic. Theorem proving, Model theory, soundness, completeness, and compactness, Herbrand's theorem, Skolem-Lowenheim theorems, Craig interpolation. ***Prerequisites:*** graduate standing or consent of instructor.

MATH 260B. Mathematical Logic II (4)

Theory of computation and recursive function theory, Church's thesis, computability and undecidability. Feasible computability and complexity. Peano arithmetic and the incompleteness theorems, nonstandard models. ***Prerequisites:*** Math 260A or consent of instructor.

MATH 261A. Probabilistic Combinatorics and Algorithms (4)

Introduction to the probabilistic method. Combinatorial applications of the linearity of expectation, second moment method, Markov, Chebyschev, and Azuma inequalities, and the local limit lemma. Introduction to the theory of random graphs. ***Prerequisites:*** graduate standing or consent of instructor.

MATH 261B. Probabilistic Combinatorics and Algorithms II (4)

Introduction to probabilistic algorithms. Game theoretic techniques. Applications of the probabilistic method to algorithm analysis. Markov Chains and Random walks. Applications to approximation algorithms, distributed algorithms, online and parallel algorithms. Math 261A must be taken before Math 261B. ***Prerequisites:*** Math 261A.

MATH 261C. Probabilistic Combinatorics and Algorithms III (4)

Advanced topics in the probabilistic combinatorics and probabilistics algorithms. Random graphs. Spectral Methods. Network algorithms and optimization. Statistical learning. Math 261B must be taken before Math 261C. ***Prerequisites:*** Math 261B.

MATH 262A. Topics in Combinatorial Mathematics (4)

Introduction to varied topics in combinatorial mathematics. In recent years topics have included problems of enumeration, existence, construction, and optimization with regard to finite sets. Recommended preparation: some familiarity with computer programming desirable but not required. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 262B. Further Topics in Combinatorial Mathematics (4)

Continued development of a topic in combinatorial mathematics. Topics include: problems of enumeration, existence, construction, and optimization with regard to finite sets. Recommended preparation: some familiarity with computer programming desirable but not required. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 262A. Students who have not completed Math 262A may enroll with consent of instructor.

MATH 264A-B-C. Combinatorics (4-4-4)

Topics from partially ordered sets, Mobius functions, simplicial complexes and shell ability. Enumeration, formal power series and formal languages, generating functions, partitions. Lagrange inversion, exponential structures, combinatorial species. Finite operator methods, q-analogues, Polya theory, Ramsey theory. Representation theory of the symmetric group, symmetric functions and operations with Schur functions.

MATH 267A. Topics in Mathematical Logic (4)

Introduction to varied topics in mathematical logic. Topics chosen from recursion theory, model theory, and set theory. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing or consent of instructor. Nongraduate students may enroll with consent of instructor.

MATH 267B. Further Topics in Mathematical Logic (4)

Continued development of a topic in mathematical logic. Topics chosen from recursion theory, model theory, and set theory. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 267A or consent of instructor. Students who have not completed Math 267A may enroll with consent of instructor.

MATH 268. Seminar in Logic (1)

Various topics in logic. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 269. Seminar in Combinatorics (1)

Various topics in combinatorics. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 270A. Numerical Linear Algebra (4)

Error analysis of the numerical solution of linear equations and least squares problems for the full rank and rank deficient cases. Error analysis of numerical methods for eigenvalue problems and singular value problems. Iterative methods for large sparse systems of linear equations. ***Prerequisites:*** graduate standing or consent of instructor.

MATH 270B. Numerical Approximation and Nonlinear Equations (4)

Iterative methods for nonlinear systems of equations, Newton's method. Unconstrained and constrained optimization. The Weierstrass theorem, best uniform approximation, least-squares approximation, orthogonal polynomials. Polynomial interpolation, piecewise polynomial interpolation, piecewise uniform approximation. Numerical differentiation: divided differences, degree of precision. Numerical quadrature: interpolature quadrature, Richardson extrapolation, Romberg Integration, Gaussian quadrature, singular integrals, adaptive quadrature. ***Prerequisites:*** Math 270A or consent of instructor.

MATH 270C. Numerical Ordinary Differential Equations (4)

Initial value problems (IVP) and boundary value problems (BVP) in ordinary differential equations. Linear methods for IVP: one and multistep methods, local truncation error, stability, convergence, global error accumulation. Runge-Kutta (RK) Methods for IVP: RK methods, predictor-corrector methods, stiff systems, error indicators, adaptive time-stepping. Finite difference, finite volume, collocation, spectral, and finite element methods for BVP; a priori and a posteriori error analysis, stability, convergence, adaptivity. ***Prerequisites:*** Math 270B or consent of instructor.

MATH 271A-B-C. Numerical Optimization (4-4-4)

Formulation and analysis of algorithms for constrained optimization. Optimality conditions; linear and quadratic programming; interior methods; penalty and barrier function methods; sequential quadratic programming methods. ***Prerequisites:*** consent of instructor.

MATH 272A. Numerical Partial Differential Equations I (4)

Survey of discretization techniques for elliptic partial differential equations, including finite difference, finite element and finite volume methods. Lax-Milgram Theorem and LBB stability. A priori error estimates. Mixed methods. Convection-diffusion equations. Systems of elliptic PDEs. ***Prerequisites:*** graduate standing or consent of instructor.

MATH 272B. Numerical Partial Differential Equations II (4)

Survey of solution techniques for partial differential equations. Basic iterative methods. Preconditioned conjugate gradients. Multigrid methods. Hierarchical basis methods. Domain decomposition. Nonlinear PDEs. Sparse direct methods. ***Prerequisites:*** Math 272A or consent of instructor.

MATH 272C. Numerical Partial Differential Equations III (4)

Time dependent (parabolic and hyperbolic) PDEs. Method of lines. Stiff systems of ODEs. Space-time finite element methods. Adaptive meshing algorithms. A posteriori error estimates. ***Prerequisites:*** Math 272B or consent of instructor.

MATH 273A. Advanced Techniques in Computational Mathematics I (4)

Models of physical systems, calculus of variations, principle of least action. Discretization techniques for variational problems, geometric integrators, advanced techniques in numerical discretization. Project-oriented; projects designed around problems of current interest in science, mathematics, and engineering. ***Prerequisites:*** graduate standing or consent of instructor.

MATH 273B. Advanced Techniques in Computational Mathematics II (4)

Nonlinear functional analysis for numerical treatment of nonlinear PDE. Numerical continuation methods, pseudo-arclength continuation, gradient flow techniques, and other advanced techniques in computational nonlinear PDE. Project-oriented; projects designed around problems of current interest in science, mathematics, and engineering. ***Prerequisites:*** Math 273A or consent of instructor.

MATH 273C. Advanced Techniques in Computational Mathematics III (4)

Adaptive numerical methods for capturing all scales in one model, multiscale and multiphysics modeling frameworks, and other advanced techniques in computational multiscale/multiphysics modeling. Project-oriented; projects designed around problems of current interest in science, mathematics, and engineering. ***Prerequisites:*** Math 273B or consent of instructor.

MATH 274. Numerical Methods for Physical Modeling (4)

(Conjoined with Math 174.) Floating point arithmetic, direct and iterative solution of linear equations, iterative solution of nonlinear equations, optimization, approximation theory, interpolation, quadrature, numerical methods for initial and boundary value problems in ordinary differential equations. Students may not receive credit for both Math 174 and PHYS 105, AMES 153 or 154. (Students may not receive credit for Math 174 if Math 170A, B, or C has already been taken.) Graduate students will complete an additional assignment/exam. ***Prerequisites:*** Math 20D or 21D, and either Math 20F or Math 31AH, or consent of instructor.

MATH 275. Numerical Methods for Partial Differential Equations (4)
(Conjoined with Math 175.) Mathematical background for working with partial differential equations. Survey of finite difference, finite element, and other numerical methods for the solution of elliptic, parabolic, and hyperbolic partial differential equations. (Formerly Math 172; students may not receive credit for Math 175/275 and Math 172.) Graduate students will do an extra paper, project, or presentation, per instructor. ***Prerequisites:*** Math 174 or Math 274 or consent of instructor.

MATH 276. Numerical Analysis in Multiscale Biology (4)
(Cross-listed with BENG 276/CHEM 276.) Introduces mathematical tools to simulate biological processes at multiple scales. Numerical methods for ordinary and partial differential equations (deterministic and stochastic), and methods for parallel computing and visualization. Hands-on use of computers emphasized, students will apply numerical methods in individual projects. ***Prerequisites:*** consent of instructor.

MATH 277A. Topics in Computational and Applied Mathematics (4)
Introduction to varied topics in computational and applied mathematics. In recent years, topics have included: applied functional analysis and approximation theory; numerical treatment of nonlinear partial differential equations; and geometric numerical integration for differential equations. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 278A. Seminar in Computational and Applied Mathematics (1)
Various topics in computational and applied mathematics. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor. (S/U grade only.)

MATH 278B. Seminar in Mathematical Physics/PDE (1)
Various topics in mathematical physics and partial differential equations. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 278C. Seminar in Optimization (1)
Various topics in optimization and applications. May be taken for credit nine times. ***Prerequisites:*** graduate standing. (S/U grade only.)

MATH 279. Projects in Computational and Applied Mathematics (4)
(Conjoined with Math 179.) Mathematical models of physical systems arising in science and engineering, good models and well-posedness, numerical and other approximation techniques, solution algorithms for linear and nonlinear approximation problems, scientific visualizations, scientific software design and engineering, project-oriented. Graduate students will do an extra paper, project, or presentation per instructor. ***Prerequisites:*** Math 174, or Math 274, or consent of instructor.

MATH 280A. Probability Theory I (4)
This is the first course in a three-course sequence in probability theory. Topics covered in the sequence include the measure-theoretic foundations of probability theory, independence, the Law of Large Numbers, convergence in distribution, the Central Limit Theorem, conditional expectation, martingales, Markov processes, and Brownian motion. Recommended preparation: completion of real analysis equivalent to Math 140A-B strongly recommended. ***Prerequisites:*** graduate standing.

MATH 280B. Probability Theory II (4)

This is the second course in a three-course sequence in probability theory. Topics covered in the sequence include the measure-theoretic foundations of probability theory, independence, the Law of Large Numbers, convergence in distribution, the Central Limit Theorem, conditional expectation, martingales, Markov processes, and Brownian motion. ***Prerequisites:*** Math 280A.

MATH 280C. Probability Theory III (4)

This is the third course in a three-course sequence in probability theory. Topics covered in the sequence include the measure-theoretic foundations of probability theory, independence, the Law of Large Numbers, convergence in distribution, the Central Limit Theorem, conditional expectation, martingales, Markov processes, and Brownian motion. ***Prerequisites:*** Math 280B.

MATH 281A. Mathematical Statistics (4)

Statistical models, sufficiency, efficiency, optimal estimation, least squares and maximum likelihood, large sample theory. ***Prerequisites:*** advanced calculus and basic probability theory or consent of instructor.

MATH 281B. Mathematical Statistics (4)

Hypothesis testing and confidence intervals, one-sample and two-sample problems. Bayes theory, statistical decision theory, linear models and regression. ***Prerequisites:*** advanced calculus and basic probability theory or consent of instructor.

MATH 281C. Mathematical Statistics (4)

Nonparametrics: tests, regression, density estimation, bootstrap and jackknife. Introduction to statistical computing using S plus. ***Prerequisites:*** advanced calculus and basic probability theory or consent of instructor.

MATH 282A. Applied Statistics I (4)

General theory of linear models with applications to regression analysis. Ordinary and generalized least squares estimators and their properties. Hypothesis testing, including analysis of variance, and confidence intervals. Completion of courses in linear algebra and basic statistics are recommended prior to enrollment. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.)

MATH 282B. Applied Statistics II (4)

Diagnostics, outlier detection, robust regression. Variable selection, ridge regression, the lasso. Generalized linear models, including logistic regression. Data analysis using the statistical software R. Students who have not taken Math 282A may enroll with consent of instructor. ***Prerequisites:*** Math 282A or consent of instructor. (S/U grades permitted.)

MATH 283. Statistical Methods in Bioinformatics (4)

This course will cover material related to the analysis of modern genomic data; sequence analysis, gene expression/functional genomics analysis, and gene mapping/applied population genetics. The course will focus on statistical modeling and inference issues and not on database mining techniques. ***Prerequisites:*** one year of calculus, one statistics course or consent of instructor.

MATH 284. Survival Analysis (4)

Survival analysis is an important tool in many areas of applications including biomedicine, economics, engineering. It deals with the analysis of time to events data with censoring. This course discusses the concepts and theories associated with survival data and censoring, comparing survival distributions, proportional hazards regression, nonparametric tests,

competing risk models, and frailty models. The emphasis is on semiparametric inference, and material is drawn from recent literature. ***Prerequisites:*** Math 282A or consent of instructor.

MATH 285. Stochastic Processes (4)

Elements of stochastic processes, Markov chains, hidden Markov models, martingales, Brownian motion, Gaussian processes. ***Recommended preparation****:* completion of undergraduate probability theory (equivalent to Math 180A) highly recommended. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 286. Stochastic Differential Equations (4)

Review of continuous martingale theory. Stochastic integration for continuous semimartingales. Existence and uniqueness theory for stochastic differential equations. Strong Markov property. Selected applications. ***Prerequisites:*** Math 280A-B or consent of instructor.

MATH 287A. Time Series Analysis (4)

Discussion of finite parameter schemes in the Gaussian and non-Gaussian context. Estimation for finite parameter schemes. Stationary processes and their spectral representation. Spectral estimation. Students who have not taken Math 282A may enroll with consent of instructor. ***Prerequisites:*** Math 282A or consent of instructor.

MATH 287B. Multivariate Analysis (4)

Bivariate and more general multivariate normal distribution. Study of tests based on Hotelling's T2. Principal components, canonical correlations, and factor analysis will be discussed as well as some competing nonparametric methods, such as cluster analysis. Students who have not taken Math 282A may enroll with consent of instructor. ***Prerequisites:*** Math 282A or consent of instructor.

MATH 287C. Advanced Time Series Analysis (4)

Nonparametric function (spectrum, density, regression) estimation from time series data. Nonlinear time series models (threshold AR, ARCH, GARCH, etc.). Nonparametric forms of ARMA and GARCH. Multivariate time series. Students who have not taken Math 287A may enroll with consent of instructor. ***Prerequisites:*** Math 287A or consent of instructor.

MATH 287D. Statistical Learning (4)

Topics include regression methods: (penalized) linear regression and kernel smoothing; classification methods: logistic regression and support vector machines; model selection; and mathematical tools and concepts useful for theoretical results such as VC dimension, concentration of measure, and empirical processes. Students who have not taken Math 282A may enroll with consent of instructor. ***Prerequisites:*** Math 282A or consent of instructor.

MATH 288. Seminar in Probability and Statistics (1)

Various topics in probability and statistics. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 289A. Topics in Probability and Statistics (4)

Introduction to varied topics in probability and statistics. In recent years, topics have included Markov processes, martingale theory, stochastic processes, stationary and Gaussian processes, ergodic theory. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 289B. Further Topics in Probability and Statistics (4)

Continued development of a topic in probability and statistics. Topics include: Markov processes, martingale theory, stochastic processes, stationary and Gaussian processes, ergodic theory. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 289A. Students who have not completed Math 289A may enroll with consent of instructor.

MATH 289C. Exploratory Data Analysis and Inference (4)

An introduction to various quantitative methods and statistical techniques for analyzing data—in particular big data. Quick review of probability continuing to topics of how to process, analyze, and visualize data using statistical language R. Further topics include basic inference, sampling, hypothesis testing, bootstrap methods, and regression and diagnostics. Offers conceptual explanation of techniques, along with opportunities to examine, implement, and practice them in real and simulated data. Recommended preparation: familiarity with linear algebra and mathematical statistics highly recommended. ***Prerequisites:***graduate standing.

MATH 290A-B-C. Topology (4-4-4)

Point set topology, including separation axioms, compactness, connectedness. Algebraic topology, including the fundamental group, covering spaces, homology and cohomology. Homotopy or applications to manifolds as time permits. ***Prerequisites:*** Math 100A-B-C and Math 140A-B-C.

MATH 291A. Topics in Topology (4)

Introduction to varied topics in topology. In recent years topics have included: generalized cohomology theory, spectral sequences, K-theory, homotophy theory. May be taken for credit six times with consent of adviser as topics vary. ***Prerequisites:*** graduate standing. Nongraduate students may enroll with consent of instructor.

MATH 291B. Further Topics in Topology (4)

Continued development of a topic in topology. Topics include generalized cohomology theory, spectral sequences, K-theory, homotophy theory. May be taken for credit three times with consent of adviser as topics vary. ***Prerequisites:*** Math 291A. Students who have not completed Math 291A may enroll with consent of instructor.

MATH 292. Seminar in Topology (1)

Various topics in topology. May be taken for credit nine times. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grade only.)

MATH 294. The Mathematics of Finance (4)

Introduction to the mathematics of financial models. Hedging, pricing by arbitrage. Discrete and continuous stochastic models. Martingales. Brownian motion, stochastic calculus. Black-Scholes model, adaptations to dividend paying equities, currencies and coupon-paying bonds, interest rate market, foreign exchange models. ***Prerequisites:*** Math 180A (or equivalent probability course) or consent of instructor.

MATH 295. Special Topics in Mathematics (1 to 4)

A variety of topics and current research results in mathematics will be presented by staff members and students under faculty direction.

MATH 296. Graduate Student Colloquium (1)

A variety of advanced topics and current research in mathematics will be presented by department faculty. (S/U grades only.) May be taken for credit six times. ***Prerequisites:*** graduate standing.

MATH 297. Mathematics Graduate Research Internship (2–4)
An enrichment program that provides work experience with public/private sector employers and researchers. Under supervision of a faculty adviser, students provide mathematical consultation services. ***Prerequisites:*** consent of instructor.
MATH 299. Reading and Research (1 to 12)
Independent study and research for the doctoral dissertation. One to three credits will be given for independent study (reading) and one to nine for research. ***Prerequisites:*** consent of instructor. (S/U grades permitted.)

Mechanical and Aerospace Engineering (MAE)

Upper Division

MAE 101A. Introductory Fluid Mechanics (4)

Fluid statics; fluid kinematics; integral and differential forms of the conservation laws for mass, momentum, and energy; Bernoulli equation; potential flows; dimensional analysis and similitude. ***Prerequisites:*** Phys 2A, Math 20D or 21D and Math 20E, or consent of instructor. Enrollment restricted to engineering majors only.

MAE 101B. Advanced Fluid Mechanics (4)

Laminar and turbulent flow. Pipe flow including friction factor. Boundary layers, separation, drag, and lift. Compressible flow including shock waves. ***Prerequisites:*** MAE 101A or CENG 101A or CENG 103A, and MAE 110A or CENG 102, or consent of instructor.

MAE 101C. Heat Transfer (4)

Extension of fluid mechanics in MAE 101A–B to viscous, heat-conducting flows. Application of the energy conservation equation to heat transfer in ducts and external boundary layers. Heat conduction and radiation transfer. Heat transfer coefficients in forced and free convection. Design applications. ***Prerequisites:*** MAE 101A or CENG 101A or CENG 103A, MAE 101B, and MAE 105, or consent of instructor.

MAE 101D. Intermediate Heat Transfer (4)

Course builds on the MAE fluids sequence, offering more advanced concepts in conduction, convection, radiation, and heat exchanger design. This course covers numerical methods in conduction, boiling, condensation and evaporation analysis, natural and turbulent convection, spectral and directional radiative transfer, heatpipes, thermal design of spacecraft, heat exchanger analysis and design. ***Prerequisites:*** senior standing and MAE 101C, or consent of instructor.

MAE 104. Aerodynamics (4)

Basic relations describing flow field around wings and bodies at subsonic and supersonic speed. Thin-wing theory. Slender-body theory. Formulation of theories for evaluating forces and moments on airplane geometries. Application to the design of high-speed aircraft. ***Prerequisites:*** grades of C– or better in MAE 101A and 101B, or consent of instructor. Enrollment restricted to MC 25, MC 27, MC 28, and SE 27 majors only.

MAE 105. Introduction to Mathematical Physics (4)

Fourier series, Sturm Liouville theory, elementary partial differential equations, integral transforms with applications to problems in vibration, wave motion, and heat conduction. ***Prerequisites:*** grades of C– or better in Phys 2A and B, and Math 20D or 21D. Enrollment restricted to engineering majors only.

MAE 107. Computational Methods in Engineering (4)

Introduction to scientific computing and algorithms; iterative methods, systems of linear equations with applications; nonlinear algebraic equations; function interpolation and differentiation and optimal procedures; data fitting and least-squares; numerical solution of ordinary differential equations. ***Prerequisites:*** MAE 8 or 9, and Math 18 or 20F or 31AH. Enrollment restricted to engineering majors only.

MAE 108. Probability and Statistical Methods for Mechanical Engineering (4)

Probability theory, conditional probability, Bayes theorem, random variables, densities, expected values, characteristic functions, central limit theorem. Engineering reliability, elements of estimation, random sampling, sampling distributions, hypothesis testing, confidence intervals. Curve fitting and data analysis. Students cannot receive credit for MAE 108 and ECE 109, Econ 120A, Math 180A, Math 183, Math 186, or SE 125. ***Prerequisites:*** Math 18 or 20F.

MAE 110. Thermodynamic Systems (4)

Thermodynamic analysis of power cycles with application to combustion driven engines: internal combustion, diesel, and gas turbines. Thermodynamics of mixtures and chemical and phase equilibrium. Computational methods for calculating chemical equilibrium. Renumbered from MAE 110B. Students may not receive credit for MAE 110 and MAE 110B. ***Prerequisites:*** MAE 11 or 110A. (Course not offered every year.)

MAE 113. Fundamentals of Propulsion (4)

Compressible flow, thermodynamics, and combustion relevant to aircraft and space vehicle propulsion. Analysis and design of components for gas turbines, including turbines, inlets, combustion chambers and nozzles. Fundamentals of rocket propulsion. ***Prerequisites:*** grades of C– or better in MAE 110A or CENG 102, and MAE 101A or CENG 101A, and MAE 101B or CENG 101C. Enrollment restricted to MC 25, MC 27, and MC 28 majors only.

MAE 117A. Elementary Plasma Physics (4)

(Cross-listed with Physics 151.) Particle motions, plasmas as fluids, waves, diffusion, equilibrium and stability, nonlinear effects, controlled fusion. Recommended preparation: Phys 100B–C or ECE 107. ***Prerequisites:*** Math 20D or 21D, or consent of instructor.

MAE 118. Introduction to Energy Systems (4)

Overview of present day primary energy sources and availability; fossil fuel, renewable, and nuclear; heat engines; energy conservation, transportation, air pollution, and climate change. Students may not receive credit for both MAE 118 and MAE 118A. ***Prerequisites:*** MAE 101A or CENG 101A, or consent of instructor.

MAE 119. Introduction to Renewable Energy: Solar and Wind (4)

Basic principles of solar radiation—diffuse and direct radiation; elementary solar energy engineering—solar thermal and solar photovoltaic; basic principles of wind dynamics—hydrodynamic laws, wind intermittency, Betz's law; elementary wind energy engineering; solar and wind energy perspectives; operating the California power grid with 33 percent renewable energy sources. Students may not receive credit for both MAE 118B and MAE 119. ***Prerequisites:*** MAE 101A or CENG 101A, or consent of instructor.

MAE 120. Introduction to Nuclear Energy (4)

Overview of basic fission and fusion processes. Elementary fission reactor physics and engineering; environmental and waste disposal issues. Survey of fusion technology issues and perspectives. May not receive credit for both MAE 118C and MAE 120. ***Prerequisites:*** MAE 101A or CENG 101A, or consent of instructor.

MAE 121. Air Pollution Transport and Dispersion Modeling (4)

Overview of air pollution and wastes and their impact. Characteristics of air pollutants. Air pollution transport. Atmospheric stability. Plume rise and dispersion. Meteorological data. Selecting the appropriate air quality model and case studies. Modeling complex terrain

situations. Current air quality modeling issues. Laws and regulations to control air pollution. ***Prerequisites:*** MAE 122 or 125A or consent of instructor.

MAE 122. Flow and Transport in the Environment (4)

Introduction to the air and aquatic environments. Buoyancy, stratification, and rotation. Earth surface energy balance. Introduction to the atmospheric boundary layer. Advection and diffusion. Turbulent diffusion and dispersion in rivers and in the atmospheric boundary layer. Surface waves and internal gravity waves. ***Prerequisites:*** MAE 101A or CENG 101A, or consent of instructor.

MAE 123. Introduction to Transport in Porous Media (4)

Introduction to groundwater flow. Pollution transport through the water table. Fundamentals of flow. Single- and multi-phase flow. Darcy law. Well hydraulics. Diffusion and dispersion. Gravity currents and plumes in porous media. Chemistry of fluid-solid interactions. Fundamentals of adsorption and surface reactions. ***Prerequisites:*** MAE 101C or CENG 101B, and MAE 105 and 107.

MAE 124. Environmental Challenges: Science and Solutions (4)

(Cross-listed with ESYS 103.) This course explores the impacts of human social, economic, and industrial activity on the environment. It highlights the central roles in ensuring sustainable development played by market forces, technological innovation and governmental regulation on local, national, and global scales. ***Prerequisites:*** Math 20B or Math 10A–C, or consent of instructor.

MAE 126A. Environmental Engineering Laboratory (4)

Analysis of experiments in Environmental Engineering: Drag in a water tunnel, shading effects on solar photovoltaic, buoyant plume dispersion in a water tank, atmospheric turbulence, and others. Use of sensors and data acquisition. Laboratory report writing; error analysis; engineering ethics. ***Prerequisites:*** MAE 101A or CENG 101A; MAE 170 and MAE 122.

MAE 126B. Environmental Engineering Design (4)

Fundamental principles of environmental design. Building a working prototype or computer model for an environmental engineering application. Work in teams to propose and design experiments and components, obtain data, complete engineering analysis, and write a report. Engineering ethics and professionalism. ***Prerequisites:*** MAE 126A.

MAE 130A. Mechanics I: Statics (4)

(Cross-listed with SE 101A.) Statics of particles and rigid bodies in two and three dimensions. Free body diagrams. Internal forces. Static analysis of trusses, frames, and machines. Shear force and bending moment diagrams in beams. Equilibrium problems with friction. Students may not receive credit for both MAE 130A and SE 101A. ***Prerequisites:*** grades of C– or better in Math 20C and Phys 2A. Students cannot also receive credit for SE 101A.

MAE 130B. Mechanics II: Dynamics (4)

(Cross-listed with SE101B.) Kinematics and kinetics of particles in 2-D and 3-D motion. Newton's equations of motion. Energy and momentum methods. Impulsive motion and impact. Systems of particles. Kinematics and kinetics of rigid bodies in 2-D. Introduction to 3-D dynamics of rigid bodies. Students may not receive credit for both MAE 130B and SE 101B. **Prerequisites:** grade of C– or better in MAE 130A or SE 101A.

MAE 130C. Mechanics III: Vibrations (4)

(Cross-listed with SE 101C.) Free and forced vibrations of undamped and damped single degree of freedom systems. Harmonically excited vibrations. Vibrations under general loading conditions. Vibrating systems with multiple degrees of freedom. Modal analysis with application to realistic engineering problems. Vibration of continuous systems. Students may not receive credit for both MAE 130C and SE 101C. ***Prerequisites:*** grades of C– or better in Math 20F and MAE 130B or SE 101B.

MAE 131A. Solid Mechanics I (4)

Concepts of stress and strain. Hooke's Law. Axial loading of bars. Torsion of circular shafts. Shearing and normal stresses in beam bending. Deflections in beams. Statically determinate and indeterminate problems. Combined loading. Principal stresses and design criteria. Buckling of columns. ***Prerequisites:*** Math 20D and MAE 130A or SE 101A.

MAE 131B. Fundamentals of Solid Mechanics II (4)

Continuous mechanics of solids and its application to the mechanical response of machine and structural elements. Stress and strain in indicial notation; field equations and constitutive relations. Linear elastic stress analysis in torsion, plane stress and plane strain; stress concentrations; fracture mechanics. Extremum principles and structural stability. Viscoelasticity, plasticity, and failure criteria. Theorems of plastic limit analysis. ***Prerequisites:*** MAE 131A or SE 110A and MAE 105. Enrollment restricted to engineering majors only.

MAE 133. Finite Element Methods in Mechanical and Aerospace Engineering (4)

Development of stiffness and mass matrices based upon variational principles and application to static, dynamic, and stability design problems in structural and solid mechanics. Architecture of computer codes for linear and nonlinear finite element analysis and basic computer implementation. The use of general purpose finite element structural analysis computer codes. ***Prerequisites:*** grade of C– or better in MAE 131A or SE 110A. (Not offered every year.)

MAE 140. Linear Circuits (4)

Steady-state and dynamic behavior of linear, lumped-parameter electrical circuits. Kirchoff's laws. RLC circuits. Node and mesh analysis. Operational amplifiers. Signal acquisition and conditioning. Electric motors. Design applications in engineering. ***Prerequisites:*** grades of C– or better in Math 20D or 21D, 20F, and Phys 2B. Enrollment restricted to engineering majors only.

MAE 142. Dynamics and Control of Aerospace Vehicles (4)

The dynamics of vehicles in space or air are derived for analysis of the stability properties of spacecraft and aircraft. The theory of flight, lift, drag, Dutch roll and phugoid modes of aircraft are discussed. Optimal state space control theory for the design of analog and digital controllers (autopilots). ***Prerequisites:*** grades of C– or better in MAE 104 and MAE 143B or ECE 171A, or consent of instructor. Enrollment restricted to engineering majors only.

MAE 143A. Signals and Systems (4)

Dynamic modeling and vector differential equations. Concepts of state, input, output. Linearization around equilibria. Laplace transform, solutions to ODEs. Transfer functions and convolution representation of dynamic systems. Discrete signals, difference equations, z-transform. Continuous and discrete Fourier transform. ***Prerequisites:*** Math 20D or 21D, Math 20E, Math 18 or 20F or 31AH, and MAE 105, or consent of instructor.

MAE 143B. Linear Control (4)

Analysis and design of feedback systems in the frequency domain. Transfer functions. Time response specifications. PID controllers and Ziegler-Nichols tuning. Stability via Routh-Hurwitz

test. Root locus method. Frequence response: Bode and Nyquist diagrams. Dynamic compensators, phase-lead and phase-lag. Actuator saturation and integrator wind-up. ***Prerequisites:*** MAE 143A or consent of instructor.

MAE 144. Embedded Control and Robotics (4)

Each student builds, models, programs, and controls an unstable robotic system built around a small Linux computer. Review/synthesis of: A) modern physical and electrical CAD. B) dynamics, signals and systems, linear circuits; PWMs, H-bridges, quadrature encoders. C) embedded Linux, C, graphical programming; multithreaded applications; bus communication to supporting ICs. D) classical control theory in both continuous-time (CT) and discrete-time (DT); interconnection of CT and DT elements. Program or materials fees may apply. ***Prerequisites:*** upper-division standing or graduate student, and MAE 143B or BENG 122A or ECE 171A, or consent of instructor.

MAE 145. Introduction to Robotic Planning and Estimation (4)

This course is an introduction to robotic planning algorithms and programming. Topics: sensor-based planning (bug algorithms), motion planning via decomposition and search (basic search algorithms on graphs, A*), the configuration-space concept, free configuration spaces via sampling, collision detection algorithms, (optimal) planning via sampling (probabilistic trees), environment roadmaps, and (extended) Kalman filtering for robot localization and environment mapping (SLAM). ***Prerequisites:*** senior standing and MAE 130B, or consent of instructor.

MAE 149. Sensor Networks (4)

(Cross-listed with ECE 156.) Characteristics of chemical, biological, seismic and other physical sensors; signal processing techniques supporting distributed detection of salient events; wireless communication and networking protocols supporting formation of robust censor fabrics; current experience with low power, low-cost sensor deployments. Students may not receive credit for both MAE 149 and ECE 156. May be coscheduled with SIOC 238. ***Prerequisites:***upper-division standing. (Not offered every year.)

MAE 150. Computer-Aided Design (4)

Computer-aided analysis and design. Design methodology, tolerance analysis, Monte Carlo analysis, kinematics and computer-aided design of linkages, numerical calculations of moments of inertia, design of cams and cam dynamics; finite element analysis, design using Pro-E, Mechanica Motion and Mechanica Structures. ***Prerequisites:*** grades of C– or better in MAE 130A or SE 101A or BENG 110, MAE 107 or SE 121, MAE 3, and senior standing in engineering major, or consent of instructor.

MAE 154. Product Design and Entrepreneurship (4)

This course will teach teams of students how to develop concepts and business plans in the design of new and innovative products. Emphasis will be placed on identifying user needs, concept generation, and prototype fabrication. ***Prerequisites:*** upper-division standing and consent of instructor.

MAE 155A. Aerospace Engineering Design I (4)

Fundamental principles of aerospace vehicle design including the conceptual, preliminary, and detailed design phases. Aeronautical or astronautical design project that integrates all appropriate engineering disciplines as well as issues associated with optimization, teamwork, manufacturability, reporting, and professionalism. ***Prerequisites:*** grades of C– or better in MAE

2, MAE 104, MAE 113, MAE 130C, MAE 142, MAE 150, SE 2, and SE 160B, or consent of instructor. Students may enroll concurrently with MAE 113, 142, and 150.

MAE 155B. Aerospace Engineering Design II (4)

The principles of aerospace vehicle design including the conceptual, preliminary, and detailed design phases. Aeronautical or astronautical design project that integrates all appropriate engineering disciplines as well as issues associated with optimization, teamwork, manufacturability, reporting, and professionalism. Program or materials fees may apply. ***Prerequisites:*** MAE 113, MAE 142, MAE 150, MAE 155A, and MAE 170, or consent of instructor.

MAE 156A. Fundamental Principles of Mechanical Design I (4)

Fundamental principles of mechanical design and the design process. Application of engineering science to the design and analysis of mechanical components. Initiation of team design projects that culminate in MAE 156B with a working prototype designed for a real engineering application. Professional ethics discussed. Program or materials fees may apply. ***Prerequisites:*** MAE 3, MAE 130B, MAE 131A, MAE 143B, MAE 150, and MAE 170, or consent of instructor. Open to major code MC 27 only.

MAE 156B. Fundamental Principles of Mechanical Design II (4)

Fundamental principles of mechanical design and the design process. Culmination of a team design project initiated in MAE 156A which results in a working prototype designed for a real engineering application. ***Prerequisites:*** MAE 156A in the immediately preceding quarter, MAE 101C, MAE 130C, and MAE 160 or MAE 131B. Open to major code MC 27 only.

MAE 160. Mechanical Behavior of Materials (4)

Elasticity and inelasticity, dislocations and plasticity of crystals, creep, and strengthening mechanisms. Mechanical behavior of ceramics, composites, and polymers. Fracture: mechanical and microstructural. Fatigue. Laboratory demonstrations of selected topics. ***Prerequisites:*** grades of C– or better in MAE 20, MAE 130A (or SE 101A) and MAE 131A, or consent of instructor.

MAE 165. Fatigue and Failure Analysis of Engineering Components (4)

The engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture in crystalline and amorphous solids. Microstructural effects on crack initiation, fatigue crack growth and fracture toughness. Methods of fatigue testing and fracture toughness testing. Fractography and microfractography. Design safe methodologies and failure prevention. Failure analysis of real engineering structures. ***Prerequisites:*** consent of instructor. (Not offered every year.)

MAE 166. Nanomaterials (4)

Basic principles of synthesis techniques, processing, microstructural control and unique physical properties of materials in nanodimensions. Nanowires, quantum dots, thin films, electrical transport, optical behavior, mechanical behavior, and technical applications of nanomaterials. ***Prerequisites:*** consent of instructor. (Not offered every year.)

MAE 167. Wave Dynamics in Materials (4)

Pressure and shear waves in infinite solids. Reflection and diffraction. Rayleigh and Love waves in semi-infinite space. Impulse load on a half space. Waveguides and group velocity. ***Prerequisites:*** consent of instructor. (Not offered every year.)

MAE 170. Experimental Techniques (4)

Principles and practice of measurement and control and the design and conduct of experiments. Technical report writing. Lectures relate to dimensional analysis, error analysis, signal-to-noise problems, filtering, data acquisition and data reduction, as well as background of experiments and statistical analysis. Experiments relate to the use of electronic devices and sensors. ***Prerequisites:*** grade of C– or better in Phys 2CL. Enrollment restricted to engineering majors only.

MAE 171A. Mechanical Engineering Laboratory I (4)

Design and analysis of experiments in fluid mechanics, solid mechanics, and control engineering. Experiments in wind tunnel, water tunnel, vibration table and material testing machines, and refined electromechanical systems. Laboratory report writing; error analysis; engineering ethics. ***Prerequisites:*** MAE 101C or CENG 101B; MAE 143B or CENG 120; MAE 160 or MAE 131B or SE 110B; MAE 130C or SE 101C; MAE 140; and MAE 170.

MAE 171B. Mechanical Engineering Laboratory II (4)

Design and analysis of original experiments in mechanical engineering. Students research projects using experimental facilities in undergraduate laboratories: wind tunnel, water channel, vibration table, and testing machine and control systems. Students propose and design experiments, obtain data, complete engineering analysis and write a major report. ***Prerequisites:*** grade of C– or better in MAE 171A. (Not offered every year.)

MAE 175A. Aerospace Engineering Laboratory I (4)

Analysis of aerospace engineering systems using experimental facilities in undergraduate laboratories: wind tunnel, water channel, vibration table, and testing machine. Students operate facilities, obtain data, complete engineering analysis and write major reports. ***Prerequisites:*** senior standing; MAE 101C or CENG 101B; MAE 143B or CENG 120; and MAE 170, or consent of instructor.

MAE 180A. Spacecraft Guidance I (4)

Astrodynamics, orbital motion, perturbations, coordinate systems and frames of reference. Geosynchronous orbits, stationkeeping. Orbital maneuvers, fuel consumption, guidance systems. Observation instrument point, tracking, control. Basic rocket dynamics. Navigation, telemetry, re-entry, and aero-assisted maneuvers. Mission design. Students perform analyses based on mission requirements. ***Prerequisites:*** upper-division standing in physics, mathematics, or engineering department.

MAE 181. Space Mission Analysis and Design (4)

Space mission concepts, architectures, and analysis. Mission geometry. Astrodynamics. Orbit and constellation design. Space environment. Payload and spacecraft design and sizing. Power sources and distribution. Thermal management. Structural design. Guidance and navigation. Space propulsion. Orbital debris and survivability. Cost modeling and risk analysis. ***Prerequisites:*** upper-division standing or consent of instructor.

MAE 197. Engineering Internship (1–4)

Students work in local industry or hospitals under faculty supervision. Units may not be applied toward graduation requirements. Salaried or unsalaried. Number of units determined by enrollment frequency. First quarter up to four units. Subsequent quarters cannot exceed one unit. ***Prerequisites:*** consent of instructor and department stamp, 2.50 overall GPA minimum, at least ninety units.

MAE 198. Directed Group Study (1–4)

Directed group study on a topic or in a field not included in the regular department curriculum, by special arrangement with a faculty member. May be taken P/NP only. ***Prerequisites:*** consent of instructor.

MAE 199. Independent Study for Undergraduates (4)

Independent reading or research on a problem by special arrangement with a faculty member. P/NP grades only. ***Prerequisites:*** consent of instructor.

Graduate

MAE 200. Controls (4)
This course covers topics in probability and stochastic processes, linear control and estimation including optimal linear control, nonlinear stabilization, and optimal control and estimation for nonlinear systems. ***Prerequisites:*** non-graduate students may enroll with consent of instructor.
MAE 201. Mechanics of Fluids (4)
This course covers topics in kinematics, equations of motion, dimensional analysis, laminar and irrotational flow, vorticity dynamics, and boundary layers. ***Prerequisites:*** non-graduate students may enroll with consent of instructor.
MAE 202. Thermal Processes (4)
This course covers topics in energy conservation, heat conduction, convection, radiation, heat transfer in ducts, external boundary layer, and heat exchangers. ***Prerequisites:*** non-graduate students may enroll with consent of instructor.
MAE 203. Solid Mechanics and Materials (4)
This course covers topics in kinematics, conservation laws, constitutive equation of linear elastic solids, plasticity, and viscoelasticity. ***Prerequisites:*** non-graduate students may enroll with consent of instructor.
MAE 204. Robotics (4)
This course covers topics in robotics, dynamics, kinematics, mechatronics, control, locomotion, and manipulation. ***Prerequisites:*** non-graduate students may enroll with consent of instructor.
MAE 205. Graduate Seminar (1)
Each graduate student in MAE is expected to attend one seminar per quarter, of his or her choice, dealing with current topics in fluid mechanics, solid mechanics, applied plasma physics and fusion, chemical engineering, applied ocean sciences, energy and combustion, environmental engineering, or materials science, and dynamics and controls. Topics will vary. (S/U grades only)
MAE 206. Energy Systems (4)
This course covers topics in primary energy sources, availability and variability, fossil fuels, renewables and nuclear, energy dependent energy sources, heat engine, energy conservation, exergy, transportation, air pollution, and climate change. ***Prerequisites:*** non-graduate students may enroll with consent of instructor.
MAE 207. Topics in Engineering Science (4)
A course to be given at the discretion of the faculty in which topics of current interest in engineering will be presented. ***Prerequisites:*** consent of instructor.
MAE 208. Mathematics for Engineers (4)
This course will reintroduce the math fundamentals necessary for success in the engineering graduate program in MAE. Topics will include calculus, ODE's, vector calculus, linear algebra, probability and PDE's. ***Prerequisites:*** consent of instructor.
MAE 209. Continuum Mechanics Applied to Medicine/Biology (4)
(Cross-listed with BENG 209.) Introduction to the basic definitions of continuum mechanics and their mathematical formulation at the graduate level with applications to problems in medicine and biology. This course is intended for students with little or no background in mechanics; it is an introduction to the Biomechanics courses BENG 250 A–B in the Department of Bioengineering and to Solid and Fluid Mechanics courses MAE 210A and MAE 231A in the

Department of Mechanical and Aerospace Engineering. This course should NOT be taken concurrently with MAE 210A or MAE 231A. ***Prerequisites:*** consent of instructor.

MAE 210A. Fluid Mechanics I (4)

(Cross-listed with CENG 210A.) Basic conservation laws. Flow kinematics. The Navier-Stokes equations and some of its exact solutions. Nondimensional parameters and different flow regimes, vorticity dynamics.

MAE 210B. Fluid Mechanics II (4)

Potential flows, boundary layers, low-Reynolds number flows. ***Prerequisites:*** BENG 209 or MAE 209 or MAE 210A; MAE 101A and B; and MAE 110A, or consent of instructor.

MAE 210C. Fluid Mechanics III (4)

Flow instabilities, linear stability theory; introduction to turbulent flows. ***Prerequisites:*** MAE 210A–B or consent of instructor.

MAE 211. Introduction to Combustion (4)

Fundamental aspects of flows of reactive gases, with emphasis on processes of combustion, including the relevant thermodynamics, chemical kinetics, fluid mechanics, and transport processes. Topics may include deflagrations, detonations, diffusion flames, ignition, extinction, and propellant combustion. ***Prerequisites:*** MAE 101A-B-C (or CENG 101A-B-C), and MAE 110A, or consent of instructor.

MAE 212. Introductory Compressible Flow (4)

Equations of motion for compressible fluids; one-dimensional gas dynamics and wave motion, waves in supersonic flow, including oblique shock waves; flow in ducts, nozzles, and wind tunnels; methods of characteristics. Nongraduate students may enroll with consent of instructor.

MAE 213. Mechanics of Propulsion (4)

Fluid mechanics, thermodynamics and combustion processes involved in propulsion of aircraft and rockets by air breathing engines, and solid and liquid propellant rocket engines characteristics and matching of engine components; diffusers, compressors, combustors, turbines, pumps, nozzles. ***Prerequisites:***MAE 101A-B-C, MAE 110A, and MAE 212, or consent of instructor.

MAE 214A. Introduction to Turbulence and Turbulent Mixing (4)

Basic features of turbulent flows. Analytical description of turbulence: random variables, correlations, spectra, Reynolds-averaging, coherent structures. Length and time scales. Kolomogorov similarity theory. Turbulence transport equations. Free shear flows. Homogeneous turbulence. Wall-bounded flows. Mixing of velocity and scalar fields. ***Prerequisites:*** MAE 210A or consent of instructor.

MAE 216. Turbulence and Mixing (4)

(Cross-listed with SIO 213.) Mixing mechanisms, their identification, description and modeling. Introduction to turbulence, semi-empirical theories, importance of coherent structures, effects of stratification and rotation on turbulent structure, entrainment and mixing. S/U grades permitted.

MAE 217A. Introduction to Gas Discharge Plasma Physics (4)

Charged particle motion in electromagnetic field, atomic processes in plasmas, electric breakdown of the gases, plasma quasi-neutrality, sheath, probes. Electron kinetics in low-

temperature plasma, particle and energy fluxes, DC and RF driven discharges, instabilities of gas discharge plasmas. ***Prerequisites:***Phys 100A-B-C or consent of instructor.

MAE 217B. Introduction to Nonmagnetized Hot Plasma Physics (4)

Coulomb collisions, collisionless approximation for hot plasma dynamics, Vlasov equation, waves in nonmagnetized plasma, dispersion equation, WKB approximation, Landau dumping, plasma instabilities, quasi-linear theory. ***Prerequisites:*** MAE 217A or consent of instructor.

MAE 217C. Introduction to Magnetized Hot Plasma Physics (4)

Drifts of magnetized charged particles, charged particle motion in different magnetic configurations, toroidal plasma equilibrium, Grad-Shafranov equation, neoclassical plasma transport in tokamak, waves in homogeneous magnetized plasma, waves in inhomogeneous magnetized plasma, instabilities of magnetized plasma. ***Prerequisites:*** MAE 217A and B, or consent of instructor.

MAE 218A. Introduction to High Energy Density Physics (MHD and Pinches) (4)

Equation of state, Saha equilibrium. Shock rarefaction, and blast waves, self-similar motion. Rayleigh-Taylor, Kelvin-Helmholtz, and Richtmyer-Meshkov instabilities. Z-pinch, Bennett equilibrium, radiation collapse, and radiation sources. ***Prerequisites:*** MAE 217A, B, and C, or consent of instructor.

MAE 218B. Introduction to High Energy Density Physics (Laser-Plasma Interactions) (4)

Propagation and absorption of laser beam in plasma, ablation pressure. Laser scattering and laser-plasma instabilities (stimulated Raman and Brillouin scattering, filamentation and decay instabilities). Electron heat transport, mechanisms of magnetic field generation. ***Prerequisites:*** MAE 217A, B, and C, or consent of instructor.

MAE 220A. Physics of Gases (4)

Thermodynamics of gases for use in gas dynamics. Derivation of thermodynamic functions from statistical mechanics. Applications of classical and quantum statistical mechanics to chemical, thermal, and radiative properties of gases. Equilibrium and nonequilibrium radiation, chemical equilibrium, and elements of chemical kinetics. Laser and reacting-flow applications. ***Prerequisites:*** MAE 110A or consent of instructor.

MAE 220B. Physical Gas Dynamics (4)

Velocity distribution functions, the Boltzmann equation, moment equations and the Navier-Stokes equations. The dynamics of molecular collisions. The Chapman-Enskog expansion and transport coefficients: shear and bulk viscosity, heat conduction, molecular and thermal diffusion. Linearizations about equilibrium: applications to acoustics and supersonic flows with relaxation. ***Prerequisites:*** MAE 101A-B-C (or CENG 101A-B-C), and MAE 220A, or consent of instructor.

MAE 221A. Heat Transfer (4)

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

MAE 221B. Mass Transfer (4)

(Cross-listed with CENG 221B.) Fundamentals of diffusive and convective mass transfer and mass transfer with chemical reaction. Development of mass conservation equations. Analytical

and numerical solutions to mass transport problems. Specific topics and applications will vary. ***Prerequisites:*** MAE 101A-B-C (or CENG 101A-B-C), or consent of instructor.

MAE 224A. Environmental Fluid Dynamics I (4)

Basics of stratified flows. Linear waves: surface waves, internal gravity waves, dispersion, reflection, mountain waves. Ray tracing. Gravity currents and intrusions. Hydraulic control. Stability of and mixing in stratified shear flows. Recommended preparation: MAE 210A.

MAE 224B. Environmental Fluid Dynamics II (4)

Plumes and thermals. Application to building ventilation. Basics of rotating flows. Geostrophic flow. Thermal wind balance. Ekman boundary layer. Shallow water equations. Normal modes of a stratified fluid. Potential vorticity. Waves in a rotating fluid. Recommended preparation: MAE 210A. ***Prerequisites:*** MAE 224A or consent of instructor.

MAE 225A. Nanoscale and Microscale Heat Transfer for Energy Conversion Applications I (4)

An advanced introduction to the principles underlying conduction, convection, and radiation phenomena at the atomic/molecular scale; overview of macroscopic thermal sciences, kinetic theory and fluidics, statistical thermodynamics and quantum theory, thermal properties as a function of dimensionality; experimental methods. ***Prerequisites:*** MAE 221A, and MAE 101A-B-C, or consent of instructor.

MAE 225B. Nanoscale and Microscale Heat Transfer for Energy Conversion Applications II (4)

Energy conversion and coupled transport processes; electron and phonons, equilibrium and non-equilibrium energy transfer in nanostructures. Ballistic-diffusive treatment, thermal radiation issues in nanomaterials, near-field energy transfer, molecular dynamics, and experimental methods. ***Prerequisites:*** MAE 221A, MAE 225A, and MAE 101A-B-C, or consent of instructor.

MAE 228. Selected Topics in Plasma Physics (4)

Collisionless magnetic reconnection, interactions of relativistic laser field with plasma, plasma in astrophysics, computational plasma physics. ***Prerequisites:***MAE 217A-B-C or consent of instructor.

MAE 231A. Foundations of Solid Mechanics (4)

Specification of stress and strain; infinitesimal and finite deformation; conservation equations; typical constitutive equations; minimum potential energy principle.

MAE 231B. Elasticity (4)

Basic field equations. Typical boundary value problems of classical linear elasticity. Problems of plane stress and plane strain. Variational principles. ***Prerequisites:*** MAE 209/BENG 209, or MAE 231A, or consent of instructor.

MAE 231C. Inelasticity (4)

(Cross-listed with SE 273.) Overview of inelastic behavior of materials. Models of plasticity, viscoplasticity, viscoelasticity. Micromechanics and modeling of damage. Fatigue phenomena. Fracture mechanics. Processes and models of the failure of materials. Students may not receive credit for both SE 273 and MAE 231C. ***Prerequisites:*** graduate standing and MAE 231A and 231B, or SE 271 and 272, or consent of instructor.

MAE 232A. Finite Element Methods in Solid Mechanics I (4)

(Cross-listed with SE 276A.) Finite element methods for linear problems in solid mechanics. Emphasis on the principle of virtual work, finite element stiffness matrices, various finite element formulations and their accuracy, and the numerical implementation required to solve

problems in small strain, isotropic elasticity in solid mechanics. ***Prerequisites:*** graduate standing.

MAE 232B. Finite Element Methods in Solid Mechanics II (4)

(Cross-listed with SE 276B.) Finite element methods for linear problems in structural dynamics. Beam, plate, and doubly curved shell elements are derived. Strategies for eliminating shear locking problems are introduced. Formulation and numerical solution of the equations of motion for structural dynamics are introduced and the effect of different mass matrix formulations on the solution accuracy is explored. ***Prerequisites:*** graduate standing and MAE 232A or SE 276A.

MAE 232C. Finite Element Methods in Solid Mechanics III (4)

(Cross-listed with SE 276C.) Finite element methods for problems with both material and geometrical (large deformations) nonlinearities. The total LaGrangian and the updated LaGrangian formulations are introduced. Basic solution methods for the nonlinear equations are developed and applied to problems in plasticity and hyperelasticity. ***Prerequisites:*** graduate standing and MAE 232B or SE 276B.

MAE 233A. Fracture Mechanics (4)

Theoretical strength; stress concentration. Linear and nonlinear fracture mechanics: stress singularity, fracture modes, crack tip plastic zone, dugdale model, the R-curve; power-law materials, the J-integral; fatigue; special topics. ***Prerequisites:*** MAE 231A, MAE 231B, or consent of instructor.

MAE 233B. Micromechanics (4)

General theory of transformation strains and corresponding elastic fields; Green's functions and other solution methods; dislocations; inclusions and inhomogeneities; micromechanics of plastic flow, microcracking, cavitation, and damage in crystalline and other solids. ***Prerequisites:*** MAE 231A-B-C or consent of instructor.

MAE 235. Computational Techniques in Finite Elements (4)

(Cross-listed with SE 255.) Practical application of the finite element method to problems in solid mechanics. Elements of theory are presented as needed. Covered are static and dynamic heat transfer and stress analysis. Basic processing, solution methods, and postprocessing are practiced with commercial finite element software. Students may not receive credit for SE 233 and MAE 235. ***Prerequisites:*** graduate standing.

MAE 238. Stress Waves in Solids (4)

Linear wave propagation; plane waves; reflection and refraction; dispersion induced by geometry and by material properties. Application of integral transform methods. Selected topics in nonlinear elastic, anelastic, and anisotropic wave propagation. ***Prerequisites:*** MAE 231A-B-C or consent of instructor.

MAE 242. Robot Motion Planning (4)

Modeling, solving, and analyzing planning problems for single robots or agents. Configuration space for motion planning, sampling-based motion planning, combinatorial motion planning, feedback motion planning, differential models, and nonholonomic constraints. Basic decision-theory and dynamic programming, sensor and information spaces.

MAE 247. Cooperative Control of Multi-agent Systems (4)

Tools for the design of cooperative control strategies for multi-agent systems are presented. Topics include continuous and discrete-time evolution models, proximity graphs, performance

measures, invariance principles, and coordination algorithms for rendezvous, deployment, flocking, formation of autonomous vehicles and consensus.

MAE 251. Structure and Analysis of Solids (4)

(Cross-listed with MATS 227 and Chem 222.) Key concepts in the atomic structure and bonding of solids. Symmetry operations, point groups, lattice types, space groups, inorganic compounds, structure/property comparisons, X-ray diffraction. Ionic, covalent, metallic bonding compared with physical properties. Atomic and molecular orbitals, bands vs. bonds, free electron theory. ***Prerequisites:*** consent of instructor.

MAE 253. Advanced Ceramics (4)

(Cross-listed with MATS 236.) Topics include phase equilibria and crystallography, defects and thermodynamics (Kröger-Vink notation), glass scona, electrical and ionic transport behavior, Bronner diagrams, powder synthesis and compaction, sintering theory and grain growth, mechanical optical, magnetic, electrical properties, fuel cells. ***Prerequisites:*** consent of instructor.

MAE 254. Energy Materials and Applications (4)

(Cross-listed with MATS 256.) This class will cover the fundamentals/engineering aspects of various energy materials based on metallic, ceramic, semiconductor, and chemical structures, and their applications related to solar cells, fuel cells, batteries, fusion energy, and hydrogen storage will be discussed. ***Prerequisites:*** consent of instructor or department stamp.

MAE 255. Boundary Layer and Renewable Energy Meteorology (4)

Radiative and convective heat transfer in the atmosphere. Surface energy balance and the urban heat island. Turbulence and dispersion in the atmospheric boundary layer. Solar and wind energy systems, resource assessment, and intermittency. ***Prerequisites:*** MAE 210A or consent of instructor.

MAE 256. Radiative Transfer for Energy Applications (4)

Global insolation heat engine; solar-wind coupling; regional/seasonal insolation patterns; atmospheric radiation balance; RTE models; scattering; optical depth and transmittance of cloud layers; Schwarzschild's equation; absorption/emission lines; rotational, vibrational and electronic transitions; Doppler/pressure broadening; Elsasser/Malkmus/Edwards models; solution methods. ***Prerequisites:*** graduate standing or consent of instructor.

MAE 260. Fundamentals and Applications of Computational Materials Science (4)

(Cross-listed with MATS 260.) Computational methods for MatSci will be discussed, dealing with atomic scale empirical or semiempirical potentials. How and why to develop such potentials for metallic materials will be a focus of the course. Molecular dynamics and Monte Carlo methods will be covered in detail. Applications of these techniques to some example problems in materials science, mechanical deformation, dislocation interactions, nucleation/growth of phases, melting solidification structures, and point defects are presented.

MAE 261. Cardiovascular Fluid Mechanics (4)

Topics in the mechanics of blood flow including analytical solutions for flow in deformable vessels, one-dimensional equations, cardiovascular anatomy, lumped parameter models, vascular trees, scaling laws, and an introduction to the biomechanics and treatment of adult and congenital cardiovascular diseases. ***Prerequisites:*** MAE 210A and 290A, or consent of instructor.

MAE 262. Biological Fluid Mechanics (4)

Fluids phenomena relevant to the function, environment, and dynamics of biological cells. Topics include: low-Reynolds number flows, cell motility, internal cellular flows, development and morphogenesis, hydrodynamics of suspensions and polymers, rheology, diffusion, hydrodynamics of deformable bodies (vesicles, membranes, filaments), cells under shear flow. ***Prerequisites:*** MAE 209 or 210A and graduate standing, or consent of instructor.

MAE 263. Experimental Methods in Cell Mechanics (4)

Methods to measure mechanical aspects of cellular nature and behavior such as intracellular rheology, intracellular force distribution and propagation, cell adhesion strength, generation of propulsive forces during locomotion, interaction with the extracellular matrix, and response to external mechanical stimuli. ***Prerequisites:*** MAE 209 or MAE 210A or MAE 131A, or consent of instructor.

MAE 264. Mechanics and Thermodynamics of Biological Membranes (4)

This course will introduce the advanced graduate student to the topics of mechanical and thermodynamic analyses of cellular membranes, lipid bilayers, and the study of synthetic vesicles. ***Prerequisites:*** MAE 209 and graduate standing, or consent of instructor.

MAE 265A. Electronic and Photonic Properties of Materials (4)

(Cross-listed with MATS 251A.) The electronic and optical properties of metals, semiconductors, and insulators. The concept of the band structure. Electronic and lattice conductivity. Type I and Type II superconductivity. Optical engineering using photonic band gap crystals in one-, two-, and three-dimensions. Current research frontiers. ***Prerequisites:*** consent of instructor.

MAE 265B. Magnetic Materials: Principles and Applications (4)

(Cross-listed with MATS 251B and NANO 251A and ECE 221.) The basis of magnetism: Classical and quantum mechanical points of view. Different kinds of magnetic materials. Magnetic phenomena including anisotropy, magnetostriction, domains, and magnetization dynamics. Current frontiers of nanomagnetics research including thin films and particles. Optical, data storage, and biomedical engineering applications of soft and hard magnetic materials. Letter grades only. Students may not receive credit for ECE 221 and MAE 265B and MATS 251B and NANO 251A. ***Prerequisites:*** graduate standing; consent of instructor.

MAE 266. Biomaterials and Medical Devices (4)

(Cross-listed with MATS 252.) This class will cover biomaterials and biomimetic materials. Metal, ceramic, and polymer biomaterials will be discussed. Emphasis will be on the structure-property relationships, biocompatibility/degradation issues and tissue/material interactions. Synthesis and mechanical testing of biomimetic materials will also be discussed. ***Prerequisites:*** consent of instructor.

MAE 267. Nanomaterials and Properties (4)

(Cross-listed with MATS 253.) This course discusses synthesis techniques, processing, microstructural control and unique physical properties of materials in nanodimensions. Topics include nanowires, quantum dots, thin films, electrical transport, electron emission properties, optical behavior, mechanical behavior, and technical applications of nanomaterials. ***Prerequisites:*** consent of instructor.

MAE 271A. Thermodynamics of Solids (4)

(Cross-listed with MATS 201A and ECE 238A.) The thermodynamics and statistical mechanics of solids. Basic concepts, equilibrium properties of alloy systems, thermodynamic information

from phase diagrams, surfaces and interfaces, crystalline defects. ***Prerequisites:*** consent of instructor.

MAE 271B. Solid State Diffusion and Reaction Kinetics (4)

(Cross-listed with MATS 201B and ECE 238B.) Thermally activated processes, Boltzmann factor, homogenous and heterogeneous reactions, solid state diffusion, Fick's laws, diffusion mechanisms, Kirkendall effect, Boltzmann-Matano analysis, high diffusivity paths. ***Prerequisites:*** consent of instructor.

MAE 271C. Phase Transformations (4)

(Cross-listed with MATS 201C and ECE 238C.) Classification of phase transformations; displacive and reconstructive transformations; classical and nonclassical theories of nucleation; Becker-Doering, Volmer-Weber, lattice instabilities, spinodal decomposition. Growth theories; interface migration, stress effects, terrace-ledge mechanisms, epitaxial growth, kinetics and mechanics. Precipitation. Order-disorder transformations. Solidification. Amorphization. ***Prerequisites:*** consent of instructor.

MAE 272. Imperfections in Solids (4)

(Cross-listed with MATS 205A.) Point, line, and planar defects in crystalline solids, including vacancies, self interstitials, solute atoms, dislocations, stacking faults, and grain boundaries; effects of imperfections on mechanical properties; interactions of dislocations with point defects; strain hardening by micro-obstacles, precipitation, and alloying elements.

MAE 273A. Dynamic Behavior of Materials (4)

(Cross-listed with MATS 213A.) Elastic waves in continuum; longitudinal and shear waves. Surface waves. Plastic waves; shock waves, Rankine-Hugoniot relations. Method of characteristics, differential and difference form of conservation equations; dynamic plasticity and dynamic fracture. Shock wave reflection and interaction. ***Prerequisites:*** consent of instructor.

MAE 276. Mechanics of Soft Materials (4)

(Cross-listed with MATS 231.) Main focus is the large deformations and instabilities in soft materials, such as elastomers, gels, and biomaterials. Some contents in thermodynamics and finite deformation theory are reviewed and summarized. Fundamental theories are applied to study the mechanics of gels, electroactive polymers, and biomaterials. This course intends to use soft material as an example to illustrate how to study the interaction between mechanics and other fields in materials (e.g., electric field, chemical field). Students may not receive credit for both MAE 276 and MATS 231. ***Prerequisites:*** graduate standing.

MAE 277A. Complexity and Large-Scale Systems (4)

(Cross-listed with AESE 278A, CSE 278A, and ECE 205.) Comprehensive introduction to system and event complexity, software and systems engineering practices for complexity management, agile and plan-driven development, development and management processes and process models, data-, information- and knowledge-management, basics of distributed data and computation. This course will meet from 8:00 a.m. to 5:00 p.m. every alternating Friday and Saturday. ***Prerequisites:*** enrollment in MAS-AESE or consent of instructor.

MAE 278A. Modeling, Simulation, and Analysis (4)

(Cross-listed with AESE 278C, CSE 278C, and ECE 206.) Model-driven architecture and development concepts, business process and workflow modeling, structured analysis and IDEF modeling methods, object-, component- and service-orientation and the Unified Modeling

Language, event- and stream models, colored Petri Nets, executable architectures, distributed simulation for performance analysis. This course will meet from 8:00 a.m. to 5:00 p.m. every alternating Friday and Saturday. ***Prerequisites:*** enrollment in MAS-AESE or consent of instructor.

MAE 280A. Linear Systems Theory (4)

Linear algebra: inner products, outer products, vector norms, matrix norms, least squares problems, Jordan forms, coordinate transformations, positive definite matrices, etc. Properties of linear dynamic systems described by ODEs: observability, controllability, detectability, stabilizability, trackability, optimality. Control systems design: state estimation, pole assignment, linear quadratic control.

MAE 280B. Linear Control Design (4)

Parameterization of all stabilizing output feedback controllers, covariance controllers, H-infinity controllers, and L-2 to L-infinity controllers. Continuous and discrete-time treatment. Alternating projection algorithms for solving output feedback problems. Model reduction. All control design problems reduced to one critical theorem in linear algebra. ***Prerequisites:*** MAE 280A.

MAE 281A. Nonlinear Systems (4)

Existence and uniqueness of solutions of EDE's, sensitivity equations. Stability, direct and converse Lyapunov theorems, LaSalle's theorem, linearization, invariance theorems. Center manifold theorem. Stability of perturbed systems with vanishing and nonvanishing perturbations, input-to-state ability, comparison method. Input-output stability. Perturbation theory and averaging. Singular perturbations. Circle and Popov criteria. ***Prerequisites:*** MAE 280A.

MAE 281B. Nonlinear Control (4)

Small gain theorem, passivity. Describing functions. Nonlinear controllability, feedback linearization, input-state and input-output linearization, zero dynamics. Stabilization, Brockett's necessary conditions (local), control Lyapunov functions, Sontag's formula (global). Integrator back stepping, forwarding. Inverse optimality, stability margins. Disturbance attenuation, deterministic and stochastic, nonlinear H-infinity. Nonlinear observers. ***Prerequisites:*** MAE 281A.

MAE 283A. Parametric Identification: Theory and Methods (4)

Constructing dynamical models from experimental data. Deterministic and stochastic discrete time signals. Discrete time systems. Nonparametric identification: correlation and spectral analysis. Parametric identification: realization and prediction error methods, least squares estimation, approximate modeling. Experiment design. Frequency domain identification. Recommended preparation: MAE 143C.

MAE 283B. Approximate Identification and Control (4)

Identification for control: approximate identification, estimation of models via closed-loop experiments. Closed-loop identification techniques. Estimation of model uncertainty. Model invalidation techniques. Iterative techniques for model estimation and control design. ***Prerequisites:*** MAE 283A.

MAE 284. Robust and Multivariable Control (4)

Multivariable feedback systems: transfer function matrices, Smith-McMillan form, poles, zeros, principal gains, operator norms, limits on performance. Model uncertainties, stability and

performance robustness. Design of robust controllers, H_inf and mu synthesis. Controller reduction. ***Prerequisites:*** MAE 280A.

MAE 285. Design of Micro/Nanoacoustofluidic Devices (4)

Acoustofluidics is a burgeoning field reliant on high frequency acoustics and underpinning many new developments and devices at micro to nano scales. First the basics, piezoelectricity, microfluidics, acoustics, and device metrology. Then, new physics arising from the unusually large accelerations (10^7 to 10^9 m/s^2) induced by acoustic waves. Finally, how various phenomena of acoustofluidics at small scales can be used in designing practical devices. ***Prerequisites:*** MAE 210A or CENG 210A, and MAE 210B, graduate standing, or consent of instructor.

MAE 286. Hybrid Systems (4)

Definition of hybrid system. Examples in mechanics, vision, and multi-agent systems. Trajectories of hybrid systems. Chattering, Zeno phenomena. Stability analysis. Arbitrary switching: common Lyapunov functions. Slow switching: dwell time. State-dependent switching: multiple Lyapunov functions, Invariance Principle. Hybrid control design. Applications. ***Prerequisites:*** MAE 281A or consent of instructor.

MAE 287. Control of Distributed Parameter Systems (4)

Lyapunov stability; exact solutions to PDEs; boundary control of parabolic PDEs (reaction-advection-diffusion and other equations); boundary observer design; control of complex-valued PDEs (Schrodinger and Gunzburg-Landau equations); boundary control of hyperbolic PDEs (wave equations) and beam equations; control of first-order hyperbolic PDEs and delay equations; control of Navier-Stokes equations; motion planning for PDEs; elements of adaptive control for PDEs and control of nonlinear PDEs. ***Prerequisites:*** graduate standing or consent of instructor.

MAE 288A. Optimal Control (4)

Deterministic methods: Pontryagin's Maximum Principle, dynamic programming, calculus of variations. Stochastic methods: Gauss-Markov processes, Linear Quadratic control, Markov chains. Linear Quadratic Gaussian Control and the Separation Principle. ***Prerequisites:*** graduate standing or consent of instructor.

MAE 288B. Optimal Estimation (4)

Least Squares and Maximum Likelihood Estimation methods, Gauss-Markov models, State Estimation and Kalman Filtering, prediction and smoothing. The extended Kalman filter. ***Prerequisites:*** MAE 280A completed or concurrent, or consent of instructor.

MAE 289A. Mathematical Analysis for Applications (4)

Topics in mathematical analysis, with the emphasis on those of use in applications. The topics may include: metric spaces, open and closed sets, compact sets, continuity, differentiation, series of functions and uniform convergence, convex sets and functions, transforms, and Stokes theorem. ***Prerequisites:***graduate standing or consent of instructor.

MAE 289B. Real Analysis for Applications (4)

Topics in real analysis, with the emphasis on those of use in applications. May include: countable/uncountable, open and closed sets, topology, Borel sets, sigma algebras, measurable functions, integration (Lebesgue), absolute continuity, function spaces, and fixed-point theorems. ***Prerequisites:*** MAE 289A, graduate standing, or consent of instructor.

MAE 289C. Functional Analysis and Applications (4)

Topics in functional analysis, with the emphasis on those of use in applications. May include: function spaces, linear functionals, dual spaces, reflexivity, linear operators, strong and weak convergence, Hahn-Banach Theorem, nonlinear functionals, differential calculus of variations, Pontryagin Maximum Principle. Students cannot obtain credit for MAE 289C if they have taken MAE 289. ***Prerequisites:*** MAE 289B, graduate standing, or consent of instructor.

MAE 290A. Numerical Methods for Linear Algebra and ODE Simulation (4)

Fundamental matrix decompositions: LU, QR, Eigen, Schur, Jordan, SVD. Exploiting sparsity, finding parallelism, minimizing storage. Pseudoinverses. Finite differences, adaptive integration. Stability and accuracy of Runge-Kutta and linear multistep methods for marching ODEs. Low-storage IMEXRK methods. ***Prerequisites:*** graduate standing or consent of instructor.

MAE 290B. Numerical Methods for Differential Equations (4)

Numerical solution of differential equations in mathematical physics and engineering, ordinary and partial differential equations. Linear and nonlinear hyperbolic parabolic, and elliptic equations, with emphasis on prototypical cases, the convection-diffusion equation, Laplace's and Poisson equation. Finite difference methods will be considered in depth, and additional topics. ***Prerequisites:*** MAE 290A or consent of instructor.

MAE 290C. Computational Fluid Dynamics (4)

Numerical methods in fluid dynamics and convective transport processes. Numerical solution of the Euler and Navier-Stokes equation. Additional topics will vary according to instructor. Examples include eigenvalue problems in hydrodynamic stability, vortex methods, spectral and panel methods. Students may not receive credit for both MAE 290C and MAE 223. ***Prerequisites:*** MAE 210A-B, 290A-B.

MAE 291. Design and Mechanics in Computer Technology (4)

Design and mechanics problems inherent in computer peripherals such as disk files, tape drives, and printers. Formulation and solution of problems involving mechanics, fluid mechanics, and materials; Reynolds equation, slider bearings; friction and wear; actuator design, impact printing; silicon fluid jets. ***Prerequisites:*** consent of instructor. (Not offered every year.)

MAE 292. Computer-Aided Design and Analysis (4)

Introduction to 2-D and 3-D computer-aided design. Design problems may include: ball bearing kinematics, Weibull statistics, nonrepeatable spindle run-out, four bar linkages, beam deflection and vibration, design of magnetic head suspension, hydrodynamic theory of lubrication, air bearings, heat transfer, optical servo, design of ink jet print head. ***Prerequisites:*** consent of instructor. (Not offered every year.)

MAE 293. Flow Control (4)

Intersection of control theory and fluid mechanics. Applications: transition delay, turbulence mitigation, noise reduction, weather forecasting, shape optimization, and UAV's (perching). Tractable feedback (Riccati-based) formulations via parallel and parabolic flow assumptions. Regularization of variational (adjoint-based) formulations for MPC and MHE. EnKF and EnVE approaches for forecasting. ***Prerequisites****:* MAE 290A or consent of instructor.

MAE 294A. Introduction to Applied Mathematics (4)

(Cross-listed with SIO 203A.) Review of exact methods for ordinary differential equations. Expansions about regular and irregular singular points. Introduction to asymptotic expansions. Approximate methods for nonlinear differential equations. Regular and singular perturbation theory. Additional topics depending upon the interests of the instructor.

MAE 294B. Introduction to Applied Mathematics II (4)
(Cross-listed with SIO 203B.) Asymptotic methods: method of steepest descent (if not covered in I) WKB, method of multiple scales, boundary layer theory. Elements of complex analysis. ***Prerequisites:*** MAE 294A or SIO 203A or consent of instructor.
MAE 294C. Introduction to Applied Mathematics III (4)
(Cross-listed with SIO 203C.) Partial differential equations: characteristics, similarity solutions, Green's functions, images, wave equation, diffusion equation, Laplace's equation. Applications to continuum mechanics, potential fields, and transport phenomena such as diffusion, linear and nonlinear waves, Burger's equation and shocks. Other topics according to the interests of the instructor. ***Prerequisites:*** MAE 294B, or SIO 203B, or SIO 215B, or consent of instructor.
MAE 295. Field Study (1–12)
Provides field study in industry with faculty supervision. Analysis and problem solving using real world applications. ***Prerequisites:*** consent of adviser and department; 3.0 GPA.
MAE 296. Independent Study (1–4)
Independent reading or research on a problem as arranged by a designated faculty member. Must be taken for a letter grade only. ***Prerequisites:*** consent of instructor.
MAE 298. Directed Group Study (1–4)
Directed group study on a topic or in a field not included in regular department curriculum, by special arrangement with a faculty member. ***Prerequisites:***consent of instructor. (S/U grades permitted.)
MAE 299. Graduate Research (1–12)
Independent work by graduate students engaged in research and writing theses. MAE graduate students only. (S/U grades only.)
MAE 501. Teaching Experience (2)
Teaching experience in an appropriate MAE undergraduate course under direction of the faculty member in charge of the course. Lecturing one hour per week in either a problem-solving section or regular lecture. (S/U grade only.) ***Prerequisites:*** consent of instructor and the MAE department.
Master of Advanced Studies—Medical Device Engineering
MDE 209. Mechanics and Transport Phenomena for Biomedical Device Design (4)
Introduction to the basic definitions of continuum mechanics and their mathematical formulation at the graduate level with applications to problems in medicine and biology. ***Prerequisites:*** MDE students only.
MDE 210. Medical Devices: Clinical Perspectives (4)
This course is a seminar series with invited clinician speakers intended to address needs and opportunities for meaningful application of engineering principles in clinical practice, with emphasis on next generation medical devices. ***Prerequisites:*** MDE students only.
MDE 225A. Biobusiness: Small to Large I (2)
First in a two-quarter series focusing on early stages of a business plan. Biotech is a special breed of business, especially in the start-up and early phases. You will study and analyze (1) start-up proposals, (2) the genesis of the biotech industry, (3) biotech categories and growth strategies, (4) the process of spinning out viable product concepts from academia, (5) financing techniques, (6) business development, (7) acquisition/IPO valuation methods, and (8)

potentially disruptive technologies. Students may not receive credit for both MDE 225 and MDE 225A. ***Prerequisites:*** MDE students only.

MDE 225B. Biobusiness: Small to Large II (2)

Second in a two-quarter series focusing on finalizing and completing a business plan. In this course, you will study and analyze (1) start-up proposals, (2) the genesis of the biotech industry, (3) biotech categories and growth strategies, (4) the process of spinning out viable product concepts from academia, (5) financing techniques, (6) business development, (7) acquisition/IPO valuation methods, and (8) potentially disruptive technologies to finalize your business plan. Students may not receive credit for both MDE 225 and MDE 225B. ***Prerequisites:*** MDE 225A. MDE students only.

MDE 230. Life Sciences and Technologies (4)

A general survey of modern high-throughput instruments used for imaging and analyzing structure-function relationships at the molecular and cellular levels. An overview of potential human genomic and systems approaches for designing and validating medical device safety and performance. ***Prerequisites:*** MDE students only.

MDE 231A. Fundamentals of Physiology and Anatomy I (2)

A basic introduction to human physiology and anatomy form and function as it relates to clinical perspectives on patient needs. Students may not receive credit for both MDE 231A and MDE 231. ***Prerequisites:*** MDE students only.

MDE 231B. Fundamentals of Physiology and Anatomy II (2)

Case studies of integrative physiology to understand how this information is used in designing combination medical devices and instruments for diagnosis or research. Students may not receive credit for both MDE 231A and MDE 231. ***Prerequisites****:* MDE 231A. MDE students only.

MDE 240. Embedded System Design (4)

This course gives an introduction to digital signal processing (DSP) techniques and data-based parameter estimation (DBPE) techniques for the measurement, filtering, and analysis of experimental data obtained with embedded systems in medical devices. ***Prerequisites****:* consent of instructor. MDE students only.

MDE 260A. Design and Implementation of Medical Device Technology I (1)

Introduction of project-based course in medical device engineering, medical product regulation, quality systems and standards, engineering project management, and business development. ***Prerequisites:*** MDE students only.

MDE 260B. Design and Implementation of Medical Device Technology II (2)

Second of a three-quarter sequence, project-based course in medical device engineering, medical product regulation, quality systems and standards, engineering project management, and business development. Students will begin to design a medical device and an engineering strategy. ***Prerequisites****:* MDE 260A and consent of instructor. MDE students only.

MDE 260C. Design and Implementation of Medical Device Technology III (1)

Third of a three-quarter sequence, project-based course in medical device engineering, medical product regulation, quality systems and standards, engineering project management, and business development. Students will complete and implement their medical device design and engineering strategy. ***Prerequisites****:* MDE 260B and consent of instructor. MDE students only.

MDE 266. Biomaterials for Medical Device Design (4)

This class will cover biomaterials and biomimetic materials. Metal, ceramic, and polymer biomaterials will be discussed. Emphasis will be on the structure-property relationships, biocompatibility/degradation issues, and tissue/material interactions. Synthesis and mechanical testing of biomimetic materials will also be discussed. ***Prerequisites****:* consent of instructor. MDE students only.

MDE 292. Computer Aided Design of Medical Devices (4)

Computer-aided analysis and design with applications to medical devices. Solid model representation, finite element analysis for strength and deformation, material selection, kinematics, statistical analysis, and visualization of analytical results. Software packages used will include 3D CAD, FEA solvers, and student generated code. Analytical methods will be applied to case studies of medical devices. ***Prerequisites:*** MDE students only.

Physics

Upper Division

PHYS 100A. Electromagnetism I (4)

Coulomb's law, electric fields, electrostatics; conductors and dielectrics; steady currents, elements of circuit theory. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2C or 4D, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH and Math 18 or 20F or 31AH. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 100B. Electromagnetism II (4)

Magnetic fields and magnetostatics, magnetic materials, induction, AC circuits, displacement currents; development of Maxwell's equations. ***Prerequisites:***Physics 100A, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH, Math 18 or 20F or 31AH. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 100C. Electromagnetism III (4)

Electromagnetic waves, radiation theory; application to optics; motion of charged particles in electromagnetic fields; relation of electromagnetism to relativistic concepts. ***Prerequisites:*** Physics 100B.

PHYS 105A. Mathematical and Computational Physics I (4)

A combined analytic and mathematically-based numerical approach to the solution of common applied mathematics problems in physics and engineering. Topics: Fourier series and integrals, special functions, initial and boundary value problems, Green's functions; heat, Laplace and wave equations. ***Prerequisites:*** Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH, Math 18 or 20F or 31AH. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 105B. Mathematical and Computational Physics II (4)

A continuation of Physics 105A covering selected advanced topics in applied mathematical and numerical methods. Topics include statistics, diffusion and Monte-Carlo simulations; Laplace equation and numerical methods for nonseparable geometries; waves in inhomogeneous media, WKB analysis; nonlinear systems and chaos. ***Prerequisites:*** Physics 105A, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH, Math 18 or 20F or 31AH.

PHYS 110A. Mechanics I (4)

Phase flows, bifurcations, linear oscillations, calculus of variations, Lagrangian dynamics, conservation laws, central forces, systems of particles, collisions, coupled oscillations. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2C or 4D, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH, Math 18 or 20F or 31AH. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 110B. Mechanics II (4)

Noninertial reference systems, dynamics of rigid bodies, Hamilton's equations, Liouville's theorem, chaos, continuum mechanics, special relativity. ***Prerequisites:*** Physics 110A, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH, Math 18 or 20F or 31AH. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 111. Introduction to Ocean Waves (4)

The linear theory of ocean surface waves, including group velocity, wave dispersion, ray theory, wave measurement and prediction, shoaling waves, giant waves, ship wakes, tsunamis, and the physics of the surf zone. Cross-listed with SIO 111. Students cannot earn credit for both Physics 111 and SIO 111. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Math 20A, Math 20B, Math 20C or 31BH, Math 20D, Math 20E or 31CH.

PHYS 116. Fluid Dynamics for Physicists (4)

This is a basic course in fluid dynamics for advanced students. The course consists of core fundamentals and modules on advanced applications to physical and biological phenomena. Core fundamentals include Euler and Navier-Stokes equations, potential and Stokesian flow, instabilities, boundary layers, turbulence, and shocks. Module topics include MHD, waves, and the physics of locomotion and olfaction. May be coscheduled with Physics 216. ***Prerequisites:*** Physics 100C and Physics 110B. Open to senior-level students only.

PHYS 120. Circuits and Electronics (5)

Laboratory and lecture course that covers principles of analog circuit theory and design, linear systems theory, and practical aspects of circuit realization, debugging, and characterization. Laboratory exercises include passive circuits, active filters and amplifiers with discrete and monolithic devices, nonlinear circuits, interfaces to sensors and actuators, and the digitization of analog signals. Physics 120 was formerly numbered Physics 120A. Program or materials fees may apply. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, and Physics 2CL. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only. ***Recommended preparation:*** Physics 100A.

PHYS 122. Experimental Techniques (4)

Laboratory-lecture course covering practical techniques used in research laboratories. Possible topics include: computer interfacing of instruments, sensors, and actuators; programming for data acquisition/analysis; electronics; measurement techniques; mechanical design/machining; mechanics of materials; thermal design/control; vacuum/cryogenic techniques; optics; particle detection. Physics 122 was formerly numbered Physics 121. Program or materials fees may apply. ***Prerequisites:*** Physics 120.

PHYS 124. Laboratory Projects (4)

A laboratory-lecture-project course featuring creation of an experimental apparatus in teams of about two. Emphasis is on electronic sensing of the physical environment and actuating physical responses. The course will use a computer interface such as the Arduino. Physics 124 was formerly numbered Physics 120B. Program or materials fees may apply. ***Prerequisites:*** Physics 120.

PHYS 130A. Quantum Physics I (4)

Development of quantum mechanics. Wave mechanics; measurement postulate and measurement problem. Piece-wise constant potentials, simple harmonic oscillator, central field and the hydrogen atom. Three hours lecture, one-hour discussion session. ***Prerequisites:*** Physics 2D or 4E, Physics 100A, Physics 110A. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 130B. Quantum Physics II (4)

Matrix mechanics, angular momentum, spin, and the two-state system. Approximation methods and the hydrogen spectrum. Identical particles, atomic and nuclear structures. Scattering theory. Three hours lecture, one-hour discussion session. ***Prerequisites:*** Physics 100B

and Physics 130A. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 130C. Quantum Physics III (4)

Quantized electromagnetic fields and introductory quantum optics. Symmetry and conservation laws. Introductory many-body physics. Density matrix, quantum coherence and dissipation. The relativistic electron. Three-hour lecture, one-hour discussion session. ***Prerequisites:*** Physics 130B.

PHYS 133. Condensed Matter/Materials Science Laboratory (4)

A project-oriented laboratory course utilizing state-of-the-art experimental techniques in materials science. The course prepares students for research in a modern condensed matter-materials science laboratory. Under supervision, the students develop their own experimental ideas after investigating current research literature. With the use of sophisticated state-of-the-art instrumentation students conduct research, write a research paper, and make verbal presentations. Program or materials fees may apply. ***Prerequisites:*** Physics 2CL and Physics 2DL.

PHYS 137. String Theory (4)

Quantum mechanics and gravity. Electromagnetism from gravity and extra dimensions. Unification of forces. Quantum black holes. Properties of strings and branes. ***Prerequisites:*** Physics 100A, Physics 110A, Physics 130A.

PHYS 139. Physics Special Topics (4)

From time to time a member of the regular faculty or a resident visitor will give a self-contained short course on a topic in his or her special area of research. This course is not offered on a regular basis, but it is estimated that it will be given once each academic year. Course may be taken for credit up to two times as topics vary (the course subtitle will be different for each distinct topic). Students who repeat the same topic in Physics 139 will have the duplicate credit removed from their academic record. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E, Math 20A, Math 20B, Math 20C or 31BH, Math 18 or 20F or 31AH.

PHYS 140A. Statistical and Thermal Physics I (4)

Integrated treatment of thermodynamics and statistical mechanics; statistical treatment of entropy, review of elementary probability theory, canonical distribution, partition function, free energy, phase equilibrium, introduction to ideal quantum gases. ***Prerequisites:*** Physics 130A. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only. (F)

PHYS 140B. Statistical and Thermal Physics II (4)

Applications of the theory of ideal quantum gases in condensed matter physics, nuclear physics and astrophysics; advanced thermodynamics, the third law, chemical equilibrium, low temperature physics; kinetic theory and transport in nonequilibrium systems; introduction to critical phenomena including mean field theory. ***Prerequisites:*** Physics 130B and Physics 140A. Open to major codes PY26, PY28, PY29, PY30, PY31, PY32, PY33, and PY34 only.

PHYS 141. Computational Physics I: Probabilistic Models and Simulations (4)

Project-based computational physics laboratory course with student's choice of Fortran 90/95, or C/C++. Applications from materials science to the structure of the early universe are chosen from molecular dynamics, classical and quantum Monte Carlo methods, physical Langevin/Fokker-Planck processes. ***Prerequisites:*** upper-division standing.

PHYS 142. Computational Physics II: PDE and Matrix Models (4)
Project-based computational physics laboratory course for modern physics and engineering problems with student's choice of Fortran90/95, or C/C++. Applications of finite element PDE models are chosen from quantum mechanics and nanodevices, fluid dynamics, electromagnetism, materials physics, and other modern topics. ***Prerequisites:*** upper-division standing.

PHYS 151. Elementary Plasma Physics (4)
Particle motions, plasmas as fluids, waves, diffusion, equilibrium and stability, nonlinear effects, controlled fusion. Cross-listed with MAE 117A. Students cannot earn credit for both Physics 151 and MAE 117A. ***Prerequisites:*** Math 20D. ***Recommended preparation:*** Physics 100B and Physics 100C or ECE 107.

PHYS 152A. Condensed Matter Physics (4)
Physics of the solid-state. Binding mechanisms, crystal structures and symmetries, diffraction, reciprocal space, phonons, free and nearly free electron models, energy bands, solid-state thermodynamics, kinetic theory and transport, semiconductors. ***Prerequisites:*** Physics 130A or Chemistry 130. ***Corequisites:***Physics 140A.

PHYS 152B. Electronic Materials (4)
Physics of electronic materials. Semiconductors: bands, donors and acceptors, devices. Metals: Fermi surface, screening, optical properties. Insulators: dia-/ferro-electrics, displacive transitions. Magnets: dia-/para-/ferro-/antiferro-magnetism, phase transitions, low temperature properties. Superconductors: pairing, Meissner effect, flux quantization, BCS theory. ***Prerequisites:*** Physics 152A.

PHYS 154. Elementary Particle Physics (4)
The constituents of matter (quarks and leptons) and their interactions (strong, electromagnetic, and weak). Symmetries and conservation laws. Fundamental processes involving quarks and leptons. Unification of weak and electromagnetic interactions. Particle-astrophysics and the Big Bang. ***Prerequisites:*** Physics 130B.

PHYS 160. Stellar Astrophysics (4)
Introduction to stellar astrophysics: observational properties of stars, solar physics, radiation and energy transport in stars, stellar spectroscopy, nuclear processes in stars, stellar structure and evolution, degenerate matter and compact stellar objects, supernovae and nucleosynthesis. Physics 160, 161, 162, and 163 may be taken as a four-quarter sequence for students interested in pursuing graduate study in astrophysics or individually as topics of interest. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E.

PHYS 161. Black Holes (4)
An introduction to Einstein's theory of general relativity with emphasis on the physics of black holes. Topics will include metrics and curved space-time, the Schwarzchild metric, motion around and inside black holes, rotating black holes, gravitational lensing, gravity waves, Hawking radiation, and observations of black holes. Physics 160, 161, 162, and 163 may be taken as a four-quarter sequence for students interested in pursuing graduate study in astrophysics or individually as topics of interest. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E.

PHYS 162. Cosmology (4)

The expanding Universe, the Friedman-Robertson-Walker equations, dark matter, dark energy, and the formation of galaxies and large scale structure. Topics in observational cosmology, including how to measure distances and times, and the age, density, and size of the Universe. Topics in the early Universe, including the cosmic microwave background, creation of the elements, cosmic inflation, the big bang. Physics 160, 161, 162, and 163 may be taken as a four-quarter sequence for students interested in pursuing graduate study in astrophysics or individually as topics of interest. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E.

PHYS 163. Galaxies and Quasars (4)

An introduction to the structure and properties of galaxies in the universe. Topics covered include the Milky Way, the interstellar medium, properties of spiral and elliptical galaxies, rotation curves, starburst galaxies, galaxy formation and evolution, large-scale structure, and active galaxies and quasars. Physics 160, 161, 162, and 163 may be taken as a four-quarter sequence in any order for students interested in pursuing graduate study in astrophysics or individually as topics of interest. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E.

PHYS 164. Observational Astrophysics Research Lab (4)

Project-based course developing tools and techniques of observational astrophysical research: photon counting, imaging, spectroscopy, astrometry; collecting data at the telescope; data reduction and analysis; probability functions; error analysis techniques; and scientific writing. ***Prerequisites:*** Physics 2A or 4A, Physics 2B or 4C, Physics 2C or 4B, Physics 2D or 4D, Physics 2D or 4E. ***Recommended preparation:*** concurrent enrollment or completion of one course from Physics 160, 161, 162, or 163 is recommended.

PHYS 170. Medical Instruments: Principles and Practice (4)

The principles and clinical applications of medical diagnostic instruments, including electromagnetic measurements, spectroscopy, microscopy; ultrasounds, X-rays, MRI, tomography, lasers in surgery, fiber optics in diagnostics. ***Prerequisites:*** Physics 1B or 2B or 4C, and Physics 1C or 2C or 4B.

PHYS 173. Modern Physics Laboratory: Biological and Quantum Physics (4)

A selection of experiments in contemporary physics and biophysics. Students select among pulsed NMR, Mossbauer, Zeeman effect, light scattering, holography, optical trapping, voltage clamp and genetic transcription of ion channels in oocytes, fluorescent imaging, and flight control in flies. ***Prerequisites:***Physics 120 and BILD 1 and Chemistry 7L.

PHYS 175. Biological Physics (4)

This course teaches how quantitative models derived from statistical physics can be used to build quantitative, intuitive understanding of biological phenomena. Case studies include ion channels, cooperative binding, gene regulation, protein folding, molecular motor dynamics, cytoskeletal assembly, and biological electricity. ***Prerequisites:*** Chemistry 132 or the combination of Physics 100A and Physics 110A. ***Corequisites:*** Physics 140A.

PHYS 176. Quantitative Molecular Biology (4)

A quantitative approach to gene regulation including transcriptional and posttranscriptional control of gene expression, as well as feedback and stochastic effects in genetic circuits. These topics will be integrated into the control of bacterial growth and

metabolism. ***Prerequisites:*** Physics 140A. ***Recommended preparation:*** an introductory course in biology is helpful but not necessary.

PHYS 177. Physics of the Cell (4)

The use of dynamic systems and nonequilibrium statistical mechanics to understand the biological cell. Topics chosen from: chemotaxis as a model system; signal transduction networks and cellular information processing; mechanics of the membrane; cytoskeletal dynamics; nonlinear Calcium waves. May be scheduled with Physics 277. ***Prerequisites:*** upper-division standing. ***Recommended preparation:*** an introductory course in biology is helpful but not necessary.

PHYS 178. Biophysics of Neurons and Networks (4)

Information processing by nervous system through physical reasoning and mathematical analysis. A review of the biophysics of neurons and synapses and fundamental limits to signaling by nervous systems is followed by essential aspects of the dynamics of phase coupled neuronal oscillators, the dynamics and computational capabilities of recurrent neuronal networks, and the computational capability of layered networks. ***Prerequisites:*** upper-division standing. ***Recommended preparation:*** a working knowledge of calculus and linear algebra.

PHYS 191. Undergraduate Seminar on Physics (1)

Undergraduate seminars organized around the research interests of various faculty members. P/NP grades only. ***Prerequisites:*** Physics 2A or Physics 4A.

PHYS 192. Senior Seminar in Physics (1)

The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in Physics (at the upper-division level). Senior Seminars may be offered in all campus departments. Topics will vary from quarter to quarter. Senior Seminars may be taken for credit up to four times, with a change in topic, and permission of the department. Enrollment is limited to twenty students, with preference given to seniors.

PHYS 198. Directed Group Study (2 or 4)

Directed group study on a topic or in a field not included in the regular departmental curriculum. (P/NP grades only.) ***Prerequisites:*** consent of instructor and departmental chair.

PHYS 199. Research for Undergraduates (2 or 4)

Independent reading or research on a problem by special arrangement with a faculty member. (P/NP grades only.) ***Prerequisites:*** consent of instructor and departmental chair.

PHYS 199H. Honors Thesis Research for Undergraduates (2–4)

Honors thesis research for seniors participating in the Honors Program. Research is conducted under the supervision of a physics faculty member. ***Prerequisites:*** admission to the Honors Program in Physics.

Graduate

PHYS 200A. Theoretical Mechanics I (4)

Lagrange's equations and Hamilton's principle; symmetry and constants of the motion. Applications to: charged particle motion; central forces and scattering theory; small oscillations; anharmonic oscillations; rigid body motion; continuum mechanics.

PHYS 200B. Theoretical Mechanics II (4)

Hamilton's equations, canonical transformations; Hamilton-Jacobi theory; action-angle variables and adiabatic invariants; introduction to canonical perturbation theory, nonintegrable systems and chaos; Liouville equation; ergodicity and mixing; entropy; statistical ensembles. ***Prerequisites:*** Physics 200A.

PHYS 201. Mathematical Physics (5)

An introduction to mathematical methods used in theoretical physics. Topics include: a review of complex variable theory, applications of the Cauchy residue theorem, asymptotic series, method of steepest descent, Fourier and Laplace transforms, series solutions for ODE's and related special functions, Sturm Liouville theory, variational principles, boundary value problems, and Green's function techniques.

PHYS 203A. Advanced Classical Electrodynamics I (5)

Electrostatics, symmetries of Laplace's equation and methods for solution, boundary value problems, electrostatics in macroscopic media, magnetostatics, Maxwell's equations, Green functions for Maxwell's equations, plane wave solutions, plane waves in macroscopic media.

PHYS 203B. Advanced Classical Electrodynamics II (4)

Special theory of relativity, covariant formulation of electrodynamics, radiation from current distributions and accelerated charges, multipole radiation fields, waveguides and resonant cavities. ***Prerequisites:*** Physics 203A.

PHYS 210A. Equilibrium Statistical Mechanics (5)

Approach to equilibrium: BBGKY hierarchy; Boltzmann equation; H-theorem. Ensemble theory; thermodynamic potentials. Quantum statistics; Bose condensation. Interacting systems: Cluster expansion; phase transition via mean-field theory; the Ginzburg criterion. ***Prerequisites:*** Physics 200A-B. ***Corequisites:*** Physics 212C.

PHYS 210B. Nonequilibrium Statistical Mechanics (4)

Transport phenomena; kinetic theory and the Chapman-Enskog method; hydrodynamic theory; nonlinear effects and the mode coupling method. Stochastic processes; Langevin and Fokker-Planck equation; fluctuation-dissipation relation; multiplicative processes; dynamic field theory; Martin-Siggia-Rose formalism; dynamical scaling theory. ***Prerequisites:*** Physics 210A.

PHYS 211A. Solid-State Physics I (5)

The first of a two-quarter course in solid-state physics. Covers a range of solid-state phenomena that can be understood within an independent particle description. Topics include: chemical versus band-theoretical description of solids, electronic band structure calculation, lattice dynamics, transport phenomena and electrodynamics in metals, optical properties, semiconductor physics.

PHYS 211B. Solid-State Physics II (4)

Deals with collective effects in solids arising from interactions between constituents. Topics include electron-electron and electron-phonon interactions, screening, band structure effects,

Landau Fermi liquid theory. Magnetism in metals and insulators, superconductivity; occurrence, phenomenology, and microscopic theory. ***Prerequisites:*** Physics 210A and Physics 211A.

PHYS 212A. Quantum Mechanics I (4)

Quantum principles of state (pure, composite, entangled, mixed), observables, time evolution, and measurement postulate. Simple soluble systems: two-state, harmonic oscillator, and spherical potentials. Angular momentum and spin. Time-independent approximations.

PHYS 212B. Quantum Mechanics II (4)

Symmetry theory and conservation laws: time reversal, discrete, translation and rotational groups. Potential scattering. Time-dependent perturbation theory. Quantization of Electromagnetic fields and transition rates. Identical particles. Open systems: mixed states, dissipation, decoherence. ***Prerequisites:*** Physics 212A.

PHYS 212C. Quantum Mechanics III (4)

Scattering with internal degrees of freedom. Path integrals, topological phases, and Bohm-Aharonov effect. Interacting fermions and bosons. Introductory quantum optics. The measurement problem. The relativistic electron. ***Prerequisites:*** Physics 212A-B.

PHYS 214. Physics of Elementary Particles (4)

Classification of particles using symmetries and invariance principles, quarks and leptons, quantum electrodynamics, weak interactions, e+p- interactions, deep-inelastic lepton-nucleon scattering, pp collisions, introduction to QCD. ***Prerequisites:*** Physics 215A.

PHYS 215A. Particles and Fields I (4)

The first quarter of a three-quarter course on field theory and elementary particle physics. Topics covered include the relation between symmetries and conservation laws, the calculation of cross sections and reaction rates, covariant perturbation theory, and quantum electrodynamics.

PHYS 215B. Particles and Fields II (4)

Gauge theory quantization by means of path integrals, SU(3) symmetry and the quark model, spontaneous symmetry breakdown, introduction to QCD and the Glashow-Weinberg-Salam model of weak interactions, basic issues of renormalization. ***Prerequisites:*** Physics 215A.

PHYS 215C. Particles and Fields III (4)

Modern applications of the renormalization group in quantum chromodynamics and the weak interactions. Unified gauge theories, particle cosmology, and special topics in particle theory. ***Prerequisites:*** Physics 215A-B.

PHYS 216. Fluid Dynamics for Physicists (4)

This is a basic course in fluid dynamics for advanced students. The course consists of core fundamentals and modules on advanced applications to physical and biological phenomena. Core fundamentals include Euler and Navier-Stokes equations, potential and Stokesian flow, instabilities, boundary layers, turbulence, and shocks. Module topics include MHD, waves, and the physics of locomotion and olfaction. May be coscheduled with Physics 116. The performance criteria for graduate students will be to complete and pass: (1) a graduate-level exam and (2) graduate-level homework problem sets. In both cases, there will be overlap with the undergraduate exam and problems, but the graduates will be expected to complete additional work at a higher level.

PHYS 217. Field Theory and the Renormalization Group (4)

Application of field theoretic and renormalization group methods to problems in condensed matter, or particle physics. Topics will vary and may include: phase transition and critical phenomena; many body quantum systems; quantum chromodynamics and the electroweak model. ***Prerequisites:*** Physics 210A.

PHYS 218A. Plasma Physics I (4)

The basic physics of plasmas is discussed for the simple case of an unmagnetized plasma. Topics include: thermal equilibrium statistical properties, fluid and Landau theory of electron and ion plasma waves, velocity space instabilities, quasi-linear theory, fluctuations, scattering or radiation, Fokker-Planck equation.

PHYS 218B. Plasma Physics II (4)

This course deals with magnetized plasma. Topics include: Appleton-Hartree theory of waves in cold plasma, waves in warm plasma (Bernstein waves, cyclotron damping). MHD equations, MHD waves, low frequency modes, and the adiabatic theory of particle orbits. ***Prerequisites:*** Physics 218A.

PHYS 218C. Plasma Physics III (4)

This course deals with the physics of confined plasmas with particular relevance to controlled fusion. Topics include: topology of magnetic fields, confined plasma equilibria, energy principles, ballooning and kink instabilities, resistive MHD modes (tearing, rippling and pressure-driven), gyrokinetic theory, microinstabilities and anomalous transport, and laser-plasma interactions relevant to inertial fusion. ***Prerequisites:*** Physics 218B.

PHYS 219. Condensed Matter/Materials Science Laboratory (4)

A project-oriented laboratory course utilizing state-of-the-art experimental techniques in materials science. The course prepares students for research in a modern condensed matter-materials science laboratory. Under supervision, the students develop their own experimental ideas after investigating current research literature. With the use of sophisticated state-of-the-art instrumentation students conduct research, write a research paper, and make verbal presentations. ***Prerequisites:*** Physics 211A.

PHYS 220. Group Theoretical Methods in Physics (4)

Study of group theoretical methods with applications to problems in high energy, atomic, and condensed matter physics. Representation theory, tensor methods, Clebsh-Gordan series. Young tableaux. The course will cover discrete groups, Lie groups and Lie algebras, with emphasis on permutation, orthogonal, and unitary groups. ***Prerequisites:*** Physics 212C.

PHYS 221A. Nonlinear and Nonequilibrium Dynamics of Physical Systems (4)

An introduction to the modern theory of dynamical systems and applications thereof. Topics include maps and flows, bifurcation theory and normal form analysis, chaotic attractors in dissipative systems, Hamiltonian dynamics and the KAM theorem, and time series analysis. Examples from real physical systems will be stressed throughout. ***Prerequisites:*** Physics 200B.

PHYS 222A. Elementary Particle Physics (4)

Weak interactions; neutrino physics; C,P, and CP violation; electroweak gauge theory and symmetry breaking. Design of detectors and experiments; searches for new phenomena. ***Prerequisites:*** Physics 214.

PHYS 223. Stellar Structure and Evolution (4)

Energy generation, flow, hydrostatic equilibrium, equation of state. Dependence of stellar parameters (central surface temperature, radius, luminosity, etc.) on stellar mass and relation

to physical constants. Relationship of these parameters to the H-R diagram and stellar evolution. Stellar interiors, opacity sources, radiative and convective energy flow. Nuclear reactions, neutrino processes. Polytropic models. White dwarfs and neutron stars. (S/U grades permitted.)

PHYS 224. Physics of the Interstellar Medium (4)

Gaseous nebulae, molecular clouds, ionized regions, and dust. Low-energy processes in neutral and ionized gases. Interaction of matter with radiation, emission and absorption processes, formation of atomic lines. Energy balance, steady state temperatures, and the physics and properties of dust. Masers and molecular line emission. Dynamics and shocks in the interstellar medium. (S/U grades permitted.)

PHYS 225A-B. General Relativity (4-4)

This is a two-quarter course on gravitation and the general theory of relativity. The first quarter is intended to be offered every year and may be taken independently of the second quarter. The second quarter will be offered in alternate years. Topics covered in the first quarter include special relativity, differential geometry, the equivalence principle, the Einstein field equations, and experimental and observational tests of gravitation theories. The second quarter will focus on more advanced topics, including gravitational collapse, Schwarzschild and Kerr geometries, black holes, gravitational radiation, cosmology, and quantum gravitation.

PHYS 226. Galaxies and Galactic Dynamics (4)

The structure and dynamics of galaxies. Topics include potential theory, the theory of stellar orbits, self-consistent equilibria of stellar systems, stability and dynamics of stellar systems including relaxation and approach to equilibrium. Collisions between galaxies, galactic evolution, dark matter, and galaxy formation.

PHYS 227. Cosmology (4)

An advanced survey of topics in physical cosmology. The Friedmann models and the large-scale structure of the universe, including the observational determination of Ho (the Hubble constant) and qo (the deceleration parameter). Galaxy number counts. A systematic exposition of the physics of the early universe, including vacuum phase transitions; inflation; the generation of net baryon number, fluctuations, topological defects and textures. Primordial nucleosynthesis, both standard and nonstandard models. Growth and decay of adiabatic and isocurvature density fluctuations. Discussion of dark matter candidates and constraints from observation and experiment. Nucleocosmo-chronology and the determination of the age of the universe.

PHYS 228. High-Energy Astrophysics and Compact Objects (4)

The physics of compact objects, including the equation of state of dense matter and stellar stability theory. Maximum mass of neutron stars, white dwarfs, and super-massive objects. Black holes and accretion disks. Compact X-ray sources and transient phenomena, including X-ray and g-ray bursts. The fundamental physics of electromagnetic radiation mechanisms: synchrotron radiation, Compton scattering, thermal and nonthermal bremsstrahlung, pair production, pulsars. Particle acceleration models, neutrino production and energy loss mechanisms, supernovae, and neutron star production.

PHYS 230. Advanced Solid-State Physics (4)

Selection of advanced topics in solid-state physics; material covered may vary from year to year. Examples of topics covered: disordered systems, surface physics, strong-coupling superconductivity, quantum Hall effect, low-dimensional solids, heavy fermion systems, high-temperature superconductivity, solid and liquid helium. ***Prerequisites:*** Physics 211B.

PHYS 232. Electronic Materials (4)
Physics of electronic materials. Semiconductors: bands, donors and acceptors, devices. Metals: Fermi surface, screening, optical properties. Insulators: dia-/ferro-electrics, displacive transitions. Magnets: dia-/para-/ferro-/antiferro-magnetism, phase transitions, low temperature properties. Superconductors: pairing, Meissner effect, flux quantization, BCS theory. ***Prerequisites:*** Physics 211A.

PHYS 235. Nonlinear Plasma Theory (4)
This course deals with nonlinear phenomena in plasmas. Topics include: orbit perturbation theory, stochasticity, Arnold diffusion, nonlinear wave-particle and wave-wave interaction, resonance broadening, basics of fluid and plasma turbulence, closure methods, models of coherent structures. ***Prerequisites:*** Physics 218C.

PHYS 238. Observational Astrophysics Research Lab (4)
Project-based course developing tools and techniques of observational astrophysical research: photon counting, imaging, spectroscopy, astrometry; collecting data at the telescope; data reduction and analysis; probability functions; error analysis techniques; and scientific writing. Students will complete a final paper of publishable quality in the format of a peer-reviewed journal, as well as an oral presentation. ***Recommended preparation:*** undergraduate or graduate background in astrophysics.

PHYS 239. Special Topics (4)
From time to time a member of the regular faculty or a resident visitor will find it possible to give a self-contained short course on an advanced topic in his or her special area of research. This course is not offered on a regular basis, but it is estimated that it will be given once each academic year. (S/U grades permitted.)

PHYS 241. Computational Physics I: Probabilistic Models and Simulations (4)
Project-based computational physics laboratory course with student's choice of Fortran90/95 or C/C++. Applications from materials science to the structure of the early universe are chosen from molecular dynamics, classical and quantum Monte Carlo methods, physical Langevin/Fokker-Planck processes, and other modern topics.

PHYS 242. Computational Physics II: PDE and Matrix Models (4)
Project-based computational physics laboratory course for modern physics and engineering problems with student's choice of Fortran90/95 or C/C++. Applications of finite element PDE models are chosen from quantum mechanics and nanodevices, fluid dynamics, electromagnetism, materials physics, and other modern topics.

PHYS 243. Stochastic Methods (4)
Introduction to methods of stochastic modeling and simulation. Topics include: random variables; stochastic processes; Markov processes; one-step processes; the Fokker-Planck equation and Brownian motion; the Langevin approach; Monte-Carlo methods; fluctuations and the Boltzmann equation; and stochastic differential equations.

PHYS 244. Parallel Computing in Science and Engineering (4)
Introduction to basic techniques of parallel computing, the design of parallel algorithms, and their scientific and engineering applications. Topics include: parallel computing platforms; message-passing model and software; design and application of parallel software packages; parallel visualization; parallel applications.

PHYS 250. Condensed Matter Physics Seminar (0–1)

Discussion of current research in physics of the solid state and of other condensed matter. (S/U grades only.)

PHYS 251. High-Energy Physics Seminar (0–1)

Discussions of current research in nuclear physics, principally in the field of elementary particles. (S/U grades only.)

PHYS 252. Plasma Physics Seminar (0–1)

Discussions of recent research in plasma physics. (S/U grades only.)

PHYS 253. Astrophysics and Space Physics Seminar (0–1)

Discussions of recent research in astrophysics and space physics. (S/U grades only.)

PHYS 254. Biophysics Seminar (1)

Presentation of current research in biological physics and quantitative biology by invited speakers from the United States and abroad. (S/U grades only.) May be taken for credit thirty times.

PHYS 255. Biophysics Research Talks (1)

Discussion of recent research in biological physics and quantitative biology by current graduate students. (S/U grades only.) May be taken for credit thirty times.

PHYS 256. Critical Reading in Quantitative Biology (1)

Critical analysis of classic and current literature in quantitative biology, involving written critiques and group discussion. (S/U grades only.) May be taken for credit thirty times.

PHYS 257. High-Energy Physics Special Topics Seminar (0–1)

Discussions of current research in high-energy physics. (S/U grades only.)

PHYS 258. Astrophysics and Space Physics Special Topics Seminar (0–1)

Discussions of current research in astrophysics and space physics. (S/U grades only.)

PHYS 260. Physics Colloquium (0–1)

Discussions of recent research in physics directed to the entire physics community. (S/U grades only.)

PHYS 261. Seminar on Physics Research at UC San Diego (0–1)

Discussions of current research conducted by faculty members in the Department of Physics. (S/U grades only.)

PHYS 264. Scientific Method Seminar (1)

Discussions of the application of the scientific method in the natural sciences. (S/U grades only.) May be taken for credit twenty-five times.

PHYS 270A. Experimental Techniques for Quantitative Biology (4)

A hands-on laboratory course in which the students learn and use experimental techniques, including optics, electronics, chemistry, machining, and computer interface, to design and develop simple instruments for quantitative characterization of living systems. Lab classes will comprise five two-week modules. ***Prerequisites:*** department approval required. ***Recommended preparation:*** knowledge of electronics and optics at the level of introductory calculus, basic statistics, programming skills; knowledge of introductory biology.

PHYS 270B. Quantitative Biology Laboratory (4)

A project-oriented laboratory course in which students are guided to develop their own ideas and tools, along with using state-of-art instruments to investigate a biological problem of current interest, under the direction of a faculty member. A range of current topics in quantitative biology is available, including microbiology, molecular and cell biology,

developmental biology, synthetic biology, and evolution. This course may be repeated up to ten times for credit as long as the student works on a different project. ***Prerequisites:*** Physics 270A. Department approval required.

PHYS 273. Information Theory and Pattern Formation in Biological Systems (4)

This course discusses how living systems acquire information on their environment and exploit it to generate structures and perform functions. Biological sensing of concentrations, reaction-diffusion equations, the Turing mechanism, and applications of information theory to cellular transduction pathways and animal behavior will be presented. ***Recommended preparation:*** familiarity with probabilities at the level of undergraduate statistical mechanics and major cellular processes; basic knowledge of information theory.

PHYS 274. Stochastic Processes in Population Genetics (4)

The course explores genetic diversity within biological populations. Genetics fundamentals, mutation/selection equilibria, speciation, Wright-Fisher model, Kimura's neutral theory, Luria-Delbrück test, the coalescent theory, evolutionary games and statistical methods for quantifying genetic observables such as SNPs, copy number variations, etc., will be discussed. ***Recommended preparation:*** familiarity with probabilities and PDEs at the undergraduate level; an introduction to basic evolutionary processes.

PHYS 275. Fundamentals of Biological Physics (4)

This course teaches how quantitative models derived from statistical physics can be used to build quantitative, intuitive understanding of biological phenomena. Case studies include ion channels, cooperative binding, gene regulation, protein folding, molecular motor dynamics, cytoskeletal assembly, and biological electricity. ***Recommended preparation:*** an introduction to statistical mechanics, at least at the level of Physics 140A or Chemistry 132.

PHYS 276. Quantitative Molecular Biology (4)

A quantitative approach to gene regulation, including transcriptional and posttranscriptional control of gene expression, as well as feedback and stochastic effects in genetic circuits. These topics will be integrated into the control of bacterial growth and metabolism. ***Recommended preparation:*** an introductory course in biology is helpful but not necessary.

PHYS 277. Physics of the Cell (4)

The use of dynamic systems and nonequilibrium statistical mechanics to understand the biological cell. Topics chosen from chemotaxis as a model system, signal transduction networks and cellular information processing, mechanics of the membrane, cytoskeletal dynamics, nonlinear Calcium waves. The graduate version will include a report at the level of a research paper. May be scheduled with Physics 177. ***Recommended preparation:*** an introductory course in biology is helpful but not necessary.

PHYS 278. Biophysics of Neurons and Networks (4)

Information processing by nervous system through physical reasoning and mathematical analysis. A review of the biophysics of neurons and synapses and fundamental limits to signaling by nervous systems is followed by essential aspects of the dynamics of phase coupled neuronal oscillators, the dynamics and computational capabilities of recurrent neuronal networks, and the computational capability of layered networks. ***Recommended preparation:*** a working knowledge of calculus and linear algebra.

PHYS 279. Neurodynamics (4)

Introduction to the nonlinear dynamics of neurons and simple neural systems through nonlinear dynamics, bifurcation theory, and chaotic motions. The dynamics of single cells is considered at different levels of abstraction, e.g., biophysical and "reduced" models for analysis of regularly spiking and bursting cells, their dynamical properties, and their representation in phase space. Laboratory exercises will accompany the lectures. Duplicate credit not allowed for cross-listed courses: BGGN 260, BENG 260, Physics 279.

PHYS 281. Extensions in Physics (1–3)

This course covers topics not traditionally taught as part of a normal physics curriculum, but nonetheless useful extensions to the classic pedagogy. Example topics may include estimation, nuclear physics, fluid mechanics, and scaling relationships.

PHYS 295. MS Thesis Research in Materials Physics (1–12)

Directed research on MS dissertation topic.

PHYS 297. Special Studies in Physics (1–4)

Studies of special topics in physics under the direction of a faculty member. ***Prerequisites:*** consent of instructor and departmental vice chair, education. (S/U grades permitted.)

PHYS 298. Directed Study in Physics (1–12)

Research studies under the direction of a faculty member. (S/U grades permitted.)

PHYS 299. Thesis Research in Physics (1–12)

Directed research on dissertation topic.

PHYS 500. Instruction in Physics Teaching (1–4)

This course, designed for graduate students, includes discussion of teaching, techniques and materials necessary to teach physics courses. One meeting per week with course instructors, one meeting per week in an assigned recitation section, problem session, or laboratory section. Students are required to take a total of two units of Physics 500.

Scripps Institution of Oceanography

Upper Division

SIO 100. Introduction to Field Methods (4)

Mapping and interpretation of geologic units. Fieldwork is done locally and the data are analyzed in the laboratory. There will be one mandatory weekend field trip to Anza Borrego State Park. Program and/or materials fees may apply. ***Prerequisites:*** SIO 50 or consent of instructor. (F)

SIO 101. California Coastal Oceanography (4)

This course emphasizes oceanographic connections between physical and climate forcing and marine ecosystem responses using examples from and activities in the California coastal environment. The approach is inquiry-based, combining classroom and experiential learning to build critical and quantitative thinking and research insights and abilities. ***Prerequisites:*** Chem 6A or consent of instructor. (F)

SIO 102. Introduction to Geochemistry (4)

An introduction to the chemical composition and evolution of the Earth and solar system. Applications of chemical methods to elucidate the origin and geologic history of the Earth and the planets, evolution of oceans and atmosphere, and human environmental impacts. ***Prerequisites:*** SIO 50, Chem 6A-B-C, or consent of instructor. (W)

SIO 103. Introduction to Geophysics (4)

An introduction to the structure and composition of the solid earth. Topics include seismology, the gravity and magnetic fields, high-pressure geophysics, and concepts in geodynamics. Emphasis is on global geophysics, i.e., on the structure and evolution of the planet. ***Prerequisites:*** Math 20A-B-C-D and Physics 2A-B-C, SIO 50, or consent of instructor. SIO 160 recommended. (W)

SIO 104/SIOG 255. Paleobiology and History of Life (6)

An introduction to the major biological transitions in Earth history from the origins of metabolism and cells to the evolution of complex societies. The nature and limitations of the fossil record, patterns of adaptation and diversity, and the tempo and mode of biological evolution. Laboratories and substantial field component complement and extend the lecture material. Program and/or materials fees may apply. ***Prerequisites:*** undergraduate: BILD 3 or consent of instructor. Graduate: graduate-level standing or consent of instructor. Graduate students, additionally, will give oral presentation or research paper. (S)

SIO 105. Sedimentology and Stratigraphy (4)

This course will examine sedimentary environments from mountain tops to the deep sea across a variety of time scales. The focus is to develop the skills to interpret stratigraphy and read the history of the Earth that it records. Laboratories and substantial field component complement and extend lecture material. Program and/or course materials fees may apply. ***Prerequisites:*** SIO 50 or consent of instructor. (S)

SIO 106. Introduction to Hydrogeology (4)

An introduction to the theory and practice of hydrogeology, emphasizing current concepts of aquifer and water properties and practical considerations related to groundwater quality, groundwater flow, and sustainability of groundwater reservoirs. ***Prerequisites:*** SIO 50, Math 20C, Physics 2C, and Chemistry 6C; upper-division standing or consent of instructor. (F)

SIO 108. Introduction to Paleoclimatology (4)
An introduction to basic principles and applications of paleoclimatology, the study of climate and climate changes that occurred prior to the period of instrumental records. A review of processes and archives of climate data will be investigated using examples from Earth history. ***Prerequisites:*** ESYS 102 or SIO 50 or SIO 12 or consent of instructor.

SIO 109. Bending the Curve: Climate Change Solutions (4)
This course will focus on scalable solutions for carbon neutrality and climate stability. The course adopts climate change mitigation policies, technologies, governance, and actions that California, the UC system, and cities around the world have adopted as living laboratories and challenges students to identify locally and globally scalable solutions. (Students may not receive credit for POLI 117 and SIO 109.)

SIO 110. Introduction to GIS and GPS for Scientists (4)
A hands-on introduction to science applications of geographic information systems and global positioning system. Students acquire data through GPS field surveys, design and construct GIS using ESRI's ArcGIS software, analyze spatial data, and present the results in a web-based environment. ***Prerequisites:***upper-division standing or consent of instructor. (W)

SIO 111. Introduction to Ocean Waves (4)
The linear theory of ocean surface waves, including: group velocity, wave dispersion, ray theory, wave measurement and prediction, shoaling waves, giant waves, ship wakes, tsunamis, and the physics of the surf zone. Cross-listed with Physics 111. ***Prerequisites:*** Physics 2A–C or Physics 4A–C and Mathematics 20A–E, or consent of instructor. (W)

SIO 113. Introduction to Computational Earth Science (4)
Computers are used in the geosciences to understand complex natural systems. This course includes beginning programming with a user-friendly language (Python). ***Prerequisites:*** SIO 50 or consent of instructor. (S)

SIO 114. The Science and Analysis of Environmental Justice (4)
Introduction to the scientific basis and critical analysis of environmental justice, with an emphasis on case studies, activism, and community engagement. This course will prepare students to critique and develop scientific models, research designs, and measurements consistent with environmental justice. Students may not receive credit for ETHN 136 and SIO 114. **Prerequisites:** upper-division standing or consent of instructor.

SIO 115. Ice and the Climate System (4)
This course examines the Earth's cryosphere, including glaciers, ice sheets, ice caps, sea ice, lake ice, river ice, snow, and permafrost. We cover the important role of the cryosphere in the climate systems and its response to climate change. ***Prerequisites:*** Math 20A–D and Physics 2A–C or consent of instructor. (S)

SIO 116. Climate Change and Global Health: Understanding the Mechanisms (4)
This course will introduce students to the public health effects of global climate change. The course will begin by understanding the climate change phenomena and explaining the direct and indirect links between climate change and human health, including the public health impacts of infectious diseases, atmospheric air pollution, and extreme weather events. The second part of the course will be dedicated to adaption and mitigation solutions with a particular focus on vulnerable populations. Students may not receive credit for SIO 116 and SIO 116GS. ***Prerequisites:*** upper-division standing or consent of instructor.

SIO 116GS. Climate Change and Global Health: Understanding the Mechanisms (4)
This course will introduce students to the public health effects of global climate change. The course will begin by understanding the climate change phenomena and explaining the direct and indirect links between climate change and human health, including the public health impacts of infectious diseases, atmospheric air pollution, and extreme weather events. The second part of the course will be dedicated to adaption and mitigation solutions with a particular focus on vulnerable populations. Students may not receive credit for SIO 116GS and SIO 116. Program or materials fees may apply. ***Prerequisites:*** students must apply for and be accepted to the Global Seminars Program.

SIO 117. The Physical Basis of Global Warming (4)
Introduction to the processes behind global warming, including the physics of the greenhouse effect, controls on greenhouse gases, atmospheric and oceanic circulation, climate feedbacks, relationship to natural climate variability, and global environmental issues related to global warming. ***Prerequisites:*** Math 20D and Physics 2C or consent of instructor. (F)

SIO 118GS. Responding to Climate Change: Possible Solutions (4)
This course will be taught in Dharamsala, India, and explores societal solutions to climate change. Course topics include mitigation and adaptation policies, including a guide to design, implement, and evaluate an adaptation policy, and the public health cobenefits of addressing climate change. ***Prerequisites:***students must apply for and be accepted to the Global Seminars Program.

SIO 119. Physics and Chemistry of the Oceans (4)
Basic physical and chemical processes that influence the biology of the oceans, such as ocean circulation, ocean acidification, carbonate chemistry, trace metal
chemistry. ***Prerequisites:*** Physics 1C or 2C, Chem 6C, or consent of instructor. (W)

SIO 120. Introduction to Mineralogy (4)
Application of mineralogical and x-ray crystallographic techniques in earth sciences. Topics include symmetry, crystal structure, chemical, and physical properties of minerals with special emphasis on the common rock-forming minerals. Laboratory component includes polarizing microscope and x-ray powder diffraction methods. ***Prerequisites:*** SIO 50, or consent of instructor. (W)

SIO 121. Biology of the Cryosphere (4)
The cryosphere comprises sea ice, glaciers, snow, and other frozen environments. Changing rapidly in the face of global climate change, these environments host unique and highly adapted ecosystems that play an important role in the global earth system. In this course we will explore the physiology and ecology of organisms in the cryosphere and peripheral habitats. A special emphasis will be placed on sea ice as a habitat archetype, but glacier, snow, and permafrost will also be covered. ***Prerequisites:*** BILD 1, BILD 2, BILD 3, or consent of instructor.

SIO 121GS. Geology of the Alps (4)
This global seminar course will examine the geology of the Alps range. Students will develop an in-depth understanding of the geology, tectonics, and geomorphology of this fascinating, beautiful, and geologically complex region. The course will focus closely on the tectonics of the region and the subsequent geologic processes that have shaped it (e.g., glaciation) since the late Mesozoic Alpine Orogeny. Classroom study will be strongly augmented with local and

regional field excursions. Program or materials fees may apply. ***Prerequisites:*** SIO 10 or SIO 50. Students must apply for and be accepted to the Global Seminars Program.

SIO 122. Ecological Developmental Biology (4)

This course will explore the rapidly expanding field of ecological developmental biology which focuses on how factors such as temperature, nutrition, microbes, predators, and hormones influence development epigenetically. Emphasis will be given to the genetic basis of responses to the environment, drawn from studies in aquatic and terrestrial animals and plants. Topics include phenotypic plasticity, teratogenesis, symbiosis, endocrine disruptors, sex determination, and genetic assimilation. Recommended preparation: BICD 100. ***Prerequisites:*** BILD 3, or consent of instructor.

SIO 123. Microbial Environmental Systems Biology (4)

Environmental systems biology is the study of the genomic basis for patterns of microbial diversity and adaptation in relation to habitat. This course introduces the microbial genome as a unit of study and surveys introductory principles in microbial genomics and bioinformatics that underlie a range of contemporary research in diverse marine habitats, such as the deep sea and polar regions, as well as studies of biomedical importance, including the human microbiome.***Prerequisites:*** BICD 100 or consent of instructor.

SIO 124. Marine Natural Products (4)

This course will provide a detailed introduction to marine natural products. It will survey the organisms that produce these compounds and introduce how they are made (biosynthesis), isolated and identified (natural products chemistry), why they are made (chemical ecology), and how they are exploited for useful purposes including drug discovery (marine biotechnology). It will leave students with a fundamental understanding of the latest techniques employed in natural product research. ***Prerequisites:*** Chem 6C and BILD 1 or BILD 3 or consent of instructor.

SIO 125. Biomechanics of Marine Life (4)

An introduction to the physical basis of the biological world. This course explores how the physical principles of solids and fluids underlay the functional morphology, ecology, and adaptations of all living things, with emphasis on marine organisms. ***Prerequisites:*** BILD 3 and Physics 1C or Physics 2C, or consent of instructor.

SIO 126. Marine Microbiology (4)

The role of microorganisms in the oceans; metabolic diversity; methods in marine microbiology; interactions of microbes with other microbes, plants and animals; biochemical cycling, pollution and water quality; microbe-mineral interactions; extremophiles. (Students may not receive credit for both SIO 126 and BIMM 126.) ***Prerequisites:*** BILD 1 or consent of instructor. (W)

SIO 127. Marine Molecular Ecology (4)

This course will survey the application of molecular methods to address diverse questions concerning the ecology and evolutionary biology in marine organisms. Focus will be on genetic and genomic approaches that are providing new insights into how marine organisms adapt to their physical and biotic environments. ***Prerequisites:*** BILD 3 and BICD 100, or consent of instructor.

SIO 128. Microbial Life in Extreme Environments (4)

Microorganisms turn up in the strangest places. This course examines the exotic and bizarre in the microbial world, including the super-sized, the rock and cloud builders, the survivors, and

those present at the limits of life. ***Prerequisites:*** BILD 1 or BILD 2 or BILD 3, or consent of instructor.

SIO 129. Marine Chemical Ecology (4)

This class explores the chemistry of marine life involved in the chemical adaptations of defense and communication. The class examines all of the marine taxa from microbes to higher plants and animals. ***Prerequisites:*** Chem 140C or consent of instructor.

SIO 130. Scientific Diving (4)

This course includes theoretical and practical training to meet Scripps Institution of Oceanography and AAUS standards for scientific diving authorization and involves classroom, field, and ocean skin and scuba diving sessions. Topics include scientific diving programs and policy; physics and physiology of diving; decompression theory; dive planning; navigation; search and recovery; equipment and environmental considerations; subtidal sampling techniques; hazardous marine life; diving first aid; and diver rescue. Please see course preparation requirements here: https://scripps.ucsd.edu/scidive/training. P/NP grades only. Program or materials fees may apply. ***Prerequisites:*** department approval required.

SIO 131. Parasitology (6)

An ecological approach to parasitology. Students will gain the intellectual and practical foundation required to undertake parasitological research. Lectures will cover ecological/evolutionary concepts and the biology of various parasitic taxa. In labs, students will learn how to survey hosts for parasites, collect and identify parasites, perform infection experiments, and collect and analyze data. Students will also develop scholarship skills by delving into the scientific literature. ***Prerequisites:*** BILD 1 or BILD 2 or BILD 3 or SIO 187, or consent of instructor.

SIO 132. Introduction to Marine Biology (4)

Overview of marine organisms and their adaptations to sea life. Selected examples of physiological, behavioral, and evolutionary adaptations in response to the unique challenges of a maritime environment. (Students may not receive credit for both SIO 132 and BIEB 132.) ***Prerequisites:*** BILD 3 or consent of instructor. (F)

SIO 133. Marine Mammal Biology (4)

Introduction to the biology, ecology, evolution, and conservation status of marine mammals. Description of marine mammal taxa (mysticetes, odontocetes, pinnipeds, sirenians), their anatomy, physiology, ecology, and behavior. Impacts of whaling, fisheries interactions, and other anthropogenic threats. ***Prerequisites:*** BILD 3 and upper-division standing or consent of instructor. (S)

SIO 134. Introduction to Biological Oceanography (4)

Basics for understanding the ecology of marine communities. The approach is process-oriented, focusing on major functional groups of organisms, their food-web interactions and community response to environmental forcing, and contemporary issues in human and climate influences. (Students may not receive credit for both SIO 134 and BIEB 134.) ***Prerequisites:*** BILD 3 and upper-division standing or consent of instructor. (W)

SIO 135/SIOG 236. Satellite Remote Sensing (4)

Satellite remote sensing provides global observations of Earth to monitor environmental changes in land, oceans, and ice. Overview, physical principles of remote sensing, including orbits, electromagnetic radiation, diffraction, electro-optical, and microwave systems. Weekly

labs explore remote sensing data sets. Graduate students will also be required to write a term paper and do an oral presentation. ***Prerequisites:*** undergraduate: Physics 2A-B or Physics 4A-B-C, or consent of instructor. Graduate: graduate-level standing or consent of instructor. (S)

SIO 136. Marine Biology Laboratory (6)

Introductory laboratory course in current principles and techniques applicable to research problems in marine biology. Field component includes introduction to intertidal, salt marsh, or other marine ecosystems. Program or materials fees may apply. ***Prerequisites:*** BILD 3, SIO 132, and SIO 134, or consent of instructor. (S)

SIO 138. The Coral Reef Environment (4)

Assessment of the physical, chemical, and biological interactions that define the coral reef system; essential geography and evolutionary history of reefs; natural and human perturbations to the coral reef ecosystem; aspects of reef management and sustainability. ***Prerequisites:*** BILD 3, Math 10A or Math 20A, Chem 6B, or consent of instructor. (S)

SIO 139. Current Research in Marine Biology Colloquium (2)

Provides an introduction to current research topics and developments in marine biology and biological oceanography. Faculty members from Scripps Institution of Oceanography will offer perspectives in these areas. Students will practice scientific research and communication skills. P/NP grades only. ***Prerequisites:*** upper-division standing or consent of instructor. (W)

SIO 141/CHEM 174. Chemical Principles of Marine Systems (4)

Introduction to the chemistry and distribution of the elements in seawater, emphasizing basic chemical principles such as electron structure, chemical bonding, and group and periodic properties and showing how these affect basic aqueous chemistry in marine systems. ***Prerequisites:*** Chem 6C or 6CH, or consent of instructor. (S)

SIO 143. Ocean Acidification (4)

This course covers the fundamentals of ocean acidification, including the chemical background; past and future changes in ocean chemistry; biological and biogeochemical consequences, including organism and ecosystem function; biodiversity; biomineralization; carbonate dissolution; and the cycling of carbon and nitrogen in the oceans. ***Prerequisites:*** Math 10C, Physics 1C, Chem 6C, or consent of instructor. (W)

SIO 144/SIOG 252A. Introduction to Isotope Geochemistry (4)

Radioactive and stable isotope studies in geology and geochemistry, including geochronology, isotopes as tracers of magmatic processes, cosmic-ray produced isotopes as tracers in the crust and weathering cycle, isotopic evolution of the crust and mantle. ***Prerequisites:*** undergraduate: SIO 50, 102, and 120 or consent of instructor. Graduate: graduate-level standing or consent of instructor. Graduate level requires student presentation.

SIO 147. Applications of Phylogenetics (6)

Overview of the computer-based methods for constructing phylogenetic trees using morphological and molecular data. Lectures and labs cover evolutionary and ecological transformations, biodiversity measurements, biogeography, systematic and taxonomy. An independent project and presentation are required. (Students may not receive credit for both SIO 147 and BIEB 147.) ***Prerequisites:*** BILD 3 or consent of instructor.

SIO 150. Physics and Chemistry of Planetary Interiors (4)

Quantitative study of the physical and chemical processes operating within planetary interiors that control the evolution of planets on geological time scales. Comparative planetology of Earth, Venus, Mars, and other terrestrial planets and satellites will focus on how the formation, differentiation, and evolution of their interiors are expressed as tectonics and volcanism on their surfaces. ***Prerequisites:*** Math 20D, Physics 2C, Chemistry 6C or consent of instructor. (F)

SIO 152. Petrology and Petrography (6)

Mineralogic, chemical, textural and structural properties of igneous, metamorphic, and sedimentary rocks; their origin and relations to evolution of the Earth's crust and mantle. Laboratory emphasizes hand specimens and microscopic studies of rocks in thin sections. ***Prerequisites:*** SIO 50 and SIO 120 or consent of instructor. (S)

SIO 155. Whole Earth Geochemistry (4)

A geochemical overview of Earth materials and chemical processes involved in the Earth's evolution. Topics include formation and differentiation of the Earth, linkages between the solid Earth and the atmosphere/hydrosphere, and isotope and trace element composition of igneous and metamorphic rocks. ***Prerequisites:*** SIO 102 or consent of instructor. (S)

SIO 160. Introduction to Tectonics (4)

The theory of plate tectonics attempts to explain how forces within the Earth give rise to continents, ocean basins, mountain ranges, earthquake belts, and most volcanoes. In this course we will learn how plate tectonics works. ***Prerequisites:*** SIO 50 or consent of instructor. (S)

SIO 162. Structural Geology (4)

Principles of stratigraphy and structural geology applicable to field geologic studies. Discussion and laboratory exercises. Two to three field trips required. Program and/or materials fees may apply. ***Prerequisites:*** SIO 100 or consent of instructor. (W)

SIO 164. Maritime Archaeology: Method, Theory, and Practice in Global Perspective (4)

Maritime archaeology provides unique access to environmental and cultural data concerning human adaptation to climate and environmental change. This course presents an overview of the methods, theories, and practice of maritime archaeology. Topics include environmental characteristics of marine settings (coasts and underwater); drowned landscapes; maritime culture, ports, and navigation; methods of research in underwater settings; and legislative issues regarding underwater and coastal heritage. Students may not receive credit for both ANAR 164 and SIO 164.

SIO 167. Geoarchaeology in Theory and Practice (6)

As specialists in human timescales, archaeologists are trained to identify subtle details that are often imperceptible for other geoscientists. This course is designed to train archaeologists to identify the natural processes affecting the archaeological record, and geoscientists to identify the influence of human behavior over land surfaces. The course, which includes lectures, laboratory training, and field observations, focuses on the articulation of sedimentology and human activity. Students may not receive credit for both ANAR 167 and SIO 167. ***Prerequisites:*** ANTH 3 and SIO 50 or consent of instructor.

SIO 170. Introduction to Volcanology (4)

This class will introduce students to the fundamentals of the science of volcanology. Topics explored will include the processes and products of various types of volcanism, magma genesis,

eruptive mechanisms, in addition to volcanic monitoring, hazards and mitigation. ***Prerequisites:*** SIO 100 and Chem 6A, or consent of instructor. (F)

SIO 170L. Introduction to Volcanology—Field Experience (1-4)

This course teaches fundamental aspects of physical and chemical volcanology through a one- to two-week field study experience prior to the start of the quarter. Subjects are introduced in lectures and reinforced and expanded upon in field exercises. Additional fees may be required for travel expenses. Program or materials fees may apply. May be taken for credit two times. ***Prerequisites:*** SIO 170 or consent of instructor; department approval required.

SIO 171. Introduction to Physical Oceanography (4)

A physical description of the sea at the upper-division level, with emphasis on currents, waves, and turbulent motions that are observed in the ocean, and on the physics governing them. ***Prerequisites:*** Math 20C and Physics 2C or Physics 4C, or consent of instructor.

SIO 172. Physics of the Atmosphere (4)

This course provides an understanding of the physical principles governing the behavior of the Earth's atmosphere, with emphasis on the thermal structure and composition of the atmosphere, air masses and fronts, and atmospheric thermodynamics, fluid dynamics, and radiation. ***Prerequisites:*** Math 20C and Physics 2C, or consent of instructor.

SIO 173. Dynamics of the Atmosphere and Climate (4)

Introduction to the dynamical principles governing the atmosphere and climate using observations, numerical models, and theory to understand atmospheric circulation, weather systems, severe storms, marine layer, Santa Ana winds, El Niño, climate variability, and other phenomena. ***Prerequisites:*** Math 20E and Physics 2C, or consent of instructor.

SIO 174. Chemistry of the Atmosphere and Oceans (4)

An introduction to chemical compounds and their biogeochemical cycles in the oceans and atmosphere, with emphasis on climate issues like ocean acidification, greenhouse gases and the carbon cycle, other biogeochemical cycles, chlorofluorocarbons and the ozone hole, urban pollutants and their photochemistry, and aerosol particles and their effects on clouds. ***Prerequisites****:* Chem 6C or Chem 6CH and Math 20C or Math 31BH or consent of instructor.

SIO 175. Analysis of Oceanic and Atmospheric Data (4)

Oceanic and atmospheric observations produce large data sets whose understanding requires analysis using computers. This course will include an introduction to Matlab for the purpose of analyzing data. Students will use modern data sets from the ocean and atmosphere to learn statistical data analysis. ***Prerequisites****:* Math 18 or Math 20F or Math 31AH or consent of instructor.

SIO 176. Observational Physical Oceanography (4)

This course gives an introduction to the methods and measurements used by observational physical oceanographers. Topics covered include sensors such as conductivity-temperature-depth (CTD), acoustic Doppler current profiler (ADCP), platforms such as autonomous gliders and ships, and services such as satellite measurements. This course includes a research project. ***Prerequisites****:* SIO 171 or consent of instructor.

SIO 177. Fluid Dynamics (4)

This course gives an introduction to ocean and atmosphere fluid properties, statics, and kinematics; fluid conservation laws; irrotational flow; Bernoulli equation; gravity waves; shallow

water equations; geophysical applications. ***Prerequisites****:* Phys 2A and Math 20D and Math 20E or consent of instructor.

SIO 178. Geophysical Fluid Dynamics (4)

This course provides an introductory look at physical principles governing ocean currents and atmospheric flow. Topics may include large-scale circulation, ocean eddies, atmospheric storms systems, coastal upwelling, equatorial dynamics, and internal waves. ***Prerequisites****:* Phys 2C and SIO 177 and Math 18 or Math 20F or Math 31AH or consent of instructor.

SIO 180. Communicating Science to Informal Audiences (4)

Students develop fundamental science communication and instructional skills through the understanding and application of learning theory, interpretive techniques, and pedagogical practices, which occur in the context of communicating ocean science concepts to a diverse audience at Birch Aquarium at Scripps. ***Prerequisites*****:** Chem 6A or SIO 50 or BILD 1 or consent of instructor. (W)

SIO 181. Marine Biochemistry (4)

Biochemical mechanisms of adaptation in organisms to the marine environment. Special emphasis will be on the effects of pressure, temperature, salinity, oxygen, and light on the physiology and biochemistry. (Students may not receive credit for both SIO 181 and BIBC 130.) ***Prerequisites:*** none. (F)

SIO 182. Environmental and Exploration Geophysics (4)

Theory and practice of nonseismic geophysics for groundwater, environmental, and exploration purposes. Lectures are supplemented by collection of gravity, magnetic, and resistivity data; data analysis; and report writing. Includes an introduction to Matlab as a tool for geophysical data interpretation. ***Prerequisites:***Math 20D and Physics 2C, or consent of instructor. (S)

SIO 183. Phycology: Marine Plant Biology (6)

Lecture and laboratory course emphasizing the biology, ecology and taxonomy of marine plants and seaweeds. Laboratory work mainly involves examination, slide preparation and dissection of fresh material collected locally. An oral presentation on a current research topic is required. Program or course fee may apply. ***Prerequisites:*** BILD 3 or consent of instructor. (W)

SIO 184. Marine Invertebrates (6)

Course emphasizing the diversity, evolution and functional morphology of marine invertebrates. Laboratory work involves examination of live and prepared specimens. An oral presentation and a paper on current research topic is required. Program or course fee may apply. ***Prerequisites:*** BILD 3 or consent of instructor. (W)

SIO 185. Marine Microbiology Laboratory (5)

Techniques and theory in marine microbiology. Students perform experiments concerning (a) enrichment, enumeration, and identification, and (b) metabolic and physiochemical adaptations, along with an independent project. Students may not receive credit for both SIO 126L and SIO 185. ***Prerequisites:*** BILD 1 and SIO 132 or SIO 134 or consent of instructor.

SIO 187. Statistical Methods in Marine Biology (4)

Introduction to statistical inference. Emphasis on constructing statistics for specific problems in marine biology. Topics include probability, distributions, sampling, replication, and experimental design. Students may not receive credit for both SIO 187 and BIEB 100. ***Prerequisites:*** BILD 3 or consent of instructor.

SIO 188. Biology of Fishes (5)

The comparative evolution, morphology, physiology, and ecology of fishes. Special emphasis on local and deep-sea and pelagic forms in laboratory. ***Prerequisites:*** BILD 3 or consent of instructor. (W)

SIO 189. Pollution, Environment and Health (4)

The goal is to understand the scope of the pollution problem facing the planet. Students will learn the properties of chemicals in the environment and survey the biological mechanisms that determine their accumulation and toxicity. ***Prerequisites:*** Chem 6C and BILD 1 or 3 or consent of instructor. (S)

SIO 190. Special Topics in Earth, Oceans, and Atmosphere (4)

A seminar course designed to treat emerging or topical subjects in the earth, ocean, or atmospheric sciences. Involves lectures, reading from the literature, and student participation in discussion. Topics vary from year to year. May be taken for credit two times. Enrollment by consent of instructor. ***Prerequisites:*** upper-division standing, a minimum UC San Diego GPA of 3.0 or consent of instructor.

SIO 192. Senior Seminar in Scripps Institution of Oceanography (1)

The Senior Seminar Program is designed to allow Scripps Institution of Oceanography senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in Scripps Oceanography (at the upper-division level). Topics will vary from quarter to quarter. Senior Seminars may be taken for credit up to four times, with a change in topic, and permission of the department. Enrollment is limited to twenty students, with preference given to seniors.

SIO 194. Research Seminar in Washington, DC (4)

Course attached to a six- to eight-unit internship taken by students participating in the UCDC Program. Involves weekly seminar meetings with faculty and teaching assistant and a substantial research paper. ***Prerequisites:*** departmental approval. Participation in the UCDC Program during quarter enrolled in seminar.

SIO 195. Methods of Teaching Earth Sciences (4)

Introduction to teaching earth sciences class section in a lower-division class, hold office hours, assist with examinations. This course counts only once toward the major. ***Prerequisites:*** junior or senior earth sciences major with GPA of 3.0 or an A in the course, overall GPA of 3.0 or higher, ninety units or more, and consent of instructor, plus department stamp.

SIO 196. Honors Thesis Research (4)

Course is for student participants in the senior honors thesis research program. Students complete individual research on a problem by special arrangement with, and under the direction of, a Scripps Institution of Oceanography faculty member. May be taken for credit two times. ***Prerequisites:*** completed ninety units of courses, including twelve units of SIO courses. Achieved a GPA of 3.3 overall and 3.5 in SIO courses. Submitted to Scripps Steering Committee, and had approved, an honors thesis research proposal. Department stamp.

SIO 197. Earth Science Internship (2 or 4)

The earth science internship program is designed to complement the program's academic curriculum with practical field experience. ***Prerequisites:*** completion of ninety units with a GPA of 2.5, and a completed and approved Special Studies form, UC San Diego Application for Enrollment Special Studies Courses 197, 198, 199, and department stamp.

SIO 197BA. Birch Aquarium Internship (4)

This internship will examine basic science learning theory and interpretive techniques best suited for learners in an aquarium or informal learning setting. Students will demonstrate learned skills by facilitating floor-based interactions and conducting visitor surveys that influence aquarium exhibit design and guest experiences. Interested students should contact the Scripps undergraduate office for application instructions. P/NP grades only. ***Prerequisites:*** upper-division standing and department stamp required.

SIO 198. Directed Group Study (2–4)

This course covers a variety of directed group studies in areas not covered by formal Scripps Oceanography courses. (P/NP grades only.) ***Prerequisites:***consent of instructor.

SIO 199. Independent Study for Undergraduates (4)

Independent reading or research on a problem. By special arrangement with a faculty member. (P/NP grades only.)

Graduate Courses

BS/MS Course

SIOG 228. Research Seminar (2)

A three-quarter required sequence for BS/MS earth sciences students to prepare students for thesis writing. ***Prerequisites:*** current earth sciences BS/MS student. Department stamp required.

Graduate

The SIO Department offers graduate courses across three broad curricular areas:

- Climate-Ocean-Atmosphere Program (COAP)
- Geosciences of Earth, Oceans, and Planets (GEO)
- Ocean Biosciences Program (OBP)

Graduate courses are organized under the following course prefixes:

- SIOC: COAP courses
- SIOG: GEO courses
- SIOB: OBP courses
- SIO: courses not specific to one program

SIOC 200A. Computational Ocean Acoustics and Signal Processing I (4)

Overview of ocean acoustics. Acoustics Wave Equation with some analytic solution techniques. Ray Methods. Introduction to Spectral and Normal Modes methods. Introduction to beamforming, including matched field processing. Computer programs will be constructed on all subjects covered. ***Prerequisites:***graduate standing or consent of instructor. Kuperman (F)

SIOC 200B. Computational Ocean Acoustics and Signal Processing II (4)

Continuation of SIOC 200A. Range dependent propagation models, including adiabatic and coupled mode models and parabolic equations. More advanced topics in matched field processing. ***Prerequisites:*** graduate standing and SIOC 200A or SIO 200A or consent of instructor. Kuperman (W)

SIOC 200C. Computational Ocean Acoustics and Signal Processing III (4)

Continuation of SIOC 200B. Modeling interference such as ambient noise. Time domain methods. Matched field tomography, nonlinear optimization methods, and geophysical inversion. ***Prerequisites:*** graduate standing and SIOC 200B or SIO 200B or consent of instructor. Kuperman (S)

SIOC 201. Geological Record of Climate Change (4)

Introduction to geological archives; the tools for paleoclimate reconstruction and a sampling of important issues from the geological record, including the development of “greenhouse” and “icehouse” worlds, the origin and evolution of glacial cycles, and the origin of “millennial scale” climate variability. ***Prerequisites:*** chemistry and physics required for graduate admission to SIO, SIO 101 or equivalent, or consent of instructor. Charles (S)

SIOC 202A–B. Fundamentals of Wave Physics (4-4)

This two-quarter sequence is designed to introduce a broad background of students to basic principles of wave physics, including generation, propagation, dispersion, refraction, diffraction, reflection, waveguides, etc. A variety of wave motions of environmental relevance, including acoustic, ocean surface and internal (SIOC 202A), optical and seismic (SIOC 202B) are used to illustrate these principles. In-class experiments, data collection, and analysis exercises are incorporated. ***Prerequisites:*** calculus and partial differential equations. Kuperman, Melville, Stramski, Gerstoft (W,S)

SIOC 203A. Introduction to Applied Mathematics I (4)

Review of exact methods for ordinary differential equations. Expansions about regular and irregular singular points. Introduction to asymptotic expansions. Approximate methods for nonlinear differential equations. Regular and singular perturbation theory. Additional topics

depending upon the interests of the instructor. Coscheduled with MAE 294BA. ***Prerequisites:*** Math 110, Math 120A, or consent of instructor. (F)

SIOC 203B. Introduction to Applied Mathematics II (4)

Asymptotic methods: method of steepest descent (if not covered in I) WKB, method of multiple scales, boundary layer theory. Elements of complex analysis. Coscheduled with MAE 294B. ***Prerequisites:*** MAE 294A or SIOC 203A or SIO 203A or consent of instructor. (W)

SIOC 203C. Introduction to Applied Mathematics III (5)

Partial differential equations: characteristics, similarity solutions, Green's functions, images, wave equation, diffusion equation, Laplace's equation. Applications to continuum mechanics, potential fields, and transport phenomena such as diffusion, linear and nonlinear waves, Burger's equation, shocks, and other topics. Other topics according to the interests of the instructor. Coscheduled with MAE 294C. ***Prerequisites:*** graduate standing and MAE 294B or SIOC 203B or SIO 203B or SIOC 215B or SIO 215B or consent of instructor. W. Young (S)

SIOC 204. Underwater Acoustics (4)

Theory of radiation, transmission, and scattering of sound with special application to ocean acoustics. ***Prerequisites:*** graduate standing or consent of instructor. Buckingham (F)

SIOC 205. Estuarine and Coastal Processes (4)

The course focuses on estuarine and coastal physical dynamics and biogeochemical/ecosystem impacts. Topics are adjusted for student interest, but include: turbulence and the bottom boundary layer, tides (origin and propagation), estuary types, tidally averaged dynamics, temporal variation, stratification, lateral processes and fronts, dispersion mechanisms, sediment transport, estuarine productivity (nutrients, oxygen, and eutrophication), estuarine ecosystems, river plumes, and coastal upwelling. ***Prerequisites:*** graduate standing or consent of instructor. (Letter grades only.) Giddings (S)

SIOC 206. Land Surface Hydrology (4)

Advanced introduction to natural processes that govern water occurrence and transport over the land surface. Principles of global hydrologic cycle and land-surface water balance, runoff and fluvial geomorphology, infiltration and subsurface water flow, evaporation and plant transpiration. ***Prerequisites:*** graduate standing or consent of instructor. (S)

SIOC 207A. Fundamentals of Digital Signal Processing (4)

Discussion of discrete-time signals and systems, Discrete-Time Fourier Transform (DFT) and window functions, Fast Fourier Transform (FFT), design of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) digital filters and their implementations, finite word length effects, applications to data acquisition and analysis. ***Prerequisites:*** graduate standing or consent of instructor. Hodgkiss (F)

SIOC 207B. Digital Signal Processing I (4)

Discrete random signals; conventional (FFT based) spectral estimation. Coherence and transfer function estimation; model-based spectral estimation; linear prediction and AR modeling, Levinson-Durbin algorithm and lattice filters, minimum variance spectrum estimation. Coscheduled with ECE 251A. (Recommended prerequisites: ECE 153 in addition to either ECE 161 or 161A and SIOC 207A or SIO 207A or equivalent background.) ***Prerequisites:***graduate standing or consent of instructor. Hodgkiss, Rao (W)

SIOC 207C. Digital Signal Processing II (4)

Adaptive filter theory, estimation errors for recursive least squares and gradient algorithms, convergence and tracking analysis of LMS, RLS, and Kalman filtering algorithms, comparative performance of Wiener and adaptive filters, transversal and lattice filter implementations, performance analysis for equalization, noise canceling, and linear prediction applications. Coscheduled with ECE 251B. (Recommended Prerequisites: ECE 251A or ECE 251AN.) **P*rerequisites:*** graduate standing ECE 251A (for ECE 251B); SIOC 207B or SIO 207B (for SIOC 207C). Hodgkiss (S)

SIOC 207D. Array Processing (4)

The coherent processing of data collected from sensors distributed in space for signal enhancement and noise rejection purposes or wavefield directionality estimation. Conventional and adaptive beamforming. Matched field processing. Sparse array design and processing techniques. Applications to acoustics, geophysics, and electromagnetics. Coscheduled with ECE 251D. (Recommended Prerequisites: ECE251A or ECE 251AN.) ***Prerequisites:*** graduate standing; ECE 251C (for ECE 251D); SIOC 207C or SIO 207C (for SIOC 207D). Hodgkiss (F)

SIOC 208. Seminar in Applied Ocean Sciences (1)

Topics in applied ocean sciences. One-hour seminar. (S/U grades only). Staff (F,W,S)

SIOC 209. Special Topics (1–4)

Within the next few years, lectures on various special subjects will be offered by members of the staff. The emphasis will be on topics that reveal the interdependence of the biological, chemical, geological, and physical processes operating in the oceans. (S/U grades permitted.) Staff (F,W,S)

SIOC 210. Physical Oceanography (4)

Physical description of the sea; physical properties of seawater, methods and measurements, boundary processes, regional oceanography. ***Prerequisites:***graduate standing or consent of instructor. Talley (F)

SIOC 211A. Ocean Waves I (4)

Propagation and dynamics of waves in the ocean, including the effects of stratification, rotation, topography, wind, and nonlinearity. ***Prerequisites:*** graduate standing or consent of instructor. Hendershott (W)

SIOC 211B. Ocean Waves II (4)

Propagation and dynamics of waves in the ocean, including the effects of stratification, rotation, topography, wind, and nonlinearity. ***Prerequisites:*** graduate standing and SIOC 211A or SIO 211A and SIOC 214A or SIO 214A or consent of instructor. Melville (S)

SIOC 212A. Geophysical Fluid Dynamics I (4)

The equations of motions for rotating stratified flow and their application to the atmospheric and oceanic dynamics; Ekman layer dynamics, potential vorticity dynamics, the quasigeostrophic approximation, theories of the wind-driven oceanic circulation, theories of the atmospheric Hadley circulation, geostrophic adjustment, and baroclinic instability. ***Prerequisites:*** graduate standing or consent of instructor. MacKinnon (W)

SIOC 212B. Geophysical Fluid Dynamics II (5)

The equations of motion for rotating stratified flow and their application to the atmospheric and oceanic dynamics; Ekman layer dynamics, potential vorticity dynamics, the quasigeostrophic approximation, theories of the wind-driven oceanic circulation, theories of the atmospheric Hadley circulation, geostrophic adjustment, and baroclinic

instability. ***Prerequisites*:** graduate standing and SIOC 212A or SIO 212A and SIOC 214A or SIO 214A or consent of instructor. Cessi (S)

SIOC 213. Turbulence and Mixing (4)

Mixing mechanisms, their identification, description, and modeling. Introduction to turbulence, semi-empirical theories, importance of coherent structures, effects of stratification and rotation on turbulent structure, entrainment and mixing. Coscheduled with MAE 216. (S/U grades permitted.) Armi (S)

SIOC 214A. Introduction to Fluid Mechanics (4)

A survey of classical problems in fluid mechanics and approximate techniques of analysis. Topics include conservation equations, straight laminar flows, low and high Reynolds number laminar flow, stability of laminar flows, turbulent flow. ***Prerequisites:*** graduate standing or consent of instructor. Hendershott (F)

SIOC 214B. Environmental Fluid Dynamics (4)

Single-layer flows with a free surface; two-layer flows, including exchange flows in harbors, estuaries, seas, and buildings. Continuously stratified flows with meteorological and oceanographic applications. Topographic effects, plumes, jets, and thermals. Planetary boundary layers. ***Prerequisites:*** graduate standing or consent of instructor. Armi (S)

SIOC 215A. Applied Mathematics for Oceanographers I (4)

Intended for first-year graduate students who seek a quantitative way to describe how the ocean works: vector analysis, complex quantities, Fourier and Laplace transforms, ordinary differential equations, nonhomogeneous ordinary differential equations, initial and boundary value problems, Heat and Laplace equations. ***Prerequisites:*** graduate standing or consent of instructor. (F)

SIOC 215B. Applied Mathematics for Oceanographers II (4)

An introduction to the mathematical description of waves, beginning with a description of the linear oscillator, and followed by normal modes, the flexible string, membranes, water waves, ray theory, method of characteristics, and basic linear algebra. ***Prerequisites:*** graduate standing and SIOC 215A or SIO 215A or consent of instructor. (W)

SIOC 215C. Applied Mathematics for Oceanographers III (4)

An introduction to Perturbation theory, including regular and singular expansions, Poincare's method, two-scale method, the WKB approximation and boundary layer theory. ***Prerequisites:*** graduate standing and SIOC 215A or SIO 215A and SIOC 215B or SIO 215B or consent of instructor. (S)

SIOC 216. Introduction to the Physics of Complex Systems (4)

Emergent complex behavior in nonlinear, dissipative, open dynamical systems will be investigated by studying fundamental properties and their manifestation in examples drawn from the physical and biological sciences. Topics to include fractals, chaos, self-organization, artificial life, and neural networks. ***Prerequisites:***graduate standing or consent of instructor. (S/U grades permitted.) Werner (W)

SIOC 216B. Applied Complexity (4)

A project-based course focusing on applying methods from the study of complex systems to messy, real-world physical, biological, or social problems. Projects will encompass choosing a problem, writing a proposal, carrying out research, writing up and presenting results, and

working collaboratively. ***Prerequisites:*** SIO 216 or SIOC 216 or SIOC 216A and graduate standing or consent of instructor. Werner (S)

SIOC 217A. Atmospheric and Climate Sciences I (4)

Thermodynamics and statics of dry and moist air, atmospheric composition, Earth radiation budget, vertical structure of the atmosphere, global energy balance, thermodynamic feedbacks in the climate system. ***Prerequisites:*** graduate standing or consent of instructor. (Letter grades only.) Russell (F)

SIOC 217B. Atmospheric and Climate Sciences II (4)

Fluid dynamics of the atmosphere; derivation of governing equations from the laws of physics, scale analysis, conservation principles, theoretical and observed structure of midlatitude synoptic systems; gradient wind and thermal wind approximations, geostrophic and quasigeostrophic approximations; potential vorticity, Rossby waves, climate and weather phenomena such as jet streams and cyclones. ***Prerequisites:*** graduate standing and SIOC 217A or SIO 217A or consent of instructor. Eisenman (W)

SIOC 217C. Atmospheric and Climate Sciences III (4)

Radiative, physical, and dynamical processes that govern the mean state, variability, and change of the atmosphere and climate, including greenhouse gases, clouds and aerosols, convection and precipitation, general circulation, and coupled atmosphere-ocean interactions. ***Prerequisites:*** graduate standing and SIOC 217A or SIO 217A and SIOC 217B or SIO 217B, or consent of instructor. Norris (S)

SIOC 217D. Atmospheric and Climate Sciences IV (4)

Atmospheric chemistry that impacts climate change, including photochemical reactions, ozone chemistry, and aerosol evolution in the troposphere and stratosphere. Atmospheric applications of catalytic cycles, heterogeneous chemistry, and microphysical processes will include the ozone hole, urban smog, and aerosol-cloud interactions. ***Prerequisites:*** SIOC 217A or SIO 217A and SIOC 217B or SIO 217B and SIOC 217C or SIO 217C. Russell (S)

SIOC 218. Cloud Dynamics and Climate (4)

Cloud identification, cloud properties, dynamical processes governing formation and dissipation of different cloud types, impact of clouds on radiation flux and climate. ***Prerequisites:*** graduate standing and SIOC 217A or SIO 217A and SIOC 217B or SIO 217B. Nongraduate students may enroll with consent of instructor.

SIOC 218A. Observational Techniques in Oceanography (4)

The course teaches practical knowledge of oceanographic methods, sensors, and platforms, with a focus on physical observations. Uses mixture of lectures, online information, lab demonstrations, practical exercises, student presentations, and manufacturers' visits. ***Prerequisites:*** graduate standing; basic knowledge of physical oceanography and physical principles. For graduate students in an oceanographic discipline, and graduate or third- or fourth-year undergraduate students in physics or engineering with an interest in ocean observations.

SIOC 218B. Observational Techniques in Oceanography: At-Sea Practicum (4)

Practicum focused on preparing for and carrying out on-site fieldwork using state-of-the art methods (e.g., executing mooring-based data collection with physical, chemical, biological sensors). Teaches ship/deck skills, sensor and mooring preparation, cruise planning/execution, data analysis, cruise-report preparation. ***Prerequisites:*** graduate standing; basic knowledge of

oceanography and data analysis. For graduate students in an oceanographic discipline, and graduate students in physics or engineering with an interest in ocean observations.

SIOC 219. Special Topics in Physical Oceanography (1–4)

Example topics are case histories and methods in physical oceanography, theories of the ocean circulation, numerical methods in large-scale ocean and atmospheric models, and natural electromagnetic phenomena in the earth and the oceans. (S/U grades permitted.) Staff (F,W,S)

SIOC 220. Observations of Large-Scale Ocean Circulation (4)

General circulation of the oceans; tropical, subtropical, and high-latitude current systems of the Atlantic, Indian, and Pacific Oceans and marginal seas; ocean heat flux and thermohaline circulations; observational basis of large-scale dynamics. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Roemmich (S)

SIOC 221A. Analysis of Physical Oceanographic Data (A) (4)

Fundamental elements of analysis of geophysical and oceanographic time series, including sampling problems, least squares techniques, spectral analysis, interpretation of series, design of experiments. ***Prerequisites:*** consent of instructor. Pinkel (F)

SIOC 221B. Analysis of Physical Oceanographic Data (B) (4)

Techniques for analysis of physical oceanographic data involving many simultaneous processes, including probability densities, sampling errors, spectral analysis, empirical orthogonal functions, correlation, linear estimation, objective mapping. ***Prerequisites:*** SIOC 221A or SIO 221A or consent of instructor. (S/U grades permitted.) Rudnick (W)

SIOC 221C. Data Analysis Laboratory (4)

This course is to give students practical experience with analysis techniques. Students complete three projects. Topics include empirical orthogonal functions, objective mapping, complex demodulation, inference of geostrophic flow, minimization of CTD salinity spiking, isolation of wind-driven currents, wavelets. ***Prerequisites:*** SIOC 221A or SIO 221A and SIOC 221B or SIO 221B or consent of instructor. (S/U grades only.) Gille (F)

SIOC 235. Ocean-Atmosphere Interaction and Climate (4)

The class discusses ocean-atmosphere interaction dynamics that cause climate to vary in space and time, and form the physical basis for predicting year-to-year climate variability and projecting future climate change in the face of global warming. ***Prerequisites:*** graduate standing, SIO 210 or SIOC 210 and SIO 211A or SIO 211B or SIO 212A or SIO 212B or SIO 217A or SIO 217B or SIOC 211A or SIOC 211B or SIOC 212A or SIOC 212B or SIOC 217A or SIOC 217B or consent of instructor.

SIOC 237A. Introduction to Ocean Optics (4)

Overview of ocean optics. Concepts in radiometry. Inherent and apparent optical properties. Radiative transfer equation. Light absorption and scattering by seawater constituents. Optics of air-water interface. Light fields within and leaving the ocean. Optics of marine particles. Measurement methods and instrumentation. Recommended preparation: basic physics and differential calculus. ***Prerequisites:*** graduate standing or consent of instructor. Stramski (F)

SIOC 237B. Ocean Color Remote Sensing (4)

Overview of ocean color satellite missions. Concepts in radiometry. Inherent and apparent optical properties. Radiative transfer equation. Solar radiation and elements of atmospheric optics. Propagation of light across the sea surface and within the ocean. Light absorption and scattering by seawater. Water-leaving radiance and remote-sensing reflectance. Ocean color

algorithms and applications. Recommended preparation: basic physics and differential calculus. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Stramski (F)

SIOC 237C. Optical-Biological Interactions in the Ocean (4)

This is a course on the interactions of underwater light with marine plankton and animals. Topics include basic physics of interaction of light and matter, optical properties of marine plankton, optical and biological effects associated with interactions of light with marine organisms, and optical methods and their applications to the study of ocean biology. Course meetings consist of approximately 75 percent lectures by instructor and 25 percent student presentations and discussions of selected papers. Renumbered from SIO 237C. Students will not receive credit for SIOC 237C and SIO 237C. Recommended preparation: basic physics and biology. (Letter grades only.) Stramski (F)

SIOC 238. Sensor Networks (4)

Characteristics of chemical, biological, seismic, and other physical sensors; signal processing techniques supporting distributed detection of salient events; wireless communication and networking protocols supporting formation of robust sensor fabrics; current experience with low power, low cost sensor deployments. Renumbered from SIO 238. Students may not receive credit for SIOC 238 and SIO 238. May be coscheduled with MAE 149 and ECE 156. ***Prerequisites:*** upper-division standing and approval of instructor, or graduate student in science or engineering. (S/U grades permitted.) Hodgkiss (S)

SIOC 241. Advanced Signal Processing for Structural Vibrations and Acoustics (4)

Review basic fluid and elastic wave propagation in infinite and finite media. Introduce signal and array-processing methods for localization, medium inversion, and nondestructive testing based on the underwater, seismic, and radar literature. Renumbered from SIO 241, students will not receive credit for SIOC 241 and SIO 241. Recommended preparation: calculus through differential equations, linear algebra; Matlab experience strongly desired. ***Prerequisites:*** graduate standing or consent of instructor. Kuperman (S)

SIOC 250. Advanced Atmospheric Dynamics (4)

Advanced topics in atmospheric dynamics not covered in the SIO 217 sequence, including baroclinic instability, mechanisms driving the general circulation of the troposphere and stratosphere, tropical waves, hurricanes and mesoscale phenomena, teleconnections, and spatially coherent patterns of variability.***Prerequisites:*** SIOC 212A or SIO 212A or SIOC 217B or SIO 217B or consent of instructor.

SIOC 251. Radiation in the Atmosphere (4)

This graduate-level core course in radiation provides an introduction to basic laws, radiative transfer under clear sky conditions, scattering by individual particles, multiple scattering, radiative properties of clouds and aerosols, the global energy budget, and applications to satellite meteorology. ***Prerequisites:***graduate standing or consent of instructor. (Letter grades only.) Evan (S)

SIOC 254. Science of Climate Change (4)

This course will provide the scientific basis for understanding climate change. The focus will be on the twentieth century and understanding the various natural and anthropogenic factors and feedback processes that are contributing to the observed climate changes, including extreme

events. The students will develop a climate model and explore ways to slow down future changes. ***Prerequisites:*** SIOC 217A or SIO 217A or consent of instructor.

SIOC 267. Biogeochemistry (4)

Examines quantitatively the impact of the biota on the chemistry of the atmosphere and ocean. Emphasis given to isotopes as tracers of biogeochemical processes. Attention given to paleoclimatic and paleoatmospheric data from ice cores to reveal mechanisms. ***Prerequisites:*** graduate standing or consent of instructor. Severinghaus, R. Keeling (S)

SIOC 290S. Climate Math (6)

This is a preparatory mathematics class for climate sciences, specifically designed to review math concepts vital to understanding climate science in preparation for SIOC 210 and SIOC 217A. The course will use statistical methods to understand the observed climate records, calculus to investigate Earth's radiation budget, and vector rotation to introduce the dynamics and transport of the atmosphere and ocean. (Letter grades only.) ***Prerequisites:*** graduate standing or consent of instructor.

SIOC 291S. @Climate (6)

This is a course in social media for the climate sciences. Students will develop a broad understanding of how to use social media to listen to, respond to, and engage in online climate science discussions. Students will learn to use digital technology to actively engage with constituents. Students will learn how social media can be used effectively for communications. (Letter grades only.) ***Prerequisites:*** graduate standing or consent of instructor.

SIOC 292. Introduction to Climate Science and Policy (4)

This course explores the interaction between climate science, policy, and the larger culture. (S/U grades permitted). ***Prerequisites:*** graduate standing or consent of instructor.

SIOC 296. Climate Science and Policy Forum (2)

This required course for MAS-CSP students will focus on the development of MAS Capstone Projects and discussions covering climate science and policy issues, including informal student presentations on political, economic, historical, educational, and natural science issues related to climate science and policy. (Letter grades only.) May be taken for credit three times. ***Prerequisites:*** graduate standing.

SIOC 299. Climate Science and Policy Capstone Project (6–10)

Building on the knowledge and experience gained from the entire curriculum of the master's in climate science and policy (MAS-CSP) program, students will design and present a specific climate science and policy project. May be taken for credit one time for a maximum of ten units. (S/U grades only.) ***Prerequisites:***graduate standing. Only students registered in MAS-CSP program.

SIOG 222. Introduction to Industry Reflection Seismic Methods (4)

Seismic methods history; land and marine seismic sources and receivers; seismic wave types; basics of reflection data processing and imaging; vertical seismic profiling; well logs, 1-D synthetics, seismic-well ties; reflection data facies and fluids interpretation in geological settings; emerging reflection seismic methods. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Srnka, Leonard

SIOG 223A. Geophysical Data Analysis I (4)
Probability and statistics and their application to make inferences from geophysical data: point processes, distributions, maximum likelihood estimation, hypothesis testing and confidence intervals, least squares, density estimation, interpolation and smoothing. ***Prerequisites:*** graduate standing or consent of instructor. (W)

SIOG 223B. Geophysical Data Analysis II (4)
Analysis of geophysical measurements, especially time series, Fourier theory digital signal processing, and spectral analysis. ***Prerequisites:*** graduate standing and SIOG 223A or SIO 223A or consent of instructor. Agnew (S)

SIOG 224. Internal Constitution of the Earth (4)
An examination of current knowledge about the composition and state of the Earth's interior revealed by geophysical observations. Seismic velocity and mass density distributions; equations of state; phase changes; energy balance and temperatures; constraints on composition from extraterrestrial samples and exposed rocks; spherical and aspherical variations of properties. Recommended preparation: calculus and differential equations, basic chemistry and physics. ***Prerequisites:*** graduate standing or consent of instructor. Masters, Stegman (S)

SIOG 225. Physics of Earth Materials (4)
Mathematics and physics of continuous media, focusing on geophysical problems. Topics include deformation, stress, conservation laws, elasticity, attenuation, viscoelasticity, fracture mechanics, and porous media. ***Prerequisites:*** graduate standing or consent of instructor. Agnew, Fialko (F)

SIOG 226. Introduction to Marine Geophysics (4)
Methods of exploration geophysics with emphasis on those useful at sea. Magnetic and gravitational potential field methods, multibeam echo sounding reflection and refraction seismology will be covered. Recent papers from the literature will also be read and discussed. Recommended preparation: differential equations; at least one geology course. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Dorman, Chadwell (S)

SIOG 227A. Introduction to Seismology (4)
Introduction to seismometers and seismograms; stress and strain; potentials and the wave equation; geometrical ray theory and travel times in layered media; representation of seismic sources; WKBJ and synthetic seismograms; seismic hazards and other applications of seismology. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Shearer (W)

SIOG 227B. Advanced Seismology I (4)
Introduction to low-frequency digital data; continuum mechanics and the equations of motion; free oscillation solutions; construction of Earth models; excitation of free-oscillations and source mechanism retrieval; array processing of long-period data; modelling aspherical structure; surface waves. ***Prerequisites:*** SIOG 227A or SIO 227A or consent of instructor. (S/U grades permitted.) Masters (S)

SIOG 227C. Advanced Seismology II (4)
High-frequency wave propagation; methods for computing synthetic seismograms, including WKBJ, reflectivity and finite differences; body-wave spectra; attenuation of body waves; source

physics; reflection and refraction seismology; seismic tomography. ***Prerequisites:*** SIOG 227A or SIO 227A and SIOG 227B or SIO 227B or consent of instructor. (S/U grades permitted.) Staff (S)

SIOG 229. Gravity and Geomagnetism (4)

Introduction to potential theory, with applications to gravity and geomagnetism. Topics include the geoid, spherical harmonics, Laplace's equation, the Dirichlet problem on a sphere, and Fourier methods. Gravity anomalies and geomagnetic field modeling and sources are discussed; also paleomagnetic observations. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) C. Constable (S)

SIOG 230. Introduction to Inverse Theory (4)

Solution of linear and nonlinear inverse problems in geophysics by optimization techniques such as norm minimization and linear programming. Construction of models by regularization; inference by bounding functionals. Illustrations from gravity, geomagnetism, and seismology. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) C. Constable (W)

SIOG 231. Introduction to EM Methods in Geophysics (4)

Introduction to electromagnetic methods for both global geophysics and applied/exploration methods. Covers history of EM induction, conduction in rocks, binary mixing laws, self potential, induced polarization, DC resistivity, magnetotellurics, geomagnetic depth sounding, elementary inverse methods, global conductivity structure, and marine EM methods. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) S. Constable (F)

SIOG 232. Ethical and Professional Science (2)

Review and group discussion of professional behavior and survival skills in the earth and ocean sciences, including ethics, data management, plagiarism, authorships, preparing proposals, public speaking, conflict of interest, working with industry. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades only.) C. Constable, S. Constable (S)

SIOG 233. Introduction to Computing at SIO (4)

Introduction to the SIO computing environment and common software tools in geophysics and other disciplines. Topics include UNIX, Matlab, Postscript, GMT, LaTex, HTML, and a scientific programming language such as C or Fortran90. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Shearer, Tauxe (F)

SIOG 234. Geodynamics (4)

A general course on the dynamics and kinematics of the solid earth based on the text of Turcotte and Schubert. Topics include plate tectonics, heat flow, lithospheric cooling, flexure, viscous flow, gravity, crustal dynamics, and other related topics. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Sandwell (W)

SIOG 236. Satellite Remote Sensing (4)

Satellite remote sensing provides global observations of Earth to monitor environmental changes in land, oceans, and ice. Overview physical principles of remote sensing, including orbits, electromagnetic radiation, diffraction, electro-optical, and microwave systems. Weekly labs explore remote sensing data sets. Graduate students will also be required to write a term paper and do an oral presentation. Coscheduled with SIO 135. ***Prerequisites:*** graduate standing or consent of instructor. Sandwell (S)

SIOG 238. Numerical Methods for Partial Differential Equations (4)

The course will discuss main numerical methods used to solve boundary and initial value problems involving partial differential equations, such as finite differences, finite elements, and boundary elements. The emphasis will be on practical implementation of the commonly used tools and algorithms. Examples from geophysical applications will be provided. Recommended preparation: calculus and linear algebra. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Fialko (W)

SIOG 239. Special Topics in Geophysics (1–4)

Special course offerings by staff and visiting scientists. Example topics are seismic source theory, geophysical prospecting methods, dislocation theory and seismic mechanisms, tectonic interpretation of geodetic data, and dynamo theory. (S/U grades permitted.) Staff (F,W,S)

SIOG 240. Marine Geology (4)

Introduction to the geomorphology, sedimentation, stratigraphy, volcanism, structural geology, tectonics, and geological history of the oceans. ***Prerequisites:***graduate standing or consent of instructor. Castillo, Charles, Gee (F)

SIOG 241. Geological Field Methods for Geophysicists (1)

This course is intended for precandidacy geophysics students who have little practical geological experience. We will learn to use: Brunton compasses, GPS, topographic and geological maps and air photos, and proper note-taking habits. We will explore the geology of Fossil Canyon (near Ocotillo), learn to determine age relationships, and how to read the rock record for clues about the geological history of the area, including the opening of the Gulf of California.***Prerequisites:*** graduate standing or consent of instructor. Tauxe (F,W,S)

SIOG 243. Material Characterization (4)

Survey course in materials characterization geared in the earth, environmental, planetary, oceanographic, and biological sciences. Emphasis placed on surface analysis techniques. The course will introduce theoretical framework for spectroscopy, diffraction, and imaging methods used in structural and compositional characterization of materials. Techniques covered include SEM, TEM, IR, and Raman spectroscopy, laser ablation ICP-MS, etc. A term project will incorporate hands-on experience using SEM. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Van Allen

SIOG 244. Shape and Structure of the Ocean Floor (4)

Description and explanation of the structural geomorphology of oceanic crust, and of the tectonic and volcanic processes responsible for it. Description and interpretation of deep-sea sedimentary landforms (e.g., deep-sea fans, drifts, bedforms) and of the bottom currents that shape them. Offered in alternate years. ***Prerequisites:*** graduate standing or consent of instructor. Lonsdale (W)

SIOG 245. Marine Sediments-Paleo Proxies (4)

On the chemical and isotopic records of marine sediments and implications for the history of seawater chemistry and paleoceanography. Will concentrate on the isotopic systems: Li, B, C, O, S, Sr, and Nd, in marine phases that reliably preserve the records, and on associated diagenetic problems. ***Prerequisites:***graduate standing or consent of instructor. (S/U grades permitted.) Kastner (S)

SIOG 246. Global Tectonics and Basin Formation (4)

Plate tectonics of the crust and upper mantle, examining a variety of environments from ridge crests to continental margins, including plate interiors, with an emphasis on basin formation in

these tectonic settings. ***Prerequisites:*** graduate standing or consent of instructor. Cande, Driscoll (W)

SIOG 247. Rock Magnetism and Paleomagnetism (4)

Rock magnetism and acquisition of magnetic remanence in geological materials as well as laboratory procedures and data analysis (isolating remanence components and statistical approaches). The paleomagnetic literature will be used to illustrate applications in geological and geophysical problems. Recommended preparation: one year each of college-level physics and geology; mathematics through calculus. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Tauxe (S)

SIOG 249. Special Topics in Marine Geology (1–4)

Special course offerings by staff and visiting scientists. (S/U grades only.) Staff (F,W,S)

SIOG 251. Whole Earth Geochemistry (4)

A geochemical overview of Earth materials and chemical processes involved in the Earth's evolution. Topics include formation and differentiation of the Earth, linkages between the solid Earth and the atmosphere/ hydrosphere, and isotope and trace element composition of igneous and metamorphic rocks. Graduate students, additionally, must submit a term paper in one aspect of work discussed during the quarter to be presented orally in class. ***Prerequisites:*** graduate standing or consent of instructor. Hilton (S)

SIOG 252A. Introduction to Isotope Geochemistry (4)

Radioactive and stable isotope studies in geology and geochemistry, including geochronology, isotopes as tracers of magmatic processes, cosmic-ray produced isotopes as tracers in the crust and weathering cycle, isotopic evolution of the crust and mantle. Graduate level requires student presentation. Conjoined with SIO 144. ***Prerequisites:*** graduate-level standing or consent of instructor. Castillo, Keeling (W)

SIOG 252B. Advanced Isotope Geochemistry I (4)

An advanced treatment of noble gas and stable isotope geochemistry. Offered in alternate years with SIO 252C. ***Prerequisites:*** SIOG 252A or SIO 252A. Castillo, Keeling (S)

SIOG 252C. Advanced Isotope Geochemistry II (4)

An advanced treatment of radiogenic and cosmogenic isotope geochemistry. Offered in alternate years with SIO 252B. ***Prerequisites:*** SIOG 252A or SIO 252A and SIOG 252B or SIO 252B. (S)

SIOG 253. Interactions of Oceanic Plates and the California Margin (4)

How the geology of Alta and Baja California has been shaped, especially in the past 30MYR, by changing patterns of ocean plates and microplates that have subducted beneath the North American Margin, slid obliquely past it, and captured continental crust. ***Prerequisites:*** graduate standing, or consent of instructor. Lonsdale

SIOG 255. Paleobiology and History of Life (6)

An introduction to the major biological transitions in Earth history from the origins of metabolism and cells to the evolution of complex societies. The nature and limitations of the fossil record, patterns of adaptation and diversity, and the tempo and mode of biological evolution. Laboratories and substantial field component complement and extend lecture material. Program and/or materials fees may apply. Graduate students, additionally, will give oral presentation or research paper. Coscheduled with SIO 104. ***Prerequisites:*** graduate-level standing or consent of instructor. R. Norris (S)

SIOG 255A. Topics in Paleobiology and History of Life (3)
Lecture topics on the major transitions in the evolutionary history of life, including origin of metabolisms, microbes, major eukaryote radiations, ecosystems, and societies. ***Prerequisites:*** graduate standing or consent of instructor. R. Norris (S)

SIOG 257. Seminar in Petrology (4)
Discussion of current research in petrology and mineralogy. (S/U grades permitted.) (W)

SIOG 260. Marine Chemistry (4)
Chemical description of the sea; the distribution of chemical species in the world oceans, and their relationships to physical, biological, and geological processes. Aluwihare, Barbeau, Dickson, Martz (W)

SIOG 261. Introduction to Rheology of Solid Earth (4)
This course provides a framework for understanding the intrinsic properties of rocks (mineralogy, diffusion, deformation). It explores fundamental aspects of geological processes with an emphasis on the interpretation of geophysical data. The course focuses on micro-, rock-, and planet-scale mechanisms. ***Prerequisites:*** graduate standing or consent of instructor. A. Pommier (S)

SIOG 263. Aqueous Chemistry (4)
This course emphasizes the chemical principles that control basic aqueous chemistry in marine systems. The focus will be to show that the geochemistry of the various elements in sea water and biological systems can be understood as a consequence of basic general chemical concepts such as electron structure, chemical bonding, and group and periodic properties. Recommended preparation: undergraduate chemistry equivalent to UC San Diego Chemistry 6 sequence. ***Prerequisites:*** graduate standing or consent of instructor. Dickson (F)

SIOG 267. Marine Chemistry Laboratory (4)
Applies modern and classic techniques for analysis of seawater chemistry, introducing concepts of signal transduction, calibration, and measurement quality control, instrument communications, data processing. ***Prerequisites:*** graduate standing or consent of instructor. T. Martz (F)

SIOG 268. Seminar in Geochemistry and Marine Chemistry (2)
Student seminars on topics related to geochemistry and the chemistry of the marine environment. (S/U grades only.) Staff (F,W,S)

SIOG 269. Special Topics in Marine Chemistry (1–4)
Special course offerings by staff and visiting scientists. (S/U grades permitted.) Staff (F,W,S)

SIOG 270. The Archaeology of Climate Change—Social Adaptation and Vulnerability in Temporal Perspective (4)
(Cross-listed with ANTH 270.) This seminar studies the dynamics of climate change and human responses through time. Topics include research methods in socioecodynamics, human responses to change in different sociopolitical and economic contexts, and lessons from the past that can inform the present. Students may not receive credit for ANTH 270 and SIOG 270. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Staff (F)

SIOB 242A. Marine Biotechnology I: Tools and Methods (4)

The course will explore cutting-edge techniques as it applies to genomics, transcriptomics, proteomics, metabolomics, and the bioinformatics needed to analyze such data sets. Next generation sequencing, state-of-the-art mass spectrometry, and NMR techniques and bioinformatic challenges. Students may not receive credit for SIO 242A and SIO 242. ***Prerequisites:*** graduate standing or consent of instructor. Gaasterland, L. Gerwick (W)

SIOB 242B. Marine Biotechnology II: Applications (4)

This course will explore the diverse biotechnological applications of marine science. Topics will include natural product drug discovery, biomaterials, nanotechnology, synthetic biology, aquaculture, and extremophiles. Students may not receive credit for SIO 242B and SIO 242. ***Prerequisites:*** SIOB 242A or SIO 242A or consent of instructor. Bartlett, Jensen (S)

SIOB 242C. Marine Biotechnology III: Introduction to Bioinformatics (4)

Introduction to Unix commands and scripting techniques required for command line interaction with open source bioinformatics tools, including installation, configuration, and use for genome and transcriptome sequencing and assembly, gene expression analysis, and DNA- and RNA-binding protein binding site identification through ChIPseq. Emphasis is on how the bioinformatics tools work, how to use them, and their application to DNA and RNA data sets. Recommended preparation: prior programming skills will help the student gain more from the course. Students may not receive credit for SIO 242C if they have previously taken SIO 242. ***Prerequisites:*** SIOB 242A or SIO 242A and SIOB 242B or SIO 242B or consent of instructor.

SIOB 243. Ecological and Medicinal Aspects of Natural Products (2)

This course will provide the foundation of the natural products sciences, including ethnobotanical uses of plants, ecological interactions and contemporary drug screening programs, and will increase awareness of the pervasiveness of natural products in pharmaceutical and other commercial products. Students may not receive credit for SPPS 281 and SIOB 243. W. Gerwick (S)

SIOB 262. Marine Chemical Biology Seminar (2)

Students will give seminars on current research topics that span the interface of marine chemistry and marine biology. Topics will include natural products chemistry, biotechnology, biogeochemistry, and biochemistry relating to marine systems. May be taken for credit eighteen times. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades only.) Fenical, W. Gerwick, Moore (F,W,S)

SIOB 264. Special Topics in Marine Natural Products Chemistry (4)

This course provides the foundation for advanced study in the field of marine natural products chemistry. Topics vary from the history of natural products to the organic chemistry of terpenes, alkaloids, acetogenins, and other natural product classes. Varying by topic quarterly, this class is given each quarter and may be repeated. ***Prerequisites:*** one-year general organic chemistry. (S/U grades only.) Fenical, W. Gerwick, Moore (F,W,S)

SIOB 269. Interdisciplinary Forum for Environmental Research (2)

This course provides students from diverse disciplines with a common language to address problems related to the environment and conservation. The purpose is to promote collaboration and communications across departments and the course is open to all graduate students. Students who take the course for credit are expected to serve in the coordinating group to invite speakers and promote events across campus. May be taken for credit up to

three times. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades only.) Staff (F,W,S)

SIOB 270. Pelagic Ecology (4)

An analysis of the concepts and theories used to explain the biological events observed in the water column. Alternate years. ***Prerequisites:*** SIOC 210 or SIO 210 and SIOB 280 or SIO 280 or consent of instructor. Ohman, A. Allen (S)

SIOB 270A. Fisheries Oceanography (4)

Aspects of marine ecology relevant to the reproduction, survival, and distribution of commercially important marine species. Alternate years only. ***Prerequisites:*** graduate standing or consent of instructor. Checkley (S)

SIOB 271. Marine Zooplankton (5)

Lectures and laboratories treating the morphological, behavioral, and life history variations of the principal phyla of planktonic invertebrates and heterotrophic protists. Constraints of life at low Reynolds numbers; principles of allometry; growth processes of heterotrophic organisms. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Ohman (S)

SIOB 272. Advanced Statistical Techniques (4)

An interactive overview of statistical methods, focusing on approaches common within the life sciences. Emphasis on the conceptual and logical basis of statistical methods. Topics include treatment of controlled experimental data through to model fitting and exploration of observational data. Recommended preparation: SIO 187, BIEB 100, or equivalent introductory statistics/ biostatistics course. ***Prerequisites:*** graduate standing or consent of instructor. Sandin (W)

SIOB 273. Professional Ethics in Science (2–4)

A seminar on the historical and contemporary ethics and ethos of scientific research, based on published documents. Given in alternate years. ***Prerequisites:*** graduate standing and consent of instructor. Department stamp required. Dayton, Leichter (W)

SIOB 274. Natural History Below the Tides (4)

Exposure to local underwater habitats by scuba with basic material to comply with AAUS certification. Lectures and shore dives in local coastal habitats (protected bay and outer coast sites). Aids students in diving research by providing experience with SIO scientists. ***Prerequisites:*** department stamp required. Students must qualify to take the SIO dive course. This includes a physical exam as well as swimming and diving proficiency. Dayton, Leichter (F)

SIOB 275A. Benthic Ecology (4)

Evolution and maintenance of benthic communities from the terrestrial margins to the deep sea. Special emphasis will be placed on physical and biological scaling and processes determining patterns of distribution and abundance; interrelationships between community structure and population phenomena, including trophic relationships, reproductive and recruitment patterns, succession, and life history biology. Offered in alternate years with SIOB 275B. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Leichter, Levin (W)

SIOB 275B. Natural History of Coastal Habitats (6)

The purpose of this class is to develop skills in natural history observation, appreciate the origins of natural diversity in the coast, desert, and mountain Southwest, and discuss the preservation and management of natural ecosystems. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Dayton, R. Norris (S)

SIOB 276. Quantitative Theory of Populations and Communities (4)

An introduction to the quantitative tools and conceptual issues underlying the study of the dynamics and structure of ecological systems. Recommended preparation: three quarters of calculus. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Sugihara (F)

SIOB 276L. Quantitative Ecology Project Lab (4)

A laboratory complement to SIOB 276, to apply quantitative tools to conceptual issues underlying the study of the dynamics and structure of ecological systems. ***Prerequisites:*** graduate standing, SIOB 276 or SIO 276 and consent of instructor. Department stamp. Sugihara (W)

SIOB 277. Deep-Sea Biology (4)

The ecology, zoogeography, taxonomy, and evolution of deep-sea organisms, with emphasis on the benthos. Course includes one day cruise to the San Diego Trough to examine deep sea organisms (700–1200 meters) (two-hour steam from Point Loma). Offered alternate years. ***Prerequisites:*** graduate standing or consent of instructor. Levin (W)

SIOB 278. Seminar in Ocean Biosciences (2)

Presentations of reports, review of literature, and discussion of current research in the marine biological and oceanographic sciences. (S/U grades permitted.) Staff (F,W,S)

SIOB 279. Ecology Seminar in Biological Oceanography (1)

Weekly seminar for students in the biological oceanography curricular group. Lectures given by visiting scientists, resident staff, and students. May be taken for credit eighteen times. ***Prerequisites:*** graduate standing. (S/U grades only) Staff (F,W,S)

SIOB 280. Biological Oceanography (4)

The biology and ecology of marine plankton, nekton, and benthos. Emphasis will be on processes regulating species, community, and ecosystem patterns and changes, including productivity, trophic relationships and species interactions with the physical, chemical, and geological environment. One or more field trips. ***Prerequisites:*** graduate standing or consent of instructor. Franks or Checkley, Levin (F)

SIOB 281. Marine Physiology (4)

Biochemical and physiological mechanisms of adaptation of organisms to the marine environment. Special emphasis is on biological responses to temperature, salinity, carbon dioxide, pH and bicarbonate levels. ***Prerequisites:*** graduate standing or consent of instructor. Tresguerres

SIOB 282. Phytoplankton Diversity (4)

Molecular, biochemical, ecological, and evolutionary perspectives on the diversity of eukaryotic and prokaryotic phytoplankton. ***Prerequisites:*** graduate standing or consent of instructor. Palenik (W)

SIOB 283. Phycology: Marine Plant Biology (5)

Lecture and laboratory course emphasizing the biology, ecology and taxonomy of marine plants and seaweeds. Laboratory work mainly involves examination, slide preparation and dissection

of fresh material collected locally. An oral presentation on a current research topic is required. Program or course fee may apply. Graduate students, additionally, are required to write a research paper. Offered in alternate years. May be coscheduled with SIO 183. Renumbered from SIO 283. Students may not receive credit for SIO 283 and SIOB 283. Program or materials fees may apply. ***Prerequisites:*** graduate standing or consent of instructor. J. Smith (W)

SIOB 284. Marine Invertebrates (6)

Course emphasizing the diversity, evolution and function morphology of marine invertebrates. Laboratory work involves examination of live and prepared specimens. An oral presentation on a current research topic is required. Graduate level additionally requires a research paper with extensive literature review and critical analyses. Program or course fee may apply. ***Prerequisites:*** graduate standing or consent of instructor. Rouse (W)

SIOB 285. Physical-Biological Interactions (4)

Physical and biological processes affecting growth and patchiness of plankton. Concepts and equations from physical oceanography will be presented and explored in a biological context. Ideas will be treated both theoretically and with examples from the literature. ***Prerequisites:*** SIOC 210 or SIO 210 or consent of instructor. Franks (S)

SIOB 286. Marine Science, Economics, and Policy (4)

This course investigates global issues in marine conservation and potential policy solutions. The approach is interdisciplinary, fast-paced, and discussion oriented. Students will become acquainted with sufficient background in marine biology, ecology, marine and conservation economics, international law, and policy as preparation for participation in discussion on real-world issues in marine conservation. Topics and instructors change each quarter. ***Prerequisites:***graduate standing or consent of instructor. (S/U grades permitted.) Staff (F,W)

SIOB 287A. Marine Microbial Ecology (4)

Recent developments in the study of marine bacteria. Emphasis will be on biochemical and physiological adaptations of marine bacteria to the ocean environment. Bacterial metabolism, growth, and death will also be discussed in the context of trophic interactions and flows of material and energy in marine ecosystems. Molecular biology techniques used in the study of bacterial ecology will also be discussed. ***Prerequisites:*** graduate standing or consent of instructor. (S/U grades permitted.) Azam (W)

SIOB 287B. Microbial Physiology (4)

Prokaryotic cell biology will be discussed primarily from physiological and biochemical standpoints with focus on conceptual understanding, integration, and mechanism. Topics will vary from year to year but will include the following themes: bioenergetics, cell polarity, cell adhesion, the molecular basis of morphogenesis and differentiation, prokaryotic motility and behavior, rotary and linear molecular machines, bacterial organelles, pheromones and messengers, circadian rhythms, biological warfare, and bioremediation. Recommended preparation: BIBC 102, Metabolic Biochemistry; BICD 110, Cell Biology; BIMM 100, Molecular Biology, or equivalent background. ***Prerequisites:*** graduate standing or consent of instructor. (S)

SIOB 289. Pollution, Environment, and Health (4)

The goal is to understand the scope of the pollution problem facing the planet. Students will learn the properties of chemicals in the environment and survey the biological mechanisms that

determine their accumulation and toxicity. Graduate students will also be required to write a research paper. ***Prerequisites:***graduate standing or consent of instructor. Hamdoun

SIOB 290. Marine Biology (4)

An introduction to the field of marine biology, especially to the diversity of marine organisms at all taxonomic levels and their adaptations to the marine environment. ***Prerequisites:*** graduate standing or consent of instructor. N. Holland (W,S)

SIOB 291. Biology Graduate Research Presentations (2)

Graduate students in the biological sciences present research in a seminar or poster format. Class participants provide oral and written feedback on presentations. Required of second through fourth year students in the marine biology curricular group. Open to all SIO graduate students. (S/U grades only.) (S)

SIOB 292. Communicating Science to Informal Audiences (4)

Graduate science students will develop fundamental communication and instructional skills through the understanding and application of learning theory, interpretive techniques, and pedagogical practices, including the development of an education/outreach plan to support a competitive research proposal. May be coscheduled with SIO 180. Renumbered from SIO 292. Students may not receive credit for SIO 292 and SIOB 292. ***Prerequisites:*** graduate standing or consent of instructor. (F)

SIOB 293. Applications of Phylogenetics (6)

Overview of the computer-based methods for constructing phylogenetic trees using morphological and molecular data. Lectures and labs cover evolutionary and ecological transformations, biodiversity measurements, biogeography, systematics and taxonomy. An independent project and presentation are required. ***Prerequisites:*** graduate standing or consent of instructor. Rouse (W)

SIOB 294. Biology of Fishes (5)

The comparative evolution, morphology, physiology, and ecology of fishes. Special emphasis on local and deep-sea and pelagic forms in laboratory. ***Prerequisites:*** graduate standing or consent of instructor. Hastings (S)

SIOB 295. Behavior and Ecology of Fishes (4)

The course will review recent literature on the behavior and ecology of fishes with emphasis on phylogenetic interpretations of character evolution and/or implications for conservation biology. Topics covered may include habitat selection, foraging strategies, reproductive biology, ontogeny of behavior, speciation, radiations, macroecological patterns, specialized behaviors. Course is a mixture of lectures on the background of topics and student presentations. **Prerequisites:** graduate standing or consent of instructor. Hastings (S)

SIOB 296. Special Topics in Ocean Biosciences (1–5)

Example topics are reproduction in marine animals, adaptation to marine environments, larval biology, marine fisheries, macromolecular evolution, physical chemical topics in physiology, philosophy of science. ***Prerequisites:*** graduate standing. (S/U grades permitted.) Staff (F,W,S)

SIOB 297. Marine Biology Seminar (1)

Lectures given by visiting scientists and resident staff and students. May be taken for credit eighteen times. ***Prerequisites:*** graduate standing. (S/U grades only.) Staff (F,W,S)

SIOB 298. Special Studies in Marine Sciences (1–4)

Reading and laboratory study of special topics under the direction of a faculty member. Exact subject matter to be arranged in individual cases. ***Prerequisites:***graduate standing. (S/U grades permitted.) Staff (F,W,S)

SIO 295S. Introduction to Marine Biodiversity and Conservation—Seminar (8)
Lectures on ecological, economic, social, and legal issues related to marine biodiversity and case studies on socioeconomic and legal issues. Students are expected to attend field trips at sea and to various sites around San Diego County as a part of the corequisite course. Students who have taken SIO 295 may not receive credit for SIO 295S. ***Corequisites:*** SIO 295LS. ***Prerequisites:*** MAS students only; consent of instructor. (Su)

SIO 295LS. Introduction to Marine Biodiversity and Conservation—Lab (8)
Laboratory work on major biological taxa, field trips on biodiversity in situ, computer labs for informatic tools. Students are expected to attend field trips at sea and to various sites around San Diego County as a part of the course. Students who have taken SIO 295L may not receive credit for SIO 295LS. ***Corequisites:***SIO 295S. ***Prerequisites:*** MAS students only; consent of instructor. (Su)

SIO 299. Research (1–12)
(S/U grades only.) Staff (F,W,S)

SIO 500. Teaching Apprenticeship (1–4)
This practicum for graduate students provides experience in teaching undergraduate oceanography courses. ***Prerequisites:*** department approval. (S/U grades only.) Staff (F,W,S)

Sociology

Upper Division

SOCI 100. Classical Sociological Theory (4)
Major figures and schools in sociology from the early nineteenth century onwards, including Marx, Tocqueville, Durkheim, and Weber. The objective of the course is to provide students with a background in classical social theory, and to show its relevance to contemporary sociology. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 100 and SOCA 100.

SOCI 102. Network Data and Methods (4)
Social network analysts view society as a web of relationships rather than a mere aggregation of individuals. In this course, students will learn how to collect, analyze, and visualize social network data, as well as utilize these techniques to answer an original sociological research question. ***Prerequisites:*** SOCI 60, upper-division standing.

SOCI 103M. Computer Applications to Data Management in Sociology (4)
Develop skills in computer management and analysis of sociological data. Practical experience with data produced by sociological research. Students will develop competency in the analysis of sociological data, by extensive acquaintance with computer software used for data analysis and management (e.g., SPSS). ***Prerequisites:*** SOCI 60. Will not receive credit for SOCI 103M and SOCA 103M.

SOCI 104. Field Research: Methods of Participant Observation (4)
Relationship between sociological theory and field research. Strong emphasis on theory and methods of participant observation: consideration of problems of entry into field settings, recording observations, description/analysis of field data, ethical problems in fieldwork. Required paper using field methods. ***Prerequisites:*** SOCI 60; majors only. Will not receive credit for SOCI 104 and SOCA 104.

SOCI 104Q. Qualitative Interviewing (4)
This course provides students with tools to conduct original research using qualitative interviews. Students will learn how to prepare, conduct, and analyze qualitative interviews. Special emphasis will be placed on the presentation of research in written form. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 104Q and SOCA 104Q.

SOCI 105. Ethnographic Film: Media Methods (6)
(Conjoined with Soc/G 227.) Ethnographic recording of field data in written and audiovisual formats including film, video, and CD-ROM applications. Critical assessment of ethnographies and audiovisual ethnographic videotape. ***Prerequisites:*** graduate standing or consent of instructor for Soc/G 227 and SOCI for SOCI 105. Will not receive credit for SOCI 105 and SOCA 105.

SOCI 106. Comparative and Historical Methods (4)
A broad-based consideration of the use of historical materials in sociological analysis, especially as this facilitates empirically oriented studies across different societies and through time, and their application in student research projects. ***Prerequisites:*** SOCI 60. Will not receive credit for SOCI 106 and SOCA 106.

SOCI 106M. Holocaust Diaries (4)

Methods for interpreting diaries, letters, and testaments written by victims and perpetrators of the Holocaust. Students use these sources for original research about life in hiding, ghettos, and death camps. Includes techniques for making comparisons and for generalizing from evidence. ***Prerequisites:*** SOCI 60 and SOCI 178 or the consent of instructor. Will not receive credit for SOCI 106M and SOCA 106M.

SOCI 107. Epidemiological Methods: Statistical Study of Disease (4)

Epidemiology is the statistical study of disease, and epidemiological methods are a powerful tool for understanding the causes of certain diseases, e.g., AIDS, scurvy, cholera, and lung cancer. These fundamental epidemiological methods will be taught. ***Prerequisites:*** SOCI 60. Will not receive credit for SOCI 107 and SOCA 107.

SOCI 108. Survey Research Design (4)

Translation of research goals into a research design, including probability sampling, questionnaire construction, data collection (including interviewing techniques), data processing, coding, and preliminary tabulation of data. Statistical methods of analysis will be limited primarily to percentaging. ***Prerequisites:***SOCI 60. Will not receive credit for SOCI 108 and SOCA 108.

SOCI 109. Analysis of Sociological Data (4)

Students test their own sociological research hypotheses using data from recent American and international social surveys and state-of-the-art computer software. Application of classical scientific method, interpretation of statistical results, and clear presentation of research findings. ***Prerequisites:*** SOCI 60. Will not receive credit for SOCI 109 and SOCA 109.

SOCI 110. Qualitative Research in Educational Settings (4)

Basic understanding of participant observation, interviewing, and other ethnographic research techniques through field experiences in school and community settings sponsored by CREATE. Students will learn to take field notes, write up interviews, and compose interpretive essays based on their field experiences. ***Prerequisites:*** SOCI 60 Will not receive credit for SOCI 110 and SOCA 110A.

SOCI 112. Social Psychology (4)

This course will deal with human behavior and personality development as affected by social group life. Major theories will be compared. The interaction dynamics of such substantive areas as socialization, normative and deviant behavior, learning and achievement, the social construction of the self, and the social identities will be considered. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 112 and SOCB 112.

SOCI 113. Sociology of the AIDS Epidemic (4)

This course considers the social, cultural, political, and economic aspects of HIV/AIDS. Topics include the social context of transmission; the experiences of women living with HIV; AIDS activism; representations of AIDS; and the impact of race and class differences. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 113 and SOCB 113.

SOCI 115. Social Problems (4)

Analyzes selected social problems in the United States, such as those regarding education, race relations, and wealth inequality from various sociological perspectives. The course also examines the various sites of debate discussion, like political institutions, TV and other media,

and religious institutions. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 115 and SOCB 115.

SOCI 116. Gender and Language in Society (4)

(Same as LIGN 174.) This course examines how language contributes to the social construction of gender identities, and how gender impacts language use and ideologies. Topics include the ways language and gender interact across the life span (especially childhood and adolescence); within ethnolinguistic minority communities; and across cultures. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 116 and SOCB 118A.

SOCI 117. Language, Culture, and Education (4)

(Same as EDS 117.) The mutual influence of language, culture, and education will be explored; explanations of students' school successes and failures that employ linguistic and cultural variables will be considered; bilingualism; cultural transmission through education. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 117 and SOCB 117.

SOCI 118. Sociology of Gender (4)

An analysis of the social, biological, and psychological components of becoming a man or a woman. The course will survey a wide range of information in an attempt to specify what is distinctively social about gender roles and identities; i.e., to understand how a most basic part of the "self"—womanhood or manhood—is socially defined and socially learned behavior. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 118 and SOCB 118.

SOCI 118E. Sociology of Language (4)

An examination of how the understanding of language can guide and inform sociological inquiries and a critical evaluation of key sociological approaches to language, including ethnomethodology, frame analysis, sociolinguistics, structuralism and poststructuralism, and others. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 118E and SOCB 118L.

SOCI 119. Sociology of Sexuality and Sexual Identities (4)

Introduction both to the sociological study of sexuality and to sociological perspectives in gay/lesbian studies. Examines the social construction of sexual meanings, identities, movements, and controversies; the relation of sexuality to other institutions; and the intersection of sexuality with gender, class, and race. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 119 and SOCB 119.

SOCI 120T. Special Topics in Culture, Language, and Social Interaction (4)

This course will examine key issues in culture, language, and social interaction. Content will vary from year to year. ***Prerequisites:*** upper-division standing.

SOCI 121. Economy and Society (4)

An examination of a central concern of classical social theory: the relationship between economy and society, with special attention (theoretically and empirically) on the problem of the origins of modern capitalism. The course will investigate the role of technology and economic institutions in society; the influence of culture and politics on economic exchange, production, and consumption; the process of rationalization and the social division of labor; contemporary economic problems and the welfare state. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 121 and SOCC 121.

SOCI 122. Social Networks (4)
This course takes a social network approach to the study of society, examining the complex web of relationships— platonic, familial, professional, romantic—in which individual behavior is embedded. Special emphasis is placed on the unprecedented opportunities created by contemporary social media (e.g. Facebook, mobile phones, online dating websites) for answering fundamental sociological questions. ***Prerequisites:*** upper-division standing.

SOCI 123 Japanese Culture Inside/Out: A Transnational Perspective (4)
We examine cultural production in Japan and abroad, national and transnational political-economic and social influences, the idea of Japan in the West, and the idea of the West in Japan. ***Prerequisites:*** upper-division standing.

SOCI 125. Sociology of Immigration (4)
Immigration from a comparative, historical, and cultural perspective. Topics include: factors influencing amount of immigration and destination of immigrants; varying modes of incorporation of immigrants; immigration policies and rights; the impact of immigration on host economies; refugees; assimilation; and return migration. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 125 and SOCB 125.

SOCI 126. Social Organization of Education (4)
(Same as EDS 126.) The social organization of education in the U.S. and other societies; the functions of education for individuals and society; the structure of schools; educational decision making; educational testing; socialization and education; formal and informal education; cultural transmission. ***Prerequisites:***upper-division standing. Will not receive credit for SOCI 126 and SOCC 126.

SOCI 127. Immigration, Race, and Ethnicity (4)
Examination of the role that race and ethnicity play in immigrant group integration. Topics include theories of integration, racial and ethnic identity formation, racial and ethnic change, immigration policy, public opinion, comparisons between contemporary and historical waves of immigration. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 127 and SOCB 127.

SOCI 129. The Family (4)
An examination of historical and social influences on family life. Analyzes contemporary families in the United States, the influences of gender, class, and race, and current issues such as divorce, domestic violence, and the feminization of poverty. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 129 and SOCC 129.

SOCI 130. Population and Society (4)
This course offers insight into why and how populations grow (and decline), and where and under what conditions changes in population size and/or structure change have positive and negative consequences for societies and environment. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 130 and SOCD 130.

SOCI 131. Sociology of Youth (4)
Chronological age and social status; analysis of social processes bearing upon the socialization of children and adolescents. The emergence of “youth cultures,” generational succession as a cultural problem. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 131 and SOCB 131.

SOCI 132. Gender and Work (4)

Examination and analysis of empirical research and theoretical perspectives on gender and work. Special attention to occupational segregation. Other topics include: the interplay between work and family; gender, work and poverty; gender and work in the Third World. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 132 and SOCC 132.

SOCI 133. Immigration in Comparative Perspective (4)

Societies across the world are confronting new immigration. In this course, we will focus on Europe, Asia, and North America, and examine issues of nationalism, cultural diversity and integration, economic impacts, and government policy. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 133 and SOCB 133.

SOCI 134. The Making of Modern Medicine (4)

A study of the social, intellectual, and institutional aspects of the nineteenth-century transformation of clinical medicine, examining both the changing content of medical knowledge and therapeutics, and the organization of the medical profession. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 134 and SOCC 134A.

SOCI 135. Medical Sociology (4)

An inquiry into the roles of culture and social structure in mediating the health and illness experiences of individuals and groups. Topics include the social construction of illness, the relationships between patients and health professionals, and the organization of medical work. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 135 and SOCC 135.

SOCI 136E. Sociology of Mental Illness: A Historical Approach (4)

An examination of the social, cultural, and political factors involved in the identification and treatment of mental illness. This course will emphasize historical material, focusing on the eighteenth, nineteenth, and early twentieth centuries. Developments in England as well as the United States will be examined from an historical perspective. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 136E and SOCC 136A.

SOCI 136F. Sociology of Mental Illness in Contemporary Society (4)

This course will focus on recent developments in the mental illness sector and on the contemporary sociological literature on mental illness. Developments in England as well as the United States will be examined. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 136F and SOCC 136B.

SOCI 137. Sociology of Food (4)

Topics include food as a marker of social differences (e.g., gender, class, ethnicity); the changing character of food production and distribution; food as an object of political conflict; and the symbolic meanings and rituals of food preparation and consumption. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 137 and SOCB 137.

SOCI 138. Genetics and Society (4)

The class will first examine the direct social effects of the “genetic revolution”: eugenics, genetic discrimination, and stratification. Second, the implications of thinking of society in terms of genetics, specifically—sociobiology, social Darwinism, evolutionary psychology, and biology. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 138 and SOCC 138.

SOCI 139. Social Inequality: Class, Race, and Gender (4)

Massive inequality in wealth, power, and prestige is ever-present in industrial societies. In this course, causes and consequences of class, gender, racial, and ethnic inequality ("stratification") will be considered through examination of classical and modern social science theory and research. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 139 and SOCC 139.

SOCI 140. Sociology of Law (4)

This course analyzes the functions of law in society, the social sources of legal change, social conditions affecting the administration of justice, and the role of social science in jurisprudence. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 140 and SOCC 140.

SOCI 140F. Law and the Workplace (4)

This course examines how the US legal system has responded to workplace inequality and demands for employee rights. Particular attention is given to racial, gender, religious, and disability discrimination, as well as the law's role in regulating unions, the global economy, and sweatshop labor. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 140F and SOCC 140F.

SOCI 141. Crime and Society (4)

A study of the social origins of criminal law, the administration of justice, causes, and patterns of criminal behavior, and the prevention and control of crime, including individual rehabilitation and institutional change, and the politics of legal, police, and correctional reform. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 141 and SOCC 141.

SOCI 142. Social Deviance (4)

This course studies the major forms of behavior seen as rule violations by large segments of our society and analyzes the major theories trying to explain them, as well as processes of rule making, rule enforcing, techniques of neutralization, stigmatization and status degradation, and rule change. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 142 and SOCB 142.

SOCI 143. Suicide (4)

Traditional and modern theories of suicide will be reviewed and tested. The study of suicide will be treated as one method for investigating the influence of society on the individual. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 143 and SOCB 143.

SOCI 144. Forms of Social Control (4)

The organization, development, and mission of social control agencies in the nineteenth and twentieth centuries, with emphasis on crime and madness; agency occupations (police, psychiatrists, correctional work, etc.); theories of control movements. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 144 and SOCC 144.

SOCI 145. Violence and Society (4)

Focusing on American history, this course explores violence in the light of three major themes: struggles over citizenship and nationhood; the drawing and maintenance of racial, ethnic, and gender boundaries; and the persistence of notions of "masculinity" and its relation to violence. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 145 and SOCB 145.

SOCI 147. Organizations, Society, and Social Justice (4)
Organizations are dynamic forces in society. This course examines how organizations address human health and social justice issues in national and international settings, focusing on the links between internal dynamics of organizations and macro-level political, economic, and cultural factors. ***Prerequisites:***upper-division standing. Will not receive credit for SOCI 147 and SOCC 147.

SOCI 148. Political Sociology (4)
Course focuses on the interaction between state and society. It discusses central concepts of political sociology (social cleavages, mobilization, the state, legitimacy), institutional characteristics, causes, and consequences of contemporary political regimes (liberal democracies, authoritarianism, communism), and processes of political change. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 148 and SOCC 148.

SOCI 148E. Inequality and Jobs (4)
Some people do much better than others in the world of work. Causes and consequences of this inequality will be examined: How do characteristics of individuals (e.g., class, gender, race, education, talent) and characteristics of jobs affect market outcomes? ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 148E and SOCC 148L.

SOCI 149. Sociology of the Environment (4)
The environment as a socially and technically shaped milieu in which competing values and interests play out. Relation of humanity to nature, conflicts between preservation and development, environmental pollution and contested illnesses. Will not receive credit for SOCI 149 and SOCC 149.

SOCI 150. Madness and the Movies (4)
Hollywood has had an ongoing obsession with mental illness. This course will examine a number of important or iconic films on this subject. By examining them against a background provided by relevant scholarly materials, we shall develop a critical perspective on these cultural artifacts. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 150 and SOCC 150.

SOCI 152. Social Inequality and Public Policy (4)
(Same as USP 133.) Primary focus on understanding and analyzing poverty and public policy. Analysis of how current debates and public policy initiatives mesh with alternative social scientific explorations of poverty. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 152 and SOCC 152.

SOCI 153. Urban Sociology (4)
(Same as USP 105.) Introduces students to the major approaches in the sociological study of cities and to what a sociological analysis can add to our understanding of urban processes. ***Prerequisites:*** upper-division standing or consent of instructor. Will not receive credit for SOCI 153 and SOCC 153.

SOCI 154. Religious Institutions in America (4)
Examination of sociological theories for why people have religious beliefs. Also examines types of religious organizations, secularization, fundamentalism, religion and immigration, religion and politics, and religiously inspired violence and terrorism. The class will tend to focus on the

American context. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 154 and SOCC 154.

SOCI 155. The City of San Diego (4)

A research-oriented course studying a specific city. Students will describe and analyze a local community of San Diego. Additional work on one citywide institution. Guest lecturers from San Diego organizations and government. Readings largely from city reports and news media. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 155 and SOCC 155.

SOCI 156. Sociology of Religion (4)

Diverse sociological explanations of religious ideas and religious behavior. The social consequences of different kinds of religious beliefs and religious organizations. The influence of religion upon concepts of history, the natural world, human nature, and the social order. The significance of such notions as "sacred peoples" and "sacred places." The religious-like character of certain political movements and certain sociocultural attitudes. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 156 and SOCC 156.

SOCI 157. Religion in Contemporary Society (4)

Sacred texts, religious experiences, and ritual settings are explored from the perspective of sociological analysis. The types and dynamic of religious sects and institutions are examined. African and contemporary US religious data provide resources for lecture and comparative analysis. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 157 and SOCC 157.

SOCI 158. Islam in the Modern World (4)

The role of Islam in the society, culture, and politics of the Muslim people during the nineteenth and twentieth centuries; attempts by Muslim thinkers to accommodate or reject rival ideologies (such as nationalism and socialism); and a critical review of the relationship between Islam and the West. ***Prerequisites:***upper-division standing. Will not receive credit for SOCI 158 and SOCD 158.

SOCI 159. Special Topics in Social Organizations and Institutions (4)

Readings and discussion of particular substantive issues and research in the sociology of organizations and institutions, including such areas as population, economy, education, family, medicine, law, politics, and religion. Topics will vary from year to year. ***Prerequisites:*** upper-division standing.

SOCI 160. Sociology of Culture (4)

This course will examine the concept of culture, its "disintegration" in the twentieth century, and the repercussions on the integration of the individual. We will look at this process from a variety of perspectives, each focusing on one cultural fragment (e.g., knowledge, literature, religion) and all suggesting various means to reunify culture and consequently the individual. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 160 and SOCB 160.

SOCI 160E. Law and Culture (4)

This course examines major formulations of the relationship between law and culture in the sociological literature. Topics include formal law versus embedded law, law and morality, law and the self, legal consciousness, the rule of law, and the construction of

legality. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 160E and SOCB 160L.

SOCI 161. Sociology of the Life Course (4)

This course explores concepts, theory and empirical research related to demographic, sociopsychological, and institutional aspects of the different stages of human development. It considers social influences on opportunities and constraints by gender, class, race/ethnicity, and historical period. ***Prerequisites:***upper-division standing. Will not receive credit for SOCI 161 and SOCB 161.

SOCI 162. Popular Culture (4)

An overview of the historical development of popular culture from the early modern period to the present. Also a review of major theories explaining how popular culture reflects and/or affects patterns of social behavior. Students may not receive credit for both SOCI 162 and SOCB 162. ***Prerequisites:*** upper-division standing.

SOCI 163. Migration and the Law (4)

Provides a global sociological perspective on the development and consequences of laws regulating migration within and across nation-state borders. The ability of the nation-state to control migration using law and its policy instruments. The effects of different legal statuses on political and socioeconomic outcomes. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 163 and SOCC 163.

SOCI 165A. American News Media (4)

History, politics, social organization, and ideology of the American news media. This course,165A, surveys the development of the news media as an institution, from earliest newspapers to modern mass news media. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 165A and SOCC 165A.

SOCI 166. Sociology of Knowledge (4)

This course provides a general introduction to the development of the sociology of knowledge, and will explore questions concerning social determination of consciousness as well as theoretical ways to articulate a critique of ideology. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 166 and SOCB 166.

SOCI 167. Science and War (4)

This class examines how science has been mobilized in the development of nuclear weapons and other weapons of mass destruction. The class applies sociological concepts to the analysis of modern technological violence. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 167 and SOCC 167.

SOCI 168E. Sociology of Science (4)

A survey of theoretical and empirical studies concerning the workings of the scientific community and its relations with the wider society. Special attention will be given to the institutionalization of the scientific role and to the social constitution of scientific knowledge. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 168E and SOCC 168E.

SOCI 169. Citizenship, Community, and Culture (4)

Will survey the liberal, communitarian, social-democratic, nationalist, feminist, post-nationalist, and multicultural views on the construction of the modern citizen and good

society. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 169 and SOCD 169.

SOCI 170. Gender and Science (4)

Scientific practices have had a tremendous impact on our understandings of gender. Gender relations have also significantly influenced the character of scientific inquiry. The course will consider how and why these two processes intertwine. ***Prerequisites:*** upper-division standing.

SOCI 171. Technology and Science (4)

Does improved technology mean progress? Or, are environmental pollution and social alienation signs that technology is out of control? This class uncovers the social problems of key modern technologies such as automobile transport, factory farming, biotechnology, and nuclear power. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 168T and SOCI 171.

SOCI 172. Films and Society (4)

An analysis of films and how they portray various aspects of American society and culture. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 172 and SOCB 172.

SOCI 175. Nationality and Citizenship (4)

Surveys the development of nationality and citizenship law in historical and comparative perspective with an emphasis on the United States, Latin America, and Europe. Examines competing sociological accounts for national variation and convergence; consequences of the law; and local, transnational, and extraterritorial forms of citizenship. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 175 and SOCD 175.

SOCI 177. International Terrorism (4)

(Same as POLI 1420.) This course covers the definitions, history, and internationalization of terrorism; the interrelation of religion, politics and terror; and the representation of terrorism in the media. A number of organizations and their activities in Europe and the Middle East are examined. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 177 and SOCD 177.

SOCI 178. The Holocaust (4)

The study of the unique and universal aspects of the Holocaust. Special attention will be paid to the nature of discrimination and racism, those aspects of modernity that make genocide possible, the relationship among the perpetrators, the victims and the bystanders, and the teaching, memory, and denial of the Holocaust. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 178 and SOCD 178.

SOCI 179. Social Change (4)

Course focuses on the development of capitalism as a worldwide process, with emphasis on its social and political consequences. Topics include: precapitalist societies, the rise of capitalism in the West, and the social and political responses to its expansion elsewhere. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 179 and SOCD 179.

SOCI 180. Social Movements and Social Protest (4)

An examination of the nature of protests and violence, particularly as they occur in the context of larger social movements. The course will further examine those generic facets of social movements having to do with their genesis, characteristic forms of development, relationship

to established political configurations, and gradual fading away. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 180 and SOCC 180.

SOCI 181. Modern Western Society (4)

This course examines the nature and dynamics of modern western society in the context of the historical process by which this type of society has emerged over the last several centuries. The aim of the course is to help students think about what kind of society they live in, what makes it the way it is, and how it shapes their lives. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 181 and SOCD 181.

SOCI 182. Ethnicity and Indigenous Peoples in Latin America (4)

Ethnicity and the reassertion of Indian identity in contemporary Latin America. Issues related to these trends are examined in comparative perspective, with attention to changes in global conditions and in the socioeconomic, political, and cultural contexts of Latin American modernization. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 182 and SOCD 182.

SOCI 184. Gender and Film (4)

This class will examine issues of masculinity and femininity through analysis of films. Emphasis is on contemporary American society and will include varying issues such as race, class, and sexualities; worlds of work; romance, marriage, and family. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 184 and SOCC 184.

SOCI 185. Globalization and Social Development (4)

Social development is more than sheer economic growth. It entails improvements in the overall quality of human life, particularly in terms of access to health, education, employment, and income for the poorer sectors of the population. Course examines the impact of globalization on the prospects for attaining these goals in developing countries. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 185 and SOCD 185.

SOCI 187. African Societies through Film (4)

Exploration of contemporary African urbanization and social change via film, including 1) transitional African communities, 2) social change in Africa, 3) Western vs. African filmmakers' cultural codes. Ideological and ethnographic representations, aesthetics, social relations, and market demand for African films are analyzed. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 187 and SOCD 187.

SOCI 187E. The Sixties (4)

A sociological examination of the era of the 1960s in America, its social and political movements, its cultural expressions, and debates over its significance, including those reflected in video documentaries. Comparisons will also be drawn with events in other countries. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 187E and SOCD 187S.

SOCI 188D. Latin America: Society and Politics (4)

Course focuses on the different types of social structures and political systems in Latin America. Topics include positions in the world economy, varieties of class structure and ethnic cleavages, political regimes, mobilization and legitimacy, class alignments, reform and revolution. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 188D and SOCD 188D.

SOCI 188E. Community and Social Change in Africa (4)

The process of social change in African communities, with emphasis on changing ways of seeing the world and the effects of religion and political philosophies of social change. The methods and data used in various village and community studies in Africa will be critically examined. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 188E and SOCD 188A.

SOCI 188F. Modern Jewish Societies and Israeli Society (4)

Contradictory effects of modernization on Jewish society in Western and Eastern Europe and the plethora of Jewish responses: assimilation, fundamentalism, emigration, socialism, diaspora nationalism, and Zionism. Special attention will be paid to issues of discontinuity between Jewish societies and Israeli society. Simultaneously, we will scrutinize the influence of the Palestinian-Israeli conflict on Israeli society, state, and identity. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 188F and SOCD 188F.

SOCI 188G. Chinese Society (4)

The social structure of the People's Republic of China since 1949, including a consideration of social organization at various levels: the economy, the policy, the community, and kinship institutions. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 188G and SOCD 188B.

SOCI 188I. The Israeli-Palestinian Conflict (4)

In this course we will examine the national and colonial dimensions of this long-lasting conflict and then turn our attention to the legal, governmental/political, and everyday aspects of the Israeli occupation of the West Bank and Gaza following the 1967 war. ***Prerequisites:*** upper-division standing.

SOCI 188J. Change in Modern South Africa (4)

Using sociological and historical perspectives, this course examines the origins and demise of apartheid and assesses the progress that has been made since 1994, when apartheid was officially ended. Contrasts of racism in South Africa and the United States. ***Prerequisites:*** upper-division standing. Will not receive credit for SOCI 188J and SOCD 188J.

SOCI 188K. American Society (4)

Comparative and historical perspectives on US society. The course highlights "American exceptionalism": Did America follow a special historical path, different from comparable nations in its social relations, politics, and culture? Specific topics include class relations, race, religion, and social policy. ***Prerequisites:***upper-division standing. Will not receive credit for SOCI 188K and SOCD 188K.

SOCI 188M. Social Movements in Latin America (4)

Course examines theories of social movements and changing patterns of popular protest and contentious mobilization in Latin America since the mid-twentieth century. Case studies include populism, guerrillas, liberation theology and movements of workers, peasants, women, and indigenous groups. ***Prerequisites:***upper-division standing.

SOCI 188O. Settlements and Peacemaking in Israel (4)

We will examine the social, political, and religious factors that affect the nexus of Israeli settlements and Israeli-Arab and Israeli-Palestinian peace making. Special attention will be paid to the period after the 1967 War when these processes begun as well as to alternative resolutions to the conflict. ***Prerequisites:***upper-division standing.

SOCI 189. Special Topics in Comparative-Historical Sociology (4)

Readings and discussion in selected areas of comparative and historical macrosociology. Topics may include the analysis of a particular research problem, the study of a specific society or of cross-national institutions, and the review of different theoretical perspectives. Contents will vary from year to year. ***Prerequisites:*** upper-division standing.

SOCI 192. Senior Seminar in Sociology (1)

The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in sociology (at the upper-division level). Topics will vary from quarter to quarter. Senior Seminars may be taken for credit up to four times, with a change in topic, and permission of the department. Enrollment is limited to twenty students, with preference given to seniors. (P/NP grades only.) ***Prerequisites:***instructor permission or department stamp, upper-division standing.

SOCI 194. Research Seminar in Washington, DC (4)

(Same as PS 194, COGN 194, ERTH 194, HIST 193, USP 194.) Course attached to six-unit internship taken by students participating in the UCDC Program. Involves weekly seminar meetings with faculty and teaching assistant and a substantial research paper. ***Prerequisites:*** department approval. Participating in UCDC Program. Will not receive credit for SOCI 194 and SOCE 194.

SOCI 196A. Honors Seminar: Advanced Studies in Sociology (4)

This seminar will permit honors students to explore advanced issues in the field of sociology. It will also provide honors students the opportunity to develop a senior thesis proposal on a topic of their choice and begin preliminary work on the honors thesis under faculty supervision. ***Prerequisites:*** acceptance into Department of Sociology Honors Program.

SOCI 196B. Honors Seminar: Supervised Thesis Research (4)

This seminar will provide honors candidates the opportunity to complete research on and preparation of a senior honors thesis under close faculty supervision. ***Prerequisites:*** completion of SOCI 196A.

SOCI 198. Directed Group Study (4)

Group study of specific topics under the direction of an interested faculty member. Enrollment will be limited to a small group of students who have developed their topic and secured appropriate approval from the departmental committee on independent and group studies. These studies are to be conducted only in areas not covered in regular sociology courses. ***Prerequisites:*** junior standing and departmental approval required.

SOCI 199. Independent Study (4)

Tutorial: individual study under the direction of an interested faculty member in an area not covered by the present course offerings. Approval must be secured from the departmental committee on independent studies. ***Prerequisites:*** junior standing and departmental approval required.

Graduate

Soc/G 201A. Classical Sociological Theory I (4)

A discussion of major themes in the work of Tocqueville and Marx. ***Prerequisites:*** graduate standing in sociology.

Soc/G 201B. Classical Sociological Theory II (4)

A discussion of major themes in the work of Weber and Durkheim. ***Prerequisites:*** graduate standing in sociology.

Soc/G 202. Contemporary Sociological Theory (4)

Themes important for social theory at the turn of the twenty-first century: Marxism (Gramsci, Althusser), critical theory (Adorno, Habermas), interpretation (Geertz), social systems (Parsons), post-structuralism (Foucault), postmodernism, and social constructivism (Bourdieu). ***Prerequisites:*** graduate standing in sociology.

Soc/G 203. Field Methods (4)

Research will be conducted in field settings. The primary focus will be on mastering the problems and technical skills associated with the conduct of ethnographic and participant observational studies. ***Prerequisites:*** graduate standing in sociology.

Soc/G 204. Text and Discourse Analysis (4)

Techniques of gathering and analyzing transcripts of naturally occurring conversations, interviews, discourse in institutional settings, public political discourse, and text of historical materials. ***Prerequisites:*** graduate standing in sociology.

Soc/G 205. Quantitative Methods I (4)

This course covers some of the elementary techniques used 1) to select random samples, 2) to detect statistical patterns in the sample data, and 3) to determine whether any patterns found in sample data are statistically significant. The course also stresses the benefits and drawbacks of survey and aggregate data and some common ways in which these data are used incorrectly. ***Prerequisites:*** graduate standing in sociology.

Soc/G 206. Quantitative Methods II (4)

The course covers some of the more advanced techniques used 1) to select random samples, 2) to detect statistical patterns in the sample data, and 3) to determine whether any patterns found in sample data are statistically significant. The course also stresses the benefits and drawbacks of survey and aggregate data and some common ways in which these data are used incorrectly. ***Prerequisites:*** graduate standing in sociology.

Soc/G 207. Comparative-Historical Methods (4)

A broad-based consideration of the use of historical materials in sociological analysis, especially as this facilitates empirically oriented studies across different societies and through time. ***Prerequisites:*** graduate standing in sociology.

Soc/G 208. Faculty Research Seminar (2)

An introduction for entering graduate students to the range and variety of research and scholarly interest of the department's faculty. Through this introduction students will be better able to relate their own research interests and professional objectives to the ongoing work of faculty. ***Prerequisites:*** graduate standing in sociology. (S/U grades only.)

Soc/G 209. Social Networks (4)

This course provides an accessible, graduate level introduction to social network analysis as a theoretical and methodological approach—one takes relationships rather than individuals as

the fundamental unit of analysis. While the course will focus on concepts and applications rather than statistical models, students will also become acquainted with basic analytic techniques as well as learn how to collect, store, inspect, and visualize original network data.***Prerequisites:*** graduate standing in sociology.

Soc/G 211. Introduction to Computational Social Science (4)

This course provides an overview and practical, hands-on introduction to some of the common tools employed in computational approaches to social science research. Students will acquire sufficient skills to use existing tools to conduct computational social science research, such as basic Python language. Recommended preparation: knowledge of or background in statistics. ***Prerequisites:*** graduate standing in sociology.

Soc/G 212. Social Stratification (4)

The causes and effects of social ranking in various societies. Theories of stratification; the dynamics of informal social grouping; determinants of institutional power, and the nature of struggles for power; the distribution of wealth and its causes; the dynamics of social mobility; the effects of stratification on life-styles, culture, and deviance. ***Prerequisites:*** graduate standing in sociology.

Soc/G 214 Urban Sociology (4)

A survey of topics in urban sociology, including the city and suburb as social forms, civility among strangers, urbanism and culture, the political economy of metropolitan development, urban poverty, and racial residential segregation. Classical and contemporary approaches will be considered. ***Prerequisites:***graduate standing in sociology.

Soc/G 216. Sociology of Culture (4)

The history of the concept of culture; cultural pluralism in advanced industrialized societies; the differentiation of cultural institutions; cultural policy and social structure; culture as a property of social groups; conflict and accommodation over efforts to change and sustain traditional culture.

Soc/G 222. Social Movements (4)

An examination of theories accounting for the causes and consequences of social movements, including a discussion of the strengths and weaknesses of such theories for understanding historically specific revolutions, rebellions, and violent and nonviolent forms of protest in various parts of the world. ***Prerequisites:***graduate standing in sociology.

Soc/G 226. Political Sociology (4)

This course discusses the relationship between state and society in a comparative perspective. The focus is on the interaction among states, domestic economic elites, and external economic and political processes in the determination of different developmental paths. Analytically, it includes topics such as characteristics and functions of the state in different types of society throughout history (with an emphasis on the varieties of capitalist and socialist state), the autonomy of the state and its causes in different settings, and developmental and predatory consequences of state activity. Readings will include both theoretical and empirical materials, the latter dealing mostly with nineteenth- and twentieth-century Europe and twentieth-century Latin America. ***Prerequisites:***graduate standing in sociology.

Soc/G 227. Ethnographic Film: Media Methods (6)

Ethnographic recording of field data in written and audiovisual formats, including film, video, and CD-ROM applications. Critical assessment of ethnographies and audiovisual data in terms

of styles, format, and approaches. Graduate students are required to submit a fifteen-page mid-term paper comparing a written and an audiovisual ethnography and a final video ethnography with a project abstract. ***Prerequisites:*** graduate standing; SOCI 1, SOCI 2; or consent of instructor.

Soc/G 232. Advanced Issues in the Sociology of Knowledge (4)

The social construction of knowledge and the social institutions in which these processes take place are examined. Topics include relationships between knowledge and social institutions, foundations of knowledge in society, knowledge and social interactions, and contrasting folk and specialized theories. ***Prerequisites:*** graduate standing in sociology.

Soc/G 234. Intellectual Foundation of the Study of Science, Technology, and Medicine (4)

This course focuses on some classic methodological and theoretical resources upon which the sociology of science, technology, and medicine all draw. It gives special attention to relationships between knowledge and social order, and between knowledge and practice, that are common to science, technology, and medicine. ***Prerequisites:*** graduate standing in sociology.

Soc/G 238. Survey of the Sociology of Scientific Knowledge (4)

An introduction to some enduring topics in the sociology of scientific knowledge and to some resources for addressing them. Attention is drawn to problems of accounting for scientific order and change, and to recurrent debates over the proper method for sociological accounts of science. ***Prerequisites:*** graduate standing.

Soc/G 243. Sociology of Social Control (4)

An examination of the sociological literature on social control, looking at theoretical developments over time and examining the contemporary literature dealing with social control in historical and comparative perspective. ***Prerequisites:*** graduate standing.

Soc/G 244. Sociology of Race and Ethnicity (4)

Analysis of enduring topics in the study of race and ethnicity, including stratification, discrimination conflict, immigration, assimilation, and politics. Other topics include racial and ethnic identity and the social construction of race and ethnic categories. A special focus is on the role of 'culture' and 'structure' for explaining race/ethnic differentiation. ***Prerequisites:*** graduate standing in sociology.

Soc/G 245. Gender, Work, and the Economy (4)

This course studies social constructions of gender within economic opportunities and constraints. We read classical sociological theory on this topic; feminist critiques; and newer research on careers, organizations, and markets. ***Prerequisites:*** graduate standing in sociology.

Soc/G 246. The Welfare State (4)

Surveys major theories of the development and functioning of the welfare state, addressing the roles of economic development, political institutions, stratification, and culture. The course focuses on the development of the US social provision in comparison with other advanced industrial societies.

Soc/G 247. Madness and Society (4)

An examination of changing Western responses from the age of Bedlam to the age of Prozac. Topics include: the rise and decline of the total institution; the emergence of psychiatry; changing cultural meanings of madness; and the therapeutics of mental disorder. ***Prerequisites:*** graduate standing in sociology.

Soc/G 252. Research Practicum I (4)
In this seminar students work on a research project, which might have originated in a paper written for another course. The goal is to produce the first draft of a paper that will be submitted to an academic journal. ***Prerequisites:*** graduate standing in sociology.
Soc/G 253. Research Practicum II (4)
In this seminar students revise an existing research paper (usually the one they wrote for Sociology 252) for submission to an academic journal. Emphasis is placed on conceptual development, writing style and structure, and drawing links to the existing theoretical and empirical literature. ***Prerequisites:*** graduate standing in sociology.
Soc/G 255A. Introduction to Science Studies (4)
(Same as Phil 209A, HIGR 238, and COGR 225A.) Study and discussion of classic work in history of science, sociology of science, and philosophy of science, and of work that attempts to develop a unified science studies approach. Required for all students in the Science Studies Program. ***Prerequisites:*** enrollment in Science Studies Program.
Soc/G 255B. Seminar in Science Studies (4)
(Same as Phil 209B, HIGR 239, and COGR 225B.) Study and discussion of selected topics in the science studies field. Required for all students in the Science Studies Program. ***Prerequisites:*** enrollment in Science Studies Program.
Soc/G 255C. Colloquium in Science Studies (4)
(Same as Phil 209C, HIGR 240, and COGR 225C.) A forum for the presentation and discussion of research in progress in science studies, by graduate students, faculty, and visitors. Required of all students in the Science Studies Program. ***Prerequisites:*** enrollment in the Science Studies Program.
Soc/G 255D. Advanced Approaches to Science Studies (4)
(Same as COGR 225D, HIGR 241, Phil 209D.) Focus on recent literature in the history, philosophy, and sociology of science, technology, and medicine. Required of all students in the Science Studies Program. ***Prerequisites:*** Soc/G 255A is a prerequisite for Soc/G 255D; enrollment in Science Studies Program or instructor's permission.
Soc/G 258. Institutional Change in the Contemporary World; Latin American Societies in a Comparative Perspective (4)
This course explores institutional change in contemporary Latin America, and compares this area with other transitional societies. Issues include social consequences of economic liberalization, changing forms of inequality, dynamics of civil society, conceptions of citizenship, quality and future of democracy. ***Prerequisites:*** graduate standing.
Soc/G 263. Graduate Seminar in the Sociology of Art (4)
This seminar explores the production and interpretation of art forms in cross-cultural context. Processes of symbolic and economic exchange in art worlds will be examined from sociological and semiotic perspectives. Contemporary and popular art forms will be analyzed as types of cultural reproduction. Graduate students will be required to submit a project abstract and final research paper of twenty-seven pages. ***Prerequisites:*** graduate standing in sociology.
Soc/G 264. Economic Sociology (4)
This course provides an overview of the classical and current debates in the economic sociology literature. It presents theories of the rise of industrial economics and addresses how economic

activities are constituted and influenced by institutions, culture, and social structure. ***Prerequisites:*** graduate standing in sociology.

Soc/G 267. Sociology of Gender (4)

Course examines social construction of gender focusing on recent contributions to the field, including micro- and macro-level topics, i.e., social psychological issues in the development of gender, gender stratification in the labor force, gender and social protest, feminist methodologies. ***Prerequisites:*** graduate standing in sociology.

Soc/G 269. The Citizenship Debates (4)

Will examine the controversies surrounding the construction of the modern citizen and the good society of the liberal outlook, and their alternatives in the communitarian, social-democratic, nationalist, feminist, and multiculturalist perspectives. ***Prerequisites:*** graduate standing in sociology.

Soc/G 278. Immigration, Assimilation, and Identity (4)

This course focuses on theoretical and empirical approaches to the study of immigration, assimilation, and identity. The course will focus primarily on the post-1965 immigrants, but consideration will also be given to earlier waves of immigration. ***Prerequisites:*** graduate standing in sociology.

Soc/G 282. Immigration and Citizen (4)

Alternative theories of the relations of immigrants and host societies, and an examination on the debates on, and dynamic of, immigration expansion and restriction. Comparison of the bearing of liberal, communitarian, and ethnic citizenship discourses on the inclusion and exclusion of immigrants and their descendants. ***Prerequisites:*** graduate standing in sociology.

Soc/G 284. Contemporary Biomedicine (4)

Develops central themes in medical sociology in order to understand twentieth- and twenty-first century medical practice and research. Topics include authority and expertise; health inequalities; managed care; health activism; biomedical knowledge production; and the construction of medical objects and subjects. ***Prerequisites:*** graduate standing.

Soc/G 288. Knowledge Capitalism (4)

This seminar examines the place of scientific knowledge and information and communication technology in the transformation of capitalist economy and society. The class explores new interactions between science studies and social theory of advanced capitalism. ***Prerequisites:*** graduate standing in sociology.

Soc/G 290. Graduate Seminar (4)

A research seminar in special topics of interest to available staff, provides majors and minors in sociology with research experience in close cooperation with faculty. (S/U grades permitted.) ***Prerequisites:*** graduate standing in sociology.

Soc/G 298. Independent Study (1–8)

Tutorial individual guides study and/or independent research in an area not covered by present course offerings. (S/U grades only.) ***Prerequisites:*** graduate standing in sociology; departmental approval.

Soc/G 299. Thesis Research (1–12)

Open to graduate students engaged in thesis research. (S/U grades only.) ***Prerequisites:*** graduate standing in sociology.

Soc/G 500. Apprentice Teaching (2–4)

Supervised teaching in lower-division contact classes, supplemented by seminar on methods in teaching sociology. (S/U grades only.) ***Prerequisites:*** graduate standing in sociology. Technology done under the direction of a faculty member. College stamp required. Pass/Not Pass grade only.

UC San Diego Business-Related Courses

This is a list of business course offerings at UCSD and UCSD Extension. This is a projected list of course offerings organized by department and quarter/term. Lower-division courses are numbered 1-99, upper-division courses are numbered 100-199 and graduate-level classes are numbered 200+. UPS students may enroll in graduate-level courses through Economics, Extension, and GPS (listed as GPEC, GPIM, GPPS, and GPGN), but no graduate-level courses may be taken through the Rady School of Management. Course enrollment is based on space availability, instructor/department approval, and prior completion of pre-requisites.

Courses offered through the Rady School of Management and the Economics Department can be found at www.tritonlink.ucsd.edu behind the "Schedule of Classes" label. Descriptions of the courses can be found at http://ucsd.edu/catalog/front/courses.html. Courses offered through UC San Diego Extension can be found at https://extension.ucsd.edu/ in the Business area of study.

During the summer, UC San Diego courses are offered in two 5-week summer sessions, listed in the table as Summer Session. During the summer, UC San Diego Extension courses are offered on a regular quarter schedule (not shorter sessions).

In the chart below:
X = The class is typically offered during this quarter\term in a regular in-class course.
O = The class is typically offered during this quarter\term as an online course. Students on F-1 visas are permitted to enroll into 1 online course per term.

Chart updated as of 1/2016

Lower Division Business Classes					
Course	**Title**	**Fall**	**Winter**	**Spring**	**Summer Session**
MGT3	Quantitative Methods in Business	x	x		
MGT5	Managerial Accounting	x	x	x	x
MGT12	Personal Financial Management	x	x	x	
MGT16	Personal Ethics at Work	x	x	x	x
MGT18	Managing Diverse Teams	x	x	x	x

MGT45	Principles of Accounting	x	x	x	x
MGT 52	Tests and Measurements at Work	X		x	
Upper Division Business Classes					
Course	**Title**	**Fall**	**Winter**	**Spring**	**Summer Session**
MGT103	Product Marketing and Management	x	x	x	x
MGT105	Product Promotion and Brand Management	x	x		
MGT106	Sales and Sales Management	x	x		
MGT 112	Global Business Strategy	x	x	x	x
MGT 117	Business Law	x	x		
MGT 119	Topics in Business			x	
MGT121A	Innovation to Market A	x		x	
MGT121B	Innovation to Market B			x	
MGT 127	Innovation and Technology Strategy		x		
MGT128	Innovation in Service Enterprise			x	
MGT129	Topics in Entrepreneurship (2 units)	x		x	
MGT 131A	Intermediate Accounting A	x	x	x	
MGT 131B	Intermediate Accounting B		x	x	
MGT 132	Auditing	x		x	
MGT 133	Advanced Cost Accounting	x			
MGT 134	Federal Taxation – Individuals			x	

MGT 135	Federal Taxation – Companies	x	x	x	
MGT 136	Advanced Accounting		x	x	
MGT 137	Financial Statement Analysis			x	
MGT 139	Accounting Information Systems	x			
MGT 146	Ethics in Accounting		x		
MGT 149	Topics in Accounting		x		
MGT153	Business Analytics	x	x	x	
MGT162	Negotiation		x		
MGT164	Organizational Leadership	x	x	x	x
MGT166	Business Ethics and Corporate Social Responsibility	x	x	x	
MGT 171	Operations Management	x		x	
MGT172	Business Project Management	x	x	x	x
MGT 173	Project Management – Health Services	x	x	x	
MGT 175	Supply Chain Management		x	x	
MGT 176	Strategic Cost Management			x	
MGT181	Enterprise Finance	x	x	x	x
MGT183	Financial Investments		x		
MGT184	Money and Banking	x			
MGT185	Investment Banking	x		x	

MGT187	New Venture Finance	x	x	x	
Lower Division Economics					
Course	**Title**	**Fall**	**Winter**	**Spring**	**Summer Session**
ECON1	Principles of Microeconomics	x	x	x	x
ECON2	Market Imperfections & Policy	x	x		x
ECON 3	Principles of Macroeconomics	x	x	x	x
ECON 4	Financial Accounting	x	x	x	x
ECON 5	Data Analytics for Social Science		x		x
Upper Division Economics					
Course	**Title**	**Fall**	**Winter**	**Spring**	**Summer Session**
ECON100A	Microeconomics A	x	x	x	x
ECON100B	Microeconomics B	x	x	x	x
ECON100C	Microeconomics C	x	x	x	x
ECON101	International Trade	x	x		
ECON102	Globalization	x			x
ECON103	International Monetary Relations			x	x
ECON 106	International Economic Agreements			x	
ECON109	Game Theory	x	x		x

ECON110A	Macroeconomics A	x	x	x	x
ECON110B	Macroeconomics B	x	x	x	x
ECON111	Monetary Economics		x		
ECON112	Macroeconomic Data Analysis	x		x	
ECON117	Economic Growth		x		
ECON120A	Econometrics A	x	x	x	x
ECON120B	Econometrics B	x	x	x	
ECON120C	Econometrics C	x	x	x	
ECON 122	Econometric Theory	x			
ECON125	Economics of Population Growth			x	
ECON 130	Public Policy	x			
ECON 131	Economics of the Environment	x	x		
ECON 132	Energy Economics		x		
ECON 134	The U.S. Safety Net			x	
ECON 138	Economics of Discrimination			x	
ECON 140	Economics of Health Producers	x		x	
ECON 142	Behavioral Economics			x	

ECON 143	Experimental Economics			x	
ECON 145	Economics of Ocean Resources		x		
ECON 146	Economic Stabilization			x	
ECON 147	Economics of Education	x			
ECON 151	Public Economics: Expenditures I			x	
ECON 152	Public Economics: Expenditures II		x		
ECON 164	The Indian Economy		x		
ECON 165	Economics of the Middle East			x	
ECON 169	Economics of Korea		x		
ECON 171	Decisions Under Uncertainty	x	x	x	x
ECON 172A	Operations Research A	x	x		
ECON 172B	Operations Research B		x	x	
ECON 173A	Financial Investments	x	x		
ECON 173B	Corporate Finance	x	x	x	
ECON 176	Marketing	x			
ECON 178	Economic & Business Forecasting		x		

Graduate Economics

Course	Title	Fall	Winter	Spring	Summer Session
ECON 205	Mathematics for Economists	x			
ECON 200ABC	Microeconomics (1st Year)	x	x	x	

ECON 210ABC	Macroeconomics (1st Year)	x	x	x	
ECON 220ABC	Econometrics (1st Year)	x	x	x	
ECON 220DEF	Econometrics (2nd Year)	x	x	x	
ECON 280	Computation	x			
ECON 201	Advanced Microeconomics				
ECON 204	Contract Theory	x			
ECON 206	Decisions		x		
ECON 214	Applied Macroeconomics				
ECON 221	Advanced Econometrics				
ECON 227	Nonparametric and Semi-parametric Methods				
ECON 230	Public Economics: Taxation				
ECON 231	Public Economics: National Government Expenditures				
ECON 232	Public Economics: Redistribution & Social Insurance		x	x	
ECON 241	Microeconomics of Development		x		
ECON 243	Organizational Economics of Development			x	
ECON 245	International Trade		x		
ECON 246	International Macroeconomics				
ECON 247	Empirical Topics: International Economics				
ECON 250	Labor Economics	x	x		

ECON 263	Modeling Behavioral Economics	x		x	
ECON 264	Experimental Economics				
ECON 265	Alternative Choice Theory		x		
ECON 266	Economics of Natural Resources	x			
ECON 267	Topics in Environmental and Resource Economics		x		
ECON 270	Finance - Core Asset Pricing		x		
ECON 272	Finance-Intertemporal Models			x	
ECON 281	Special Topics in Economics	x	x	x	
School of Global Policy and Strategy (GPS, formerly IR/PS)					
Course	**Title**	**Fall**	**Winter**	**Spring**	
GPS: Core Curriculum					
GPCO 400	Policy Making Pressures		x		
GPCO 401	Microeconomics for Policy and Management	x			
GPCO 403	International Economics			x	
GPCO 410	International Policy & Security			x	
GPCO 412	Globalization, the World System, and the Pacific	x			
GPCO 415	Accounting and Finance for Policy Makers		x		
GPCO 453	Quantitative Methods I	x			
GPCO 454	Quantitative Methods II		x		
GPCO 467	Policy Responses to Global Problems		x		

GPS: Economics Courses					
GPEC 411	Topics in China's Development	x			
GPEC 412	Comparative Development of the East Asian Economies			x	
GPEC 431	Fiscal and Monetary Policy		x		
GPEC 432	Immigration and Immigration Policy		x		
GPEC 435	Topics in International Trade			x	
GPEC 443	GIS and Spatial Data Analysis	x			
GPEC 444	Advanced GIS and Spatial Data Analysis		x		
GPEC 446	Applied Data Analysis and Statistical Decision Making			x	
GPEC 449	Corruption and Development			x	
GPEC 450	Macroeconomics of Development	x			
GPEC 451	Economic Development		x		
GPEC 462	Southeast Asian Economies	x			
GPEC 464	Designing Field Experiments			x	
GPEC 468	International Health Economics	x			
GPEC 485	The Korean Economy		x		
GPEC 486	Economic and Social Development of China		x		
GPEC 488	Environmental and Regulatory Economics	x			
GPS: International Management					
GPIM 410	Innovation and Entrepreneurship in Japan			x	

GPIM 411	Business and Management in Japan	x			
GPIM 419	Risk Management			x	
GPIM 424	Corporate Finance			x	
GPIM 438	Operations and Technology Management	x			
GPIM 447	Organizational Economics		x		
GPIM 452	Big Data Analysis			x	
GPIM 457	Cost-Benefit Analysis	x			
GPIM 470	International Business		x		
GPIM 482	Market Microstructure			x	
GPS: Policy Analysis					
GPPA 472	Latin American Environmental and Energy Policy	x			
GPPA 477	Cyber Security			x	
GPPA 483	Food Security			x	
GPS: Political Science					
GPPS 400	International Relations of Asia-Pacific	x			
GPPS 401	The New "New" Civil Wars	x			
GPPS 403	Chinese Security, Technology, and Innovation	x			
GPPS 404	Chinese Politics	x			
GPPS 406	China in the Global Economic Order			x	
GPPS 407	The International Relations and National Security of China		x		

GPPS 416	Postwar Politics in Japan			x	
GPPS 417	International Trade Economy: Trade and Investments		x		
GPPS 423	Corporate Social Responsibility		x		
GPPS 427	International Law and Regulation			x	
GPPS 428	The Politics of Energy and Environmental Regulation		x		
GPPS 430	Human Right, Public Policy, and International Relations			x	
GPPS 433	Debating US Security Policy	x			
GPPS 441	Government and Regulation	x			
GPPS 442	Foundations of Strategic Studies			x	
GPPS 446	Democratization in Latin America			x	
GPPS 449	The Making of US Foreign Policy	x			
GPPS 450	The Political Economy of Foreign Aid		x		
GPPS 451	Public Opinion and Foreign Policy		x		
GPPS 454	Current Issues in US-Latin American Relations		x		
GPPS 455	Financing the Chinese Miracle	x			
GPPS 456	Program Design and Evaluation			x	
GPPS 463	Politics of Southeast Asia		x		
GPPS 465	Management of Nonprofit Organizations			x	
GPPS 469	Comparative Grand Strategy and Defense Policy		x		
GPPS 473	Political Economy of Energy in Asia	x			
GPPS 476	Chinese Sources and Methods	x			

GPPS 479	Politics and Institutions in Latin America	x			
GPS: General Courses					
GPGN 490	Special Topics in Pacific International Affairs	x	x	x	
GPGN 499	Independent Research	x	x	x	
Extension Business Classes					
Course	**Title**	**Fall**	**Winter**	**Spring**	**Summer Session**
BUSA 40342	Introduction to Business		x	x	x
BUSA40064	Project Management Essentials	x	x		x
BUSA 40714	Project Management Bootcamp	x	x	x	x
BUSA 097990	Work Team Concepts and Skills	x	x		
BUSA40805	Six Sigma Yellow Belt	x			
BUSA40128	Interest Based Negotiations	x		x	x
BUSA 40742	The Green Supply Chain			x	
BUSA 40011	Elements of Marketing	x	x	x	x
BUSA40863	Elements of Marketing for Science and Tech	x		x	
BUSA40451	Product Management Branding	x	x	x	x
BUSA40442	Practical Market Research	x	x	x	x
BUSA40446	Creative Advertising Strategies	x	x		x
BUSA40691	Global Marketing	x	x	x	x
BUSA40453	Online Marketing Strategies	x		x	x

BUSA40453	Marketing via Social Media	x	x	x	x
BUSA40811	Innovation and Integration of Sustainable Practices	x	x	x	
BUSA40448	Promotional Copywriting	x			
BUSA40437	Public Relations Tools Tactics	x		x	x
BUSA40063	Principles of Facilities Management	x		x	
BUSA40341	Overview of Fundraising & Development Processes	x		x	x
BUSA40342	Introduction to Business	x	x		x
BUSA40050	Business & Entrepreneurship	x			
BUSA40803	Transformational Leadership	x			
BUSA40727	Communication Across Cultures	x			
BUSA40695	International Trade Operations	x	x	x	x
BUSA40673	Managing f/Maximum Performance	x			
BUSA40441	Business Decision Making	x			
BUSA40368	Business Communications Skills	x			
BUSA40729	Introduction to Sustainability	x	x		x
BUSA40692	Environment Economics & Analysis	x	x		x
BUSA40009	Financial Accounting for Non Accountants	x	x	x	x
BUSA40439	Finance Management	x	x	x	x
BUSA40130	Financial Statement Analysis	x	x	x	x

BUSA40477	Financing Strategy	x	x	x	x
BUSA40477	Business Valuation	x	x	x	x
BUSA40549	Financial Modeling	x	x	x	x
BUSA40162	International Finance	x	x	x	x
BUSA40014	Financial Markets & Investment Strategies	x	x	x	x
BUSA-40546	Leveraging Human Capital	x	x	x	x
RELE40006	Real Estate Property Management	x	x	x	x

Chemistry and Biochemistry

Upper Division

CHEM 100A. Analytical Chemistry Laboratory (4)
Laboratory course emphasizing classical quantitative chemical analysis techniques, including separation and gravimetric methods, as well as an introduction to instrumental analysis. Program or materials fees may apply. ***Prerequisites:*** CHEM 6C or 6CH and CHEM 6BL, 7L, or 7LM. Recommended: PHYS 2CL or 2BL.

CHEM 100B. Instrumental Chemistry Laboratory (5)
Hands-on laboratory course focuses on development of correct laboratory work habits and methodologies for the operation of modern analytical instrumentation. Gas chromatography, mass spectrometry, high performance liquid chromatography, ion chromatography, atomic absorption spectroscopy, fluorescence spectrometry, infrared spectrometry. Lecture focuses on fundamental theoretical principles, applications, and limitations of instrumentation used for qualitative and quantitative analysis. Program or materials fees may apply. Students may not receive credit for both CHEM 100B and 10. ***Prerequisites:***CHEM 100A and PHYS 2C or 2D and PHYS 2BL or 2CL or 2DL.

CHEM 105A. Physical Chemistry Laboratory (4)
Laboratory course in experimental physical chemistry. Program or materials fees may apply. ***Prerequisites:*** one or more of CHEM 126, 127, 131, 133 and CHEM 100A and one or more of PHYS 2BL, 2CL, or 2DL.

CHEM 105B. Physical Chemistry Laboratory (4)
Laboratory course in experimental physical chemistry. Program or materials fees may apply. ***Prerequisites:*** CHEM 105A.

CHEM 108. Protein Biochemistry Laboratory (6)
The application of techniques to study protein structure and function, including electrophoresis, protein purification, column chromatography, enzyme kinetics, and immunochemistry. Students may not receive credit for CHEM 108 and BIBC 103. A materials fee may be required for this course***. Prerequisites:*** CHEM 43A, 143A, 43AM or 143AM, and CHEM 114A.

CHEM 109. Recombinant DNA Laboratory (6)
This laboratory will introduce students to the tools of molecular biology and will involve experiments with recombinant DNA techniques. Students may not receive credit for both CHEM 109 and BIMM 101. A materials fee may be required for this course. ***Prerequisites:*** CHEM 43A, 143A, 43AM, or 143AM and CHEM 114A.

CHEM 111. Origins of Life and the Universe (4)
A chemical perspective of the origin and evolution of the biogeochemical systems of stars, elements, and planets through time. The chemical evolution of the earth, its atmosphere, and oceans, and their historical records leading to early life are discussed. The content includes search techniques for chemical traces of life on other planets. ***Prerequisites****:* CHEM 6C or 6CH.

CHEM 113. Physical Chemistry of Biological Macromolecules (4)
A discussion of the physical principles governing biomolecular structure and function. Experimental and theoretical approaches to understand protein dynamics, enzyme kinetics, and mechanisms will be covered. May be coscheduled with CHEM 213B. ***Prerequisites****:* CHEM 40C, 140C, 40CH, or 140CH; and CHEM 127 or 131.

CHEM 114A. Biochemical Structure and Function (4)
Introduction to biochemistry from a structural and functional viewpoint. Students may not receive credit for both CHEM 114A and BIBC 100. ***Prerequisites:***CHEM 40A or 140A.
CHEM 114B. Biochemical Energetics and Metabolism (4)
This course is an introduction to the metabolic reactions in the cell which produce and utilize energy. The course material will include energy-producing pathways: glycolysis, Krebs cycle, oxidative phosphorylation, fatty-acid oxidation. Biosynthesis of amino acids, lipids, carbohydrates, purines, pyrimidines, proteins, nucleic acids. Students may not receive credit for both CHEM 114B and BIBC 102. ***Prerequisites:*** CHEM 40B, 140B, 40BH, or 140BH.
CHEM 114C. Biosynthesis of Macromolecules (4)
Mechanisms of biosynthesis of macromolecules—particularly proteins and nucleic acids. Emphasis is on how these processes are controlled and integrated with metabolism of the cell. Students may not receive credit for both CHEM 114C and BIMM 100. ***Prerequisites:*** CHEM 114A or BIBC 100.
CHEM 114D. Molecular and Cellular Biochemistry (4)
This course represents a continuation of 114C, or an introductory course for first- and second-year graduate students, and covers topics in molecular and cellular biochemistry. Emphasis will be placed on contemporary approaches to the isolation and characterization of mammalian genes and proteins, and molecular genetic approaches to understanding eukaryotic development and human disease. May be coscheduled with CHEM 214. ***Prerequisites:*** CHEM 114A, 114B, and 114C.
CHEM 116. Chemistry of Enzyme Catalyzed Reactions (4)
A discussion of the chemistry of representative enzyme catalyzed reactions is presented. Enzyme reaction mechanisms and their relation to enzyme structure are emphasized. ***Prerequisites:*** CHEM 40C, 40CH, 140C, or 140CH, and CHEM 114A. (May not be offered every year.)
CHEM 118. Pharmacology and Toxicology (4)
A survey of the biochemical action of drugs and toxins as well as their absorption and excretion. ***Prerequisites:*** CHEM 114A.
CHEM 120A. Inorganic Chemistry I (4)
The chemistry of the main group elements in terms of atomic structure, ionic and covalent bonding. Structural theory involving s, p, and unfilled d orbitals. Thermodynamic and spectroscopic criteria for structure and stability of compounds and chemical reactions of main group elements in terms of molecular structure and reactivity. ***Prerequisites:*** CHEM 6C or 6CH and CHEM 40A or 140A.
CHEM 120B. Inorganic Chemistry II (4)
A continuation of the discussion of structure, bonding, and reactivity with emphasis on transition metals and other elements using filled d orbitals to form bonds. Coordination chemistry in terms of valence bond, crystal field, and molecular orbital theory. The properties and reactivities of transition metal complexes including organometallic compounds. ***Prerequisites:*** CHEM 120A.
CHEM 123. Advanced Inorganic Chemistry Laboratory (4)

Synthesis, analysis, and physical characterization of inorganic chemical compounds. Program or materials fees may apply. Recommended preparation: concurrent or prior enrollment in CHEM 120B. ***Prerequisites:*** CHEM 120A and 43A, 143A, 43AM or 143AM.

CHEM 125. Bioinorganic Chemistry (4)

The roles of metal ions in biological systems, with emphasis on transition metal ions in enzymes that transfer electrons, bind oxygen, and fix nitrogen. Also included are metal complexes in medicine, toxicity, and metal ion storage and transport. May be coscheduled with CHEM 225. ***Prerequisites:*** CHEM 114A or 120A.

CHEM 126. Physical Chemistry: Quantum Mechanics (4)

With CHEM 127, CHEM 126 condenses Physical Chemistry into two quarters. They may be taken in either order. The emphasis is on biochemical and environmental applications. Quantum mechanics and molecular structure, spectroscopy. Students may receive credit for only one of the following: CHEM 126, 133, or 130. ***Prerequisites:*** CHEM 6B or 6AH and PHYS 2C or 2D, and MATH 20D.

CHEM 127. Physical Chemistry: Thermodynamics (4)

With CHEM 126, CHEM 127 condenses Physical Chemistry into two quarters. They may be taken in either order. The emphasis is on biochemical and environmental applications. Thermodynamics, first and second laws, thermochemistry, chemical equilibrium, solutions, kinetic theory, reaction kinetics. Students may not receive credit for both CHEM 127 and 131. ***Prerequisites:*** CHEM 6C or 6BH, PHYS 2C or 2D, and MATH 20C.

CHEM 130. Chemical Physics: Quantum Mechanics (4)

With CHEM 131 and 132, CHEM 130 is part of the Physical Chemistry sequence taught over three quarters. Recommended as the first course of the sequence. Key topics covered in this course include quantum mechanics, atomic and molecular spectroscopy, and molecular structure. Students may not receive credit for both CHEM 130, 133, or 126. ***Prerequisites:*** CHEM 6C or 6CH, and PHYS 2C or 2D, and MATH 20D.

CHEM 131. Chemical Physics: Stat Thermo I (4)

With CHEM 130 and 132, CHEM 131 is part of the Physical Chemistry sequence taught over three quarters. Recommended as the second course of the sequence. Key topics covered in this course include thermodynamics, chemical equilibrium, phase equilibrium, and chemistry of solutions. Students may receive credit for only one of the following: CHEM 131 or 127. ***Prerequisites:*** CHEM 6C or 6CH, MATH 20C, and PHYS 2C or 2D.

CHEM 132. Chemical Physics: Stat Thermo II (4)

With CHEM 130 and 131, CHEM 132 is part of the Physical Chemistry sequence taught over three quarters. Recommended as the third course of the sequence. Key topics covered in this course include chemical statistics, kinetic theory, and reaction kinetics. ***Prerequisites:*** CHEM 130 or 133, and CHEM 131.

CHEM 134. Polymeric Materials (4)

Foundations of polymeric materials. Topics: structure of polymers; mechanisms of polymer synthesis; characterization methods using calorimetric, mechanical, rheological, and X-ray-based techniques; and electronic, mechanical, and thermodynamic properties. Special classes of polymers: engineering plastics, semiconducting polymers, photoresists, and polymers for medicine. Students may not receive credit for both CENG 134, CHEM 134, or NANO 134. ***Prerequisites:*** CHEM 6C and PHYS 2C.

CHEM 135. Molecular Spectroscopy (4)
Time-dependent behavior of systems; interaction of matter with light; selection rules. Radiative and nonradiative processes, coherent phenomena, and the density matrices. Instrumentation, measurement, and interpretation. May be coscheduled with CHEM 235. Prior or concurrent enrollment in CHEM 105A recommended. ***Prerequisites:*** CHEM 126 or 130 or 133 and MATH 20D.

CHEM 141. Organic Nanomaterials (4)
This course will provide an introduction to the physics and chemistry of soft matter, followed by a literature-based critical examination of several ubiquitous classes of organic nanomaterials and their technological applications. Topics include self-assembled monolayers, block copolymers, liquid crystals, photoresists, organic electronic materials, micelles and vesicles, soft lithography, organic colloids, organic nanocomposites, and applications in biomedicine and food science. ***Prerequisites:*** CHEM 40A, 140A, 40AH, or 140AH.

CHEM 142. Introduction to Glycosciences (4)
The primary aim of this course is to provide an overview of fundamental facts, concepts, and methods in glycoscience. The course is structured around major themes in the field, starting from basic understanding of structure and molecular interactions of carbohydrates, to the mechanisms of their biological functions in normal and disease states, to their applications in materials science and energy generation. May be coscheduled with CHEM 242. CHEM 40C and at least one course in either general biology, molecular biology, or cell biology is strongly encouraged. ***Prerequisites:*** CHEM 40B, 140B, 40BH, or 140BH and BIBC 100 or BILD 1 or CHEM 114A.

CHEM 143B. Organic Chemistry Laboratory (4)
Continuation of CHEM 43A, 143A, 43AM, and 143AM, emphasizing synthetic methods of organic chemistry. Enrollment is limited to majors in the Department of Chemistry and Biochemistry unless space is available. A materials fee is required. ***Prerequisites:*** CHEM 43A, 143A, 43AM or 143AM, and CHEM 140B.

CHEM 143C. Organic Chemistry Laboratory (5)
Identification of unknown organic compounds by a combination of chemical and physical techniques. This course is intended for chemistry majors only (CH25, CH28, CH31, CH32, CH33, CH34, CH35, CH36, CH37). Program or materials fees may apply. ***Prerequisites:*** CHEM 43AM, 143AM, 43A, or 143A and CHEM 140B.

CHEM 143D. Molecular Design and Synthesis (4)
Advanced organic synthesis. Relationships between molecular structure and reactivity using modern synthetic methods and advanced instrumentation. Stresses importance of molecular design, optimized reaction conditions for development of practically useful synthesis, and problem-solving skills. A materials fee is required. ***Prerequisites:*** CHEM 40C, 140C, 40CH, or 140CH and CHEM 143B.

CHEM 145. Chemistry and Biochemistry of Biofuels (4)
Fundamentals of the chemistry and biochemistry of petroleum and biofuel technologies. This course explores chemical identity and properties, metabolic pathways and engineering, refining processes, and analytical techniques related to current and future biofuels. ***Prerequisites:*** CHEM 40C, 140C, 40CH, or 140CH.

CHEM 146. Kinetics and Mechanism of Organic Reactions (4)

Methodology of mechanistic organic chemistry; integration of rate expression, determination of rate constants, transition state theory; catalysis, kinetic orders, isotope effects, solvent effects, linear free energy relationship; product studies, stereochemistry; reactive intermediates; rapid reactions. May be coscheduled with CHEM 246. ***Prerequisites****:* CHEM 40C, 140C, 40CH, or 140CH.

CHEM 151. Molecules that Changed the World (4)

A look at some of nature's most intriguing molecules and the ability to discover, synthesize, modify, and use them. The role of chemistry in society, and how chemical synthesis—the art and science of constructing molecules—shapes our world. ***Prerequisites:*** CHEM 40A, 140A, 40AH, or 140AH.

CHEM 152. Synthetic Methods in Organic Chemistry (4)

A survey of reactions of particular utility in the organic laboratory. Emphasis is on methods of preparation of carbon-carbon bonds and oxidation reduction sequences. May be coscheduled with CHEM 252. ***Prerequisites****:* CHEM 40C, 140C, 40CH, or 140CH.

CHEM 154. Mechanisms of Organic Reactions (4)

A qualitative approach to the mechanisms of various organic reactions; substitutions, additions, eliminations, condensations, rearrangements, oxidations, reductions, free-radical reactions, and photochemistry. Includes considerations of molecular structure and reactivity, synthetic methods, spectroscopic tools, and stereochemistry. The topics emphasized will vary from year to year. This is the first quarter of the advanced organic chemistry sequence. May be coscheduled with CHEM 254. ***Prerequisites:*** CHEM 40C, 140C, 40CH, or 140CH.

CHEM 155. Synthesis of Complex Molecules (4)

(Conjoined with CHEM 255.) This course discusses planning economic routes for the synthesis of complex organic molecules. The uses of specific reagents and protecting groups will be outlined as well as the control of stereochemistry during a synthesis. Examples will be selected from the recent literature. CHEM 255 students will be required to complete an additional paper/exam. (May not be offered every year.) ***Prerequisites:*** CHEM 152 or 252 or consent of instructor.

CHEM 156. Structure and Properties of Organic Molecules (4)

Introduction to the measurement and theoretical correlation of the physical properties of organic molecules. Topics covered include molecular geometry, molecular-orbital theory, orbital hybridization, aromaticity, chemical reactivity, stereochemistry, infrared and electronic spectra, photochemistry, and nuclear magnetic resonance. May be coscheduled with CHEM 256. ***Prerequisites:*** CHEM 40C, 140C, 40CH, or 140CH.

CHEM 157. Bioorganic and Natural Products Chemistry (4)

A comprehensive survey of modern bioorganic and natural products chemistry. Topics will include biosynthesis of natural products, molecular recognition, and small molecule-biomolecule interactions. May be coscheduled with CHEM 257. ***Prerequisites:*** CHEM 40C, 140C, 40CH, or 140CH.

CHEM 158. Applied Spectroscopy (4)

Intensive coverage of modern spectroscopic techniques used to determine the structure of organic molecules. Problem solving and interpretation of spectra will be emphasized. May be coscheduled with CHEM 258. ***Prerequisites:*** CHEM 40C, 140C, 40CH, or 140CH.

CHEM 164. Structural Biology of Viruses (4)

(Cross-listed with BIMM 164.) An introduction to virus structures, how they are determined, and how they facilitate the various stages of the viral life cycle from host recognition and entry to replication, assembly, release, and transmission to uninfected host cells. (May not be offered every year.) ***Prerequisites:*** CHEM 114A or BIBC 100. Recommended: a basic course in cell biology.

CHEM 165. 3D Electron Microscopy of Macromolecules (4)

(Conjoined with CHEM 265; cross-listed with BIMM 162/BGGN 262.) Biological macromolecules and supramolecular complexes as well as organelles, and small cells are being examined in three dimensions by modern electron cryomicroscopy and image reconstruction techniques. The basic principles of transmission electron microscopy and 3D image reconstruction are discussed. CHEM 265/BGGN 262 students will be required to complete an additional assignment/exam beyond that expected of students in CHEM 165/BIMM 162. ***Prerequisites:*** CHEM 114A, BIBC 100, or BIBC 110, and PHYS 1C, 2C, or 2D.

CHEM 167. Medicinal Chemistry (4)

Basics of medicinal chemistry, emphasizing rigorous descriptions of receptor-protein structure, interactions, and dynamics; their implications for drug development; and an integrated treatment of pharmacodynamic and pharmacokinetic considerations in drug design. Treats computational approaches as well as practical experimental approaches. ***Prerequisites:*** CHEM 40C, 140C, 40CH or 140CH and CHEM 114A.

CHEM 168. Drug Synthesis and Design (4)

Practical methods to make drugs currently in use and to design future drugs. Treats both chemical synthesis and biologics like monoclonal antibodies. Topics include fragment-based screening, solid phase synthesis, directed evolution, and bioconjugation as well as efficacy, metabolism, and toxicity. ***Prerequisites:***CHEM 40C, 40CH, 140C, or 140CH and CHEM 114A.

CHEM 171. Environmental Chemistry I (4)

An introduction to chemical concerns in nature with emphasis on atmospheric issues like air pollution, chlorofluorocarbons and the ozone hole, greenhouse effects and climate change, impacts of radioactive waste, sustainable resource usage, and risks and benefits of energy sources. Students may only receive credit for one of the following: CHEM 149A or 171. ***Prerequisites:*** CHEM 6C or 6CH.

CHEM 172. Environmental Chemistry II (4)

An introduction to chemical concerns in nature with emphasis on soil and water issues like agricultural productivity, biological impacts in the environment, deforestation, ocean desserts, natural and manmade disasters (fires, nuclear winter, volcanoes), and waste handling. Recommended preparation: CHEM 171 (formerly 149A). Students may only receive credit for one of the following: CHEM 172 or 149B. ***Prerequisites:*** CHEM 6C or 6CH.

CHEM 173. Atmospheric Chemistry (4)

Chemical principles applied to the study of atmospheres. Atmospheric photochemistry, radical reactions, chemical lifetime determinations, acid rain, greenhouse effects, ozone cycle, and evolution are discussed. May be coscheduled with CHEM 273. ***Prerequisites:*** CHEM 6C or 6CH.

CHEM 174. Chemical Principles of Marine Systems (4)

(Cross-listed with SIO 141.) Introduction to the chemistry and distribution of the elements in seawater, emphasizing basic chemical principles such as electron structure, chemical bonding, and group and periodic properties and showing how these affect basic aqueous chemistry in

marine systems. ***Prerequisites:***CHEM 6C with a grade of C– or better, or consent of instructor. (May not be offered every year.)

CHEM 182. Biological Databases (4)

(Cross-listed with BIMM 182/BENG 182/CSE 182.) This course provides an introduction to the features of biological data, how those data are organized efficiently in databases, and how existing data resources can be utilized to solve a variety of biological problems. Object oriented databases, data modeling, and description. Survey of current biological database with respect to above, implementation of database on a biological topic. Bioinformatics majors only. ***Prerequisites:*** CSE 100 or MATH 176.

CHEM 184. Computational Molecular Biology (4)

(Cross-listed with BIMM 184/BENG 184/CSE 184.) This advanced course covers the application of machine learning and modeling techniques to biological systems. Topics include gene structure, recognition of DNA and protein sequence patterns, classification, and protein structure prediction. Pattern discovery, Hidden Markov models/support vector machines/neural network/profiles, protein structure prediction, functional characterization or proteins, functional genomics/proteomics, metabolic pathways/gene networks. Bioinformatics majors only. ***Prerequisites:*** BIMM 181 or BENG 181 or CSE 181; BIMM 182 or BENG 182 or CSE 182 or CHEM 182.

CHEM 185. Introduction to Computational Chemistry (4)

Course in computational methods building on a background in mathematics and physical chemistry. Brief introduction and background in computational theory, molecular mechanics, semi-empirical methods, and ab initio-based methods of increasing elaboration. Emphasis on applications and reliability. ***Prerequisites:***CHEM 126 or 133 and MATH 20C or 21C. (May not be offered every year.)

CHEM 187. Foundations of Teaching and Learning Science (4)

(Cross-listed with EDS 122.) Examine theories of learning and how they are important in the science classroom. Conceptual development in the individual student, as well as the development of knowledge in the history of science. Key conceptual obstacles in science will be explored. ***Prerequisites:*** CHEM 6C or 6CH and CHEM 96 or EDS 31.

CHEM 188. Capstone Seminar in Science Education (4)

(Cross-listed with EDS 123.) In the lecture and observation format, students continue to explore the theories of learning in the science classroom. Conceptual development is fostered, as well as continued development of knowledge of science history. Students are exposed to the science of teaching in science in actual practice. ***Prerequisites:*** CHEM 6C or 6CH and CHEM 187 or EDS 122.

CHEM 192. Senior Seminar in Chemistry and Biochemistry (1)

The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in chemistry or biochemistry. May be taken for credit up to four times, with a change in topic, and permission of the department. P/NP grades only. ***Prerequisites:*** department stamp and/or consent of the instructor.

CHEM 194. Special Topics in Chemistry (2 or 4)

Selected topics in the field of chemistry. Course will vary in title and content. Students are expected to actively participate in course discussions, read, and analyze primary literature.

Current subtitles will be listed on the Schedule of Classes. May be taken for credit up to four times as topics vary. Students may not receive credit for the same topic.

CHEM 195. Methods of Teaching Chemistry (4)

An introduction to teaching chemistry. Students are required to attend a weekly class on methods of teaching chemistry and will teach a discussion section of one of the lower-division chemistry courses. Attendance at lecture of the lower-division course in which the student is participating is required. P/NP grades only. ***Prerequisites:*** consent of instructor.

CHEM 196. Reading and Research in Chemical Education (2 or 4)

Independent literature or classroom research by arrangement with, and under the direction of, a member of the Department of Chemistry and Biochemistry faculty. P/NP grades only. ***Prerequisites:*** upper-division standing, 2.5 minimum GPA, consent of instructor and department.

CHEM 197. Chemistry Internship (2 or 4)

An internship program that provides work experience with public/private sector employers. Subject to the availability of positions, students will work in a local company under the supervision of a faculty member and site supervisor. P/NP grades only. May be taken for credit three times. ***Prerequisites:*** Completion of ninety units with a GPA of 2.5, and a completed and approved Special Studies form (UC San Diego Application for Enrollment Special Studies Courses 197, 198, 199), and department stamp.

CHEM 198. Directed Group Study (1–4)

Directed group study on a topic or in a field not included in the regular department curriculum, by arrangement with a chemistry and biochemistry faculty member. P/NP grades only. May be taken for credit two times. ***Prerequisites:*** department approval required and a completed and approved Special Studies form (UC San Diego Application for Enrollment Special Studies Courses 197, 198, 199).

CHEM 199. Reading and Research (2 or 4)

Independent literature or laboratory research by arrangement with, and under the direction of, a member of the Department of Chemistry and Biochemistry faculty. Students must register on a P/NP basis. ***Prerequisites:*** upper-division standing, 2.5 minimum GPA, consent of instructor and department and the completion of the online CHEM 199 application.)

Graduate

CHEM 200B. Fundamentals of Instrumental Analysis (4)

Fundamental theoretical principles, capabilities, applications, and limitations of modern analytical instrumentation used for qualitative and quantitative analysis. Students will learn how to define the nature of an analytical problem and how to select an appropriate analytical method. Letter grades only. Recommended preparation: background equivalent to CHEM 100A and introductory optics and electricity from physics. (W)

CHEM 204. Introduction to X-ray Crystallography (4)

(Conjoined with CHEM 104.) Analysis of macromolecular structures by X-ray diffraction. Topics include symmetry, geometry of diffraction, detection of diffraction, intensity of diffracted waves, phase problem and its solution, heavy atom method, isomorphous replacement, anomalous dispersion phasing methods (MAD), direct methods, molecular replacement. CHEM 204 students will be required to complete additional paper and/or exam beyond that expected of students in CHEM 104.

CHEM 207. Protein NMR (4)

A broad introduction to the uses of nuclear magnetic resonance to characterize and understand proteins. Not highly mathematical, this course should be accessible to chemistry graduate students working with proteins.

CHEM 209. Macromolecular Recognition (4)

Structures and functions of nucleic acids, folding and catalysis of nucleic acids, motifs and domains of proteins, principles of protein-protein interactions, chemistry of protein/DNA and protein/RNA interfaces, conformational changes in macromolecular recognition. ***Prerequisites:*** biochemistry background and graduate standing, or approval of instructor.

CHEM 210. Lipid Cell Signaling Genomics, Proteomics, and Metabolomics (2)

Overview of new systems biology "-omics" approached to lipid metabolism and cell signaling, including interrogating gene and lipid databases, techniques for lipidomics, and implications for profiling and biomarker discovery in blood and tissues relevant to inflammatory and other human diseases. Cross-listed with BIOM 209 and PHAR 208. Recommended preparation: one quarter of undergraduate biochemistry.

CHEM 213A. Structure of Biomolecules and Biomolecular Assemblies (4)

A discussion of structures of nucleic acids and proteins and their larger assemblies. The theoretical basis for nucleic acid and protein structure, as well as methods of structure determination including X-ray crystallography, cryoEM, and computational modeling approaches will be covered. Letter grades only. ***Prerequisites:*** graduate standing.

CHEM 213B. Biophysical Chemistry of Macromolecules (4)

Renumbered from CHEM 213. A discussion of the physical principles governing biomolecular structure and function. Experimental and theoretical approaches to understand protein dynamics, enzyme kinetics, and mechanisms will be covered. Students may only receive credit for one of the following: CHEM 213 or 213B. May be coscheduled with CHEM 113.

CHEM 214. Molecular and Cellular Biochemistry (4)

This course represents a continuation of 114C, or an introductory course for first- and second-year graduate students, and covers topics in molecular and cellular biochemistry. Emphasis will be placed on contemporary approaches to the isolation and characterization of mammalian

genes and proteins, and molecular genetic approaches to understanding eukaryotic development and human disease. May be coscheduled with CHEM 114D. ***Prerequisites:*** graduate standing.

CHEM 216. Chemical Biology (4)

A discussion of current topics in chemical biology including mechanistic aspects of enzymes and cofactors, use of modified enzymes to alter biochemical pathways, chemical intervention in cellular processes, and natural product discovery. ***Prerequisites:*** graduate standing or consent of instructor. (May not be offered every year.)

CHEM 217. RNA Structure, Function, and Biology (4)

Selected topics in RNA structure and function, such as the ribosome, ribozyme, antibiotics, splicing and RNA interference, as they relate to the RNA role in gene expression and regulation. Emphasis on techniques to study the dynamics of macromolecular complexes and the mechanism of RNA catalysis. ***Prerequisites:*** graduate standing or consent of instructor.

CHEM 219A. Special Topics in Biochemistry (4)

This special-topics course is designed for first-year graduate students in biochemistry. Topics presented in recent years have included protein processing, the chemical modification of proteins, the biosynthesis and function of glycoproteins, lipid biochemistry and membrane structure, and bioenergetics. ***Prerequisites:*** undergraduate courses in biochemistry, CHEM 114A or equivalent. (May not be offered every year.)

CHEM 219B. Special Topics in Biochemistry (4)

Various advanced topics in biochemistry. May be taken for credit up to three times as topics vary.

CHEM 219C. Special Topics in Biochemistry (2 or 4)

Various advanced topics in biochemistry. May be taken for credit up to three times as topics vary.

CHEM 220. Regulatory Circuits in Cells (4)

Modulation cellular activity and influencing viral fate involve regulatory circuits. Emergent properties include dose response, cross-regulation, dynamic, and stochastic behaviors. This course reviews underlying mechanisms and involves mathematical modeling using personal computer tools. Recommended: some background in biochemistry and/or cellular biology. Mathematical competence at the level of lower-division college courses.

CHEM 221. Signal Transduction (4)

The aim of this course is to develop an appreciation for a variety of topics in signal transduction. We will discuss several historical developments while the focus will be on current issues. Both experimental approaches and results will be included in our discussions. Topics may vary from year to year. ***Prerequisites:***biochemistry and molecular biology. (May not be offered every year.)

CHEM 222. Structure and Analysis of Solids (4)

(Cross-listed with MATS 227.) Key concepts in the atomic structure and bonding of solids such as metals, ceramics, and semiconductors. Symmetry operations, point groups, lattice types, space groups, simple and complex inorganic compounds, structure/property comparisons, structure determination with X-ray diffraction. Ionic, covalent, metallic bonding compared with physical properties. Atomic and molecular orbitals, bands versus bonds, free electron theory.

CHEM 223. Organometallic Chemistry (4)

A survey of this field from a synthetic and mechanistic viewpoint. Fundamental reactivity patterns for transition element organometallic compounds will be discussed and organized according to periodic trends. Transition metal catalyzed reactions of importance to organic synthesis and industrial chemistry will be presented from a mechanistic perspective. Letter grades only. ***Prerequisites:*** graduate standing.

CHEM 224. Spectroscopic Techniques (4)

Application of physical techniques to the elucidation of the structure of inorganic complex ions and organometallic compounds. Topics covered include group theory, and its application to vibrational, magnetic resonance and Raman spectroscopy. (May not be offered every year.)

CHEM 225. Bioinorganic Chemistry (4)

The role of metal ions in biological systems, with emphasis on transition metal ions in enzymes that transfer electrons, bind oxygen, and fix nitrogen. Also included are metal complexes in medicine, toxicity, and metal ion storage and transport. May be coscheduled with CHEM 125. ***Prerequisites:*** graduate standing.

CHEM 226. Transition Metal Chemistry (4)

Advanced aspects of structure and bonding in transition metal complexes with major emphasis on Molecular Orbital Theory. Electronic structure descriptions are used to rationalize structure/reactivity relationships. Other topics include computational chemistry, relativistic effects, metal-metal bonding, and reaction mechanisms. ***Prerequisites:*** graduate standing or consent of instructor.

CHEM 227. Seminar in Inorganic Chemistry (2)

Seminars presented by faculty and students on topics of current interest in inorganic chemistry, including areas such as bioinorganic, organometallic and physical-inorganic chemistry. The course is designed to promote a critical evaluation of the available data in specialized areas of inorganic chemistry. Each quarter three or four different topics will be discussed. (S/U grades only.) ***Prerequisites:*** graduate standing or consent of instructor.

CHEM 228. Solid State Chemistry (4)

Survey of the chemistry of semiconductors, superconductors, molecular magnetic materials, zeolites, fast ion conductors, electronically conducting polymers and ceramics. Synthetic techniques such as molecular precursor design, the sol-gel process, electrosynthesis, and high-temperature thermolysis will be covered. (May not be offered every year.)

CHEM 229. Special Topics in Inorganic Chemistry (2–4)

Selection of topics of current interest. May be repeated for credit when topics vary. (May not be offered every year.)

CHEM 230A. Quantum Mechanics I (4)

Theoretical basis of quantum mechanics; postulates; wave packets; matrix representations; ladder operators; exact solutions for bound states in 1, 2, or 3 dimensions; angular momentum; spin; variational approximations; description of real one and two electron systems. Recommended background: CHEM 133 and MATH 20D or their equivalents.

CHEM 230B. Quantum Mechanics II (4)

Continuation of theoretical quantum mechanics: evolution operators and time dependent representations, second quantization, Born-Oppenheimer approximation, electronic structure methods, selected topics from among density operators, quantized radiation fields, path integral methods, scattering theory. ***Prerequisites:*** CHEM 230A or consent of instructor.

CHEM 231. Chemical Kinetics and Molecular Reaction Dynamics (4)
Classical kinetics, transition state theory, unimolecular decomposition, potential energy surfaces; scattering processes and photodissociation processes. (May not be offered ever year.)

CHEM 232A. Statistical Mechanics I (4)
Derivation of thermodynamics from atomic descriptions. Ensembles, fluctuations, classical (Boltzmann) and quantum (Fermi-Dirac and Bose-Einstein) statistics, partition functions, phase space, Liouville equation, chemical equilibrium, applications to weakly interacting systems, such as ideal gases, ideal crystals, radiation fields. Recommended background: CHEM 132 or its equivalent. Classical and quantum mechanics, thermodynamics, and mathematical methods will be reviewed as needed, but some background will be necessary.

CHEM 232B. Statistical Mechanics II (4)
Interacting systems at equilibrium, both classical (liquids) and quantum (spins). Phase transitions. Non-equilibrium systems: glasses, transport, time correlation functions, Onsager relations, fluctuation-dissipation theorem, random walks, Brownian motion. Applications in biophysics. ***Prerequisites:*** CHEM 232A or consent of instructor.

CHEM 235. Molecular Spectroscopy (4)
Time-dependent behavior of systems; interaction of matter with light; selection rules. Radiative and nonradiative processes, coherent phenomena and the density matrices. Instrumentation, measurement, and interpretation. ***Prerequisites:*** graduate standing or consent of instructor. (May not be offered every year.)

CHEM 236. Chemical Dynamics on Surfaces (4)
Explore physical and analytical chemistry of surfaces. Topics include chemisorption and physisorption, sticking probabilities, adsorption isotherms, and passivation of semiconductors.

CHEM 239. Special Topics in Chemical Physics (2 or 4)
Topics of special interest will be presented. Examples include NMR, solid-state chemistry, phase transitions, stochastic processes, scattering theory, nonequilibrium processes, tensor transformations, and advanced topics in statistical mechanics, thermodynamics, and chemical kinetics. (May not be offered every year.)

CHEM 240. Electrochemistry (4)
(Cross-listed with NANO 255.) Application of electrochemical techniques to chemistry research. Basic electrochemical theory and instrumentation: the diffusion equations, controlled potential, and current methods. Electro-chemical kinetics, Butler-Volmer, Marcus-Hush theories, preparative electrochemistry, analytical electrochemistry, solid and polymer electrolytes, semiconductor photoelectrochemistry. (May not be offered every year.)

CHEM 241. Organic Nanomaterials (4)
(Cross-listed with NANO 241.) This course will provide an introduction to the physics and chemistry of soft matter, followed by a literature-based critical examination of several ubiquitous classes of organic nanomaterials and their technological applications. Topics include self-assembled monolayers, block copolymers, liquid crystals, photoresists, organic electronic materials, micelles and vesicles, soft lithography, organic colloids, organic nanocomposites, and applications in biomedicine and food science.

CHEM 242. Introduction to Glycosciences (4)

The primary aim of this course is to provide an overview of fundamental facts, concepts, and methods in glycoscience. The course is structured around major themes in the field starting from the basic understanding of structure and molecular interactions of carbohydrates, to the mechanisms of their biological functions in normal and disease states, to their applications in materials science and energy generation. This course is geared to introduce students with limited prior exposure to the field, supported by selected readings and class notes. May be coscheduled with CHEM 142. Recommended preparation: undergraduate-level organic chemistry and at least one previous course in either general biology, molecular biology, or cell biology is strongly encouraged.

CHEM 246. Kinetics and Mechanism (4)

Methodology of mechanistic organic chemistry: integration of rate expressions, determination of rate constants, transition state theory; catalysis, kinetic orders, isotope effects, substituent effects, solvent effects, linear free energy relationship; product studies, stereochemistry; reactive intermediates; rapid reactions. (May not be offered every year.)

CHEM 250. Research Survival Skills (2)

Course offers training in responsible conduct of research in chemistry and biochemistry, as well as presentation skills, teamwork, and other survival skills for a career in research. Objectives include learning rules, issues, and resources for research ethics; understanding the value of ethical decision-making; and creating a positive disposition toward learning about research ethics. The course is designed to meet federal grant requirements for training in the responsible conduct of research. (S/U grades only.)

CHEM 251. Research Conference (2)

Group discussion of research activities and progress of the group members. (S/U grades only.) ***Prerequisites:*** consent of instructor.

CHEM 252. Synthetic Methods in Organic Chemistry (4)

A survey of reactions of particular utility in the organic laboratory. Emphasis is on methods of preparation of carbon-carbon bonds and oxidation reduction sequences. May be coscheduled with CHEM 152. ***Prerequisites:*** graduate standing.

CHEM 253. Antibiotics (4)

The course focuses on the discovery and development of modern antibiotics. We will discuss the discovery, synthesis, medicinal chemistry, mechanism of action studies, and preclinical as well as clinical development of drugs that are currently being used in the therapy of bacterial infections. Emphasis will be given to compounds approved over the last three decades and investigational drugs that are in clinical trials.

CHEM 254. Mechanisms of Organic Reactions (4)

A qualitative approach to the mechanisms of various organic reactions; substitutions, additions, eliminations, condensations, rearrangements, oxidations, reductions, free-radical reactions, and photochemistry. Includes considerations of molecular structure and reactivity, synthetic methods, spectroscopic tools, and stereochemistry. The topics emphasized will vary from year to year. This is the first quarter of the advanced organic chemistry sequence. May be coscheduled with CHEM 154. ***Prerequisites:*** graduate standing.

CHEM 255. Synthesis of Complex Molecules (4)

(Conjoined with CHEM 155.) This course discusses planning economic routes for the synthesis of complex organic molecules. The uses of specific reagents and protecting groups will be

outlined as well as the control of stereochemistry during a synthesis. Examples will be selected from the recent literature. CHEM 255 students will be required to complete an additional paper and/or exam beyond that expected of students in CHEM 155. (May not be offered every year.) ***Prerequisites:*** CHEM 152 or 252 or consent of instructor.

CHEM 256. Structure and Properties of Organic Molecules (4)

Introduction to the measurement and theoretical correlation of the physical properties of organic molecules. Topics covered include molecular geometry, molecular-orbital theory, orbital hybridization, aromaticity, chemical reactivity, stereochemistry, infrared and electronic spectra, photochemistry, and nuclear magnetic resonance. May be coscheduled with CHEM 156. ***Prerequisites:*** graduate standing.

CHEM 257. Biorganic and Natural Products Chemistry (4)

A comprehensive survey of modern bioorganic and natural products chemistry. Topics include biosynthesis of natural products, molecular recognition, and small molecule-biomolecule interactions. May be coscheduled with CHEM 157. ***Prerequisites:*** graduate standing.

CHEM 258. Applied Spectroscopy (4)

Intensive coverage of modern spectroscopic techniques used to determine the structure of organic molecules. Problem solving and interpretation of spectra will be strongly emphasized. Students will be required to write and submit a paper that reviews a recent research publication that reports the structure determination by spectroscopic methods of natural products. May be coscheduled with CHEM 158. ***Prerequisites:*** graduate standing.

CHEM 259. Special Topics in Organic Chemistry (2–4)

Various advanced topics in organic chemistry. Includes but is not limited to: advanced kinetics, advanced spectroscopy, computational chemistry, heterocyclic chemistry, medicinal chemistry, organotransition metal chemistry, polymers, solid-phase synthesis/combinatorial chemistry, stereochemistry, and total synthesis classics.

CHEM 260. Light and Electron Microscopy of Cells and Tissue (4)

Students will review basic principles of light and electron microscopy and learn a variety of basic and advanced microscopy methods through lecture and hands-on training. Each student will have his or her own project. Additional supervised instrument time is available. ***Prerequisites:*** consent of instructor.

CHEM 262. Inorganic Chemistry and NMR (4)

A survey of inorganic chemistry to prepare for graduate research in the field, including a detailed introduction to nuclear magnetic resonance (NMR), followed by applications of NMR to structural and mechanistic problems in inorganic chemistry.

CHEM 264. Structural Biology of Viruses (4)

(Cross-listed with BGGN 264.) An introduction of virus structures, how they are determined, and how they facilitate the various stages of the viral life cycle from host recognition and entry to replication, assembly, release, and transmission to uninfected host cells. Students will be required to complete a term paper. (May not be offered every year.) Recommended: elementary biochemistry as treated in CHEM 114A or BIBC 100 and a basic course in cell biology or consent of the instructor.

CHEM 265. 3D Electron Microscopy of Macromolecules (4)

(Cross-listed with BGGN 262.) Biological macromolecules and supramolecular complexes as well as organelles, and small cells are being examined in three-dimensions by modern electron

cryomicroscopy and image reconstruction techniques. The basic principles of transmission electron microscopy and 3D image reconstruction are discussed. CHEM 265/BGGN 262 students will be required to complete an additional oral presentation or paper or exam beyond that expected of students in CHEM 165/BGGN 162. (May not be offered every year.) Recommended: elementary biochemistry as treated in CHEM 114A or BIBC 100 and a basic course in cell biology, or consent of instructor.

CHEM 270A-B-C. Current Topics in Environmental Chemistry (2-2-2)

Seminar series on the current topics in the field of environmental chemistry. Emphasis is on current research topics in atmospheric, oceanic, and geological environments. ***Prerequisites:*** consent of instructor. (S/U grades only.) (May not be offered every year.)

CHEM 271. Special Topics in Analytical Chemistry (4)

Topics of special interest in analytical chemistry. May include, but is not limited to, chemical separation, sample introductions, mass analyzers, ionization schemes, and current state-of-the-art applications in environmental and biological chemistry.

CHEM 273. Atmospheric Chemistry (4)

Chemical principles applied to the study of atmospheres. Atmospheric photochemistry, radical reactions, chemical lifetime determinations, acid rain, greenhouse effects, ozone cycle, and evolution are discussed. May be coscheduled with CHEM 173. ***Prerequisites:*** graduate standing.

CHEM 276. Numerical Analysis in Multiscale Biology (4)

Introduces mathematical tools to simulate biological processes at multiple scales. Numerical methods for ordinary and partial differential equations (deterministic and stochastic), and methods for parallel computing and visualization. Hands-on use of computers emphasized; students will apply numerical methods in individual projects. ***Prerequisites:*** consent of instructor.

CHEM 280. Applied Bioinformatics (4)

Publicly available databases and bioinformatics tools are now an indispensable component of biomedical research. This course offers an introductory survey of selected tools and databases; the underlying concepts, the software, and advice on using them. Practical exercises will be included.

CHEM 283. Supramolecular Structure Determination Laboratory (4)

A laboratory course combining hands-on mass spectrometry and bioinformatics tools to explore the relationship between structure and function in macromolecules. Tools for peptide sequencing, analysis of post-translational modification, and fragmentation analysis by mass spectrometry are examples of experiments students will run. ***Prerequisites:*** consent of instructor.

CHEM 285. Introduction to Computational Chemistry (4)

Course in computational methods building on a background in mathematics and physical chemistry. Brief introduction and background in computational theory, molecular mechanics, semi-empirical methods, and ab initio-based methods of increasing elaboration. Emphasis on applications and reliability. May be coscheduled with CHEM 185. ***Prerequisites:*** graduate student standing.

CHEM 294. Organic Chemistry Seminar (2)

Formal seminars or informal puzzle sessions on topics of current interest in organic chemistry, as presented by visiting lecturers, local researchers, or students. (S/U grades only.) ***Prerequisites:*** advanced graduate-student standing.

CHEM 295. Biochemistry Seminar (2)

Formal seminars or informal puzzle sessions on topics of current interest in biochemistry, as presented by visiting lecturers, local researchers, or students. (S/U grades only.) ***Prerequisites:*** advanced graduate-student standing.

CHEM 296. Chemical Physics Seminar (2)

Formal seminars or informal sessions on topics of current interest in chemical physics as presented by visiting lecturers, local researchers, or students. (S/U grades only.) ***Prerequisites:*** advanced graduate-student standing.

CHEM 297. Experimental Methods in Chemistry (4)

Experimental methods and techniques involved in chemical research are introduced. Hands-on experience provides training for careers in industrial research and for future thesis research. (S/U grades only.) ***Prerequisites:*** graduate-student standing.

CHEM 298. Special Study in Chemistry (1–4)

Reading and laboratory study of special topics for first-year graduate students under the direction of a faculty member. Exact subject matter to be arranged in individual cases. (S/U grades only.) ***Prerequisites:*** first-year graduate-student standing.

CHEM 299. Research in Chemistry (1–12)

Prerequisites: graduate-student standing and consent of instructor. (S/U grades only.)

CHEM 500. Apprentice Teaching (4)

Under the supervision and mentorship of a course instructor, MS and PhD students serve as teaching assistants to undergraduate laboratory and lecture courses. To support teaching competency, regular meetings with the instructor and attendance at lectures are required. S/U grades only. May be taken for credit twelve times. ***Prerequisites:*** graduate-student standing and consent of instructor.

CHEM 509. Teaching Methods in Chemistry and Biochemistry (2)

This course explores teaching strategies specific to chemistry at the college level, and promotes the development of skills for facilitating active, student-centered learning in both lecture and laboratory settings. It is required for first-time teaching assistants. S/U grades only. ***Prerequisites:*** graduate-student standing and consent of instructor.

Computer Science and Engineering (CSE)

Upper Division

CSE 100. Advanced Data Structures (4)

High-performance data structures and supporting algorithms. Use and implementation of data structures like (un)balanced trees, graphs, priority queues, and hash tables. Also memory management, pointers, recursion. Theoretical and practical performance analysis, both average case and amortized. Uses C++ and STL. Credit not offered for both Math 176 and CSE 100. Equivalent to Math 176. Recommended preparation: background in C or C++ programming. ***Prerequisites:*** CSE 12, CSE 15L, CSE 21 or Math 15B or Math 154 or Math 184A, and CSE 5A or CSE 30 or ECE 15 or MAE 9; restricted to undergraduates. Graduate students will be allowed as space permits.

CSE 101. Design and Analysis of Algorithms (4)

Design and analysis of efficient algorithms with emphasis of nonnumerical algorithms such as sorting, searching, pattern matching, and graph and network algorithms. Measuring complexity of algorithms, time and storage. NP-complete problems. Credit not offered for both Math 188 and CSE 101. Equivalent to Math 188. ***Prerequisites:*** CSE 100 or Math 176; restricted to undergraduates. Graduate students will be allowed as space permits.

CSE 103. A Practical Introduction to Probability and Statistics (4)

Distributions over the real line. Independence, expectation, conditional expectation, mean, variance. Hypothesis testing. Learning classifiers. Distributions over R^n, covariance matrix. Binomial, Poisson distributions. Chernoff bound. Entropy. Compression. Arithmetic coding. Maximal likelihood estimation. Bayesian estimation. CSE 103 is not duplicate credit for ECE 109, Econ 120A, or Math 183. ***Prerequisites:*** Math 20A-B and Math 184A or CSE 21 or Math 154; restricted to CS25, CS26, CS27, and CS28 majors. Other students will be allowed as space permits.

CSE 105. Theory of Computability (4)

An introduction to the mathematical theory of computability. Formal languages. Finite automata and regular expression. Push-down automata and context-free languages. Computable or recursive functions: Turing machines, the halting problem. Undecidability. Credit not offered for both Math 166 and CSE 105. Equivalent to Math 166. ***Prerequisites:*** CSE 12 and CSE 15L and Math 15A or Math 109 or CSE 20 and Math 184 or CSE 21 or Math 100A or Math 103A; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 107. Introduction to Modern Cryptography (4)

Topics include private and public-key cryptography, block ciphers, data encryption, authentication, key distribution and certification, pseudorandom number generators, design and analysis of protocols, zero-knowledge proofs, and advanced protocols. Emphasizes rigorous mathematical approach including formal definitions of security goals and proofs of protocol security. ***Prerequisites:*** CSE 21 or Math 15B or Math 154 or Math 184A and CSE 101 and CSE 105 or Math 166; restricted to students within the CS25, CS26, CS27, CS28, and EC26 majors. All other students will be allowed as space permits.

CSE 110. Software Engineering (4)

Introduction to software development and engineering methods, including specification, design, implementation, testing, and process. An emphasis on team development, agile methods, and use of tools such as IDE's, version control, and test harnesses. ***Prerequisites:*** CSE 100; restricted to students with junior or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. All other students will be allowed as space permits.

CSE 112. Advanced Software Engineering (4)

This course will cover software engineering topics associated with large systems development such as requirements and specifications, testing and maintenance, and design. Specific attention will be given to development tools and automated support environments. ***Prerequisites:*** CSE 110; restricted to students with junior or senior standing. Graduate students will be allowed as space permits.

CSE 118. Ubiquitous Computing (4)

Explores emerging opportunities enabled by cheap sensors and networked computing devices. Small research projects will be conducted in teams, culminating in project presentations at the end of the term. Section will cover material relevant to the project, such as research methods, software engineering, teamwork, and project management. ***Prerequisites:*** any course from the following: CSE 131, CSE 132B, Cog Sci 102C, Cog Sci 121, Cog Sci 184, COMT 111B, COMT 115, ECE 111, ECE 118, ECE 191, ECE 192, or ICAM 160B; or consent of instructor.

CSE 120. Principles of Computer Operating Systems (4)

Basic functions of operating systems; basic kernel structure, concurrency, memory management, virtual memory, file systems, process scheduling, security and protection. ***Prerequisites:*** CSE 30, and CSE 101, and CSE 110; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 123. Computer Networks (4)

Introduction to concepts, principles, and practice of computer communication networks with examples from existing architectures, protocols, and standards with special emphasis on the Internet protocols. Layering and the OSI model; physical and data link layers; local and wide area networks; datagrams and virtual circuits; routing and congestion control; internetworking. Transport protocols. Credit may not be received for both CSE 123 and ECE 158A. ***Prerequisites:*** CSE 30 and CSE 101 and CSE 110; restricted to students with sophomore, junior, or senior standing sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. Graduate students will be allowed as space permits.

CSE 124. Networked Services (4)

(Renumbered from CSE 123B.) The architecture of modern networked services, including data center design, enterprise storage, fault tolerance, and load balancing. Protocol software structuring, the Transmission Control Protocol (TCP), remote procedure calls, protocols for digital audio and video communication, overlay and peer-to-peer systems, secure communication. Credit may not be received for both CSE 124 and ECE 158B. Students may not receive credit for both CSE 123B and CSE 124. ***Prerequisites:*** CSE 30 and CSE 101 and CSE 110; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. Graduate students will be allowed as space permits.

CSE 125. Software System Design and Implementation (4)

Design and implementation of large, complex software systems involving multiple aspects of CSE curriculum. Emphasis is on software system design applied to a single, large group project

with close interaction with instructor. ***Prerequisites:*** senior standing with substantial programming experience, and consent of instructor. Department stamp required.

CSE 127. Introduction to Computer Security (4)

Topics include basic cryptography, security/threat analysis, access control, auditing, security models, distributed systems security, and theory behind common attack and defense techniques. The class will go over formal models as well as the bits and bytes of security exploits. ***Prerequisites:*** CSE 21 or Math 154 or Math 184A and CSE 120 or CSE 123 or CSE 124; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. Graduate students will be allowed as space permits.

CSE 130. Programming Languages: Principles and Paradigms (4)

(Formerly CSE 173.) Introduction to programming languages and paradigms, the components that comprise them, and the principles of language design, all through the analysis and comparison of a variety of languages (e.g., Pascal, Ada, C++, PROLOG, ML.) Will involve programming in most languages studied. ***Prerequisites:*** CSE 12, and CSE 100 or Math 176, CSE 105 or Math 166.

CSE 131. Compiler Construction (4)

(Formerly CSE 131B.) Introduction to the compilation of programming languages, practice of lexical and syntactic analysis, symbol tables, syntax-directed translation, type checking, code generation, optimization, interpretation, and compiler structure. (Students may receive repeat credit for CSE 131A and CSE 131B by completing CSE 131.) ***Prerequisites:*** CSE 100 and CSE 105 and CSE 110 and CSE 130; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 132A. Database System Principles (4)

Basic concepts of databases, including data modeling, relational databases, query languages, optimization, dependencies, schema design, and concurrency control. Exposure to one or several commercial database systems. Advanced topics such as deductive and object-oriented databases, time allowing. ***Prerequisites:*** CSE 100; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. All other students will be allowed as space permits.

CSE 132B. Database Systems Applications (4)

Design of databases, transactions, use of trigger facilities and datablades. Performance measuring, organization of index structures. ***Prerequisites:*** CSE 132A; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 134B. Web Client Languages (4)

Design and implementation of interactive World Wide Web clients using helper applications and plug-ins. The main language covered will be Java. ***Prerequisites:*** CSE 100 or Math 176; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 135. Online Database Analytics Applications (4)

Database, data warehouse, and data cube design; SQL programming and querying with emphasis on analytics; online analytics applications, visualizations, and data exploration; performance tuning. ***Prerequisites:*** CSE 100 or Math 176; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. Graduate students will be allowed as space permits.

CSE 136. Enterprise-Class Web Applications (4)
Design and implementation of very large-scale, web-based applications. Topics covered typically include modeling organizational needs, design and revision management, J2EE or similar software platforms, web server and application server functionality, reuse of object-oriented components, model-view-controller and other design patterns, clustering, load-balancing, fault-tolerance, authentication, and usage accounting. ***Prerequisites:*** CSE 135.

CSE 140. Components and Design Techniques for Digital Systems (4)
Design of Boolean logic and finite state machines; two-level, multilevel combinational logic design, combinational modules and modular networks, Mealy and Moore machines, analysis and synthesis of canonical forms, sequential modules. ***Prerequisites:*** CSE 20 or Math 15A or Math 109 and CSE 30; CSE 140L must be taken concurrently; restricted to students with junior or senior standing. All other students will be allowed as space permits.

CSE 140L. Digital Systems Laboratory (2)
Implementation with computer-aided design tools for combinational logic minimization and state machine synthesis. Hardware construction of a small digital system. ***Prerequisites:*** CSE 20 or Math 15A or Math 109 and CSE 30; CSE 140 must be taken concurrently; restricted to students with junior or senior standing. All other students will be allowed as space permits.

CSE 141. Introduction to Computer Architecture (4)
Introduction to computer architecture. Computer system design. Processor design. Control design. Memory systems. ***Prerequisites:*** CSE 30, CSE 140, and CSE 140L; CSE 141L should be taken concurrently; restricted to students with junior or senior standing. All other students will be allowed as space permits.

CSE 141L. Project in Computer Architecture (2)
Hands-on computer architecture project aiming to familiarize students with instruction set architecture, and design of process. Control and memory systems. ***Prerequisites:*** CSE 30 and CSE 110 and CSE 140 and CSE 140L; CSE 141 should be taken concurrently; restricted to students with junior or senior standing. All other students will be allowed as space permits.

CSE 143. Microelectronic System Design (4)
VSLI process technologies; circuit characterization; logic design styles; clocking strategies; computer-aided design tools; subsystem design; design case studies. System design project from hardware description, logic synthesis, physical layout to design verification. ***Prerequisites:*** CSE 140 or CSE 170A or ECE 81.

CSE 145. Embedded System Design Project (4)
Project class building an embedded computing system. Learn fundamental knowledge of microcontrollers, sensors, and actuators. Introduction to the hardware and software tools to build project in a team environment and end-to-end system building. ***Prerequisites:*** CSE 30.

CSE 148. Advanced Processor Architecture Design Project (4)
Students will use hardware description language tools to add advanced architectural features to a basic processor design. These features may include pipelining, superscalar execution, branch prediction, and advanced cache features. Designs will be implemented in programmable logic devices. ***Prerequisites:*** CSE 141 and CSE 141L; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 150. Introduction to Artificial Intelligence: Search and Reasoning (4)

Search algorithms including BFS, DFS, iterative deepening and A*, randomized search algorithms including Walksat, syntax and semantics of first-order logic (FOL), knowledge representation in FOL including reasoning, basic reasoning with probabilities, basic Bayesian learning. ***Prerequisites:*** CSE 100 or Math 176; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. All other students will be allowed as space permits.

CSE 151. Introduction to Artificial Intelligence: Statistical Approaches (4)

Reasoning with probabilities, reasoning and learning with Bayesian networks, decision making under uncertainty, sequential decision making, statistical learning methods, and reinforcement learning. ***Prerequisites:*** CSE 100 or Math 176; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. All other students will be allowed as space permits.

CSE 152. Introduction to Computer Vision (4)

The goal of computer vision is to compute scene and object properties from images and video. This introductory course includes feature detection, image segmentation, motion estimation, object recognition, and 3-D shape reconstruction through stereo, photometric stereo, and structure from motion. ***Prerequisites:*** Math 20F and CSE 100 and CSE 101 or Math 188; restricted to students with sophomore, junior, or senior standing within the CS25, CS26, CS27, CS28, and EC26 majors. All other students will be allowed as space permits.

CSE 153. Cognitive Modeling (4)

Construction of computational models that "do the same things people do," in terms of perception, categorization, memory, language, action, etc. and typically in a fashion that is plausibly carried out by the neural networks in our brains. The model must fit behavioral, neurophysiological, and/or neuropsychological data. Recommended preparation: background knowledge in computer science, cognitive science, psychology, or neuroscience, and a basic understanding of the most fundamental concepts of differential calculus, linear algebra, and statistics. Computer programming skills may be useful to some students as they conduct their term projects, but such skills are not required. ***Prerequisites:*** CSE 100 or Math 176 or consent of instructor.

CSE 158. Recommender Systems and Web Mining (4)

Current methods for data mining and predictive analytics. Emphasis is on studying real-world data sets, building working systems, and putting current ideas from machine learning research into practice. ***Prerequisites:*** CSE 100; restricted to students with sophomore, junior, or senior standing. Graduate students will be allowed as space permits.

CSE 160. Introduction to Parallel Computing (4)

Introduction to high performance parallel computing: parallel architecture, algorithms, software, and problem-solving techniques. Areas covered: Flynns' taxonomy, processor-memory organizations, shared and nonshared memory models: message passing and multithreading, data parallelism; speedup, efficiency and Amdahl's law, communication and synchronization, isoefficiency and scalability. Assignments given to provide practical experience. ***Prerequisites:*** CSE 100 or Math 176.

CSE 163. Advanced Computer Graphics (4)

Topics include an overview of many aspects of computer graphics, including the four main computer graphics areas of animation, modeling, rendering, and imaging. Programming

projects in image and signal processing, geometric modeling, and real-time rendering. ***Prerequisites:*** CSE 167; restricted to students with junior or senior standing. Graduate students will be allowed as space permits.

CSE 164. GPU Programming (4)

Principles and practices of programming graphics processing units (GPUs). GPU architecture and hardware concepts, including memory and threading models. Modern hardware-accelerated graphics pipeline programming. Application of GPU programming to rendering of game graphics, including physical, deferring, and global lighting models. Recommended preparation: *Practical Rendering and Computation with Direct3D 11* by Jason Zink, Matt Pettineo, and Jack Hoxley. ***Prerequisites:*** CSE 167.

CSE 165. 3D User Interaction (4)

This course focuses on design and evaluation of three-dimensional (3D) user interfaces, devices, and interaction techniques. The course consists of lectures, literature reviews, and programming assignments. Students will be expected to create interaction techniques for several different 3D interaction devices. Program or materials fees may apply. ***Prerequisites:*** CSE 167.

CSE 166. Image Processing (4)

Principles of image formation, analysis, and representation. Image enhancement, restoration, and segmentation; stochastic image models. Filter design, sampling, Fourier and wavelet transforms. Selected applications in computer graphics and machine vision. ***Prerequisites:*** Math 20F, CSE 100 or Math 176.

CSE 167. Computer Graphics (4)

Representation and manipulation of pictorial data. Two-dimensional and three-dimensional transformations, curves, surfaces. Projection, illumination, and shading models. Raster and vector graphic I/O devices; retained-mode and immediate-mode graphics software systems and applications. Students may not receive credit for both Math 155A and CSE 167. ***Prerequisites:*** CSE 100 or Math 176.

CSE 168. Computer Graphics II: Rendering (4)

Weekly programming assignments that will cover graphics rendering algorithms. During the course the students will learn about ray tracing, geometry, tessellation, acceleration structures, sampling, filtering, shading models, and advanced topics such as global illumination and programmable graphics hardware. ***Prerequisites:*** CSE 167.

CSE 169. Computer Animation (4)

Advanced graphics focusing on the programming techniques involved in computer animation. Algorithms and approaches for both character animation and physically based animation. Particular subjects may include skeletons, skinning, key framing, facial animation, inverse kinematics, locomotion, motion capture, video game animation, particle systems, rigid bodies, clothing, and hair. Recommended preparation: An understanding of linear algebra. ***Prerequisites:*** CSE 167 or consent of instructor.

CSE 170. Interaction Design (5)

Introduces fundamental methods and principles for designing, implementing, and evaluating user interfaces. Topics: user-centered design, rapid prototyping, experimentation, direct manipulation, cognitive principles, visual design, social software, software tools. Learn by doing: Work with a team on a quarter-long design project. Cross-listed with COGS 120. Students may

not receive credit for COGS 120 and CSE 170. Recommended preparation: Basic familiarity with HTML. ***Prerequisites****:* CSE 11 or CSE 8A and COGS 187A or COGS 1 or DSGN 1.

CSE 176A. Maker Topics: Health Care Robotics (4)

Robotics has the potential to improve well-being for millions of people and support caregivers and to aid the clinical workforce. We bring together engineers, clinicians, and end-users to explore this exciting new field. The course is project-based, interactive, and hands-on, and involves working closely with stakeholders to develop prototypes that solve real-world problems. Students will explore the latest research in health care robotics, human-robot teaming, and health design. Program or materials fees may apply. ***Prerequisites:*** CSE 110 or CSE 170 or COGS 120; restricted to sophomore, junior, and senior students.

CSE 180. Biology Meets Computing (4)

Topics include an overview of various aspects of bioinformatics and will simultaneously introduce students to programming in Python. The assessments in the course represent various programming challenges and include solving diverse biological problems using popular bioinformatics tools. ***Prerequisites:*** BILD 1.

CSE 181. Molecular Sequence Analysis (4)

This course covers the analysis of nucleic acid and protein sequences, with an emphasis on the application of algorithms to biological problems. Topics include sequence alignments, database searching, comparative genomics, and phylogenetic and clustering analyses. Pairwise alignment, multiple alignment, DNS sequencing, scoring functions, fast database search, comparative genomics, clustering, phylogenetic trees, gene finding/DNA statistics. ***Prerequisites:*** CSE 100 or Math 176 and CSE 101 or Math 188 and BIMM 100 or Chem 114C. Bioinformatics majors only. CSE 181 is cross-listed with BIMM 181 and BENG 181.

CSE 182. Biological Databases (4)

This course provides an introduction to the features of biological data, how those data are organized efficiently in databases, and how existing data resources can be utilized to solve a variety of biological problems. Object oriented databases, data modeling and description. Survey of current biological database with respect to above, implementation of a database on a biological topic. Cross-listed with BIMM 182/BENG 182/CHEM 182. ***Prerequisites:*** CSE 100 or Math 176. Bioinformatics majors only.

CSE 184. Computational Molecular Biology (4)

This advanced course covers the application of machine learning and modeling techniques to biological systems. Topics include gene structure, recognition of DNA and protein sequence patterns, classification, and protein structure prediction. Pattern discovery, Hidden Markov models/support victor machines/neural network/profiles. Protein structure prediction, functional characterization or proteins, functional genomics/proteomics, metabolic pathways/gene networks. Cross-listed with BIMM 184/BENG 184/Chem 184. ***Prerequisites:*** BIMM 181 or BENG 181 or CSE 181, BENG 182 or BIMM 182 or CSE 182 or CHEM 182. Bioinformatics majors only.

CSE 190. Topics in Computer Science and Engineering (4)

Topics of special interest in computer science and engineering. Topics may vary from quarter to quarter. May be repeated for credit with the consent of instructor. ***Prerequisites:*** consent of instructor. Department stamp required.

CSE 191. Seminar in CSE (1–4)

A seminar course on topics of current interest. Students, as well as, the instructor will be actively involved in running the course/class. This course cannot be counted toward a technical elective. ***Prerequisites:*** consent of instructor. Department stamp required.

CSE 192. Senior Seminar in Computer Science and Engineering (1)

The Senior Seminar Program is designed to allow senior undergraduates to meet with faculty members in a small group setting to explore an intellectual topic in CSE (at the upper-division level). Topics will vary from quarter to quarter. Senior seminars may be taken for credit up to four times, with a change in topic, and permission of the department. Enrollment is limited to twenty students, with preference given to seniors. (P/NP grades only.) ***Prerequisites:*** upper-division standing; department stamp required and consent of instructor.

CSE 195. Teaching (4)

Teaching and tutorial assistance in a CSE course under the supervision of the instructor. (P/NP grades only.) ***Prerequisites:*** consent of the department chair. Department stamp required.

CSE 197. Field Study in Computer Science and Engineering (4, 8, 12, or 16)

Directed study and research at laboratories away from the campus. (P/NP grades only.) ***Prerequisites:*** consent of the instructor and approval of the department. Department stamp required.

CSE 198. Directed Group Study (2 or 4)

Computer science and engineering topics whose study involves reading and discussion by a small group of students under the supervision of a faculty member. (P/NP grades only.) ***Prerequisites:*** consent of the instructor. Department stamp required.

CSE 199. Independent Study for Undergraduates (2 or 4)

Independent reading or research by special arrangement with a faculty member. (P/NP grades only.) ***Prerequisites:*** consent of the instructor. Department stamp required.

CSE 199H. CSE Honors Thesis Research for Undergraduates (4)

Undergraduate research for completing an honors project under the supervision of a CSE faculty member. May be taken across multiple quarters. Students should enroll for a letter grade. May be taken for credit three times. ***Prerequisites:*** Admission to the CSE department honors program. Consent of the instructor. Department stamp required.

Graduate

CSE 200. Computability and Complexity (4)

Computability review, including halting problem, decidable sets, r.e. sets, many-one reductions; TIME(t(n)), SPACE(s(n)) and general relations between these classes; L, P, PSPACE, NP; NP—completeness; hierarchy theorems; RP, BPP. ***Prerequisites:*** CSE 105 or equivalent.

CSE 201A. Advanced Complexity (4)

Polynomial-time hierarchy (PH), BPP in second level of PH, Savitch's theorem, NL=coNL, nonuniform and circuit complexity, some circuit lower bounds, IP=PSPACE, probabilistic proof checking (PCP), application of PCP to approximation hardness, complexity of proof systems, parallel complexity classes NC and AC, P-completeness. Recommended preparation: CSE 200. ***Prerequisites:*** graduate standing.

CSE 202. Algorithm Design and Analysis (4)

The basic techniques for the design and analysis of algorithms. Divide-and-conquer, dynamic programming, data structures, graph search, algebraic problems, randomized algorithms, lower bounds, probabilistic analysis, parallel algorithms. ***Prerequisites:*** CSE 101 or equivalent.

CSE 203A. Advanced Algorithms (4)

Modern advances in design and analysis of algorithms. Exact syllabus varies. Topics include approximation, randomized algorithms, probabilistic analysis, heuristics, online algorithms, competitive analysis, models of memory hierarchy, parallel algorithms, number-theoretic algorithms, cryptanalysis, computational geometry, computational biology, network algorithms, VLSI CAD algorithms. ***Prerequisites:*** CSE 202.

CSE 205A. Logic in Computer Science (4)

(Formerly CSE 208D) Mathematical logic as a tool in computer science. Propositional logic, resolution, first-order logic, completeness and incompleteness theorems with computational viewpoint, finite model theory, descriptive complexity, logic programming, nonmonotonic reasoning, temporal logic. Applications to databases, automatic theorem proving, program verification, and distributed systems. ***Prerequisites:*** CSE 200 or consent of instructor.

CSE 206A. Lattice Algorithms and Applications (4)

(Formerly CSE 207C) Introduction to the algorithmic theory of point lattices (aka algorithmic geometry of numbers), and some of its most important applications in cryptography and cryptanalysis. Topics usually include: LLL basis reduction algorithm, cryptanalysis of broadcast RSA, hardness of approximating lattice problems. ***Prerequisites:*** CSE 202, CSE 200, or concurrent.

CSE 207. Modern Cryptography (4)

Private and public key cryptography, introduction to reduction based proofs of security, concrete security, block ciphers, pseudorandom functions and generators, symmetric encryption, asymmetric encryption, computational number theory, RSA and discrete log systems, message authentication, digital signatures, key distribution and key management. ***Prerequisites:*** CSE 202 or consent of instructor.

CSE 208. Advanced Cryptography (4)

Zero-knowledge, secure computation, session-key distribution, protocols, electronic payment, one-way functions, trapdoor permutations, pseudorandom bit generators, hardcore bits. ***Prerequisites:*** CSE 202, CSE 200, and CSE 207 or consent of instructor.

CSE 209A. Topics/Seminar in Algorithms, Complexity, and Logic (1–4)

Topics of special interest in algorithms, complexity, and logic to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 209B. Topics/Seminar in Cryptography (1–4)

Topics of special interest in cryptography to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 210. Principles of Software Engineering (4)

(Formerly CSE 264A.) General principles in modern software engineering. Both theoretical and practical topics are covered. Theoretical topics include proofs of correctness, programming language semantics, and theory of testing. Practical topics include structured programming, modularization techniques, design of languages for reliable programming, and software tools. ***Prerequisites:*** CSE 100, 131A, 120, or consent of instructor.

CSE 211. Software Testing and Analysis (4)

Survey of testing and analysis methods. Introduction to advanced topics in area as well as traditional production methods. Topics include inspections and reviews, formal analysis, verification and validation standards, nonstatistical testing, statistical-testing and reliability models, coverage methods, testing and analysis tools, and organization management and planning. Methods special to special development approaches such as object-oriented testing will also be described. ***Prerequisites:*** undergraduate major in computer science or extensive industrial experience.

CSE 216. Research Topics in Human-Computer Interaction (4)

Prepares students to conduct original HCI research by reading and discussing seminal and cutting-edge research papers. Topics include design, social software, input techniques, mobile, and ubiquitous computing. Student pairs perform a quarter-long mini research project that leverages campus research efforts. Cross-listed with COGS 230. ***Prerequisites:*** none.

CSE 218. Advanced Topics in Software Engineering (4)

This course will cover a current topic in software engineering in depth. Topics in the past have included software tools, impacts of programming language design, and software system structure. (S/U grades permitted.) ***Prerequisites:*** none.

CSE 219. Design at Large (1)

New societal challenges, cultural values, and technological opportunities are changing design—and vice versa. The seminar explores this increased scale, real-world engagement, and disruptive impact. Invited speakers from UC San Diego and beyond share cutting-edge research on interaction, design, and learning. Cross-listed with COGS 229. (S/U grades only.) ***Prerequisites:*** none.

CSE 221. Operating Systems (4)

Operating system structures, concurrent computation models, scheduling, synchronization mechanisms, address spaces, memory management protection and security, buffering, streams, data-copying reduction techniques, file systems, naming, caching, disk organization, mapped files, remote file systems, case studies of major operating systems. ***Prerequisites:*** CSE 120 and 121, or consent of instructor.

CSE 222A. Computer Communication Networks (4)

(Formerly CSE 222.) Computer communication network concepts, protocols, and architectures, with an emphasis on an analysis of algorithms, protocols, and design methodologies. Topics will include layering, error control, flow control, congestion control, switching and routing, quality of service management, mobility, naming, security, and selected contemporary topics. ***Prerequisites:*** CSE 123A or consent of instructor.

CSE 222B. Internet Algorithmics (4)

(Formerly CSE 228H.) Techniques for speeding up Internet implementations, including system restructuring, new algorithms, and hardware innovations. Topics include: models for protocols, systems and hardware; efficiency principles; applying these principles to deriving techniques for efficient implementation of common endnode and router functions. ***Prerequisites:*** CSE 123A or CSE 222A, or consent of instructor.

CSE 223B. Distributed Computing and Systems (4)

Efficient primitives for distributed operating systems and high-performance network servers, including concurrent and event-driven server architectures, remote procedure calls, and load shedding. Distributed naming, directory, and storage services, replication for fault tolerance, and security in distributed systems. ***Prerequisites:*** CSE 221, CSE 222A, or consent of instructor.

CSE 224. Graduate Networked Systems (4)

This course will provide a broad understanding of network design and implementation. Topics include techniques for building distributed applications, sockets programming, remote procedure calls (RPC), scale-out distributed directories, distributed consensus and state management, fault tolerance, networked storage, indirection, overlay networks, load balancing, and datacenter design. ***Prerequisites:*** graduate standing or consent of instructor. This course is intended for MS students. PhD students may only take the course if they are not in systems/networking concentrations.

CSE 227. Computer Security (4)

Security and threat models, risk analysis, authentication and authorization, auditing, operating systems security, access control mechanisms, protection mechanisms, distributed systems/network security, security architecture, electronic commerce security mechanisms, security evaluation. ***Prerequisites:*** CSE 221 or consent of instructor.

CSE 229A. Topics/Seminar in Computer Systems (1–4)

Discussion on problems of current research interest in computer systems. Possible areas of focus include: distributed computing, computational grid, operating systems, fault-tolerant computing, storage systems, system services for the World Wide Web. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 229C. Topics/Seminar in Computer Security (1–4)

Discussion on problems of current research interest in computer security. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 230. Principles of Programming Languages (4)

(Formerly CSE 273.) Functional versus imperative programming. Type systems and polymorphism; the ML language. Higher order functions, lazy evaluation. Abstract versus concrete syntax, structural and well-founded induction. The lambda calculus, reduction

strategies, combinators. Denotational semantics, elementary domain theory. ***Prerequisites:*** CSE 130 or equivalent, or consent of instructor.

CSE 231. Advanced Compiler Design (4)

(Formerly CSE 264C.) Advanced material in programming languages and translator systems. Topics include compilers, code optimization, and debugging interpreters. ***Prerequisites:*** CSE 100, 131A–B, or consent of instructor.

CSE 232. Principles of Database Systems (4)

(Formerly CSE 264D.) Database models including relational, hierarchic, and network approaches. Implementation of databases including query languages and system architectures. ***Prerequisites:*** CSE 100 or consent of instructor.

CSE 232B. Database System Implementation (4)

A hands-on approach to the principles of databases implementation. Algebraic rewriters/optimizers, query processors, triggers. Beyond centralized relational databases. ***Prerequisites:*** CSE 232.

CSE 233. Database Theory (4)

Theory of databases. Theory of query languages, dependency theory, deductive databases, incomplete information, complex objects, object-oriented databases, and more. Connections to logic and complexity theory including finite model theory and descriptive complexity. ***Prerequisites:*** CSE 200.

CSE 237A. Introduction to Embedded Computing (4)

Embedded system technologies including processors, DSP, memory, and software. System interfacing basics, communication strategies, sensors, and actuators. Mobile and wireless technology in embedded systems. Using predesigned hardware and software components. Design case studies in wireless, multimedia, and/or networking domains. ***Prerequisites:*** basic courses in digital hardware, algorithms and data structures, elementary calculus, and probability; or consent of instructor.

CSE 237B. Software for Embedded Systems (4)

Embedded computing elements, device interfaces, time-critical IO handling. Embedded software design under size, performance, and reliability constraints. Software timing and functional validation. Programming methods and compilation for embeddable software. Embedded runtime systems. Case studies of real-time software systems. ***Prerequisites:*** CSE 237A; or basic courses in programming, algorithms and data structures, elementary calculus, discrete math, computer architecture; or consent of instructor.

CSE 237C. Validation and Testing of Embedded Systems (4)

Embedded system building blocks including IP cores. Cosimulation. Formal verification using model checking. Verification environments. Test challenges in core integration: compliance, feature, random, and collision testing. Core access and test integration. Interface-based verification and standards. ***Prerequisites:*** CSE 237A; or basic courses in algorithms and data structures, elementary calculus, discrete math, symbolic logic, computer architecture; or consent of instructor.

CSE 237D. Design Automation and Prototyping for Embedded Systems (4)

System representation and modeling. Abstract and language models. Simulation as a modeling activity. Computational and hw/sw system prototypes. System analysis using models. Constraint and interface modeling. Behavioral compilation and synthesis. ***Prerequisites:*** CSE

237A; or basic courses in digital logic design, algorithms and data structures, elementary calculus, discrete math, symbolic logic, computer architecture; or consent of instructor.

CSE 239A. Topics/Seminar in Databases (1–4)

Discussion on problems of current research interest in databases. Possible areas of focus include: core database issues, data management on the web, data integration, new database models and applications, formal methods in databases. Topics to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 240A. Principles of Computer Architecture (4)

(Formerly CSE 240.) This course will cover fundamental concepts in computer architecture. Topics include instruction set architecture, pipelining, pipeline hazards, bypassing, dynamic scheduling, branch prediction, superscalar issue, memory-hierarchy design, advanced cache architectures, and multiprocessor architecture issues. ***Prerequisites:*** CSE 141 or consent of instructor.

CSE 240B. Parallel Computer Architecture (4)

This course covers advanced topics in parallel computer architecture, including on-chip and off-chip interconnection networks, cache coherence, cache consistency, hardware multithreading, multi-core and tiled architectures. It incorporates the latest research and development on parallel architectures and compilation techniques for those architectures. CSE 240A recommended. ***Prerequisites:*** graduate standing.

CSE 240C. Advanced Microarchitecture (4)

This course covers advanced topics in computer architecture. It incorporates the latest research and development on topics such as branch prediction, instruction-level parallelism, cache hierarchy design, speculative multithreading, reliable architectures, and power-management techniques. CSE 240A recommended. ***Prerequisites:*** graduate standing.

CSE 241A/ECE 260B. VLSI Integration of Computing Circuitry (4)

VLSI integrated-circuit building blocks of computing systems, and their implementation. Computer-aided design and performance simulations, design exercises and projects. Devices, standard cells and interconnects, clocking, power/ground distribution, arithmetic modules, memories. Methodologies and tradeoffs in system implementation. ***Prerequisites:*** layout (CSE 165 or ECE 260A) and logic design (CSE 140 or ECE 111), or consent of instructor.

CSE 243A. Introduction to Synthesis Methodologies in VLSI CAD (4)

Hardware software co-design, architectural level synthesis, control synthesis and optimization, scheduling, binding, register and bus sharing, interconnect design, module selection, combinational logic optimization, state minimization, state encoding, and retiming. ***Prerequisites:*** none.

CSE 244A. VLSI Test (4)

Design for test, testing economics, defects, failures and faults, fault models, fault simulation, automatic test pattern generation, functional testing, memory, PLA, FPGA, microprocessor test, and fault diagnosis. ***Prerequisites:*** none.

CSE 245. Computer Aided Circuit Simulation and Verification (4)

This course is about the computer algorithms, techniques, and theory used in the simulation and verification of electrical circuits. ***Prerequisites:*** CSE 241A or consent of instructor.

CSE 248. Algorithmic and Optimization Foundations for VLSI CAD (4)

Algorithmic techniques and optimization frameworks for large-scale, difficult optimizations. Primal-dual multicommodity flow approximations, approximations for geometric and graph Steiner formulations, continuous placement optimization, heuristics for Boolean satisfiability, multilevel methods, semidefinite programming, and application to other formulations (e.g., scheduling). ***Prerequisites:*** CSE 241A or CSE 242A, or consent of instructor.

CSE 249A. Topics/Seminar in Computer Architecture (1–4)

Topics of special interest in computer architecture to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 249B. Topics/Seminar in VLSI (1–4)

Topics of special interest in VLSI to be presented by faculty and students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. ***Prerequisites:*** consent of instructor.

CSE 250A. Principles of Artificial Intelligence: Probabilistic Reasoning and Learning (4)

Methods based on probability theory for reasoning and learning under uncertainty. Content may include directed and undirected probabilistic graphical models, exact and approximate inference, latent variables, expectation-maximization, hidden Markov models, Markov decision processes, applications to vision, robotics, speech, and/or text. Recommended preparation: CSE 103 or similar course. ***Prerequisites:*** graduate standing in CSE or consent of instructor.

CSE 250B. Principles of Artificial Intelligence: Learning Algorithms (4)

Algorithms for supervised and unsupervised learning from data. Content may include maximum likelihood; log-linear models, including logistic regression and conditional random fields; nearest neighbor methods; kernel methods; decision trees; ensemble methods; optimization algorithms; topic models; neural networks; and backpropagation. Recommended preparation: CSE 103 or similar course. ***Prerequisites:*** graduate standing or consent of instructor.

CSE 250C. Machine Learning Theory (4)

Theoretical foundations of machine learning. Topics include concentration of measure, the PAC model, uniform convergence bounds, and VC dimension. Possible topics include online learning, learning with expert advice, multiarmed bandits, and boosting. Recommended preparation: CSE 103 and CSE 101 or similar course. ***Prerequisites:*** graduate standing or consent of instructor.

CSE 252A. Computer Vision I (4)

Comprehensive introduction to computer vision providing broad coverage including low-level vision (image formation, photometry, color, image feature detection), inferring 3-D properties from images (shape-from shading, stereo vision, motion interpretation) and object recognition. Companion to CSE 252B covering complementary topics. ***Prerequisites:*** Math 10D and Math 20A–F or equivalent.

CSE 252B. Computer Vision II (4)

Comprehensive introduction to computer vision providing focused coverage of multiview geometry, structure from motion, image segmentation, motion segmentation, texture analysis and recognition, object detection, and image-based rendering. Companion to CSE 252A covering complementary topics. ***Prerequisites:*** Math 10D and Math 20A–F or equivalent.

CSE 252C. Selected Topics in Vision and Learning (1–4)

Selected topics in computer vision and statistical pattern recognition, with an emphasis on recent developments. Possible topics include: grouping and segmentation, object recognition

and tracking, multiple view geometry, kernel-based methods, dimensionality reduction, and mixture models. ***Prerequisites:***CSE 252 or equivalent and CSE 250B or equivalent.

CSE 253. Neural Networks for Pattern Recognition (4)

Probability density estimation, perceptrons, multilayer neural networks, radial basis function networks, support vector machines, error functions, data preprocessing. Possible topics include unsupervised learning methods, recurrent networks, and mathematical learning theory. Recommended preparation: CSE 250B or equivalent. ***Prerequisites:*** graduate standing.

CSE 254. Statistical Learning (4)

Learning algorithms based on statistics. Possible topics include minimum-variance unbiased estimators, maximum likelihood estimation, likelihood ratio tests, resampling methods, linear logistic regression, feature selection, regularization, dimensionality reduction, manifold detection. An upper-division undergraduate course on probability and statistics such as Math 183 or 186, or any graduate course on statistics, pattern recognition, or machine learning is recommended. ***Prerequisites:*** graduate standing.

CSE 255. Data Mining and Predictive Analytics (4)

Learning methods for applications. Content may include data preparation, regression and classification algorithms, support vector machines, random forests, class imbalance, overfitting, decision theory, recommender systems and collaborative filtering, text mining, analyzing social networks and social media, protecting privacy, A/B testing. Recommended preparation: CSE 103 or similar. ***Prerequisites:*** graduate standing or consent of instructor.

CSE 258. Recommender Systems and Web Mining (4)

Current methods for data mining and predictive analytics. Emphasis is on studying real-world data sets, building working systems, and putting current ideas from machine learning research into practice. Recommended preparation: No previous background in machine learning is required, but students should be comfortable with programming (all example code will be in Python), and with basic optimization and linear algebra. ***Prerequisites:*** graduate standing.

CSE 258A. Cognitive Modeling (4)

Connectionist models and a sampling of other cognitive modeling techniques. Models of language processing, memory, sequential processes, and vision. Areas covered may vary depending on student and faculty interests. Can be repeated for credit. CSE 151 or CSE 250B or CSE 253 or CSE 254, or equivalent experience recommended. ***Prerequisites:*** graduate standing.

CSE 259. Seminar in Artificial Intelligence (1)

A weekly meeting featuring local (and occasional external) speakers discussing their current research in Artificial Intelligence Neural Networks, and Genetic Algorithms. (S/U grades only.) ***Prerequisites:*** none.

CSE 260. Parallel Computation (4)

(Formerly CSE 274A.) This course provides an overview of parallel hardware, algorithms, models, and software. Topics include Flynn's taxonomy, interconnection networks, memory organization, a survey of commercially available multiprocessors, parallel algorithm paradigms and complexity criteria, parallel programming environments and tools for parallel debugging, language specification, mapping, performance, etc. ***Prerequisites:*** graduate standing or consent of instructor.

CSE 262. System Support for Applications of Parallel Computation (4)

This course will explore design of software support for applications of parallel computation. Topics include: programming languages, run time support, portability, and load balancing. The course will terminate in a project. ***Prerequisites:*** consent of instructor.

CSE 272. Advanced Image Synthesis (4)

Computer graphics techniques for creating realistic images. Topics include ray tracing, global illumination, subsurface scattering, and participating media. CSE 168 or equivalent recommended.

CSE 274. Selected Topics in Graphics (2–4)

Selected topics in computer graphics, with an emphasis on recent developments. Possible topics include computer animation, shape modeling and analysis, image synthesis, appearance modeling, and real-time rendering. CSE 168 or CSE 169 recommended. ***Prerequisites:*** graduate standing or consent of instructor.

CSE 276A. Introduction to Robotics (4)

This course provides an introduction to the fundamentals of robotics across kinematics, sensor systems, estimation, control, and planning. The contents include introduction to robotics in general, kinematics of robot systems, robot arm systems, sensors for robots, basic vision for robots, estimation methods, perception, robot localization and navigation, control of robot systems, robot motion planning, robot task planning, robot architectures, and evaluation of robot systems. It is expected that students have a solid understanding of linear algebra, can program in Python or C++, and have a basic understanding of methods for reasoning under uncertainty. ***Prerequisites:*** graduate standing.

CSE 276B. Human Robot Interaction (4)

Robots are entering human spaces. How do we make them functional, useful, and acceptable? This course explores the core computational, engineering, and experimental challenges in human-robot interaction. Course topics include shared autonomy, perception of people and context, coordination, collaboration, human-guided learning, robot design, and experimental robotics. Students will review seminal and recent papers in the field and engage in team-based projects with physical, mobile robots. This class requires expertise in software development. Prior exposure to robotics, computer vision, or machine learning is recommended. Students should be comfortable reading and analyzing scientific papers at the graduate level. Students may not receive credit for CSE 276B and CSE 291 (A00) taught winter 2017 with the same subtitle. ***Prerequisites:*** graduate standing.

CSE 276C. Mathematics for Robotics (4)

The course will provide a comprehensive introduction to the key mathematical concepts used for modeling, implementing, and evaluation of robot systems. The course will use small home assignments tasks and a larger robot project to exercise the topics covered in class. The students should have a basic knowledge of mathematics and know one or more programming languages such as Python or Matlab for completion of homework assignments. ***Prerequisites:***graduate standing.

CSE 276D. Healthcare Robotics (4)

Robotics has the potential to improve well-being for millions of people, support care givers, and aid the clinical workforce. This course brings together engineers, clinicians, and end-users to explore this exciting new field. It is project-based, interactive, and hands on, and involves working closely with stakeholders to develop prototypes that solve real-world

problems. Students will explore the latest research in healthcare robotics, human-robot teaming, and health design. JSOE students should be comfortable building and experimenting within their area of expertise (e.g., CSE, software development, MAE, rapid prototyping). Students with clinical backgrounds should be familiar with translational research methods. Students may not receive credit for CSE 276D and CSE 291 (H00) taught spring 2017 with the same subtitle. Program or materials fees may apply. ***Prerequisites:*** graduate standing.

CSE 280A. Algorithms in Computational Biology (4)

(Formerly CSE 206B.) The course focuses on algorithmic aspects of modern bioinformatics and covers the following topics: computational gene hunting, sequencing, DNA arrays, sequence comparison, pattern discovery in DNA, genome rearrangements, molecular evolution, computational proteomics, and others. ***Prerequisites:*** CSE 202 preferred or consent of instructor.

CSE 282/BENG 202. Bioinformatics II: Sequence and Structure Analysis—Methods and Applications (4)

(Formerly CSE 257A/BENG 202.) Introduction to methods for sequence analysis. Applications to genome and proteome sequences. Protein structure, sequence-structure analysis. ***Prerequisites:*** Pharm 201 or consent of instructor.

CSE 283/BENG 203. Bioinformatics III: Functional Genomics (4)

Annotating genomes, characterizing functional genes, profiling, reconstructing pathways. ***Prerequisites:*** Pharm 201, BENG 202/CSE 282, or consent of instructor.

CSE 284. Personal Genomics for Bioinformaticians (4)

This course provides an introduction to bioinformatics techniques for analyzing and interpreting human genomes. Topics covered include an introduction to medical and population genetics, ancestry, finding and interpreting disease-causing variants, genome-wide association studies, genetic risk prediction, analyzing next-generation sequencing data, how to scale current genomics techniques to analyze hundreds of thousands of genomes, and the social impact of the personal genomics revolution. Programming experience, familiarity with the UNIX command line, and a basic course in probability and statistics are strongly recommended. Students may not receive credit for CSE 284 and CSE 291 (E00) taught winter 2017 with the same subtitle. ***Prerequisites:*** graduate standing.

CSE 290. Seminar in Computer Science and Engineering (1–4)

(Formerly CSE 280A.) A seminar course in which topics of special interest in computer science and engineering will be presented by staff members and graduate students under faculty direction. Topics vary from quarter to quarter. May be repeated for credit. (S/U grades only.) ***Prerequisites:*** consent of instructor. (Offered as faculty resources permit.)

CSE 291. Topics in Computer Science and Engineering (1–4)

Topics of special interest in computer science and engineering. Topics may vary from quarter to quarter. May be taken for credit nine times with the consent of instructor. ***Prerequisites:*** consent of instructor. (S/U grades permitted.) (Offered as faculty resources permit.)

CSE 292. Faculty Research Seminar (1)

(Formerly CSE 282.) Computer science and engineering faculty will present one-hour seminars of the current research work in their areas of interest. ***Prerequisites:*** CSE graduate status.

CSE 293. Special Project in Computer Science and Engineering (1–12)

The student will conceive, design, and execute a project in computer science under the direction of a faculty member. The project will typically include a large programming or hardware design task, but other types of projects are possible. ***Prerequisites:*** CSE graduate student status. (CS 75, 76, 77, 78, 79, 80, 81) (S/U grades only.)

CSE 294. Research Meeting in CSE (2)

Advanced study and analysis of active research in computer science and computer engineering. Discussion of current research and literature in the research specialty of the staff member teaching the course. ***Prerequisites:*** consent of instructor.

CSE 298. Independent Study (1–16)

Open to properly qualified graduate students who wish to pursue a problem through advanced study under the direction of a member of the staff. (S/U grades only.) ***Prerequisites:*** consent of instructor.

CSE 299. Research (1–16)

Research. ***Prerequisites:*** consent of faculty.

CSE 500. Teaching Assistantship (2–4)

A course in which teaching assistants are aided in learning proper teaching methods by means of supervision of their work by the faculty: handling of discussions, preparation and grading of examinations and other written exercises, and student relations. May be used to meet teaching experience requirement for candidates for the PhD degree. Number of units for credit depends on number of hours devoted to class or section assistance. ***Prerequisites:*** graduate standing and consent of instructor.

CSE 599. Teaching Methods in Computer Science (2)

Training in teaching methods in the field of computer science. This course examines theoretical and practical communication and teaching techniques particularly appropriate to computer science. ***Prerequisites:*** consent of faculty.

Economics

Upper Division

ECON 100A. Microeconomics A (4)
Economic analysis of household determination of the demand for goods and services, consumption/saving decisions, and the supply of labor. ***Prerequisites:*** Econ 1 and Math 10C or 20C or 31BH.

ECON 100B. Microeconomics B (4)
Analysis of firms' production and costs, the supply of output and demand factors of production. Analysis of perfectly competitive markets. ***Prerequisites:*** Econ 100A.

ECON 100C. Microeconomics C (4)
Analysis of the effects of imperfect market structure, strategy, and imperfect information. ***Prerequisites:*** Econ 100B.

ECON 100AH. Honors Microeconomics A (1)
Honors sequence expanding on the material taught in Econ 100A. Major GPA of 3.5 or better required. May be taken concurrently with Econ 100A or after successful completion of Econ 100A with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 100BH. Honors Microeconomics B (1)
Honors sequence expanding on the material taught in Econ 100B. Major GPA of 3.5 or better required. May be taken concurrently with Econ 100B or after successful completion of Econ 100B with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 100CH. Honors Microeconomics C (1)
Honors sequence expanding on the material taught in Econ 100C. Major GPA of 3.5 or better required. May be taken concurrently with Econ 100C or after successful completion of Econ 100C with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 101. International Trade (4)
Examines theories of international trade in goods and services and relates the insights to empirical evidence. Explains international trade at the level of industries and firms and analyzes the consequences of trade for resource allocation, welfare, and the income distribution. Discusses sources of comparative advantage, motives for trade policies, and the effects of trade barriers and trading blocs on welfare and incomes. ***Prerequisites:*** Econ 100B or 102.

ECON 102. Globalization (4)
Presents theories of global economic integration, grounded in the principle of comparative advantage. Investigates patterns of trade when trade is balanced and capital flows when trade is not balanced. Assesses the consequences of global economic integration and economic policies for industry location, incomes, welfare and economic growth, and studies goods, services and sovereign debt markets. ***Prerequisites:*** Econ 1 or 100B and 2 or 3 or Math 20C.

ECON 102T. Advanced Topic in Globalization (2)
This course presents a selection of empirical applications and advanced topics that build on the material covered in Econ 102, Globalization. Students have the opportunity to analyze global trade and capital market data and to prepare a presentation and brief paper on a specific

topic. ***Prerequisites:*** department approval required. May be taken concurrently with Econ 102 or after completion of Econ 102.

ECON 103. International Monetary Relations (4)

Analyzes exchange rates and the current account. Relates their joint determination to financial markets and the real-side macroeconomy using international macroeconomic models and presents empirical regularities. Discusses macroeconomic policies under different exchange rate regimes and implications for financial stability and current account sustainability. ***Prerequisites:*** Econ 102 or 110B or 173A.

ECON 104. Economics of Network Industries (4)

Economics of industries with network effects such as telecommunications, internet, software, and airlines. Analysis of standards, complementarities, switching costs, economies of scale, and optimal price setting in the presence of network effects. ***Prerequisites:*** Econ 100C.

ECON 105. Industrial Organization and Firm Strategy (4)

Theory of monopoly and oligopoly pricing, price discrimination, durable goods pricing, cartel behavior, price wars, strategic entry barriers, mergers, pro- and anti-competitive restraints on business. ***Prerequisites:*** Econ 100C.

ECON 106. International Economic Agreements (4)

Examines reasons for international economic agreements, their design, the strategic interactions that determine how the agreements are implemented and sustained, and consequences for global welfare and inequality. Draws on international economics, game theory, law and economics, and political economy to understand international economic agreements. These tools are used to understand multilateral trade and investment agreements, such as NAFTA, and international organizations, such as the WTO. ***Prerequisites:*** Econ 100B and 102.

ECON 107. Economic Regulation and Antitrust Policy (4)

Detailed treatment of antitrust policy: Sherman Act, price fixing, collusive practices, predatory pricing, price discrimination, double marginalization, exclusive territories, resale price maintenance, refusal to deal, and foreclosure. Theory of regulation and regulatory experience in electrical utilities, oil, telecommunications, broadcasting, etc. ***Prerequisites:*** Econ 2 or 100B; and Math 10C or 20C or 31BH.

ECON 109. Game Theory (4)

Introduction to game theory. Analysis of people's decisions when the consequences of the decisions depend on what other people do. This course features applications in economics, political science, and law. ***Prerequisites:*** Econ 100C or Math 31CH or Math 109 or (CSE 20 and Math 20 C).

ECON 109T. Advanced Topics in Game Theory (2)

This course presents a selection of applications and advanced topics that build on the material covered in the Econ 109. Game Theory course. ***Prerequisites:***department approval required. May be taken concurrently with Econ 109 or after completion of Econ 109.

ECON 110A. Macroeconomics A (4)

Analysis of the determination of long run growth and models of the determination of output, interest rates, and the price level. Analysis of inflation, unemployment, and monetary and fiscal policy. ***Prerequisites:*** Econ 1 and Econ 3 and Math 10C or 20C or 31BH.

ECON 110B. Macroeconomics B (4)

Analysis of the determination of consumption spending at the aggregate level; extension of the basic macro model to include exchange rates and international trade; the aggregate money supply, and the business cycle. ***Prerequisites:*** Econ 110A.

ECON 110AH. Honors Macroeconomics A (1)

Honors sequence expanding on the material taught in Econ 110A. Major GPA of 3.5 or better required. May be taken concurrently with Econ 110A or after successful completion of Econ 110A with A–or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 110BH. Honors Macroeconomics B (1)

Honors sequence expanding on the material taught in Econ 110B. Major GPA of 3.5 or better required. May be taken concurrently with Econ 110B or after successful completion of Econ 110B with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 111. Monetary Economics (4)

Financial structure of the US economy. Bank behavior. Monetary control. ***Prerequisites:*** Econ 3 and Math 10A or 20A.

ECON 112. Macroeconomic Data Analysis (4)

Examines time series methods for data analysis with an emphasis on macroeconomic applications. Students are provided with an overview of fundamental time series techniques, hands-on experience in applying them to real-world macroeconomic data, and expertise in performing empirical tests of policy-relevant macroeconomic theories, such as the permanent income hypothesis, the Keynesian fiscal multiplier, and the Phillips curve. ***Prerequisites:*** Econ 110B and Econ 120B or Math 181B.

ECON 113. Mathematical Economics (4)

Mathematical concepts and techniques used in advanced economic analysis; applications to selected aspects of economic theory. ***Prerequisites:*** Econ 100C; or Math 140A or Math 142A.

ECON 114. Economics of Immigration (4)

Impact of immigration on the US economy. Empirical evidence on the labor market and fiscal impacts of immigration. Consequences of US immigration policies on the economy. ***Prerequisites:*** Econ 1 and 3.

ECON 116. Economic Development (4)

Introduction to the economics of less developed countries, covering their international trade, human resources, urbanization, agriculture, income distribution, political economy, and environment. ***Prerequisites:*** Econ 2 or 100B.

ECON 117. Economic Growth (4)

Models of the economic growth of developed economies. ***Prerequisites:*** Econ 100A.

ECON 118. Law and Economics: Torts, Property, and Crime (4)

Uses economic theory to evaluate the economic effects of US law in several legal fields, including tort law (accidents), products liability law, property law, criminal law (law enforcement), and litigation. Also considers risk bearing and why people buy insurance. ***Prerequisites:*** Econ 2 or 100A; and Math 10A or 20A.

ECON 119. Law and Economics: Contracts and Corporations (4)

This course asks how firms are organized and why the corporate form dominates, how corporations are governed and the distortions that result, when firms borrow and how they

deal with financial distress and bankruptcy. The course will present basic legal doctrines in corporate law, contract law, debtor-creditor law, and bankruptcy, and use economic models to analyze whether and when these doctrines promote economically efficient behavior. ***Prerequisites:*** Econ 2 or 100A and Math 10A or 20A.

ECON 120A. Econometrics A (4)

Probability and statistics used in economics. Probability and sampling theory, statistical inference, and use of spreadsheets. Credit not allowed for Econ 120A after ECE 109, MAE 108, Math 180A, Math 183, or Math 186. ***Prerequisites:*** Econ 1; and Math 10C or 20C or 31BH.

ECON 120B. Econometrics B (4)

Basic econometric methods, including the linear regression, hypothesis testing, quantifying uncertainty using confidence intervals, and distinguishing correlation from causality. Credit not allowed for both Econ 120B and Math 181B. ***Prerequisites:*** Econ 120A or ECE 109 or Math 180A or Math 183 or Math 186.

ECON 120C. Econometrics C (4)

Advanced econometric methods: estimation of linear regression models with endogeneity, economic methods designed for panel data sets, estimation of discrete choice models, time series analysis, and estimation in the presence of autocorrelated and heterskedastic errors. ***Prerequisites:*** Econ 120B or Math 181B.

ECON 120AH. Honors Econometrics A (1)

Honors sequence expanding on the material taught in Econ 120A. Major GPA of 3.5 or better required. May be taken concurrently with Econ 120A or after successful completion of Econ 120A with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 120BH. Honors Econometrics B (1)

Honors sequence expanding on the material taught in Econ 120B. Major GPA of 3.5 or better required. May be taken concurrently with Econ 120B or after successful completion of Econ 120B with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 120CH. Honors Econometrics C (1)

Honors sequence expanding on the material taught in Econ 120C. Major GPA of 3.5 or better required. May be taken concurrently with Econ 120C or after successful completion of Econ 120C with A– or better or consent of instructor. Priority enrollment given to majors in the department. ***Prerequisites:*** department approval required.

ECON 121. Applied Econometrics (4)

Application of econometric methods to such areas as labor supply, human capital, and financial time series. Concurrent enrollment in Econ 120C is permitted. ***Prerequisites:*** Econ 120C.

ECON 122. Econometric Theory (4)

Detailed study of the small sample and asymptotic properties of estimators commonly used in applied econometric work: multiple linear regression, instrumental variables, generalized method of moments, and maximum likelihood. Econometric computation using MATLAB. Recommended preparation: Econ 120C. ***Prerequisites:*** Econ 120B or Math 181B and Math 18 or Math 31AH.

ECON 125. Demographic Analysis and Forecasting (4)

Interaction between economic forces and demographic changes are considered, as are demographic composition and analysis; fertility, mortality, and migration processes and trends. Course emphasizes the creation, evaluation, and interpretation of forecasts for states, regions, and subcounty areas. Econ 178 is recommended. ***Prerequisites:*** Econ 120B or Math 181B.

ECON 130. Public Policy (4)

Course uses basic microeconomic tools to discuss a wide variety of public issues, including the war on drugs, global warming, natural resources, health care and safety regulation. Appropriate for majors who have not completed Econ 100A-B-C and students from other departments. ***Prerequisites:*** Econ 2 or 100A.

ECON 131. Economics of the Environment (4)

Environmental issues from an economic perspective. Relation of the environment to economic growth. Management of natural resources, such as forest and fresh water. Policies on air, water, and toxic waste pollution. International issues such as ozone depletion and sustainable development. ***Prerequisites:*** Econ 2 or 100A.

ECON 132. Energy Economics (4)

Energy from an economic perspective. Fuel cycles for coal, hydro, nuclear, oil, and solar energy. Emphasis on efficiency and control of pollution. Comparison of energy use across sectors and across countries. Global warming. Role of energy in the international economy. ***Prerequisites:*** Econ 1 and (Econ 2 or 3 or 100A or 131 or ESYS 103 or MAE 124) and Math 10C or 20C or 31BH.

ECON 133. International Environmental Agreements (4)

Addresses environmental issues that transcend national boundaries, such as climate change, biodiversity loss, over-fishing. Examines why international agreements are required, how they are negotiated and implemented, and studies their effectiveness. Explores whether more effective environmental treaties could be designed. ***Prerequisites:*** Econ 2 or 100A.

ECON 135. Urban Economics (4)

(Cross-listed with USP 102.) Economic analysis of why cities develop, patterns of land use in cities, why cities suburbanize, and the pattern of urban commuting. The course also examines problems of urban congestion, air pollution, zoning, poverty, crime, and discusses public policies to deal with them. Credit not allowed for both Econ 135 and USP 102. ***Prerequisites:*** Econ 2 or 100A; and Math 10A or 20A.

ECON 136. Human Resources (4)

A practical yet theory-based study of the firm's role in managing workers, including issues related to hiring, education and training, promotions, layoffs and buyouts, and the overarching role that worker compensation plays in all of these. ***Prerequisites:*** Econ 100B.

ECON 138. Economics of Discrimination (4)

This course will investigate differences in economic outcomes on the basis of race, gender, ethnicity, religion, and sexual orientation. We will study economic theories of discrimination, empirical work testing those theories, and policies aimed at alleviating group-level differences in economic outcomes. ***Prerequisites:***Econ 1.

ECON 139. Labor Economics (4)

Theoretical and empirical analysis of labor markets. Topics include: labor supply, labor demand, human capital investment, wage inequality, labor mobility, immigration, labor market discrimination, labor unions and unemployment. ***Prerequisites:*** Econ 2 or 100B.

ECON 140. Economics of Health Producers (4)
Provides an overview of the physician, hospital, and pharmaceutical segments of the health sector. Uses models of physician behavior, for-profit and nonprofit institutions to understand the trade-offs facing health-sector regulators and the administrators of public and private insurance arrangements. ***Prerequisites:***Econ 2 or 100B.

ECON 141. Economics of Health Consumers (4)
Demand for health care and health insurance, employer-provision of health insurance and impact on wages and job changes. Cross-country comparisons of health systems. ***Prerequisites:*** Econ 100C.

ECON 142. Behavioral Economics (4)
Course will study economic models in which standard economic rationality assumptions are combined with psychologically plausible assumptions on behavior. We consider whether the new models improve ability to predict and understand phenomena including altruism, trust and reciprocity, procrastination, and self-control. ***Prerequisites:*** Econ 109.

ECON 143. Experimental Economics (4)
Explore use of experiments to study individual and interactive (strategic) decision-making. Topics may include choice over risky alternatives, altruism and reciprocity, allocation and information aggregation in competitive markets, cooperation and collusion, bidding in auctions, strategy in coordination and "outguessing" games. ***Prerequisites:*** Econ 100C.

ECON 144. Economics of Conservation (4)
Examines conservation of biodiversity from an economic perspective. Topics include valuing biodiversity, defining successful conservation, and evaluating the cost effectiveness of policies such as conservation payments, ecotourism, and privatization. Emphasis on forests, coral reefs, elephants, tigers, and sea turtles. ***Prerequisites:*** Econ 2 or 100A.

ECON 145. Economics of Ocean Resources (4)
Economic issues associated with oceans. Economics of managing renewable resources in the oceans, with an emphasis on fisheries, economics of conservation and biodiversity preservation for living marine resources, with an emphasis on whales, dolphins, sea turtles, and coral reefs. ***Prerequisites:*** Econ 2 or 100A.

ECON 146. Economic Stabilization (4)
Theory of business cycles and techniques used by governments to stabilize an economy. Discussion of recent economic experience. ***Prerequisites:*** Econ 110B.

ECON 147. Economics of Education (4)
Examination of issues in education using theoretical and empirical approaches from economics. Analysis of decisions to invest in education. Consideration of various market structures in education, including school choice and school finance programs. ***Prerequisites:*** Econ 2 or 100A; and Econ 120B or Math 181B.

ECON 150. Public Economics: Taxation (4)
Overview of the existing national tax structure in the United States, its effects on individual and firm decisions, and the resulting efficiency costs and distributional consequences. The course concludes with an examination of several commonly proposed tax reforms. ***Prerequisites:*** Econ 100C.

ECON 151. Public Economics: Expenditures I (4)

Overview of the public sector in the United States and the scope of government intervention in economic life. Theory of public goods and externalities. Discussion of specific expenditure programs such as education and national defense. ***Prerequisites:*** Econ 100C.

ECON 152. Public Economics: Expenditures II (4)

Overview of the public sector in the United States and the justifications for government intervention in economic life. Theory of income redistribution and social insurance. Applications to current policy in such areas as health insurance, welfare, unemployment insurance, and Social Security. ***Prerequisites:*** Econ 100C.

ECON 158. Economic History of the United States I (4)

(Cross-listed with HIUS 140.) The United States as a raw materials producer, as an agrarian society, and as an industrial nation. Emphasis on the logic of the growth process, the social and political tensions accompanying expansion, and nineteenth- and early twentieth-century transformations of American capitalism. Credit not allowed for both Econ 158 and HIUS 140. ***Prerequisites:*** upper-division standing.

ECON 159. Economic History of the United States II (4)

(Cross-listed with HIUS 141.) The United States as a modern industrial nation. Emphasis on the logic of the growth process, the social and political tensions accompanying expansion, and twentieth-century transformations of American capitalism. Credit not allowed for both Econ 159 and HIUS 141. ***Prerequisites:***upper-division standing.

ECON 161. Global Integration of Latin America (4)

Examines the integration of Latin American and Caribbean countries into the global economy. Topics include trade in agricultural and manufactured goods, regional trade agreements, international capital flows to Latin America, financial vulnerabilities, and policy responses. ***Prerequisites:*** Econ 1 and 3.

ECON 162. Economics of Mexico (4)

Survey of the Mexican economy. Topics such as economic growth, business cycles, saving-investment balance, financial markets, fiscal and monetary policy, labor markets, industrial structure, international trade, and agricultural policy. ***Prerequisites:*** Econ 1 and 3.

ECON 163. Japanese Economy (4)

Survey of the Japanese economy. Economic growth, business cycles, saving-investment balance, financial markets, fiscal and monetary policy, labor markets, industrial structure, international trade, and agricultural policy. ***Prerequisites:*** Econ 1 and 3.

ECON 164. The Indian Economy (4)

Survey of the Indian economy. Historical overview and perspective; political economy; democracy and development; economic growth; land, labor, and credit markets; poverty and inequality; health, education, and human development; technology and development; institutions and state capacity; contemporary policy issues and debates. ***Prerequisites****:* Econ 1 and 3.

ECON 165. Middle East Economics (4)

Socioeconomic development in the Arab world, Iran, and Turkey. Historical perspective; international trade and fuel resources; education, health, and gender gaps; unemployment and migration; population and environment; Islam and democracy. ***Prerequisites:*** Econ 1 and 3.

ECON 165T. Advanced Topics in Middle East Economics (2)

This course will cover certain country experiences and certain topics in more depth than in Econ 165. Students will also have the opportunity to choose countries and topics of particular interest to them for further reading and as subjects for a presentation and brief paper. ***Prerequisites:*** department approval required. May be taken concurrently with Econ 165 or after completion of Econ 165.

ECON 166. Economics of Southeast Asia (4)

Long-run economic development and current economic issues of Southeast Asia. Topics include: economic growth, industrialization, financial development, demography, human capital and labor, inequality and poverty, corporate sector, institutions, and government. Designed to teach how to apply economics to the real world, with examples and case studies from Southeast Asian economies. Will start with general economic frameworks then use them to discuss issues from countries in Southeast Asia. ***Prerequisites:*** Econ 110B.

ECON 167. Economics of China (4)

Survey of the Chinese economy. Topics such as economic growth, China's transition to a market economy, international trade, financial markets, labor markets, and industrial structure. ***Prerequisites****:* Econ 1 and 3.

ECON 168. Economics of Modern Israel (4)

This course explores economic processes that shape the Israeli economy. Topics include: biblical economics, economics of religion, economic growth, income inequality and consumer protests, employment, globalization, inflation, the high-tech sector, terrorism, and education. ***Prerequisites****:* Econ 1 and 3.

ECON 169. Economics of Korea (4)

This course covers long-run economic development and current economic issues of South Korea. Topics include: examination of major policy changes (e.g., shifts toward export promotion, heavy and chemical industries promotion); Korea's industrial structure, including the role of large enterprises (chaebol); role of government; and links between Korea and other countries. ***Prerequisites****:* Econ 3 and 100A.

ECON 171. Decisions Under Uncertainty (4)

Decision making when the consequences are uncertain. Decision trees, payoff tables, decision criteria, expected utility theory, risk aversion, sample information. ***Prerequisites:*** Econ 100A and Econ 120A or ECE 109 or Math 180A or Math 183 or Math 186.

ECON 172A. Operations Research A (4)

Linear and integer programming, elements of zero-sum, two-person game theory, and specific combinatorial algorithms. Credit not allowed for both Econ 172A and Math 171A. ***Prerequisites:*** Econ 100A; and Econ 120A or ECE 109 or Math 180A or Math 183 or Math 186; and Math 18 or 31AH.

ECON 172B. Operations Research B (4)

Nonlinear programming, deterministic and stochastic dynamic programming, queuing theory, search models, and inventory models. Credit not allowed for both Econ 172B and Math 171B. ***Prerequisites:*** Econ 172A or Math 171A.

ECON 173A. Financial Markets (4)

Financial market functions, institutions and instruments: stocks, bonds, cash instruments, derivatives (options), etc. Discussion of no-arbitrage arguments, as well as investors' portfolio

decisions and the basic risk-return trade-off established in market equilibrium. ***Prerequisites:*** Econ 100A and Econ 120B or Math 181B; and Math 18 or 31AH.

ECON 173AL. Applied Finance Laboratory (2)

Empirical, case-based analysis requiring students to use economic theory from Econ 173A: Financial Markets and data to address real-world issues such as conducting market research, conducting discounted cash flow analyses, and applying the CAPM model to identify issues in investment management, and more. Presentation of student analyses both orally and in writing. Can be used in conjunction with another two-unit upper-division Econ course to meet major elective requirements by petition. ***Prerequisites:*** Econ 173A.

ECON 173B. Corporate Finance (4)

Introduces the firm's capital budgeting decision, including methods for evaluation and ranking of investment projects, the firm's choice of capital structure, dividend policy decisions, corporate taxes, mergers and acquisitions. ***Prerequisites:*** Econ 4 or MGT 4; and Econ 173A.

ECON 174. Financial Risk Management (4)

Risk measures, hedging techniques, value of risk to firms, estimation of optimal hedge ratio, risk management with options and futures. Econ 171 is recommended. ***Prerequisites:*** Econ 173A.

ECON 176. Marketing (4)

Role of marketing in the economy. Topics such as buyer behavior, marketing mix, promotion, product selection, pricing, and distribution. Concurrent enrollment in Econ 120C is permitted. ***Prerequisites:*** Econ 120C.

ECON 177L. Applied Management Laboratory (4)

Applied theory and case-based class requiring students to develop hypothesis-driven, problem-solving skills. Students will work in teams and will develop management consultant skills by applying microeconomic theory, marketing, accounting, and econometric analyses to real-world business problems. Presentation of student analyses both orally and in writing. ***Prerequisites:*** Econ 4 and Econ 100C and Econ 176.

ECON 178. Economic and Business Forecasting (4)

Survey of theoretical and practical aspects of statistical and economic forecasting. Such topics as long-run and short-run horizons, leading indicator analysis, econometric models, technological and population forecasts, forecast evaluation, and the use of forecasts for public policy. Concurrent enrollment in Econ 120C is permitted. ***Prerequisites:*** Econ 120C.

ECON 182. Topics in Microeconomics (4)

Selected topics in microeconomics. ***Prerequisites:*** Econ 100C, consent of department is required.

ECON 191A. Senior Essay Seminar A (4)

Senior essay seminar for students with superior records in department majors. Students must complete Econ 191A and Econ 191B in consecutive quarters. ***Prerequisites:*** department stamp required.

ECON 191B. Senior Essay Seminar B (4)

Senior essay seminar for students with superior records in department majors. Students must complete Econ 191A and Econ 191B in consecutive quarters. ***Prerequisites:*** department stamp required.

ECON 195. Introduction to Teaching Economics (4)

Introduction to teaching economics. Each student will be responsible for a class section in one of the lower-division economics courses. Limited to advanced economics majors with at least a 3.5 GPA in upper-division economics work. (P/NP grades only.) Students may not earn more than eight units credit in 195 courses. ***Prerequisites:*** consent of the department.

ECON 198. Directed Group Study (2 or 4)

Directed study on a topic or in a group field not included in regular department curriculum by special arrangement with a faculty member. ***Prerequisites:*** upper-division standing and consent of instructor. May be repeated up to three times when course topics vary. (P/NP grades only.)

ECON 199. Independent Study (2 or 4)

Independent reading or research under the direction of and by special arrangement with a Department of Economics faculty member. (P/NP grades only.) ***Prerequisites:*** consent of instructor and departmental approval.

Graduate

ECON 200A. Microeconomics A (4)

Modern consumer and producer theory. Preferences, utility maximization, demand, choice under uncertainty, intertemporal choice. Production, cost, profit maximization and supply. Comparative statics, duality. ***Prerequisites:*** none. Enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 200B. Microeconomics B (4)

Arrow-Debreu model of general economic equilibrium and welfare economics. Axiomatic theory of the firm and household. Existence of general economic equilibrium. First and Second Fundamental Theorems of Welfare Economics. Futures and contingent commodity markets. Core and core convergence. ***Prerequisites:*** Econ 200A. Enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 200C. Mircoeconomics C (4)

Information economics: static and dynamic games of incomplete information, signaling, screening, and lemons. Institutional analysis: social choice, mechanism design, cooperative bargaining, contracts, strategic theory of the firm. ***Prerequisites:*** Econ 200B. Enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 201. Advanced Economic Theory (4)

An intensive examination of selected topics in economic theory. Course topic nonrepetitive in a three-year cycle. ***Prerequisites:*** Econ 207 and 213.

ECON 202A-B-C. Workshop in Economic Theory (0–4/0–4/0–4)

An examination of recent research in economic theory, including topics in general equilibrium, welfare economics, duality, and social choice; development of related research topics by both graduate students and faculty. Course may be repeated an unlimited number of times. (S/U grades only.) ***Prerequisites:*** Econ 207 or consent of instructor.

ECON 204. Contract Theory (4)

This course reviews the theoretical foundations for the analysis of contractual interaction and it covers a selection of game-theoretic models and applications. The course is intended to provide a foundation for theoretical research on contracts as well as applied research on topics in behavioral/experimental, development, environmental, international, and labor economics, law and economics, and macroeconomics. ***Prerequisites:*** Econ 200A-B-C.

ECON 205. Mathematics for Economists (4)

Advanced calculus review for new graduate students. ***Prerequisites:*** none. Enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 206. Decisions (4)

Further topics in consumer and producer theory, intertemporal optimization, and decision making under uncertainty. (Previously numbered Econ 200D.) ***Prerequisites:*** Econ 200A-B-C or consent of instructor.

ECON 208. Games and Information (4)

Further topics in game theory and the economics of information. (Previously numbered Econ 200F.) ***Prerequisites:*** Econ 200A-B-C or consent of instructor.

ECON 210A. Macroeconomics A (4)

Dynamic optimization: Lagrangean methods and recursive methods. The neoclassical growth model: social planner, competitive equilibrium, first and second welfare theorems, steady state

analysis, dynamic analysis, shocks, heterogeneity and aggregation, applications. ***Prerequisites:*** none. Enrollment limited to Economics PhD students (EN75); or consent of instructor.

ECON 210B. Macroeconomics B (4)

Models of the household's intertemporal consumption/saving decision, and implications for risk aversion, basic portfolio allocation, and asset pricing. Models with heterogeneous agents—overlapping generations, incomplete markets, precautionary saving. Implications of labor market frictions for equilibrium employment. ***Prerequisites:*** Econ 210A. Enrollment limited to Economics PhD students (EN75); or consent of instructor.

ECON 210C. Macroeconomics C (4)

Basic facts and time series for macroeconomics. Modern theories of short-run fluctuations: sources of business cycle and the evolution of income, employment, interest rate, and prices. Monetary and fiscal policy theories in the presence of real and nominal rigidities. ***Prerequisites:*** Econ 210B. Enrollment limited to Economics PhD students (EN75); or consent of instructor.

ECON 210D. Monetary Economics and Business Cycles (4)

Study of the determinants of economic fluctuations, inflation, and interest rates with particular focus on the effects of monetary policy. Overview of key methods and findings of empirical research in macroeconomics. Recommended preparation: Econ 220D. ***Prerequisite:*** graduate standing and Econ 210A-B-C.

ECON 211. Advanced Macroeconomics (4-4-4)

Covers various topics in macroeconomics at the frontiers of research, including theory, computation, and empirical work. Emphasis depends on the instructor. Students will read the latest working papers and publications in the covered areas. ***Prerequisites:*** graduate standing and Econ 210A-B-C or consent of instructor.

ECON 212A-B-C. Workshop in Macroeconomics (0–4/0–4/0–4)

Examination of recent research in macroeconomics; development of own research by graduate students and faculty. Course may be repeated an unlimited number of times. (S/U grades only.) ***Prerequisites:*** Econ 210C.

ECON 213. Advanced Macroeconomic Theory (4)

This course develops purely theoretical models for problems in macroeconomics. Topics include dynamic general equilibrium, asset market equilibrium, and economic growth and distribution. ***Prerequisites:*** Econ 210A-B-C or consent of instructor.

ECON 214. Applied Macroeconomics (4)

This course focuses on applied macroeconomics, including econometric testing of macroeconomic theories and empirical measurement guided by theoretical insights. Topics will vary from year to year depending on the latest developments in research. Students will complete the course with a broader understanding of a number of leading topics in macroeconomics as well as a toolkit of estimation and simulation programs. Recommended preparation: Econ 220D. ***Prerequisites:*** graduate standing and Econ 210A-B-C or consent of instructor.

ECON 215. Macroeconomic Policy (4)

This course focuses on theoretical models and empirical analysis aimed at understanding and directing macroeconomic policy, including monetary, fiscal, and structural policies. ***Prerequisites:*** Econ 210A-B-C or consent of instructor.

ECON 216. Computation for Macroeconomics (4)

This course covers advanced computation techniques that are widely used in macroeconomics, finance, and other fields. Students will learn a range of numerical methods for handling systems of equations, integration, optimization, and other problems. ***Prerequisites:*** Econ 210A-B-C or consent of instructor.

ECON 217. Real Frictions and Financial Frictions (4)

While understanding how the macro economy behaves in the ideal, frictionless setting is indispensable; most of the interesting issues in macro arise as a consequence of some sort of friction or missing market. In this course, we will study some models based on real frictions and financial frictions. Topics covered include convex and nonconvex adjustment costs, housing markets and investment decisions, and financial crises. ***Prerequisites:*** Econ 210A-B-C or consent of instructor.

ECON 219. Readings in Macroeconomics (4)

This course will cover numerical analysis of dynamic macroeconomic models. Topics include numerical techniques, dynamic programming, linear systems, solution algorithms, and applications to dynamic general equilibrium. ***Prerequisites:*** graduate standing or consent of instructor.

ECON 220A. Econometrics A (4)

An introduction to probability and statistics for graduate students in economics. Topics include: random variables, sampling distributions, the law of large numbers, the central limit theorem, maximum likelihood estimation, hypothesis testing. Knowledge of multivariable calculus and linear algebra is assumed. ***Prerequisites:*** graduate standing; enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 220B. Econometrics B (4)

Introduction to regression analysis and other estimation methods. Topics covered include: ordinary and generalized least squares, asymptotic approximations, specification testing, two-stage least squares, generalized method of moments, and maximum likelihood estimation. ***Prerequisites:*** Econ 220A, graduate standing; Enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 220C. Econometrics C (4)

This course focuses on econometric analysis of panel data and cross-section data. Topics covered include: static/dynamic panel data models, discrete choice models, censored and truncated regression models, sample selection models, and evaluation of treatment effects. Theory of extreme estimators is used to study the specification, estimation, and testing of these models. ***Prerequisites:*** Econ 220B, graduate standing; enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 220D. Econometrics D (4)

Examines modern time series econometrics, extending methods from Econ 220A-C to dependent data. Topics covered include spectral density theory, HAC estimation, vector autoregressions, nonstationary econometrics, filtering. ***Prerequisites:*** Econ 220C, graduate

standing; enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 220E. Econometrics E (4)

Identification of economic models. Topics include: rank and order conditions for identification in linear simultaneous equations systems; identification in nonlinear models; likelihood based identification criteria; nonparametric identification; identification in models with multiple equilibria. ***Prerequisites:*** Econ 220D, graduate standing; enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 220F. Econometrics F (4)

This course focuses on the application of econometric techniques to issues in microeconomics and macroeconomics. The major emphasis in the class is on the completion of an empirical project. ***Prerequisites:*** Econ 220E, graduate standing; enrollment limited to Economics PhD students (EN75) or Rady PhD students (RS79); or consent of instructor.

ECON 221. Advanced Econometrics (4)

Advanced topics in econometrics. Topics may vary from year to year, covering areas such as cross-section, time-series, panel, limited dependent variables, conditional quantile estimation, bootstrapping, and large- and small-sample distribution theory. ***Prerequisites:*** graduate standing and Econ 220A, 220B, 220C, 220D, and 220E or consent of instructor.

ECON 222A-B-C. Workshop in Econometrics (4-4-4)

Examination of recent econometric research; development of own research by students and faculty. Course may be repeated an unlimited number of times. (S/U grades only.)

ECON 225. Forecasting (4)

Topics include testing for rationality of forecasts, Mincer-Zarnowitz regressions, asymmetric loss functions, tests for equal (superior) predictive ability, multivariate forecasting. ***Prerequisites:*** graduate standing and Econ 220A, 220B, 220C, 220D, and 220E or consent of instructor.

ECON 226. Bayesian and Numerical Methods (4)

Topics include Bayesian inference and decision theory, loss functions, estimation of dynamic stochastic general equilibrium models, nonlinear time series, state-space models, spatial-temporal models, and high-frequency data. ***Prerequisites:*** graduate standing and Econ 220A, 220B, 220C, 220D, and 220E or consent of instructor.

ECON 227. Nonparametric and Semiparametric Models (4)

Topics include neural networks, kernels, series, splines, estimation of densities and spectra, smoothing parameter selection, semiparametric models, efficiency and adaptation, forecasting with nonlinear models, over-fit, computation, and interpretation. ***Prerequisites:*** graduate standing and Econ 220A, 220B, 220C, 220D, and 220E or consent of instructor.

ECON 228. Nonstandard Inference (4)

Topics include weak instruments, unit roots, break tests, switching models, set-based inference, maximum likelihood estimation and meaning of misspecified models, consistency, asymptotic normality, consistent covariance matrix estimation, and tests of model misspecification. ***Prerequisites:*** graduate standing and Econ 220A, 220B, 220C, 220D, and 220E or consent of instructor.

ECON 230. Public Economics: Taxation (4)

Exploration of existing theoretical literature evaluating the efficiency and distribution effects of income and commodity taxes. Characterization of an "optimal" tax structure, and examination of problems faced in tax administration. Scrutiny of behavioral responses to existing tax structures. ***Prerequisites:*** Econ 200A-B-C and Econ 220A-B-C.

ECON 231. Public Economics: Public Goods and Externalities (4)

Justifications for government intervention in the context of public goods and externalities. Exploration of normative and positive models of government behavior. Lessons from fiscal federalism for federal, state, and local roles. Applications to specific expenditure programs, such as national defense and education. ***Prerequisites:*** graduate standing and Econ 200A-B-C and Econ 220A-B-C.

ECON 232. Public Economics: Redistribution and Social Insurance (4)

Justifications for government involvement in redistribution and insurance markets. Optimal design of transfer and social insurance programs. Theoretical and empirical analyses of programs including cash welfare assistance, unemployment insurance, social security, Medicaid, and Medicare. ***Prerequisites:*** graduate standing and Econ 200A-B-C and Econ 220A-B-C.

ECON 235A-B-C. Workshop in Applied Economics (0–4/0–4/0–4)

Examination of recent research in applied economics; development of own research by graduate students and faculty. Course may be repeated an unlimited number of times. (S/U grades only.)

ECON 237. Political Economy: Microeconomic Perspectives (4)

Governments serve functions key to economic development, including correcting market failures, raising taxes, delivering services, and protecting property rights. Correspondingly, research in development economics is increasingly focused on how institutions affect development. Generally, the aim of the course is to provide PhD students a complete introduction to the growing literature in this area. Students may not receive credit for Econ 237 and POLI 231E. ***Prerequisites:*** graduate standing.

ECON 241. Microeconomics of Development (4)

Course introduces the household as a decision-making unit, and the contracts and institutions that emerge to compensate for imperfect markets. Emphasis is placed on data and identification strategies that can be used to measure the impact of policy interventions. ***Prerequisites:*** graduate standing or consent of instructor.

ECON 242. Macroeconomics of Development (4)

This course covers development accounting, growth accounting, human capital accumulation, skill-biased technological change, multisector growth models, structural transformation, urban-rural migration, misallocation, informality, technology adoption and diffusion, and other related topics. ***Prerequisites:*** graduate standing or consent of instructor.

ECON 243. Organizational Economics of Development (4)

The study of organizational effectiveness, in both the private and public sectors, bridges the gap between microeconomic analysis of individual and household behavior and macroeconomic analysis of economic aggregates such as capital and output. Topics covered include organizational capacity, leadership and management, staffing, incentives, contracting, finance, learning, market structure, regulations, and politics. ***Prerequisites:*** graduate standing or consent of instructor.

ECON 245. International Trade (4)

This course covers the determinants of the pattern and volume of trade in goods and services, the interaction of international trade with income distribution and economic growth, and commercial policy. The emphasis is on theory, with some empirical illustration and motivation. ***Prerequisites:*** consent of instructor.

ECON 246. International Macroeconomics (4)

This course presents open-economy macroeconomics and international finance. Topics include theories of the exchange rate, foreign-exchange regimes, current account adjustments, and international portfolio investments. The course examines real and monetary explanations, and implications of international capital market integration. ***Prerequisites:*** consent of instructor.

ECON 247. Empirical Topics in International Economics (4)

This course examines the empirical work in international trade or international macroeconomics. International trade topics include empirical tests of theories of international trade and international capital movements. International macroeconomic topics include empirical studies of exchange rate and relative price adjustments. ***Prerequisites:*** consent of instructor.

ECON 249A. International Development Workshop I (1–4)

Presentation of recent research in international and development economics by faculty and graduate students, covering micro and macroeconomic aspect of both areas. Regular attendance is required. ***Prerequisites:*** graduate standing or consent of instructor.

ECON 249C. International Development Workshop III (1–4)

Presentation of recent research in international and development economics by faculty and graduate students, covering micro and macroeconomic aspect of both areas. Regular attendance is required. ***Prerequisites:*** graduate standing or consent of instructor.

ECON 250. Labor Economics (4)

Theoretical and empirical issues in labor economics. (Previously numbered Econ 236A-B.) ***Prerequisites:*** consent of instructor.

ECON 260. Industrial Organization: Firms (4)

This course covers theory and empirical applications in the following areas of industrial organization: dynamic pricing, price discrimination, collusion, market power, discrete choice demand modeling, entry, asymmetric information, and search. ***Prerequisites:*** Econ 220C. Enrollment by completion of prerequisites or by consent of instructor.

ECON 261. Industrial Organization: Markets (4)

This course covers theory and empirical applications in the following areas of industrial organization: mergers, vertical integration, and innovation. Optional topics include network effects, technology adoption, and regulation. ***Prerequisites:*** Econ 200C and 220C. Enrollment by completion of prerequisites or by consent of instructor.

ECON 262. Behavioral Game Theory (4)

This course is intended to give students an introduction to the study of strategic interaction through a behavioral lens. We will review game theory experiments and analyze which theoretical predictions are validated and which are violated in practice. We will characterize the systematic violations of the theory that come from experiments and study how these behavioral regularities can be incorporated into new equilibrium concepts. ***Prerequisites:*** graduate standing and Econ 200A-B-C.

ECON 263. Modeling Behavioral Economics (4)

Covers various models in behavioral economics including self-control, bounded memory, belief manipulation, framing effects, and behavioral game theory. The course will also discuss their role in industrial organization, finance, and political economy, and their implications for welfare. ***Prerequisites:*** graduate standing and Econ 200A-B-C.

ECON 264. Experimental Economics (4)

Design and interpretation of controlled experiments using human subjects. (Previously numbered Econ 207.) ***Prerequisites:*** consent of instructor.

ECON 265. Alternative Choice Theory (4)

Experimental findings by economists and psychologists of systematic departures from the classical model of decision making under risk and uncertainty. Issues of dynamic consistency in choice. Development, formal analysis and application of alternative models of risk preferences and beliefs. ***Prerequisites:***graduate standing and Econ 200A-B-C.

ECON 266. Economics of Natural Resources (4)

Theoretical and empirical issues in natural resource economics. (Previously numbered Econ 242.) ***Prerequisites:*** consent of instructor.

ECON 267. Topics in Environmental and Resource Economics (4)

The course will cover any of a variety of topics in environmental and resource economics, including climate change, exhaustible and renewable resources, international environmental agreements, nonmarket valuation, energy economics, and water allocation. ***Prerequisites:*** graduate standing.

ECON 270. Finance—Core Asset Pricing (4)

Theoretical and empirical issues in finance. (Previously numbered Econ 214A.)

ECON 272. Finance—Theory and Testing of Intertemporal Asset Pricing Models (4)

Theoretical and empirical issues in finance. (Previously numbered Econ 214C.)

ECON 280. Computation (2)

Introduction to computing for economists. ***Prerequisites:*** enrollment limited to economics PhD students (EN75).

ECON 281. Special Topics in Economics (4)

Lecture course at an advanced level on a special topic. May be repeated for credit if topic differs. (Previously numbered Econ 267.) ***Prerequisites:*** consent of instructor.

ECON 285. Precandidacy Presentation (2)

This course is a workshop in which students make formal presentations on the literature and on their own projects and receive input from other students and the instructor. ***Prerequisites:*** graduate standing.

ECON 286. Graduate Research Presentation Workshop (3)

The aim of the course is to train students to present their research effectively to a broad audience. Students are required to prepare a formal presentation, and then to provide feedback on the presentations made by other students. Depending on student demand, meetings may be divided into multiple sections, based on field interests. ***Prerequisites:*** graduate standing, Econ 285.

ECON 291. Advanced Field Advising (4)

Controlled reading and discussion with adviser; literature survey. May be repeated for credit. (S/U grades only.)

ECON 296. Original Research Paper (1–12)

In this course, students are guided toward the formulation of an original research idea and the writing of an original paper. Students receive support and input through group discussion and also through interaction with the instructor. ***Prerequisites:*** graduate standing.

ECON 297. Independent Study (1–5)

(S/U grades only.)

ECON 299. Research in Economics for Dissertation (1–9)

(S/U grades only.)

ECON 500A-B-C. Teaching Methods in Economics (4-4-4)

The study and development of effective pedagogical materials and techniques in economics. Students who hold appointments as teaching assistants must enroll in this course, but it is open to other students as well. (S/U grades only.)