Interdisciplinary Undergraduate Programs

INTERDISCIPLINARY MINORS

Several minors are interdisciplinary in nature and are available to all undergraduate students who have the interest and the necessary prerequisites.

Nuclear energy plays a key role in generating clean and reliable electric power. There is a demand to fill the shortage of engineers in existing nuclear power plants and to work with innovative and exciting design concepts of the next generation of power plants. Minoring in nuclear engineering will add value to an engineering degree for students planning to enter the energy-related workforce or seek an advanced degree in engineering.

Sustainable Engineering could be defined as engineering for human development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Due to population growth and expanded global development, the next generation of professionals must be able design with fewer resources for a wider variety and greater number of end users. The sustainable engineering minor prepares engineering and science students to work across multidisciplinary teams to plan and design products/processes by evaluating them from economic, environmental, and societal perspectives**.**

REQUIREMENTS FOR A MINOR IN NUCLEAR ENGINEERING

To receive a minor in Nuclear Engineering, a student must complete the following courses with a grade of C or better in each:

NE 3301	INTRODUCTION TO NUCLEAR ENGINEERING	3
NE 4302	NUCLEAR REACTOR THEORY AND TECHNOLOGY OF THE NUCLEAR POWER PLANT	3
NE 4303	NUCLEAR POWER PLANT ENGINEERING	3
Select three of the following (with a grade of C or better in each):		
MAE 3311	THERMODYNAMICS II	3
MAE 3309	THERMAL ENGINEERING	3
MAE 3314	HEAT TRANSFER	3
MAE 4347	HEAT EXCHANGER DESIGN	3
MAE 4310	INTRODUCTION TO AUTOMATIC CONTROL	3
EE 3302	FUNDAMENTALS OF POWER SYSTEMS	3
EE 4314	CONTROL SYSTEMS	3
PHYS 3446	NUCLEAR AND PARTICLE PHYSICS	4
TOTAL HOURS		18

REQUIREMENTS FOR A MINOR IN SUSTAINABLE ENGINEERING

To receive a minor in Sustainable Engineering, a student must complete the following courses with a grade of C or better in each:

CE 3300	INTRODUCTION TO SUSTAINABLE ENGINEERING (INTRODUCTION TO SUSTAINABLE ENGINEERING)	3
ENGR 4395	SUSTAINABLE ENGINEERING DESIGN PROJECT	3
Select one from the following Societal Context Electives (3 hours)		
ECON 2305	PRINCIPLES OF MACROECONOMICS	3
IE 2308	ECONOMICS FOR ENGINEERS	3
Select three from the following Sustainable Engineering Electives (9-10 hours)		
ARCH 3354	INTRODUCTION TO ENVIRONMENTAL & SUSTAINABILITY STUDIES	3
ARCH 3357	DESIGN TECHNOLOGIES - BUILDING INFORMATION MODELING FOR ARCHITECTS/ENGINEERS	3
ARCH 3361	ARCHITECTURE AND ENVIRONMENT	3
ARCH 3551	BASIC DESIGN FOR ENGINEERS	5
ARCH 3553	DESIGN STUDIO: ARCHITECTURE I	5
ARCH 4332	ENERGY USE AND CONSERVATION IN ARCHITECTURE	3
AREN 4307	CONSTRUCTION SUSTAINABILITY	3
AREN 4326	GIS/HYDROLOGIC & HYDRAULIC MODELING	3
BE 3415	FUNDAMENTALS OF BIOMOLECULAR ENGINEERING	4
BE 4331	BIOPOLYMERS AND BIOCOMPATIBILITY	3
BE 4368	AN INTRODUCTION TO TISSUE ENGINEERING AND DRUG DELIVERY	3
BE 4373	FORMULATION AND CHARACTERIZATION OF DRUG DELIVERY SYSTEMS	3

CE 4307	CONSTRUCTION SUSTAINABILITY	3
CE 4310	SYSTEM EVALUATION IN CIVIL ENGINEERING	3
CE 4323	LANDFILL DESIGN	3
CE 4326	GIS/HYDROLOGIC AND HYDRAULIC MODELING	3
CE 4350	INTRODUCTION TO AIR POLLUTION	3
CE 4351	PHYSICAL UNIT PROCESSES	3
CE 4353	WATER CHEMISTRY	3
CE 4354	INTRODUCTION TO SOLID WASTE ENGINEERING	3
CE 4355	DESIGN OF WATER AND WASTEWATER TREATMENT FACILITIES	3
CM 3337	CONSTRUCTION ADMINISTRATION AND ECONOMICS	3
CM 4357	SUSTAINABLE BUILDING PRACTICE	3
ECON 2337	ECONOMICS OF SOCIAL ISSUES	3
EE 3302	FUNDAMENTALS OF POWER SYSTEMS	3
EE 4314	CONTROL SYSTEMS	3
IE 3315	OPERATIONS RESEARCH I	3
IE 4345	DECISION ANALYSIS IN SYSTEM DESIGN	3
IE 4351	FUNDAMENTALS OF SYSTEMS ENGINEERING	3
MAE 4324	POWER PLANT ENGINEERING	3
MAE 4382	RESEARCH TRENDS IN RENEWABLE ENERGY TECHNOLOGIES	3
MAE 4386	WIND & OCEAN CURRENT ENERGY HARVESTING FUNDAMENTALS	3
GEOL 1301	EARTH SYSTEMS	3
GEOL 1330	GLOBAL WARMING	3
GEOL 2406	NATURAL RESOURCES & SUSTAINABILITY	4
GEOL 4323	ISSUES IN ENVIRONMENTAL HEALTH	3
GEOL 4356	ENVIRONMENTAL RISK ASSESSMENT	3
GEOL 4455	ENVIRONMENTAL DATA SCIENCE	4
PHYS 1351	ENERGY AND ENVIRONMENT	3
TOTAL HOURS		18

COURSES

ARCH 1101. ACADEMIC SUCCESS SKILLS IN ARCHITECTURE. 1 Hour.
This is a required course intended to establish a solid overview of the School of Architecture and the architecture program for all first semester UTA students who intend to declare as an architecture major. Topics for the class include: critical thinking, presentation techniques, internships, attendance of exhibitions and lectures, navigating the advising process, portfolio review and techniques, and using the library and other university resource sources. Other topics may also be discussed. The course be taken only once for credit.

ARCH 1191. CONFERENCE COURSE. 1 Hour.
Independent study guided by an instructor on a regular basis. May be repeated for credit. Permission of the instructor and architecture undergraduate advisor required. Restricted to architecture-intended majors.

ARCH 1301. INTRODUCTION TO ARCHITECTURE AND INTERIOR DESIGN. 3 Hours.
The interrelationships between society, culture, and the built environment. Prerequisite: Department consent.

ARCH 1341. DESIGN COMMUNICATIONS I. 3 Hours.
Design Communications I is an introduction course to analog and digital representation with emphasis on notational techniques of freehand drawing, proportioning strategies, and analysis. Students will also be exposed to physical and digital model-making, craftsmanship, file organization, orthographic and axonometric delineation, line weights, and digital documentation. Prerequisite: Restricted to Architecture-Intended, ARCH_UNIV, Interior Design-Intended and INTD_UNIV majors.

ARCH 1342. DESIGN COMMUNICATIONS II. 3 Hours.
Design Communications II is a continuation of ARCH 1341 with emphasis on refined techniques and more complex drawing problems. This course focuses on scale and proportion, relational design strategies, circulation, spatial hierarchy, design narrative, and digital documentation. Students will also be exposed to in-situ notational drawing. This course is offered as INTD 1342; credit will be granted only once. Prerequisites: "C" or better in ARCH 1301 and ARCH 1341. Restricted to Architecture-Intended, ARCH_UNIV, Interior Design-Intended and INTD_UNIV majors.

ARCH 2300. MASTERWORKS OF WESTERN ARCHITECTURE. 3 Hours.
Selected architectural complexes as representative of various periods of Western culture. Stresses cultural relevance rather than stylistic analysis. Intended as humanities elective for non-architecture majors.

ARCH 2303. HISTORY OF ARCHITECTURE AND INTERIOR DESIGN I. 3 Hours.
A global survey of architecture emphasizing the material and cultural context for design. Focused primarily on the period from prehistory through 1750. Prerequisite: "C" or better in ARCH 1301, ARCH 1341, and ARCH 1342 or INTD 1342. Restricted to Architecture-intended and Interior Design-intended majors.

ARCH 2304. HISTORY OF ARCHITECTURE AND INTERIOR DESIGN II. 3 Hours.
A global survey of architecture emphasizing the material and cultural context for design. Focused on the period from 1750 to the present. Prerequisites: "C" or better in ARCH 1301, ARCH 1341, ARCH 1342 or INTD 1342, and ARCH 2303. Sophomore standing in the program. Restricted to Architecture-intended and Interior Design-intended majors.

ARCH 2341. DESIGN COMMUNICATION FOR ENGINEERS. 3 Hours.
This course introduces engineering students to design communication skills. Content includes sketching, drawing, graphic layout, diagramming and an introduction to orthographic projections and perspectives. Media will be both analog and digital. Digital tools may include image processing software, graphic design software and computer aided design (CAD) software. Prerequisite: Restricted to AREN students.

ARCH 2391. TOPICS IN ARCHITECTURE. 3 Hours.
Selected topics in concepts, philosophy, and models of architecture and allied arts of design. Prerequisite: Department Consent.

ARCH 2551. BASIC DESIGN AND DRAWING I. 5 Hours.
Basic Design and Drawing I course, the first design studio in the Basic Studies Foundation, is an introduction to architectural design, basic design theory and methodologies relating to spatial abstractions and forms. The course focuses on heuristic thinking with an emphasis on process and making. Two- and three-dimensional studio exercises develop a sensibility to design fundamentals, architectural vocabulary and design decision based on analysis and critique towards process-based learning strategies. As a continuation to the first-year courses, the role of design communications is reiterated in drawing exercises focusing on form, color theory, texture, and spatial determinants, historical precedence, sketching, orthographic projection and modeling. Prerequisite: "C" or better in ARCH 1342 or INTD 1342, credit or concurrent enrollment in ARCH 2303. Sophomore standing in the program. Restricted to Architecture-intended, ARCH_UNIV, Interior Design-intended, and INTD_UNIV majors.

ARCH 2552. BASIC DESIGN AND DRAWING II. 5 Hours.
Basic Design and Drawing II, the second design studio in the Basic Studies Foundation builds on disciplinary principles of basic design theory, 2D and 3D projects, with emphasis on visual and verbal representation. The course follows established methodologies that develop an understanding of foundational design principles of space, hierarchy, scale, proportion, circulation, and enclosure. Studio exercises and projects develop individual skills and collectively apply analog and digital processes to understand the design of architectural spaces and forms, their constituent parts, and their conditional relationships to the context, as a coherent, inter-related design process. The study of historical and contemporary masterworks of architecture serves to inform the projects toward the role of historical precedent in design. Design communication focuses on accurate orthographic projections, drawing conventions, graphic sensibility, and the exploration of 2D and 3D representation with physical models using a range of techniques, which exhibit understanding of tectonics, craft, materiality, and the representation of ideas. Prerequisite: "C" or better in ARCH 2303, ARCH 2551, and credit or concurrent enrollment in ARCH 2304. Restricted to Architecture-intended and Interior Design-intended majors.

ARCH 3312. HISTORY OF CONTEMPORARY THEORY. 3 Hours.
This course will familiarize students with major intellectual paradigms and themes that have informed postwar architectural practice in Western tradition. Through reading primary theoretical texts that have had major impact on practice, students will hone their skills of critical thinking and be better able to position themselves in their navigation of contemporary theoretical issues. Prerequisite: ARCH 2303 and ARCH 2304 and Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 3323. CONSTRUCTION MATERIALS AND METHODS. 3 Hours.
This course discusses the nature of materials and structural concepts to be used in the construction process. The principles and fundamentals of building construction materials and methods is evaluated, and the project development process and construction delivery systems are introduced. The course provides an understanding of building standards and codes; the impact of materials and buildings on the environment and human health, safety, and welfare; the material properties including structural properties of materials as well as performance properties and the major materials and construction systems such as light wood frame, mass timber, and steel and concrete frame construction. Prerequisite: ARCH 2552. Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3324. STRUCTURES I. 3 Hours.
This course is the foundation for all advanced structures courses in the undergraduate and graduate architecture programs. In an engineering curriculum, this course is offered in two separate courses referred to as: (a) Statics and (b) Strength of Materials, each of one-semester duration. the present course capsules the information yet is rigorous enough and covers all important topics in the two engineering courses including equilibrium of particles and rigid bodies, analysis of important structural load bearing items such as cables, beams and Trusses, Definition of Stress and strain and their role in structural design, cross-sectional properties of structural members and analysis of strength for the beams. Prerequisite: ARCH 3323, PHYS 1441 or PHYS 1443, MATH 1327 or MATH 1426. Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3336. STRUCTURAL SYSTEMS FOR ARCHITECTURAL ENGINEERS. 3 Hours.
This course covers the engineering design of various concrete, steel and masonry structural systems used in the construction of buildings. Building types vary from single-story commercial buildings to low-rise and high-rise buildings. Current building codes and project examples are examined from a fundamental structural engineering perspective, in which the rationale for the structural system is analyzed, calculations performed, and systematic construction design processes are developed for gravity loads and lateral loads from start to completion of each project. The project examples culminate with a detailed cost analysis based on current industry trends. Prerequisite: Restricted to CE_AENUCOL, CE_ARENINT, CE_ARENBS, and CE_AREPROB majors.

ARCH 3343. ARCHITECTURE COMPUTER GRAPHICS (DESIGN COMMUNICATION III). 3 Hours.
An advanced course to develop visual sensitivity and awareness of digital techniques to enable the student to study design ideas and present those ideas in the various design disciplines. Emphasis on the relationship of computer graphics with the design process. This course is offered as ARCH 3343 and INTD 2343, credit will only be granted once. Prerequisite: Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3354. INTRODUCTION TO ENVIRONMENTAL & SUSTAINABILITY STUDIES. 3 Hours.
Introduces major topics, questions, issues and methods within interdisciplinary and cross-disciplinary environmental studies. Includes a study of some of the most significant texts, studies, practices, and creative works from at least four different fields as they pertain to questions of environment, ecology, and sustainability.

ARCH 3357. DESIGN TECHNOLOGIES - BUILDING INFORMATION MODELING FOR ARCHITECTS/ENGINEERS. 3 Hours.
Introduction to Building Information Modeling (BIM); discussions of the roles and impacts of BIM in the design process, energy assessment, and facility management. The course includes creating building elements such as walls, windows, doors, roof, ceiling, stairs, ramp, and structural and MEP systems. Course provides an overview of BIM applications such as daylight and energy analysis. Prerequisite: AREN 2352. Restricted to CE_AENUCOL, CE_ARENINT, CE_ARENBS, and CE_AREPROB majors.

ARCH 3361. ARCHITECTURE AND ENVIRONMENT. 3 Hours.
An overview of sustainable design integrated with natural resource conservation. Prerequisite: ARCH 2552. Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3364. SITE DESIGN. 3 Hours.
The related site design process includes site planning pertaining to land use, case studies, siting of structures, codes, and topography. Prerequisite: Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3551. BASIC DESIGN FOR ENGINEERS. 5 Hours.
This course is an introduction to design communication (verbal and graphic), the process of design, architectural principles and the process of navigating the relationship between architectural design and engineering. Precedent studies introduce students to Architecture and two- and three-dimensional studio exercises develop a sensibility to design fundamentals and vocabulary. Prerequisite: ARCH 1301 and ARCH 2341 and restricted to AREN students.

ARCH 3553. DESIGN STUDIO: ARCHITECTURE I. 5 Hours.
The reiteration of basic design principles, formal ordering systems and spatial concepts toward the synthesis of simple building types, with application of materials, introduction of structural systems, rudimentary building systems, limited program, with preliminary understanding of site design, and environmental issues. Projects will investigate small scale institutional, civic, or cultural buildings set in cities of historical significance that respond directly to their context. Research and analysis of influential precedent buildings and cities, whether historical or contemporary will inform the design process and methodologies. Credit will be given for only one of ARCH 3553 or INTD 3553. Prerequisite: ARCH 2552 or INTD 2552. Credit or concurrent enrollment in ARCH 3323 and ARCH 3343 or ARCH 3364. Junior standing in the program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3554. DESIGN STUDIO: ARCHITECTURE II. 5 Hours.
A continuation of ARCH 3553 with an increased complexity and scale of projects which address buildings within urban contexts. Projects will incorporate design theory with technical, site and structural considerations. Research of local specifics as design imperatives will inform building and site integration, which respond to context. Projects will investigate and subsequently integrate rudimentary building systems including those for formal ordering, spatial organization, structural support, materiality, building assembly, envelopes, building services, life safety, and circulation, with a particular attention towards sustainability, accessibility, efficiency, and code compliance. Design communication will demonstrate understanding of project components by developing an encompassing set of orthographic projections Three dimensional models will test and communicate spatial intentions relating to the context addressing, proportion, massing, materiality, environment, and project character. Prerequisite: ARCH 3323, ARCH 3553, and ARCH 3343 or ARCH 3364. Credit or concurrent enrollment in ARCH 3324 and ARCH 3343 or ARCH 3364. Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 3595. SELECTED TOPICS ARCHITECTURE. 5 Hours.
A transitional studio course to explore and present selected topics in architecture and design. May be repeated for credit as topics change. Prerequisite: Department consent. Junior standing in program. Restricted to Architecture majors.

ARCH 4191. CONFERENCE COURSE. 1 Hour.
Independent study guided by an instructor on a regular basis. May be repeated for credit. Prerequisite: Permission of the instructor or the Architecture Undergraduate Advisor.

ARCH 4305. THE CITY OF ROME. 3 Hours.
History, topography, and monuments of the city of Rome and its environs from its legendary founding in 753 B.C. until the 20th Century. Urban form and architecture will be inspected in context of contemporaneous culture, with special emphasis on imperial and papal Rome. Prerequisite: Department consent. Restricted to Architecture and Interior Design Majors.

ARCH 4306. URBAN DESIGN THEORY. 3 Hours.
Design theory and its application to the urban scale, as applied to historical and contemporary examples. Prerequisite: ARCH 2552. Department consent. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4307. THE LIFE OF CITIES. 3 Hours.
A look at a series of world cities by situating their architectural context, with a particular focus on the impact of 20th century modernism and postmodernism on city fabric. Prerequisite: ARCH 2303 and ARCH 2304 and Junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4308. HISTORY OF URBAN FORM. 3 Hours.
The history of cities as physical form, influenced by political, economic, and social forces. Prerequisite: Department consent. Restricted to Architecture and Interior Design majors.

ARCH 4309. MUSEUMS: HISTORY, CULTURE, DESIGN. 3 Hours.
This course investigates the historical and cultural forces driving the design of museums in the 19th and 20th centuries with special attention to the development of a diverse range of new museum types beyond traditional art and natural science museums. Field trips to local museum sites are required. Prerequisite: ARCH 2303 and ARCH 2304, junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4310. SKYSCRAPER HISTORIES. 3 Hours.
This course considers the history of the skyscraper from multiple perspectives, seeking consensus about what a skyscraper really is. This course will allow students to begin to develop their skills in reading, writing, critical thinking, visual memory, and visual analysis using the history of architecture as a medium. Students will also develop basic research skills using primary sources to document architecture. Prerequisite: ARCH 2303 and ARCH 2304, junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4311. TOPICS IN ARCHITECTURAL THEORY. 3 Hours.
Selected topics in concepts, philosophy, and models of architecture and allied arts of design with specific application to 20th Century problems. May be repeated for credit as specific topics vary. Prerequisites: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4312. WHAT MAKES A CITY: CRITICAL ISSUES IN ARCHITECTURE, PLANNING, AND URBAN DESIGN. 3 Hours.
This class is a critical exploration of the physical environment of the city, looking at a range of issues--mobility, housing, landscape, gentrification, sustainability, health-to understand how the built world shapes the way we live every day. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4313. THE ARCHITECT IN CONTEMPORARY SOCIETY. 3 Hours.
Readings on the Culture of Architecture The focus of this course is to examine this social construct in the belief that critical self-reflection can assist in improving success within it. This examination will be conducted through readings in a collection of publications both historical and contemporary that offer critical insight into the professional/social culture of architects. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4314. HISTORIC PRESERVATION AND RESTORATION. 3 Hours.
Concepts and implementation of the restoration and preservation of historic structures and places, including archaeological, bibliographic, legislative, institutional, and physical parameters to the retention and adaptive re-use of significant architecture. This course is offered as ARCH 4314 and INTD 4314; credit will be granted only once. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4315. TOPICS IN THE HISTORY OF ARCHITECTURE AND DESIGN. 3 Hours.
Selected topics in architecture and the allied arts of design. Some recent topics include: Architecture of Texas, The Life of Cities, History of Architecture Theory, Developing World Slum Housing, Architecture and Politics, and Contemporary Architecture. Certain topics may be offered every second or third year. The course may be repeated up to four times as the topics change. Prerequisite: ARCH 2303 and ARCH 2304, junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4316. MODERN ARCHITECTURE I. 3 Hours.
Development of 20th Century architecture from the origins of the modern movement in the 1890s until its diffusion in Europe and America in the 1930s. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4317. MODERN ARCHITECTURE II. 3 Hours.
Development of 20th Century architecture from the diffusion of modernism in the 1930s to the present day. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4318. ARCHITECTURE ON SCREEN. 3 Hours.
How do the things we watch shape our perceptions of architecture and the city? How do the environments in film and on television frame our vision, shape character, and convey themes? How are architects and other design professionals portrayed? What do they suggest about changes in the physical and technological world in which we live? This course explores those questions and others through screen history, from the earliest films to contemporary television and digital productions. Themes will include the dystopian city, suburbia, the evolving depiction of modernism, architecture as documentary subject, and the history of the city on screen. Students will explore these questions and will have to make their own short films. May be repeated for credit as specific topics vary. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4319. HOUSING PROTOTYPES: 1920s TO PRESENT. 3 Hours.
An extensive investigation of the many states of housing that architects and educators have encountered in the last 100 years. The course is organized through introduction, research, analysis, and case study of various housing typologies, unit design principles, density concerns, site, relationship of inside and outside, zoning and building codes, and new emerging housing building types. Prerequisite: ARCH 2303 and ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4320. PERFORMANCE-BASED DESIGN IN ARCHITECTURE. 3 Hours.
An overview of Performance-Based Building Design (PBBD) in architecture and how clients' expectations are translated into performance requirements, how we describe performance objectives, how we define performance indicators, and finally, how we can quantify and assess building performance. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4322. ARCHITECTURE + POLITICS. 3 Hours.
This course examines how notions of national identity are expressed in parliament buildings and other important buildings of state. Throughout the course, questions about what constitutes national identity, capital cities, and how architecture is used as a manifestation of these political aspects will be addressed. Buildings within nations or subnational regions across six continents are examined, giving students a global understanding of these issues. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4325. ENVIRONMENTAL CONTROL SYSTEMS I. 3 Hours.
Acoustics and illumination and their significance in the total design. Prerequisite: PHYS 1442. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4326. ENVIRONMENTAL CONTROL SYSTEMS II. 3 Hours.
Climate controls, mechanical and electrical systems, and their significance in the total design. Prerequisite: ARCH 4325 or AREN 3331. Junior standing in program. Restricted to Architecture, Interior Design, and Architectural Engineering majors.

ARCH 4329. TOPICS IN COMPUTERS AND DESIGN. 3 Hours.
Selected topics in the range and potential of digital computer applications in the design professions. May be repeated for credit as specific topics vary. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4332. ENERGY USE AND CONSERVATION IN ARCHITECTURE. 3 Hours.
Basic concepts of the efficient use and conservation of energy related to architectural design principles. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4338. CODES AND REGULATIONS. 3 Hours.
A study of accessibility, building and energy codes and related regulations including the architects' responsibility for compliance. This course is offered as ARCH 4338 and INTD 3338; credit will be granted only once. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4339. DIGITAL FABRICATION METHODOLOGY. 3 Hours.
The history, theory, and methodology framing the discourse for parametric design and digital fabrication with an emphasis on digital fabrication techniques and introduction to parametric modeling software. Prerequisites: Junior standing in program. Open to ARCH and INTD majors.

ARCH 4340. MODERN + CONTEMPORARY ARCHITECTURE IN MEXICO. 3 Hours.
This course examines notions of Mexican national identity as expressed through architecture. Part 1 looks at late 19th and early 20th century architecture during the Porfiriato, as well as that occurring shortly after the Mexican Revolution of 1910-20, including the critical role that cement played. Part 2 considers how the so-called First Generation of architects adapted and transformed Modernism in Mexico. Part 3 examines how the Second and Third Generations moved beyond Modernism, including. The course concludes with Mexico's "First Generation" of women architects as issues of gender are addressed. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors, or Department consent.

ARCH 4341. NOTATIONAL DRAWING. 3 Hours.
Seminar concerned with analytical drawing techniques and how to use the sketchbook as a tool and process for architectural production. Emphasis will be on cultivating drawing strategies that will heighten the ability to make observations through first-hand experience and record them with the correct conventions in order to enable recovery for future use in architectural design. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4344. CONCEPTUAL DRAWING. 3 Hours.
A seminar to explore the aspects of conceptual drawing for the architect and the relationship of design ideas in the drawing process. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4345. DIGITAL CONSTRUCTION. 3 Hours.
A workshop exploring video cartography using photography, animation, motion graphics and digital video. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4346. CONSTRUCTION DRAWINGS. 3 Hours.
The techniques of building construction, the communication of technical information, and the process of preparing contract drawings for construction. Prerequisite: ARCH 3343. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4347. DIGITAL TECTONICS & PROTOTYPING. 3 Hours.
The use of digital technology in the architectural design process focusing on the research and fabrication of full-scale production of prototypes. ARCH 4339 Digital Fabrication Methodology is highly recommended. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4348. ARCHITECTURAL PHOTOGRAPHY. 3 Hours.
Basic photography for architects. The use of photography as an investigative and presentation device in architecture. Emphasis on composition and black and white technique. Prerequisite: ARCH 2552. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4349. PORTFOLIO DESIGN. 3 Hours.
Principles and techniques of producing an architectural/interior design portfolio and resume including graphic design, layout, typography, grid systems, model photography as well as use of layout and photographic software. Prerequisite: ARCH 3553, ARCH 3554. Restricted to Architecture and Interior Design majors.

ARCH 4350. ARCHITECTURE, ENGAGEMENT + COMMUNITY POWER. 3 Hours.
Architecture, Engagement and Community Power will unpack the role of the citizen architect. It will examine participatory design processes that center community voice and shift existing power structures. In this country, constructed systems of oppression including racist practices, policies and financial systems have shaped the way our neighborhoods have developed. These acts have created inequities across communities that impact one's ability to thrive. Starting from the notion that all places are designed, and can therefore be undesigned, this course will explore the ways in which design processes can strengthen community power for marginalized communities. This course will encourage activism as an inherent quality in the development of an architect; encourage students to make connections between classroom learning and the larger community; require students to develop the skill to see and hear multiple voices; and encourage the development of visual, written, & oral communication tools. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4351. WILDERNESS: A CONDITION OF MIND. 3 Hours.
Changing conceptions of wilderness in Western thought, from ancestral prejudices to recent, revolutionary appreciation. Literary and visual documentation. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4352. HOUSING: FROM CAVES TO MANSIONS IN THE CLOUDS. 3 Hours.
This course examines the evolution of American urban settlements as they evolved from French, Spanish and English concepts of town-planning. The course begins with the Native American settlements in the American Southwest, particularly Mesa Verde and Hovenweep, followed by examination of the earliest European capital cities of Rome, Paris and London. Since the wholesale transplanting of European principles of town-planning traditions could not take root in the New World, distinctly American housing settlements evolved such as Savannah, Santa Fe, Taos and St. Augustine. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4353. HISTORY OF LANDSCAPE ARCHITECTURE. 3 Hours.
Development of landscape design from prehistory through 19th century with emphasis upon rural gardens and urban parks as representative of the social, cultural, and intellectual circumstances of the times and places in which they were created. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4354. CONVERGENCES: BETWEEN ART AND ARCHITECTURE. 3 Hours.
This course explores the convergences of artist methods of production with the processes of architectural practices. The course traces the work of leading filmmakers, both artistic and documentarian, whose professional leanings verge on the province of the architect. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4357. BUILDING INFORMATION MODELING & VISUALIZATION. 3 Hours.
To gain a working knowledge of Building Information Modeling software (Revit) and advanced 3D modeling software. This course is offered as ARCH 4357 and INTD 3357, credit will only be granted once. Prerequisite: ARCH 3343, INTD 2343, or INTD 3343; and Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4360. POLITICS AND PRACTICE OF PRESERVATION. 3 Hours.
The history and theory of preservation and of the political context that influence these. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4362. STRUCTURAL SYSTEMS IN BUILDINGS. 3 Hours.
An overview of various structural systems including those used in long-span and high-rise buildings. Numerical work limited to the explanation of relevant structural concepts. Prerequisite: ARCH 3324. Junior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 4365. CATALYTIC MAPPING. 3 Hours.
An advanced theory elective course and workshop using the potential of mapping as a design, analytic and research mechanism for exploring complex contexts. Prerequisite: Junior standing in Architecture, Interior Design or permission of the advisor.

ARCH 4366. RADICAL URBANISM. 3 Hours.
An advanced theory course focused on the exposure to and critical analysis of some of the most radical, inspirational, and transformative urban design ideas and projects from Vitruvius to today. Prerequisite: Junior standing in Architecture, Interior Design or permission by the advisor.

ARCH 4367. HIGH PERFORMANCE FACADE SYSTEMS. 3 Hours.
Examines the role of the façade and building envelope as it relates to design, indoor comfort, energy and carbon usage, and overall performance through an exploration of materiality, assembly, and construction. The course also introduces the potential of generative technologies, smart materials, passive-active combinations, and integrated systems. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4368. GREEN DESIGN + CONSTRUCTION. 3 Hours.
Green building design, construction, and operation is an opportunity to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. It provides cost savings to all tax-payers through improved human health and productivity, lower cost building operations, and resource efficiency. Green design and construction focuses on strategies and technologies to improve the energy efficiency and performance of buildings, and to reduce the environmental impact of buildings. The course emphasizes on different aspects of green building during all phases of a building's life-cycle, including design, construction, operation and decommissioning. All LEED categories are covered throughout the course and students get prepared to take LEED Green Associate exam by the end of the semester. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4369. TERRITORIAL STRATEGIES. 3 Hours.
Territorial Strategies focus on climate resilience of the built environment on the territorial scale. In Territorial Strategies, students explore how macro-level drivers of spatial (trans)formation impact micro-level strategies and actions in distinct climatic regions. Students apply a systems-thinking approach to map, diagram, model, draw, and visualize project outcomes, research findings, and data through various media. Prerequisite: Junior standing in Architecture, Interior Design, Sustainable Urban Design, or permission by the advisor.

ARCH 4371. FUTURE CITIES. 3 Hours.
Future Cities focus on climate resilience of the built environment on the urban scale. In Future Cities, students explore historical and contemporary concepts of ecological design and combine mitigative and adaptive strategies and actions for urban landscapes in the age of anthropogenic climate change. Students apply a participatory mixed-methods approach to map, diagram, model, draw, and visualize project outcomes, research findings, and data through various media. Prerequisite: Junior standing in Architecture, Interior Design, Sustainable Urban Design, or permission by the advisor.

ARCH 4372. ADAPTIVE TYPOLOGIES. 3 Hours.
Adaptive Typologies focus on climate resilience of the built environment on the architectural object scale. In Adaptive Typologies, students explore architectural objects, their characteristics, and their performative aspects as integrated parts of the urban ecosystem. Students analyze, transform, and develop hybrid typologies merging physical, digital, and biological concepts and apply a digital mixed-methods approach, utilizing analytical, representational, and generative tools. Prerequisite: Junior standing in Architecture, Interior Design, Sustainable Urban Design, or permission by the advisor.

ARCH 4377. SPATIAL [IN] JUSTICE. 3 Hours.
Through lectures and discussions, Spatial [in] Justice will provide students with historical perspectives on how American cities became segregated, the creation and lack of inclusivity of 'public space', and the architect's role within a socially engaged practice. The course will begin by studying key philosophies and theories of justice. Students will work with a community partner to produce a community engagement and development plan. They will research publicly available data and organize it into a package for the community and other stakeholders. Prerequisite: ARCH 2303, ARCH 2304. Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4391. CONFERENCE COURSE. 3 Hours.
Independent study guided by an instructor on a regular basis. May be repeated for credit. Prerequisite: Permission of the instructor or the Architecture Undergraduate Advisor.

ARCH 4395. SELECTED TOPICS ARCHITECTURE. 3 Hours.
Studio and lecture courses to explore and present selected topics in architecture and design. May be repeated for credit as topics change. Prerequisite: Junior standing in program. Restricted to Architecture and Interior Design majors.

ARCH 4556. DESIGN STUDIO: ARCHITECTURE III. 5 Hours.
Advanced architectural design projects integrating research on contemporary issues intrinsic to architecture. Prerequisites: ARCH 3324, ARCH 3343, ARCH 3364, and ARCH 3554. Senior standing in program. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 4557. DESIGN STUDIO: ARCHITECTURE IV. 5 Hours.
Advanced architectural projects focusing on contemporary design issues that address topics extrinsic to the disciplines of architecture. Prerequisite: ARCH 3324, ARCH 3343, ARCH 3364, and ARCH 3554. Restricted to Architecture majors. Minimum 2.8 GPAs both cumulative and within the major required.

ARCH 4591. CONFERENCE COURSE. 5 Hours.
Independent study guided by an instructor on a regular basis. May be repeated for credit. Prerequisite: Permission of the instructor or the Architecture Undergraduate Advisor. Senior standing in program. Restricted to Architecture majors.

ARCH 4595. SELECTED TOPICS ARCHITECTURE. 5 Hours.
A transitional studio course to explore and present selected topics in architecture and design. May be repeated for credit as topics change. Prerequisite: Department consent.

ARCH 5191. CONFERENCE COURSE. 1 Hour.
Special subjects and issues as arranged with individual students and faculty members. May be repeated for credit as topic changes.

ARCH 5301. INTRODUCTION TO ARCHITECTURE AND INTERIOR DESIGN. 3 Hours.
A survey study of the interrelationships between society, culture, and architecture. Concurrent enrollment of ARCH 5591 and ARCH 5342 required.

ARCH 5303. HISTORY OF ARCHITECTURE AND INTERIOR DESIGN I. 3 Hours.
A global survey of architecture emphasizing the material and cultural context for design. Focused primarily on the period from prehistory through 1750. Prerequisite: Permission of the instructor.

ARCH 5304. HISTORY OF ARCHITECTURE AND INTERIOR DESIGN II. 3 Hours.
A global survey of architecture emphasizing the material and cultural context for design. Focused on the period from 1750 to the present. Prerequisite: ARCH 5303 and permission of the instructor.

ARCH 5305. CITY OF ROME. 3 Hours.
History, topography, and monuments of Rome and its environs from its legendary founding in 753 B.C. until the 20th Century, with special emphasis on imperial and papal Rome.

ARCH 5306. URBAN DESIGN. 3 Hours.
Urban design theory, method, and implementation using contemporary and historic examples.

ARCH 5307. THE LIFE OF CITIES. 3 Hours.
A look at a series of world cities by situating their architectural context, with a particular focus on the impact of 20th century modernism and postmodernism on city fabric. Prerequisites: ARCH 2303 & ARCH 2304 or ARCH 5303 & ARCH 5304.

ARCH 5308. HISTORY OF URBAN FORM. 3 Hours.
The history of cities as physical form, influenced by political, economic, and social forces.

ARCH 5309. MUSEUMS: HISTORY, CULTURE, DESIGN. 3 Hours.
This course investigates the historical and cultural forces driving the design of museums in the 19th and 20th centuries with special attention to the development of a diverse range of new museum types beyond traditional art and natural science museums. Field trips to local museum sites are required. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5310. SKYSCRAPER HISTORIES. 3 Hours.
This course considers the history of the skyscraper from multiple perspectives, seeking consensus about what a skyscraper really is. This course will allow students to begin to develop their skills in reading, writing, critical thinking, visual memory, and visual analysis using the history of architecture as a medium. Students will also develop basic research skills using primary sources to document architecture. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5311. ARCHITECTURAL THEORY. 3 Hours.
A review and analysis of the concepts, philosophy, ideology, and models that promulgated 20th Century architectural design. May be repeated for credit as topics change. Prerequisite: ARCH 2303 or ARCH 5303, ARCH 2304 or ARCH 5304, and permission of the department.

ARCH 5312. WHAT MAKES A CITY: CRITICAL ISSUES IN ARCHITECTURE, PLANNING, AND URBAN DESIGN. 3 Hours.
This class is a critical exploration of the physical environment of the city, looking at a range of issues--mobility, housing, landscape, gentrification, sustainability, health-to understand how the built world shapes the way we live every day. Prerequisite: ARCH 2303 or ARCH 5303, ARCH 2304 or ARCH 5304, and permission of the department.

ARCH 5313. THE ARCHITECT IN CONTEMPORARY SOCIETY. 3 Hours.
Readings on the Culture of Architecture The focus of this course is to examine this social construct in the belief that critical self-reflection can assist in improving success within it. This examination will be conducted through readings in a collection of publications both historical and contemporary that offer critical insight into the professional/social culture of architects. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304.

ARCH 5314. HISTORIC PRESERVATION AND RESTORATION. 3 Hours.
Concepts and implementation of the restoration and preservation of historic structures and places, including archaeological, bibliographic, legislative, institutional, and physical parameters to the retention and adaptive re-use of significant architecture.

ARCH 5315. TOPICS IN ARCHITECTURAL HISTORY. 3 Hours.
Courses to explore and present selected topics in architecture and related fields of the Ancient Mediterranean, the Classical World, the Middle Ages, the 19th Century, and the Non-Western Traditions. May be repeated for credit as topics change. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5316. MODERN ARCHITECTURE I 1890 TO 1945. 3 Hours.
Origins and development of Modern Architecture in Europe from 1890 to World War II, and its further evolution in Europe and America from 1918 to 1945. Prerequisites: ARCH 2303 and ARCH 2304.

ARCH 5317. MODERN ARCHITECTURE II 1945 TO PRESENT. 3 Hours.
Architectural developments in Europe, Asia, and America since World War II. Prerequisites: ARCH 2303 and ARCH 2304.

ARCH 5318. ARCHITECTURE ON SCREEN. 3 Hours.
How do the things we watch shape our perceptions of architecture and the city? How do the environments in film and on television frame our vision, shape character, and convey themes? How are architects and other design professionals portrayed? What do they suggest about changes in the physical and technological world in which we live? This course explores those questions and others through screen history, from the earliest films to contemporary television and digital productions. Themes will include the dystopian city, suburbia, the evolving depiction of modernism, architecture as documentary subject, and the history of the city on screen. Students will explore these questions and will have to make their own short films. Prerequisite: ARCH 2303 or ARCH 5303, ARCH 2304 or ARCH 5304, and permission of the department.

ARCH 5319. HOUSING PROTOTYPES: 1920s TO PRESENT. 3 Hours.
An extensive investigation of the many states of housing that architects and educators have encountered in the last 100 years. The course is organized through introduction, research, analysis, and case study of various housing typologies, unit design principles, density concerns, site, relationship of inside and outside, zoning and building codes, and new emerging housing building types. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304.

ARCH 5320. PERFORMANCE-BASED DESIGN IN ARCHITECTURE. 3 Hours.
An overview of Performance-Based Building Design (PBBD) in architecture and how clients' expectations are translated into performance requirements, how we describe performance objectives, how we define performance indicators, and finally, how we can quantify and assess building performance.

ARCH 5321. ADVANCED COMPUTER APPLICATIONS. 3 Hours.
The study and application of specialized computer programs in environmental design. Prerequisites: ARCH 3343 or INTD 3343 or ARCH 5343, or the equivalent. Department consent.

ARCH 5322. ARCHITECTURE + POLITICS. 3 Hours.
This course examines how notions of national identity are expressed in parliament buildings and other important buildings of state. Throughout the course, questions about what constitutes national identity, capital cities, and how architecture is used as a manifestation of these political aspects will be addressed. Buildings within nations or subnational regions across six continents are examined, giving students a global understanding of these issues. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5323. CONSTRUCTION MATERIALS AND METHODS. 3 Hours.
This course discusses the nature of materials and structural concepts to be used in the construction process. The principles and fundamentals of building construction materials and methods is evaluated, and the project development process and construction delivery systems are introduced. The course provides an understanding of building standards and codes; the impact of materials and buildings on the environment and human health, safety, and welfare; the material properties including structural properties of materials as well as performance properties and the major materials and construction systems such as light wood frame, mass timber, and steel and concrete frame construction. Prerequisite: Permission of the instructor.

ARCH 5324. STRUCTURES I. 3 Hours.
This course is the foundation for all advanced structures courses in the undergraduate and graduate architecture programs. In an engineering curriculum, this course is offered in two separate courses referred to as: (a) Statics and (b) Strength of Materials, each of one-semester duration. The present course encapsulates the information yet is rigorous enough and covers all important topics in the two engineering courses including equilibrium of particles and rigid bodies, analysis of important structural load bearing items such as cables, beams and Trusses, Definition of Stress and strain and their role in structural design, cross-sectional properties of structural members and analysis of strength for the beams. Prerequisite: ARCH 5323 or ARCH 3323.

ARCH 5325. ENVIRONMENTAL CONTROL SYSTEMS I. 3 Hours.
Illumination,acoustics, climate controls, mechanical and electrical systems, and their significance in the total design.

ARCH 5326. ENVIRONMENTAL CONTROL SYSTEMS II. 3 Hours.
Climate controls, mechanical and electrical systems, and their significance in the total design.

ARCH 5327. STRUCTURES II. 3 Hours.
This course is a continuation of ARCH 5324 with an emphasis on structural theory and systems in steel construction. It covers the design and investigation of structural steel. The course begins with a general introduction to structural behavior, strength, and modulus of elasticity of steel material. The elastic and plastic behavior of structural steel material is discussed, and the definition of yield strength is addressed as one of the main structural measures of steel material. Loads and load combinations are the next part of the course. This part describes how the gravity and lateral loads are distributed in a steel structure and what combination of loads should be considered for the design. To address the requirements of the design of structural members, simple methods of structural analysis are covered by which the internal moments and shear in members can be found. The course is continued by formulating and step by step description of the design of decks, beams and girders, open-web steel joists and joist girders as well as columns. Prerequisite: ARCH 5324.

ARCH 5328. STRUCTURES III. 3 Hours.
This course is a continuation of ARCH 5327 with an emphasis on structural theory and systems in concrete construction. It covers the design and investigation of structural concrete. The course begins with a general introduction to structural behavior, strength, and modulus of elasticity of concrete material. To ensure that the concrete has the required minimum strength, special field sampling and tests are necessary. Loads and load combinations are the next part of the course. This part describes how the gravity and lateral loads are distributed in a concrete structure and what combination of loads should be considered for the design. To address the requirements of the design of structural members, a simplified method of structural analysis is defined by which the internal moments and shear in members can be found. Course is continued by formulating and step by step description of the design of beams, columns, and footings in a concrete structure. Prerequisite: ARCH 5327.

ARCH 5329. TOPICS IN COMPUTERS AND DESIGN. 3 Hours.
Computer aided design, drafting and graphic techniques as applied to architecture. May be repeated for credit as topics change.

ARCH 5330. COMPARATIVE STRUCTURES. 3 Hours.
Comparative analysis and design of structural systems and construction techniques, including architectural and economic determinants. Prerequisite: ARCH 5328 or permission of the instructor.

ARCH 5331. PROFESSIONAL PRACTICE. 3 Hours.
Survey of the administrative functions, and the ethical and legal responsibilities of the architect. Prerequisite: ARCH 5670.

ARCH 5332. ENERGY USE AND CONSERVATION IN ARCHITECTURE. 3 Hours.
Basic concepts of the efficient use and conservation of energy related to architectural design principles. Prerequisite: permission of the instructor.

ARCH 5333. CONSTRUCTION II. 3 Hours.
Advanced construction assemblies and methods, including the principles of cost control. Prerequisites: ARCH 5670.

ARCH 5335. ADVANCED PROFESSIONAL PRACTICE II: MARKETING DESIGN SERVICES. 3 Hours.
A study of the strategies and methods for marketing professional services. Presented as case studies of architecture, interior design, and landscape architecture firms.

ARCH 5336. PROGRAMMING AND SITE DESIGN II. 3 Hours.
The course focuses on project programming and the technical aspects of site design. Prerequisite: ARCH 5670.

ARCH 5337. SOILS AND FOUNDATIONS. 3 Hours.
Soil classifications, field and laboratory identification, physical properties and load-bearing characteristics, retaining walls and foundations.

ARCH 5338. CODES AND REGULATIONS. 3 Hours.
A study of accessibility, building and energy codes and related regulations including the architects' responsibility for compliance. Prerequisite: Permission of Department.

ARCH 5339. DIGITAL FABRICATION METHODOLOGY. 3 Hours.
The conceptualizing and making of objects lying outside the traditional scope of architectural practice, including elements of industrial and product design and the development of working prototypes.

ARCH 5340. MODERN + CONTEMPORARY ARCHITECTURE IN MEXICO. 3 Hours.
This course examines notions of Mexican national identity as expressed through architecture. Part 1 looks at late 19th and early 20th century architecture during the Porfiriato, as well as that occurring shortly after the Mexican Revolution of 1910-20, including the critical role that cement played. Part 2 considers how the so-called First Generation of architects adapted and transformed Modernism in Mexico. Part 3 examines how the Second and Third Generations moved beyond Modernism, including. The course concludes with Mexico's "First Generation" of women architects as issues of gender are addressed. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5341. NOTATIONAL DRAWING. 3 Hours.
Seminar concerned with analytical drawing techniques and how to use the sketchbook as a tool and process for architectural production. Emphasis will be on cultivating drawing strategies that will heighten the ability to make observations through first-hand experience and record them with the correct conventions in order to enable recovery for future use in architectural design.

ARCH 5342. DESIGN COMMUNICATIONS. 3 Hours.
Architectural drawing, perception, projections, and three-dimensional representation. Prerequisite: Concurrent enrollment in ARCH 5591 is required.

ARCH 5343. ARCHITECTURAL GRAPHICS II. 3 Hours.
An advanced course to develop visual sensitivity and awareness of digital techniques to enable the student to study design ideas and present those ideas in the various design disciplines. Emphasis on the relationship of computer graphics to the design process. Prerequisite: ARCH 5342 or program approval.

ARCH 5344. CONCEPTUAL DRAWING. 3 Hours.
Seminar to explore aspects of conceptual drawing for the architect and the relationship of design ideas in the drawing process.

ARCH 5345. DIGITAL CONSTRUCTION. 3 Hours.
A workshop exploring video cartography using photography, animation, motion graphics and digital video.

ARCH 5346. CONSTRUCTION DRAWINGS I. 3 Hours.
The techniques of building construction, the communication of technical information, and the process of preparing contract drawings for construction.

ARCH 5347. DIGITAL TECTONICS & PROTOTYPING. 3 Hours.
The use of digital technology in the architectural design process focusing on the research and fabrication of full-scale production of prototypes. Completion of ARCH 4339 or ARCH 5339 Digital Fabrication Methodology is highly recommended.

ARCH 5348. ARCHITECTURAL PHOTOGRAPHY. 3 Hours.
The use of photography as an investigative and presentation medium in architecture. Emphasis on composition in black and white technique.

ARCH 5349. ARCHITECTURE PORTFOLIO. 3 Hours.
Seminar concerned with goal toward the production of a personal design portfolio.

ARCH 5350. ARCHITECTURE, ENGAGEMENT + COMMUNITY POWER. 3 Hours.
Architecture, Engagement and Community Power will unpack the role of the citizen architect. It will examine participatory design processes that center community voice and shift existing power structures. In this country, constructed systems of oppression including racist practices, policies and financial systems have shaped the way our neighborhoods have developed. These acts have created inequities across communities that impact one's ability to thrive. Starting from the notion that all places are designed, and can therefore be undesigned, this course will explore the ways in which design processes can strengthen community power for marginalized communities. This course will encourage activism as an inherent quality in the development of an architect; encourage students to make connections between classroom learning and the larger community; require students to develop the skill to see and hear multiple voices; and encourage the development of visual, written, & oral communication tools. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5351. WILDERNESS: A CONDITION OF MIND. 3 Hours.
Changing conceptions of wilderness in Western thought, from ancestral prejudices to recent, revolutionary appreciation. Literary and visual documentation.

ARCH 5352. HOUSING: FROM CAVES TO MANSIONS IN THE CLOUDS. 3 Hours.
This course examines the evolution of American urban settlements as they evolved from French, Spanish and English concepts of town-planning.

ARCH 5354. CONVERGENCES: BETWEEN ART AND ARCHITECTURE. 3 Hours.
This course explores the convergences of artist methods of production with the processes of architectural practices. The course traces the work of leading filmmakers, both artistic and documentarian, whose professional leanings verge on the province of the architect.

ARCH 5355. HEMISPHERES. 3 Hours.
The study and analysis of Japanese arts and contemporary culture. The arts of ceramics, painting, calligraphy, and sculpture are examined. Prerequisite: departmental approval.

ARCH 5357. BUILDING INFORMATION MODELING & VISUALIZATION. 3 Hours.
To gain a working knowledge of Autodesk Revit and 3D Studio Max. Prerequisites: ARCH 3343 or ARCH 5343 or INTD 3343.

ARCH 5361. ARCHITECTURE AND ENVIRONMENT. 3 Hours.
An overview of sustainable design integrated with natural resource conservation.

ARCH 5362. STRUCTURAL SYSTEMS IN BUILDING. 3 Hours.
An overview of various structural systems including those used in long-span and high-rise buildings. Numerical work limited to the explanation of relevant structural concepts. Prerequisite: ARCH 5324.

ARCH 5363. DESIGN RESEARCH. 3 Hours.
Seminar directed toward the understanding of research methods and the programming of an independent design project, leading to the thesis substitute.Graded P/F/R.Prerequisite: Permission of Graduate Advisor.

ARCH 5364. SITE DESIGN. 3 Hours.
The related site design process includes site planning pertaining to land use, case studies, siting of structures, codes, and topography.

ARCH 5365. CATALYTIC MAPPING. 3 Hours.
An advanced theory elective course and workshop using the potential of mapping as a design, analytic and research mechanism for exploring complex contexts.

ARCH 5366. RADICAL URBANISM. 3 Hours.
An advanced theory course focused on the exposure to and critical analysis of some of the most radical, inspirational, and transformative urban design ideas and projects from Vitruvius to today.

ARCH 5367. HIGH PERFORMANCE FACADE SYSTEMS. 3 Hours.
Examines the role of the façade and building envelope as it relates to design, indoor comfort, energy and carbon usage, and overall performance through an exploration of materiality, assembly, and construction. The course also introduces the potential of generative technologies, smart materials, passive-active combinations, and integrated systems.

ARCH 5368. GREEN DESIGN + CONSTRUCTION. 3 Hours.
Green building design, construction, and operation is an opportunity to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. It provides cost savings to all tax-payers through improved human health and productivity, lower cost building operations, and resource efficiency. Green design and construction focuses on strategies and technologies to improve the energy efficiency and performance of buildings, and to reduce the environmental impact of buildings. The course emphasizes on different aspects of green building during all phases of a building's life-cycle, including design, construction, operation and decommissioning. All LEED categories are covered throughout the course and students get prepared to take LEED Green Associate exam by the end of the semester.

ARCH 5369. TERRITORIAL STRATEGIES. 3 Hours.
Territorial Strategies focus on climate resilience of the built environment on the territorial scale. In Territorial Strategies, students explore how macro-level drivers of spatial (trans)formation impact micro-level strategies and actions in distinct climatic regions. Students apply a systems-thinking approach to map, diagram, model, draw, and visualize project outcomes, research findings, and data through various media. Prerequisite: Graduate level in Architecture, Landscape Architecture, Urban Planning, and Public Administration and Public Policy majors.

ARCH 5370. ADVANCED DESIGN STUDIO. 3 Hours.
Studio course in the generation and development of architectural ideas in formal and environmental contexts. May be repeated for credit. Two of these courses are equivalent to ARCH 5670.

ARCH 5371. FUTURE CITIES. 3 Hours.
Future Cities focus on climate resilience of the built environment on the urban scale. In Future Cities, students explore historical and contemporary concepts of ecological design and combine mitigative and adaptive strategies and actions for urban landscapes in the age of anthropogenic climate change. Students apply a participatory mixed-methods approach to map, diagram, model, draw, and visualize project outcomes, research findings, and data through various media. Prerequisite: Graduate level in Architecture, Landscape Architecture, Urban Planning, and Public Administration and Public Policy majors.

ARCH 5372. ADAPTIVE TYPOLOGIES. 3 Hours.
Adaptive Typologies focus on climate resilience of the built environment on the architectural object scale. In Adaptive Typologies, students explore architectural objects, their characteristics, and their performative aspects as integrated parts of the urban ecosystem. Students analyze, transform, and develop hybrid typologies merging physical, digital, and biological concepts and apply a digital mixed-methods approach, utilizing analytical, representational, and generative tools. Prerequisite: Graduate level in Architecture, Landscape Architecture, Urban Planning, and Public Administration and Public Policy majors.

ARCH 5377. SPATIAL [IN] JUSTICE. 3 Hours.
Through lectures and discussions, Spatial [in] Justice will provide students with historical perspectives on how American cities became segregated, the creation and lack of inclusivity of 'public space', and the architect's role within a socially engaged practice. The course will begin by studying key philosophies and theories of justice. Students will work with a community partner to produce a community engagement and development plan. They will research publicly available data and organize it into a package for the community and other stakeholders. Prerequisite: ARCH 2303 or ARCH 5303 and ARCH 2304 or ARCH 5304. Department consent.

ARCH 5381. PRACTICUM. 3 Hours.
Internship program including work done through an approved architect's office, designed to give practical experience leading to a broader knowledge of the profession. Placement in offices must be approved, and in some cases may also be arranged by the school. Students may enroll in ARCH 5381 for half-time employment or ARCH 5681 for full-time employment. Students enrolled in Practicum may also participate in the Intern Development Program of the American Institute of Architects. No more than six total credit hours in Practicum are allowed for degree. Graded P/F/R.

ARCH 5391. CONFERENCE COURSE. 3 Hours.
Special subjects and issues as arranged with individual students and faculty members. May be repeated for credit as content changes.Prerequisite: Permission of Graduate Advisor.

ARCH 5395. TOPICS IN ARCHITECTURE. 3 Hours.
Studio, lecture or seminar courses to explore and present special topics in architecture and environmental design. May be repeated for credit as topics change.

ARCH 5591. DESIGN STUDIO I. 5 Hours.
An intensive studio course in architectonic theory and operations. Emphasis on analytic, conceptual, and manipulation procedures.

ARCH 5592. DESIGN STUDIO II. 5 Hours.
Continuation of ARCH 5591. Studio course emphasizing the interrelationship of formal/spatial ideas, use, and the building fabric. Prerequisite: ARCH 5591.

ARCH 5593. DESIGN STUDIO III. 5 Hours.
Continuation of ARCH 5592. Studio course emphasizing the interrelationship of formal/spatial ideas, use, and the building fabric with special attention to the urban context. Prerequisite: ARCH 5592.

ARCH 5594. DESIGN STUDIO IV. 5 Hours.
Continuation of ARCH 5593. Emphasis on complex building designs in urban environments. Off campus study may be substituted. Prerequisite: ARCH 5593.

ARCH 5665. INTERMEDIATE DESIGN STUDIO. 6 Hours.
Advanced architectural design problems in programming, schematic organization, synthesis and design of buildings in their environmental context.

ARCH 5670. ADVANCED DESIGN STUDIO. 6 Hours.
Studio course emphasizing the analysis and design of building aggregations within the urban context. May be repeated for credit.

ARCH 5671. INTEGRATIVE DESIGN STUDIO I. 6 Hours.
Introduces the design of a small to moderate scaled architectural building program. Focus on pre-design, site design, structural resolution, building assembly, building performance, detailing and materiality will be made through graphical identification, analysis, and evaluation. Additional considerations of codes, regulations, cost analysis, and life-cycle cost, are areas of emphasis informing the design process. Prerequisite: ARCH 5325 or ARCH 4325, ARCH 5327, and ARCH 5670. Credit or concurrent enrollment in ARCH 5357, ARCH 4357, or INTD 3357.

ARCH 5672. INTEGRATIVE DESIGN STUDIO II. 6 Hours.
Introduces the design of a larger-scaled architectural project with more complex programming requirements. Focus on the integration of environmental stewardship, accessibility, site conditions, life safety, environmental systems, structural systems, and building envelope systems will be made through graphical identification, analysis, and evaluation, and technical documentation. Project demonstration includes problem identification, contextual evaluative criteria, analyzing solutions, and predicting the effectiveness of implementation. Prerequisite: ARCH 5671 with a grade of C or above.

ARCH 5681. PRACTICUM. 6 Hours.
Internship program including work done through an approved architect's office, designed to give practical experience leading to a broader knowledge of the profession. Placement in offices must be approved, and in some cases may also be arranged by the school. Students may enroll in ARCH 5381 for half-time employment or ARCH 5681 for full-time employment. Students enrolled in Practicum may also participate in the Intern Development Program of the American Institute of Architects. No more than six total credit hours in Practicum are allowed for degree. Graded P/F/R.

ARCH 5691. CONFERENCE COURSE. 6 Hours.
Special subjects and issues as arranged with individual students and faculty members. May be repeated for credit. Prerequisite: Permission of Graduate Advisor.

ARCH 5693. DESIGN THESIS. 6 Hours.
Individual study project conducted by a supervising committee, with program and statement of intent to be filed with the Graduate Advisor during the previous semester. Graded R. Prerequisite: ARCH 5363.

ARCH 5695. TOPICS IN ARCHITECTURE. 6 Hours.
Studio, lecture or seminar courses to explore and present special topics in architecture and environmental design. May be repeated for credit as topics change. Prerequisite: Permission of Graduate Advisor.

ARCH 5698. RESEARCH THESIS. 6 Hours.

COURSES

ECON 2110. SELECTED TOPICS IN ECONOMICS. 1 Hour.
Topics of current interest in economics. The subject title is to be listed in the class schedule. May be repeated for credit when the topic changes. Prerequisite: ECON 2305 or ECON 2306.

ECON 2305. PRINCIPLES OF MACROECONOMICS. 3 Hours. (TCCN = ECON 2301)
(ECON 2301). Elementary models of the macroeconomy. Measures of aggregate economic activity and unemployment and inflation, money and banking, monetary and fiscal policy, international trade and payments, and applications of theory to society's problems.

ECON 2306. PRINCIPLES OF MICROECONOMICS. 3 Hours. (TCCN = ECON 2302)
(ECON 2302) The science of choice; develops demand, supply, and the market mechanism for allocating society's scarce resources; analyzes the impact of different industry structures in the market; applies the tools of microeconomic analysis to various topics such as price controls and international trade.

ECON 2337. ECONOMICS OF SOCIAL ISSUES. 3 Hours.
Economic analysis and application of basic economic principles to a variety of social issues and topics. Students will become familiar with the U.S. economy, its structure, and how economics applies to an assortment of public policy topics such as crime, energy, immigration, drug use, prostitution, minimum wage, our aging population, healthcare, gender driven wages, recycling, and the macro economy, to name a few. In addition, current economic issues and events may be incorporated into the course via lecture and/or class discussions. This is a non-technical course which satisfies the core requirement for social and behavioral studies. Will not serve to meet degree requirements for College of Business Administration majors. Offered as ECON 2337 and AAST 2337; credit will be granted in only one department.

ECON 3301. THE ECONOMICS OF HEALTH. 3 Hours.
Applies economic analysis to the health sector; examines issues involving health insurance and how these issues have been addressed by the market and by the government; role of market structure in health care markets such as the hospital and pharmaceutical industries; compares the U.S. health care system to health care systems in other countries. Prerequisite: ECON 2306.

ECON 3302. THE ECONOMICS OF CRIME. 3 Hours.
Economic analysis of criminal activity and its impact on the allocation of scarce resources; economic models of criminal behavior, optimum allocation of criminal justice resources, public and private sector approaches to deterrence, and current issues such as gun control and drug abuse prevention. Prerequisite: ECON 2306.

ECON 3303. MONEY AND BANKING. 3 Hours.
Monetary and banking systems of the United States, including the roles that money and interest rates play in the economy, the functions and organization of financial markets, financial institutions, central banks, operations of monetary policy, recent developments in the financial industry and the response of monetary authority. Prerequisite: ECON 2305.

ECON 3304. PUBLIC SECTOR ECONOMICS. 3 Hours.
Examines various economic reasons that may justify government involvement in the economy with particular focus on the problems inherent in government intervention. It considers topics such as the efficiency and fairness of alternative taxing systems, the growth and effects of government debt, and public choice (how spending and taxing decisions are made). It analyzes various government programs such as Social Security, health care, expenditure programs for the poor, etc. Prerequisite: ECON 2306.

ECON 3305. LAWS AND ECONOMICS. 3 Hours.
A review of the economic effects of laws and legal institutions, including property rights, the common law of contracts and torts, regulations, and crime and punishment. Prerequisite: ECON 2306.

ECON 3306. SPORTS ECONOMICS AND BUSINESS. 3 Hours.
Economic principles applied to the analysis of professional and amateur sports. Topics include fan demand, team output decisions, league/conference organization, the societal costs and benefits of government financing of sports facilities, player value, and collective bargaining. The course is designed for both business and economics majors. Prerequisite: ECON 2306.

ECON 3310. MICROECONOMICS. 3 Hours.
Develops the theory of consumer and firm behavior using tools of marginal analysis. Students learn motivations behind consumer behavior (utility maximization) and firm behavior (profit maximization). This includes the features of competitive equilibrium, price discrimination, and imperfect competition models. Prerequisite: ECON 2306 and 60 credit hours.

ECON 3312. MACROECONOMICS. 3 Hours.
Aggregate economic performance, including economic growth and business cycles. Models and real data will be used. Interactions among private sector behavior, government policies, central bank actions and international events, and their effects on GDP, employment, growth, and prices will be studied. Prerequisite: ECON 2305, ECON 3303, and 60 credit hours.

ECON 3313. INDUSTRIAL ORGANIZATION AND PUBLIC POLICY. 3 Hours.
Explains market structure and its relation to strategic behavior, advertising, pricing and product differentiation decisions. Further topics include the organization of the firm, takeovers, mergers and acquisitions, research and development, and the various regulatory controls placed on firms and industries. Prerequisite: ECON 2306.

ECON 3317. ECONOMIC DATA LITERACY & VISUALIZATION. 3 Hours.
Students learn how to answer questions with real-world data by exploring the connections between variables visually. Data visualization software is used to perform analysis and present results in a clear and concise manner. Emphasis is placed on best practices in data visualization, applications, and hands-on data analysis. Prerequisite: BSTAT 2305.

ECON 3318. ECONOMIC DATA ANALYSIS. 3 Hours.
Students learn how to answer questions with real-world data by exploring the connections between variables. Programs are used to perform analysis and present results in a clear and concise manner. Emphasis is placed on applications and hands-on data analysis. Prerequisite: BSTAT 3321 or permission of instructor.

ECON 3322. BITCOIN AND ECONOMICS OF CRYPTOCURRENCIES. 3 Hours.
Bitcoin (BTC) is a digital asset with unique characteristics that spawned an industry of similar assets called cryptocurrencies. The course examines the evolution of digital money in the historical context of the U.S. financial system. Students will examine cryptocurrencies, with a focus on BTC, as a vehicle for wealth storage and as a transactions asset (money). The course will cover valuation of cryptocurrencies compared to other assets in the context of asset pricing theory at an introductory level. Prerequisite: ECON 2306.

ECON 3328. PRINCIPLES OF TRANSPORTATION. 3 Hours.
The application of microeconomic and statistical tools in the analysis of the various modes of transportation. Topics for discussion include transportation as a derived demand, regulation of transportation, mass transit, and international issues in transportation. Prerequisite: ECON 2306.

ECON 3335. ECONOMICS OF PUBLIC POLICIES. 3 Hours.
Applies the principles of microeconomics to a wide range of public policy topics, including education, energy, health care, immigration, drugs, crime, recycling, risk and safety, Social Security, sports stadiums, tax policy, and topics on the economics of the family. Prerequisite: ECON 2306.

ECON 3388. EUROPEAN ECONOMIC HISTORY, 1750 TO PRESENT. 3 Hours.
An economic analysis of historical events leading up to and following the Industrial Revolution, large-scale industry, early banking, commerce, Utopian movements, war, postwar economic integration and the continuing debate over economic globalization. Prerequisite: ECON 2305.

ECON 4191. STUDIES IN ECONOMICS. 1 Hour.
Advanced studies, on an individual basis, in the various fields of economics. Prerequisite: ECON 2306 and 90 credit hours and departmental permission.

ECON 4291. STUDIES IN ECONOMICS. 2 Hours.
Advanced studies, on an individual basis, in the various fields of economics. Prerequisite: ECON 2306 and 90 credit hours and departmental permission.

ECON 4300. ADVANCED COMMUNICATION FOR BUSINESS AND ECONOMIC PROFESSIONALS. 3 Hours.
The course includes the creation of documents that can include financial formulas and economic forecasting, industry-specific reports, and presentations incorporating the results of a financial or economic theory and corresponding research. The course will use a variety of learning methods including lecture, class discussion, case analysis and presentation, guest speakers, and written exercises. This course is required to be eligible to sit for the Certified Business Economic (CBE) Exam. Students who receive credit for this course in the undergraduate program may not repeat the course at the Master's level. Prerequisite: BCOM 3360.

ECON 4302. ENVIRONMENTAL ECONOMICS. 3 Hours.
Economic forces that influence the quality of the environment; economic theory and environmental management; regulatory requirements for economic impact analysis; international issues including trade and implications for Third World economies. Prerequisite: ECON 2306.

ECON 4305. THE ECONOMICS OF DISCRIMINATION. 3 Hours.
Course reviews the economic theory of discrimination that arises from personal preference and social forces, that is revealed in numerous market situations. Empirical evidence of the impact on employment, careers, purchasing, business practice, and economic outcomes are studied. Students will prepare presentations on the topic. Students who receive credit for this course in the undergraduate program may not repeat the course at the Master's level. Prerequisite: ECON 2306.

ECON 4306. COMPARATIVE ECONOMIC SYSTEMS. 3 Hours.
Studies how differing economies are organized with respect to market, command, and traditional institutions. Several empirical economies are evaluated and compared with respect to performance and efficiency. Each economy is placed within its unique historical and social context to explore why certain institutions work in one situation but may fail in others. Prerequisite: ECON 2306.

ECON 4311. MANAGERIAL ECONOMICS. 3 Hours.
Applies Economic Optimization as the fundamental methodology to guide decisions at the firm level. Microeconomic Theory provides the foundation for decision making and strategy. Topics include investment decisions, pricing, price discrimination, strategy, bargaining, uncertainty, moral hazard and adverse selection, and incentive structures for employees and for units of the firm. The class is real-world-oriented exploring actual decisions of firms. Prerequisite: ECON 2306 and 60 credit hours.

ECON 4316. DIGITIZATION, ECONOMICS AND STRATEGY. 3 Hours.
Economics and strategy applied to emerging online markets: the gig economy (e.g., Airbnb, Uber, Slashdot), digital entertainment (e.g., Spotify, Netflix, Hulu), and video gaming (e.g., World of Warcraft, Play Store, Twitch). Economic concepts covered will include platforms, pricing, product positioning, product bundling, social networks, and collaboration. Explores how various IT innovations have disrupted business models and the strategic implications of future innovations. Prerequisite: ECON 2306 or Consent of the instructor.

ECON 4318. ECONOMIC REGRESSION ANALYSIS CAPSTONE. 3 Hours.
The course builds on data analysis techniques learned in ECON 3318. Students explore the difference between correlation and causation and learn how to use advanced techniques to analyze causal relationships between variables. Students display their mastery of analysis through a capstone project and present their findings in a professional manner. Prerequisite: ECON 3318 or consent of instructor.

ECON 4319. ECONOMIC GROWTH AND DEVELOPMENT. 3 Hours.
The issues underlying vast differences in development among the nations of the world. Course covers the elements of theories of growth, the role of international trade, and issues of institutional structures related to economic progress in a nation. Prerequisite: ECON 2306.

ECON 4320. GAMES AND DECISION MAKING. 3 Hours.
Game theory studies the strategic interactions between two or more parties. These interactions are common in business, law, politics, and sports. Examples include analysis of "games" in the real world such as competition among firms, complex business decisions, and political campaigns. This course starts with the basics of game theory (such as Nash equilibrium and dominant strategies) and moves to more complicated games such as repeated and stochastic games, and auctions. The course includes in-class demonstrations, hands-on experiments, and real-world examples. Students will think analytically and frame strategic interactions by accessing the incentives of those involved through the tools discussed. Prerequisite: ECON 2306.

ECON 4321. INTERNATIONAL TRADE. 3 Hours.
The course provides an understanding of international trade (international movement of goods and services), migration (international movement of labor), and investment (cross-border movement of assets) theories. It is designed to better understand the implications of such theories as they relate to international business management. It helps managers deal with the opportunities and challenges created by the global environment. Prerequisite: ECON 2306.

ECON 4322. INTERNATIONAL FINANCE. 3 Hours.
The nature and instruments of international payments. International financial institutions and arrangements. Exchange rate, balance of payment, and income determination theories. Prerequisite: ECON 2305.

ECON 4323. MATHEMATICAL ECONOMICS. 3 Hours.
This course focuses on applying mathematical concepts to solve economic and business problems. Course will upgrade mathematical skills for graduate work in economics and business. The emphasis is on calculus and linear algebra and their economic applications. Students who receive credit for this course in the undergraduate program may not repeat the course at the Master's level. Prerequisite: MATH 1315 or MATH 1316 and ECON 3310 and ECON 3312.

ECON 4324. MONETARY AND FISCAL POLICY. 3 Hours.
The effects of money on production and national income; quantity and commodity theories of money; various theories of interest rates; instruments and policies of Federal Reserve monetary action; proposals for monetary reform. Central bank systems. Prerequisite: ECON 2306 and ECON 3303 and 60 credit hours.

ECON 4325. ECONOMIC FORECASTING. 3 Hours.
The class presents methods that allow users to capture movement in data related to seasonality, trend and cycles to produce forecasts for economic date. Students are exposed to practical coding applications in software including R. Prerequisites: ECON 3318 or equivalent.

ECON 4330. HUMAN RESOURCE ECONOMICS. 3 Hours.
Application of economic principles to labor topics such as the demand for marriage, the demand for children, the economics of beauty, the economics of highly paid sports and entertainment stars, the effects of immigration on U.S. wages and employment, workplace discrimination, the effects of affirmative action policies, and the effects of minimum wage legislation. Prerequisite: ECON 2306.

ECON 4331. SEMINAR IN ECONOMICS. 3 Hours.
Readings and discussions of special topics in economics. Prerequisite: 60 or 90 credit hours and consent of instructor. May be repeated for credit with consent of department chair.

ECON 4391. STUDIES IN ECONOMICS. 3 Hours.
Advanced studies, on an individual basis, in the various fields of economics. Prerequisite: ECON 2306 and 90 credit hours and departmental permission.

ECON 4393. ECONOMICS INTERNSHIP. 3 Hours.
Practical training in economics. Analysis of theory applied to real life situations. May be used as an advanced business elective only; graded on a pass/fail basis. No credit will be given for previous experience or activities. May not be repeated for credit. Prerequisite: Junior standing and consent of department internship advisor.

ECON 5182. INDEPENDENT STUDIES IN ECONOMICS. 1 Hour.
Extensive analysis of an economic topic. Prerequisite: Departmental Permission Required.

ECON 5199. GRADUATE ECONOMICS INTERNSHIP. 1 Hour.
Practical training in economics. Analysis of theory applied to real life situations. Course counts as an elective and has a pass/fail grade. No credit will be given for previous experience or activities. Prerequisite: Minimum nine graduate semester hours completed.

ECON 5282. INDEPENDENT STUDIES IN ECONOMICS. 2 Hours.
Extensive analysis of an economic topic. Prerequisite: Departmental Permission Required.

ECON 5299. GRADUATE ECONOMICS INTERNSHIP. 2 Hours.
Practical training in economics. Analysis of theory applied to real life situations. Course counts as an elective and has a pass/fail grade. No credit will be given for previous experience or activities. Prerequisite: Minimum nine graduate semester hours completed.

ECON 5300. ADVANCED COMMUNICATION FOR BUSINESS AND ECONOMIC PROFESSIONALS. 3 Hours.
This course focuses on developing industry-specific acumen necessary to work in the fields of economics, finance, marketing, management, and information systems. The course includes the creation of documents that can include financial formulas and economic forecasting, industry-specific reports, and presentations incorporating the results of a financial or economic theory and corresponding research. The course will use a variety of learning methods including lecture, class discussion, case analysis and presentation, guest speakers, and written exercises. This course is required to be eligible to sit for the Certified Business Economic (CBE) Exam.

ECON 5301. MATHEMATICAL ECONOMICS. 3 Hours.
Course is designed to upgrade mathematical skills for graduate work in economics and business. The emphasis is on calculus and linear algebra and their applications in economic analysis. Mathematical tools covered include optimization, comparative-statics analysis, and simple dynamic analysis. Prerequisite: MATH 1316 or other calculus course.

ECON 5305. THE ECONOMICS OF DISCRIMINATION. 3 Hours.
Course reviews the economic theory of discrimination that arises from personal preference and social forces, that is revealed in numerous market situations. Empirical evidence of the impact on employment, careers, purchasing, business practice, and economic outcomes is studied. Students will prepare presentations on the topic. Students who receive credit for this course in the undergraduate program may not repeat the course at the Master's level. Prerequisite: Graduate student standing regardless of major.

ECON 5306. ENVIRONMENTAL ECONOMICS. 3 Hours.
An examination of the development of laws and policies that concern the environment followed by an application of economic analysis for environmental issues such as water use, air pollution, land controls, public lands, and global environmentalism. Other topics include: property rights, theories of regulation, and enviropreneurship. Participants will produce and present a case study on an environmental economic subject of interest.

ECON 5310. MICROECONOMIC THEORY. 3 Hours.
Development of marginal analysis and game theory tools in economics; focus on the analysis of consumer choice and decision making by firms; development of competitive model and various deviations from competition including the exercise of market power, externalities, and information asymmetries. Prerequisite: ECON 3310.

ECON 5311. ECONOMIC ANALYSIS. 3 Hours.
Provides an overview of microeconomic foundations of economic analysis with a focus on business applications. Topics include supply and demand, marginal analysis, pricing issues, and theory of the firm. An overview of macroeconomics is also provided, covering monetary and fiscal policy, inflation, growth, and international trade. Non-credit for MS in Economics.

ECON 5312. MACROECONOMIC THEORY. 3 Hours.
Study of contemporary macroeconomic theory and applications, including stylized facts of macroeconomics, the general framework for macroeconomic analysis, the analysis of modern macroeconomic models, and the long-run economic growth. Prerequisite: ECON 3312.

ECON 5313. DECISIONS AND STRATEGY. 3 Hours.
Decision analysis applied to pricing, hiring, investing, and partnering. Analyze conditions needed to create competitive advantage. Applications to decisions regarding: entering markets, launching products, developing informational advantages, establishing contractual and non-contractual relationships, and managing incentives within the organization.

ECON 5314. ECONOMIC ANALYSIS FOR BUSINESS DECISIONS. 3 Hours.
This course demonstrates how microeconomic theory can be used in business decision-making. Analytical tools are developed to study competitive analysis, strategic position and dynamics, internal organization of the firm, and the firm's strategic position in the supply chain. Through the use of real business information, the class provides an understanding of how to link economic theory with practice. Students will engage in empirical analysis. Prerequisite: ECON 5336 or BSAD 6317 concurrent.

ECON 5315. COMPETITION, INNOVATION, AND STRATEGY. 3 Hours.
Based on economic analysis, students develop the skills to assess the competitive landscape and identify appropriate strategic responses. Applications include: Strategic Pricing, Product Positioning, Project Selection, Entry/Exit, R&D Investments, Organizational Structure, and Supply Chain Incentives. Prerequisite: ECON 3310 or equivalent.

ECON 5316. DIGITAL BUSINESS TRANSFORMATION. 3 Hours.
Economics and strategy applied to emerging online markets: the gig economy (e.g., Airbnb, Uber, Slashdot), digital entertainment (e.g., Spotify, Netflix, Hulu), and video gaming (e.g., World of Warcraft, Play Store, Twitch). Economic concepts covered will include platforms, pricing, product positioning, social media, collaboration. Explores how various aspects of IT has transformed previous business models and how future developments could transform it further. Prerequisite: ECON 5313 or ECON 5314 or ECON 3310 or Consent of the instructor.

ECON 5317. DATA VISUALIZATION. 3 Hours.
Students learn how to answer questions with real-world data by exploring the connections between variables visually. Data visualization software is used to perform analysis and present results in a clear and concise manner. Emphasis is placed on best practices in data visualization, applications, and hands-on data analysis. Prerequisite: Graduate student standing.

ECON 5318. ECONOMICS OF SPORTS. 3 Hours.
Economic principles applied to the analysis of professional and amateur sports. Topics include fan demand, team output decisions, league/conference organization, the societal costs and benefits of government financing of sports facilities, player value, and collective bargaining. The course is designed for both business and economics majors. Prerequisite: ECON 5311 or equivalent.

ECON 5319. INTERNATIONAL TRADE AND INVESTMENT. 3 Hours.
The course provides an understanding of international trade, direct investment, and migration theories and policies pertaining to the movement of goods, services, assets, and labor across borders. It focuses on the implications of such theories and policies related to household welfare and international business management. It aims to provide a working knowledge of tools to help managers better navigate the opportunities and challenges in the global business environment. Prerequisite: ECON 5313 or ECON 5314 or ECON 3310 or consent of the instructor.

ECON 5321. GLOBAL BUSINESS ANALYTICS. 3 Hours.
This course provides a working knowledge of tools that influence the decisions multinational firms make in the global environment. It is designed to understand the implications of international trade, investment, and institutional theories as they relate to international business management. It focuses on how to test the implications of theories using global data sets. Participants will complete an empirical research project and present their findings. Prerequisite: ECON 5336 or BSAD 6317, or consent of the instructor.

ECON 5325. TRANSFER PRICING. 3 Hours.
Course concerns the theory, practice, strategy and taxation of intra-firm trade among affiliated entities of a multinational enterprise (MNE). Transfer pricing is important for maximizing profits, monitoring performance of segments of an MNE, establishing control over cash and income flows, advancing strategic objectives, and reducing overall corporate tax burden. Issues arise in accounting, economics, taxation, and law.

ECON 5327. MONETARY POLICY AND FINANCIAL SYSTEM ANALYSIS. 3 Hours.
This course reviews the link between financial systems, monetary policy, and the macro economy, with an emphasis on the role that financial markets and institutions play in the domestic and global business environment. Contemporary policy issues are considered and we study how monetary policy actions affect financial markets and institutions. Students will engage in empirical applications using actual data and simulation exercises. Prerequisite: ECON 5336 or BSAD 6317 concurrent.

ECON 5329. RESEARCH METHODS IN APPLIED ECONOMICS. 3 Hours.
Each student presents a replication of a published article that uses methods from Econometrics I/II, Forecasting, Forecasting and/or Time Series. The instructor will present replications of several published papers and assist students in choosing studies that they will attempt to replicate. Class meetings will focus on answering specific questions that arise as students carry out their replication exercises. The course concludes with student presentations, along with submission of a written report summarizing the replication effort and detailing the extent to which published results were replicable. The goal is to develop the skills to write quality papers using a variety of statistical techniques. Prerequisite: ECON 5336 or BSAD 6317.

ECON 5330. HUMAN RESOURCE ECONOMICS. 3 Hours.
This course studies labor supply decisions made by households, labor demand decisions made by firms, and the equilibrium wage differences that result from these decisions. Other topics include unemployment, human capital investments, efficiency wages and other incentive schemes, inequality, labor mobility and migration, and discrimination. Prerequisites: ECON 5311 or equivalent.

ECON 5331. PROJECT EVALUATION AND FEASIBILITY ANALYSIS. 3 Hours.
This course introduces feasibility analysis including demand/market evaluation, cost estimation, and benefit-cost analysis. Students gain the ability to apply economic analysis methods (present worth, annual cost, rate of return, benefit-cost ratios, and breakeven) to basic economic problems. Other issues include depreciation; risk and uncertainty; sensitivity analysis; and global economic factors that impact the economy and project funding. Students will perform an empirical evaluation of project feasibility using cost-benefit tools. Prerequisite: ECON 5314 or consent of instructor.

ECON 5332. GOVERNMENT, TAXES, AND BUSINESS STRATEGY. 3 Hours.
The interaction between government and business is broad. Effective business leadership requires the ability to analyze and respond to public policy. Economics provides a framework for understanding the incentives of consumers, businesses, bureaucrats, and civil servants in different policy environments and predicting their behavior in response to policy changes. This course focuses primarily on tax policy at the federal, state and local levels, including issues in corporate taxation, personal income tax, treatment of capital gains and loses, tax incidence, work-leisure choices, fiscal competition among state and local governments, capital flight, and fiscal federalism. Prerequisite: Graduate Standing.

ECON 5333. ECONOMICS OF HEALTH. 3 Hours.
Economic analysis applied to current health policy issues, including health expenditures, public and private insurance, incentives, provider education and labor markets, hospitals, prescription drugs, malpractice, long-term care, the Internet. and various proposals for reform.

ECON 5336. APPLIED BUSINESS AND ECONOMICS DATA ANALYSIS I. 3 Hours.
Develops an understanding of statistical and econometric techniques. Participants exploit real data and computational power to uncover patterns/trends and examine relationships. Focus on conceptual frameworks and the application of techniques to data sets in various fields. Participants learn to use statistical packages such as R and SAS to apply the tools to real data and will complete an empirical analysis paper. Prerequisite: Graduate standing.

ECON 5337. BUSINESS & ECONOMIC FORECASTING. 3 Hours.
The course analyzes univariate and multivariate methods that allow users to capture patterns in data related to seasonality, trend and other random components to produce forecasts that are useful in virtually any business environment. Participants gain practical experience coding in relevant software. By the end of the course, students will be able to use statistical tools to critically assess the usefulness of alternative methods, which range from simple exponential smoothing to those that use machine learning. Prerequisite: ECON 5336 or BSAD 6317 or BSTAT 5325 or consent of instructor.

ECON 5338. APPLIED TIME SERIES. 3 Hours.
Covers topics of time series data analysis popularly used in many fields, including economics and business. Begins with univariate analysis of time series data with the focus on ARIMA, GARCH model, and unit-root tests, and extends to multivariate analysis of distributed lag model, VAR, and cointegration tests. The last part of the course is devoted to discussion of popular nonlinear dynamic models, such as TAR and structural breaks, before moving on to dynamic panel data models. Since emphasis is put on empirical applications, students will spend time in the computer lab to apply the techniques they learn to a variety of time series data. Students will undertake empirical analysis using statistical software. Prerequisite: ECON 5336 or BSAD 6317.

ECON 5339. APPLIED BUSINESS AND ECONOMICS DATA ANALYSIS II. 3 Hours.
The course covers cross-section, panel data, and limited dependent variables methods. Topics may include analysis of natural experiments/differences-in-differences, panel data methods, instrumental variable estimation, simultaneous equation models, sample selection corrections, and limited dependent variable and hierarchical models. Participants learn how to use statistical packages such as R, SAS, and STATA to apply these methods to data to examine causal relationships. They build an understanding of appropriate methods for different research design. Participants will complete an empirical research paper. Prerequisite: BSTAT 5325 or ECON 5336 or BSAD 6317 or the consent of the instructor.

ECON 5341. ADVANCED BUSINESS AND ECONOMIC DATA ANALYTICS. 3 Hours.
Students use advanced modeling and estimation techniques applied to large data sets collected by both business and government. The course includes assignments designed to give practical experience at applying the advanced statistical methods, culminating in a final project that includes a written report and class presentation. Projects will exploit data from various sources, such as sales transactions, individual health records, Internet search results, Twitter feeds, and environmental data. The advanced techniques covered may include data mining, statistical visualization, computational statistics, and other computer-intensive statistical methods. Prerequisite: ECON 5336 and ECON 5339; or BSAD 6317 and BSAD 6318.

ECON 5343. CAUSAL INFERENCE FOR BUSINESS DECISIONS. 3 Hours.
Students learn methods to identify and measure the outcomes of business decisions. In particular, students will learn various issues pertaining to the miss-attribution of causal effects. The course surveys multiple methods to overcome the misidentification problem. Students will engage in empirical analysis. Prerequisites: ECON 5336 or BSAD 6317 and ECON 5339 or BSAD 6318.

ECON 5382. INDEPENDENT STUDIES IN ECONOMICS. 3 Hours.
Extensive analysis of an economic topic. Prerequisite: Departmental Permission Required.

ECON 5391. SPECIAL TOPICS IN ECONOMICS. 3 Hours.
In-depth study of selected topics in economics. May be repeated when topics vary. Prerequisite: Departmental Permission Required.

ECON 5398. THESIS. 3 Hours.
Graded R/F only. Prerequisite: Permission of Graduate Advisor in Economics.

ECON 5399. GRADUATE ECONOMICS INTERNSHIP. 3 Hours.
Practical training in economics. Analysis of theory applied to real life situations. Course counts as an elective and has a pass/fail grade. No credit will be given for previous experience or activities. Prerequisite: Minimum nine graduate semester hours completed.

ECON 5698. THESIS. 6 Hours.
Graded P/F/R. Prerequisite: Permission of Graduate Advisor in Economics.

ECON 5998. THESIS. 9 Hours.
Graded P/F/R. Prerequisite: Permission of Graduate Advisor in Economics.

ECON 6310. ADVANCED MICROECONOMIC THEORY. 3 Hours.
Investigates the advanced neoclassical theory of microeconomics. The course develops formal models of consumer behavior, market structure, general equilibrium, and welfare. The objective of the course is to acquaint students with the analytical tools necessary to evaluate the formal literature in economics and to conduct scientific, hypothesis- driven statistical studies. Prerequisites: ECON 5301 and ECON 5310.

ECON 6312. ADVANCED MACROECONOMIC THEORY. 3 Hours.
Topics include dynamic general equilibrium analysis of model economies, monetary theory in overlapping generations models, advanced growth theory, and new open-economy macroeconomics. Prerequisites: ECON 5301 and ECON 5312.

COURSES

AREN 1105. INTRODUCTION TO ARCHITECTURAL ENGINEERING. 1 Hour.
Introduction to basic architectural engineering practice. There are several writing assignments and an oral presentation. Use of spreadsheet and word processor software in solving architectural engineering problems and presenting solutions. Professional engineering licensure and the various specializations within civil engineering are covered.

AREN 1205. INTRODUCTION TO ARCHITECTURAL ENGINEERING. 2 Hours.
This course introduces students to the education and practice of architectural engineering, a discipline of engineering that prepares engineers to work effectively on teams that are creating buildings. Course content addresses engineering ethics, professional licensure, sustainability, creative approaches to problem solving and the role of architectural engineering and other engineering disciplines on building construction projects.

AREN 1252. COMPUTER TOOLS - AUTOCAD. 2 Hours.
Introduction to computer aided design, using AutoCAD. Creation of precise two-dimensional engineering drawings and solid models. Prerequisite: Grade of C or better in MATH 1421.

AREN 2152. COMPUTER TOOLS - MATHCAD. 1 Hour.
Introduction to computer aided mathematics, using Mathcad. Solution of engineering problems involving systems of simultaneous linear and nonlinear equations and elementary calculus, use of the tools for visualization. Prerequisite: Grade of C or better in PHYS 1443.

AREN 2153. COMPUTER TOOLS - CIVIL 3D. 1 Hour.
Introduction to civil engineering construction documentation and building information modeling (BIM) using AutoCAD Civil 3D. Prerequisite: Grade of C or better in AREN 1252.

AREN 2191. PROBLEMS IN ARCHITECTURAL ENGINEERING. 1 Hour.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the department chair.

AREN 2221. DYNAMICS. 2 Hours.
Planar and spatial kinematics and kinetics of particles and rigid bodies utilizing Newton's Laws of Motion, the principle of work and energy, and the principle of impulse and momentum; introduction to single degree of freedom vibration. Prerequisite: Grade of C or better in AREN 2311; grade of C or better in MATH 2425.

AREN 2252. INTRODUCTION TO CONSTRUCTION DRAFTING. 2 Hours.
This course will introduce students to basic concepts of construction drafting including an introduction to orthographic drawings (plans, sections, elevations), principles of scale, line weight, drawing types and drawing conventions. The course introduces students to 2-dimensional Computer Aided Design tools which they use to produce the construction drawings. Prerequisite: Grade of C or better in MATH 1421; or concurrent enrollment in MATH 1426 or HONR-SC 1426; or grade of C or better in MATH 1426 or HONR-SC 1426.

AREN 2291. PROBLEMS IN ARCHITECTURAL ENGINEERING. 2 Hours.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the department chair.

AREN 2311. STATICS. 3 Hours.
Vector algebra; composition and resolution of forces; equivalence of force couple systems; equilibrium of force systems acting on particles, and force - couple systems acting on rigid bodies, and systems of rigid bodies; internal forces in rigid bodies; shear and moment diagrams; centroids and moments of inertia; frictional forces. Prerequisite: Grade of C or better in PHYS 1443.

AREN 2313. MECHANICS OF MATERIALS I. 3 Hours.
Concepts of stress and strain; stress-strain relationships. Behavior of members subjected to tension, compression, shear, bending, torsion, and combined loading. Deflections and elastic curves, shear and bending moment diagrams for beams, and column theory. Prerequisite: Grade of C or better in AREN 2311; Grade of C or better in MATH 2425.

AREN 2315. CONSTRUCTION MATERIALS AND METHODS. 3 Hours.
Materials, methods and sequences of the construction process; emphasis on design, specification, purchase and use of concrete, steel, masonry and wood. An understanding of the uses of construction materials. Prerequisite: Grade of C or better in AREN 1205.

AREN 2391. PROBLEMS IN ARCHITECTURAL ENGINEERING. 3 Hours.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the chair of the department.

AREN 3110. ARCHITECTURAL ENGINEERING COMMUNICATIONS. 1 Hour.
Technical writing, oral communication, professional presentations, and other related topics. Prerequisite: Grade of C or better in COMS 2302.

AREN 3143. PROPERTIES AND BEHAVIOR OF SOILS. 1 Hour.
An introduction to determination of civil engineering properties of soil and their behavior, identification, grain size analysis, Atterberg limits, compaction, permeability, consolidation, and shear strength. Also an introduction to sampling of soil materials. Prerequisite: Concurrent enrollment in AREN 3343.

AREN 3191. PROBLEMS IN ARCHITECTURAL ENGINEERING. 1 Hour.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the department chair.

AREN 3213. BUILDING SCIENCE I. 2 Hours.
This course introduces the physical phenomena that affect human comfort and building energy performance. The basic principles of thermodynamics applied to building systems are discussed to understand heat and mass transfer analysis techniques. This includes development and application of energy balance equation and psychrometric process with respect to building energy performance. Prerequisite: Grade of C or better in CHEM 1465 and PHYS 1444.

AREN 3218. ARCHITECTURAL ENGINEERING GEOMETRIC DESIGN TOOLS. 2 Hours.
This course will address principles of Euclidean and non-Euclidean Geometry in the area of architectural engineering. Topics include golden ratio, golden mean, geodesics on surfaces, conic sections, parametric equations with focus on the techniques, skills, and modern engineering tools necessary for architectural engineering practices. Prerequisite: MATH 1421 or equivalent, AREN 1205.

AREN 3291. PROBLEMS IN ARCHITECTURAL ENGINEERING. 2 Hours.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the department chair.

AREN 3301. STOCHASTIC MODELS FOR CIVIL ENGINEERING. 3 Hours.
Basic theory of probability and statistics with practical applications to civil and environmental engineering problems. Emphasis on sampling, distribution functions, tests of significance, and regression modeling. Prerequisite: Grade of C or better in MATH 2425.

AREN 3305. BASIC FLUID MECHANICS. 3 Hours.
Fundamentals of fluid statics, kinematics of fluid flow, fluid energy, fluid forces, similitude, and dimensional analysis. Related to steady flow of incompressible fluids in confined and free surface systems. Prerequisite: Grade of C or better in AREN 2311; Grade of C or better in MATH 3319 or concurrent enrollment.

AREN 3311. CONSTRUCTION ENGINEERING. 3 Hours.
Principles of construction engineering and the project management process, value engineering, specifications, different construction contracts and delivery methods, estimating and scheduling fundamentals and project control, and management of construction process. Prerequisite: Grade of C or better in IE 2308.

AREN 3331. MECHANICAL AND ELECTRICAL SYSTEMS. 3 Hours.
Mechanical and electrical systems with a major emphasis on estimating and installation, design and control of the electrical, heating, ventilation and cooling system, site planning and acoustical treatments. Prerequisite: Grade of C or better in PHYS 1444.

AREN 3341. STRUCTURAL ANALYSIS. 3 Hours.
Structural analysis/design process, structural forms, and basic structural elements. Analysis of statically determinate structures including beams, trusses, frames, and composite structures, shear and moment diagrams, influence lines, and moving loads. Methods to compute deflections including double integration, moment area, and virtual work. Methods of analysis for statically indeterminate structures including consistent deformation, slope deflection and moment distribution. Use of structural analysis programs. Prerequisite: Grade of C or better in AREN 2313.

AREN 3343. SOIL MECHANICS. 3 Hours.
An introduction to the significant geophysical and soil science properties and behavior of materials making up the earth's crust as they apply to civil engineering, sources of materials, classification, plasticity, permeability, stress distribution, consolidation, shear strength, and settlement. Also an introduction to basic foundation engineering concepts. Prerequisite: Grade of C or better in AREN 2313; Concurrent enrollment in AREN 3143.

AREN 3391. PROBLEMS IN ARCHITECTURAL ENGINEERING. 3 Hours.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the department chair.

AREN 4300. ADVANCED TOPICS IN ARCHITECTURAL ENGINEERING. 3 Hours.
Advanced topics of current interest in any one of the various fields of architectural engineering. The subject title to be listed in the class schedule. May be repeated for credit when topic changes. Prerequisite: Consent of instructor required and Admission to the AREN Professional Program.

AREN 4301. ADVANCED TOPICS IN ARCHITECTURAL ENGINEERING WITH LAB. 3 Hours.
Advanced topics of current interest in any one of the various fields of architectural engineering. The subject title to be listed in the class schedule. May be repeated for credit when topic changes. Prerequisite: Consent of instructor required and Admission to the AREN Professional Program.

AREN 4307. CONSTRUCTION SUSTAINABILITY. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Credit not granted for both AREN 4307 and CE 5382. Prerequisite: Grade of C or better in AREN 3311; Admission to the AREN Professional Program.

AREN 4309. THERMODYNAMICS FOR ARCHITECTURAL ENGINEERS. 3 Hours.
Basic concepts and definitions of thermodynamics, entropy, and introduction to first law of thermodynamics, second law of thermodynamics, and introduction to conductive, convective, and radiative transfer. Application of thermodynamics to building heating, cooling and ventilation (HVAC) systems; use of modern techniques for design and specifications of selected thermal and mechanical systems for buildings. Prerequisite: Grade of C or better in MATH 2425 (or HONR-SC 2425), PHYS 1444, and CHEM 1465 (or concurrent enrollment) or CHEM 1441 and CHEM 1442 (or concurrent enrollment).

AREN 4314. BUILDING SCIENCE II. 3 Hours.
The interactions of climate conditions, building systems, and occupant behavior are critical for energy efficiency of building systems while maintaining human comfort. This course discusses high performance building design and control strategies by understanding analytical techniques and building energy standards. The application topics such as thermal comfort, building enclosures, mechanical & electrical systems, and energy simulations are discussed. Prerequisite: Grade of C or better in AREN 3213. Admission to the AREN Professional Program.

AREN 4326. GIS/HYDROLOGIC & HYDRAULIC MODELING. 3 Hours.
Use of Geographic Information Systems (GIS) and design of GIS-developed hydrologic/hydraulic models commonly applied in the water resources field. The course will have three main areas of emphasis including: principles and operations of ArcGIS, design and implementation of standard hydrologic and hydraulic models, and the linkage of these models to engineering analysis of current water resources problems including flooding, water quality and water supply. Prerequisite: Grade of C or better in AREN 3305; Admission to the AREN Professional Program.

AREN 4331. BUILDING HVAC SYSTEMS DESIGN. 3 Hours.
This course will introduce the fundamental principles and engineering procedures for basic building science; design of heating, ventilating, and air conditioning (HVAC) systems; system and equipment selection; and duct design and layout. This course will also include energy conservation techniques and computer applications, including building energy modeling. Prerequisite: Grade of C or better in PHYS 1444; Admission to the AREN Professional Program.

AREN 4334. DRONES & ADVANCED CONSTRUCTION TECHNOLOGY. 3 Hours.
A practical course for technologies and their applications used on construction job sites. Topics include drones (also known as sUAS, or small unmanned aircraft systems), robotics, extended reality, artificial intelligence, blockchain, wearables, etc. Practical sessions are included to train students to operate drones for various construction applications. Credit not granted for both CE 4334 and AREN 4334. Prerequisite: Grade of C or better in AREN 3311; Admission to the AREN Professional Program.

AREN 4341. SUSTAINABLE BUILDING ENERGY MODELING. 3 Hours.
This course will introduce a whole process of net-zero energy building design in which students work in teams to design, analyze, and provide full documentation for a net-zero energy building. Students are expected to effectively and affordably integrate principles of building science, construction engineering and management, economic analysis, and architectural design in an integrated design process. The course projects will align with a design competition, typically the Department of Energy's Solar Decathlon Design Challenge. The course prepares the next generation of architects, engineers, and construction managers with skills and expertise to start their careers and generate creative solutions for real-world net zero energy buildings. Prerequisite: Grade of C or better in AREN 3213; Admission to the AREN Professional Program.

AREN 4343. HUMAN INTERACTION IN THE BUILT ENVIRONMENT. 3 Hours.
Understanding human interaction in the built environment is critical for assessing comfort levels and system performance. This course would cover theories of human computer interaction, environmental monitoring, and advanced data analytics. Students would be given a hands-on opportunity to build their own data acquisition system to collect and model human behavior. This course meets the emerging trend in a nexus of computer science and facility management. Prerequisite: Admission to the AREN Professional Program.

AREN 4346. ELECTRICAL SYSTEMS & LIGHTING FOR ARCHITECTURAL ENGINEERS. 3 Hours.
Basic fundamentals of electrical principles and electric lighting principles; application of basic electrical science for the design and specification of electrical systems and lighting for buildings using modern techniques; safety and protection systems in buildings and national electrical code and standards. Prerequisite: Grade of C or better in MATH 2425 (or HONR-SC 2425) and PHYS 1444; Admission to the AREN Professional Program.

AREN 4347. REINFORCED CONCRETE DESIGN. 3 Hours.
An analysis, design and synthesis course for concrete structures, emphasizing strength design method. Topics include strength and serviceability requirements, design of one way slabs, rectangular beams, flanged sections and columns, for strength, shear, bond, bearing, and serviceability. Building codes, American Concrete Institute (ACI) specifications, material specifications, test methods, and recommended practice documents are involved. Prerequisite: Grade of C or better in AREN 3341 and admission to the AREN Professional Program.

AREN 4348. STRUCTURAL DESIGN IN STEEL. 3 Hours.
A design synthesis course for structural steel structures using Allowable Strength Design and Load Resistance Factor Design. Topics include tension members, compression members, flexural members and simple connections. Building codes, American Institute of Steel Construction (AISC) specs, material specs, test methods, and recommended practice documents. Prerequisite: Grade of C or better in AREN 3341 and admission to the AREN Professional Program.

AREN 4352. PROFESSIONAL PRACTICE. 3 Hours.
Professional practice issues in the private and public sector are addressed by visiting practitioners. Topics include project management, teamwork, obtaining work, regulatory requirements, specifications, issues in design/build, design alternatives, cost estimation, design and construction drawings, contract and construction law, legal issues, ethics and professionalism, design reports, licensure, lifelong learning, ethical and engineering practice organizations. Learning principles of engineering practice by working as a team is emphasized. Oral and written presentations are required. Prerequisite: Admission to the AREN Professional Program.

AREN 4356. ADVANCED STEEL DESIGN. 3 Hours.
Covers torsional design of beams, beams with web holes, composite design of beams, lateral-torsional buckling of beams, plate buckling, column design and behavior, frame stability, bracing requirements for compression members. Prerequisite: Grade of C or better in AREN 4348 and Admission to the AREN Professional Program.

AREN 4360. DESIGN OF STRUCTURAL MASONRY. 3 Hours.
Covers masonry unit types and mortar types, reinforcing and connections. Design of beams, columns, pilasters, and walls. Structural behavior and construction practices. Includes plain and reinforced masonry. Building Codes, Masonry Standards Joint Committee (MSJC) specifications, material specifications, test methods, and recommended practice documents. Prerequisite: Grade of C or better in AREN 3341; Admission to the AREN Professional Program.

AREN 4361. ADVANCED REINFORCED CONCRETE DESIGN. 3 Hours.
Advanced topics on structural design of concrete structures. Topics include slender columns, shear walls, torsion, deep beams, brackets, retaining walls, strut and tie model for shear torsion, two-way slabs, and shear friction. Building codes, American Concrete Institute (ACI) specifications, material specifications, test methods, and recommended practice documents are involved. Prerequisite: Grade of C or better in AREN 4347 and Admission to the AREN Professional Program.

AREN 4365. STRUCTURAL WOOD DESIGN. 3 Hours.
Covers material grade and properties of wood, design criteria using structural lumber, glue laminated lumber and structural panels. Design of bending and compression members, trusses and diaphragms. Building codes, National Design Specification for Wood Construction (NDS) specifications, material specifications, test methods, and recommended practice documents. Prerequisite: Grade of C or better in AREN 3341; Admission to the AREN Professional Program.

AREN 4383. SENIOR PROJECT. 3 Hours.
This course will provide architectural engineering students the opportunity to apply tools, skills and principles of architecture engineering towards the planning, analysis of alternatives, and designs of engineering solutions for projects identified by the instructor. Projects will address engineering standards and multiple realistic constraints. Application of computer-aided design and engineering tools will be utilized for analysis and design. Student presentations will address alternative solutions, application of building code and engineering standards within architectural context. Students will work together and submit a team project. Prerequisite: Grade of C or better in AREN 4347; Grade of C or better in AREN 4348; Grade of C or better in AREN 4352; Completion of all required 3000 level courses; or permission of instructor.

AREN 4391. PROBLEMS IN ARCHITECTURAL ENGINEERING. 3 Hours.
Selected problems in architectural engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the chair of the department.

AREN 4393. INDUSTRIAL INTERNSHIP. 3 Hours.
Student to experience industrial internship under supervision of an industrial mentor and internship committee. Prerequisite: Admission to the AREN Professional Program.

AREN 4394. RESEARCH INTERNSHIP. 3 Hours.
Student to experience research internship under supervision of a CE faculty. Prerequisite: Admission to the AREN Professional Program.

COURSES

BE 1000. UNDERGRADUATE RESEARCH. 0 Hours.
Freshman level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

BE 1105. MEDICAL APPLICATIONS OF ENGINEERING. 1 Hour.
Introduction to basic biology and engineering problems associated with living systems and health care delivery. Examples will be used to illustrate how basic concepts and tools of science & engineering can be brought to bear in understanding, mimicking and utilizing biological processes.

BE 1325. INTRODUCTION TO BIOENGINEERING. 3 Hours.
Topics include introduction to basic engineering principles and quantitative methods, their applications in analyzing and solving problems in biology and medicine. Also includes new trends in the development of bioengineering and biotechnology.

BE 2000. UNDERGRADUATE RESEARCH. 0 Hours.
Sophomore level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

BE 2300. SPECIAL TOPICS IN BIOENGINEERING. 3 Hours.
A study of selected topics in Bioengineering. May be repeated when topics vary.

BE 2310. ENGINEERING APPROACHES TO SOLVING CLINICAL CHALLENGES. 3 Hours.
In this sophomore course, students will apply engineering principles to find solutions to current clinical problems presented to the class. As small groups, students will work as teams to design a process or system to meet the desired needs of the given clinical challenges based on the necessary constraints. As a final project presentation, students will use what they have learned to identify a new clinical challenge and work to define a meaningful set of manufacturing, fiscal, safety, ethical, and health-related constraints associated with the problem. Students will be highly encouraged to identify solutions to these newly derived clinical problems and to integrate this clinical challenge as part of their future senior design project. Prerequisite: C or better in BE 1105, BE 1325, MATH 2425, CHEM 1442, and BE 2315 or consent of BE undergraduate advisor.

BE 2315. INTRODUCTORY COMPUTATIONAL TOOLS FOR BIOENGINEERS. 3 Hours.
Students learn programming concepts (variable, array, command, logics, do-loop, etc.) through the use of SolidWorks, MatLab, and Image J, etc. Students learn to use these computational tools by working on problems and exercises of biological, physiological relevance and clinical applications. Prerequisite: A course grade of C or better in BE 1325, and MATH 1426 or consent of BE undergraduate advisor.

BE 3000. UNDERGRADUATE RESEARCH. 0 Hours.
Junior level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum 3 times.

BE 3101. SEMINAR IN BIOENGINEERING. 1 Hour.
University and guest lecturers speak on topics of current research interest in the field of bioengineering. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3180. INTRODUCTION TO MEDICAL DEVICE REGULATORY REQUIREMENTS AND QUALITY STANDARDS. 1 Hour.
Topics include introduction to fundamentals of regulatory requirements for medical devices, broadly defined as mechanical and electronic equipment or tissue-implantable constructs. Familiarization with national and international regulatory agencies, and presentation of the processes of securing regulatory approvals for medical devices. Emphasis will be on the U.S. Food and Drug Administration, but examples from other regulatory agencies will also be presented. The course also introduces students to the U.S. National Institute of Standards and Technology as well as various professional engineering societies that provide quality standards for bioengineering design. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3191. DIRECTED RESEARCH IN BIOENGINEERING. 1 Hour.
Student participates in a research project under the individual instruction of a faculty supervisor. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor and the instructor.

BE 3195. INTERNSHIP IN BIOENGINEERING. 1 Hour.
Students receive training in a bioengineering company or a hospital to gain firsthand industrial or clinical engineering experience. The company or hospital assign projects and a faculty member monitors the student's progress. Prerequisite: Completion of at least 70 undergraduate credit hours in BE and good standing in the undergraduate program. Permission of Undergraduate Academic Advisor.

BE 3295. INTERNSHIP IN BIOENGINEERING. 2 Hours.
Students receive training in a bioengineering company or a hospital to gain first hand industrial or clinical engineering experience. The company or hospital assigns projects and a faculty member monitors the student's progress. Prerequisite: Completion of at least 70 undergraduate credit hours in BE and good standing in the undergraduate program. Permission of Undergraduate Academic Advisor.

BE 3301. CELL PHYSIOLOGY FOR BIOENGINEERS. 3 Hours.
This course will cover principles of molecular omics (i.e., genomics, transcriptomics, proteomics and synthetic biology); the field of molecular bioengineering and processes involving inducible transcription and chimeric proteins; the composition of cell membranes, ion transport and the application of optogenetics in cell physiology regulation; the way cells communicate and integrate signals and translate them in intracellular metabolic cascades through the understanding of phosphoproteomics, energy metabolism, metabolomics, cellular motility, and molecular motors; the processes involved in cell proliferation, abnormal cell division dysregulation in cancer, and nanotechnology techniques for tumor treatment. Preferred background: basic understanding of general biology and general chemistry. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3310. BIOMECHANICS AND FLUID FLOW WITH COMPUTATIONAL LABORATORY. 3 Hours.
Following an introduction to the basics of solid, fluid mechanics, student learn the fundamental behavior of various biological materials, flow properties of blood, viscoelastic properties of cells, tissue matrix, as well as their roles in human physiology at normal and disease states. Examples also include the design aspects of medical prosthetic devices. The course will cover biomechanics across a wide range of scales from organism, organ, tissue, cell and to protein levels. Students learn computational modeling to formulate and solve bioengineering problems. Preferred background: basic understanding of general physics, general biology and basic calculus. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3317. LINEAR SYSTEMS IN BIOENGINEERING. 3 Hours.
Time-domain transient analysis, convolution, Laplace Transforms, Fourier Series, Transforms and their applications, transfer functions, signal flow diagrams, Bode plots, stability criteria, sampling, filter designs, and Discrete-time signals and systems. Examples with applications in bioengineering will be emphasized. Preferred background: basic understanding of general physics, general biology and basic calculus. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3320. MEASUREMENT LABORATORY. 3 Hours.
Hands-on experiments with use of transducers used for chemical, mechanical, electrical, and thermal biomedical measurements. Computer-based means of converting analog transducer output into digital form. Analysis of experimentally collected data including error analysis, repeatability, resolution, and functional specifications. Prerequisite: C or better in MATH 2326, BE 2315 and PHYS 1444 (PHYS 1444 may be taken concurrently), or consent of the BE undergraduate advisor.

BE 3325. FLUORESCENCE MICROSCOPY. 3 Hours.
Introduction to the anatomy of fluorescence microscopy and the physical principles of its operation; confocal and multi-photon microscopy; molecular imaging applications based on Forster Resonance Energy Transfer (FRET), Fluorescence Lifetime Imaging (FLIM), Fluorescence Correlation Spectroscopy (FCS), Fluorescence Recovery After Photobleaching (FRAP) and Total Internal Reflection Fluorescence (TIRF) Microscopy. Preferred background: basic understanding of general physics, general chemistry, general biology and basic calculus. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3327. TISSUE OPTICS. 3 Hours.
Introduction to the science and technology behind tissue optical imaging systems and their design requirements for different clinical applications; diffuse optical tomography; fluorescence tomography; bioluminescence tomography; multi-modality imaging. Preferred background: basic understanding of general physics, general chemistry, general biology and basic calculus. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3343. MATLAB AND APPLICATIONS FOR BIOENGINEERS. 3 Hours.
This course consists of two parts: the first part teaches students how to use MATLAB for engineering computation, quantitative analysis, scientific plotting/graphing presentation, and numerical modeling in solving real-world problems. After enabling students to generate arrays, files, functions, and to write MATLAB programs, the course will focus on using MATLAB for bioengineering applications, including 2D and 3D graphing for biological images, data processing for time-varying signals, and 2D Fourier transform for medical image processing. A variety of examples often encountered in the biological, biomedical engineering field will be used as class demonstration, presentation and project assignments. Preferred background: basic programming skills. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3344. BIOINSTRUMENTATION. 3 Hours.
Fundamental principles of bioinstrumentation, including operational amplifiers and instrumentation amplifiers; measurements of biopotentials; signals and noise in biological systems; mechanical transducers; resistive, inductive, capacitive transducers; measurement of temperature, blood pressure and flow; electrical safety. Prerequisite: C or better in EE 2440 or CSE 2440; accepted in BE Professional Program or consent of the BE undergraduate advisor.

BE 3346. MEDICAL IMAGING. 3 Hours.
This course introduces basic medical imaging modalities, including X-ray Computed Tomography (CT), Nuclear Medicine Imaging (PET and SPECT), Magnetic Resonance Imaging (MRI), and image-guided interventions. Through this course, the students will learn fundamental knowledge on how medical images are obtained and how they can be used for diagnosis, therapy, and surgery. Preferred background: basic understanding of general physics, general biology and basic calculus. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3352. DIGITAL PROCESSING OF BIOLOGICAL SIGNALS. 3 Hours.
Fundamental techniques for extraction of useful information from signals acquired from biological systems. Topics include time and frequency domain analysis, cross correlation, spectrum analysis, and convolution. Design of finite impulse response (FIR) and infinite impulse response (IIR) filters for processing biological signals are described. Examples include cardiac, respiratory, and biomechanical movements. Preferred background: basic understanding of general physics and differential equations. Prerequisite: Accepted into the BE Professional Program and BE 3317 (or equivalent course) or consent of the BE undergraduate advisor.

BE 3367. CELL CULTURE AND DRUG DELIVERY LABORATORY. 3 Hours.
This course will cover techniques commonly used in tissue engineering and biomaterial research, including culture media preparation, cell culture/subculture, degradable scaffold, their modification, histological staining, and imaging analyses. The course will also include development of systems for delivery of pharmaceutical agents used for treating different diseases; an understanding of the underlying pharmacokinetics principles is emphasized. Preferred background: basic understanding of general chemistry and general biology. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3380. HUMAN PHYSIOLOGY IN BE. 3 Hours.
An introduction to human physiology emphasizing biomedical engineering related topics. The course focuses on understanding basic function with the relationships on the cellular as well as organ level in both healthy and diseased states. Preferred background: basic understanding of general biology. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 3395. INTERNSHIP IN BIOENGINEERING. 3 Hours.
Students receive training in a bioengineering company or a hospital to gain first hand industrial or clinical engineering experience. The company or hospital assigns projects and a faculty member monitors the student's progress. Prerequisite: Completion of at least 70 undergraduate credit hours in BE and good standing in the undergraduate program. Permission of Undergraduate Academic Advisor.

BE 3415. FUNDAMENTALS OF BIOMOLECULAR ENGINEERING. 4 Hours.
The course will introduce the principles of engineering living systems at the atomic, molecular, and cellular levels. Fundamentals covered in the course will include topics such as chemical bonding and reactions; synthesis, structure and function of carbohydrates, polypeptides, nucleic acids, and lipids; as well as analytical and engineering tools for characterization, design, and production of synthetic biological systems. A laboratory component will provide hands on experience including methods important to synthetic biochemistry, protein engineering, cellular reprogramming, and metabolic engineering. Knowledge of college level general chemistry is required. Prerequisite: C or better in BE 1105, BE 1325, BIOL 1441, CHEM 1442, and MATH 2425, or consent of the BE undergraduate advisor.

BE 4000. UNDERGRADUATE RESEARCH. 0 Hours.
Senior level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

BE 4191. DIRECTED RESEARCH IN BIOENGINEERING. 1 Hour.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 4291. DIRECTED RESEARCH IN BIOENGINEERING. 2 Hours.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 4300. SPECIAL TOPICS IN BIOENGINEERING. 3 Hours.
A study of selected topics in Bioengineering. May be repeated when topics vary. Prerequisite: Consent of instructor and undergraduate advisor.

BE 4312. TISSUE BIOMECHANICS AND BIOENGINEERING. 3 Hours.
This course introduces biomechanics as a means to describe mechanical behavior of biological tissues. A comprehensive course, it covers the fundamental concepts, experimental and theoretical approaches of biomechanics, and their applications in modern bioengineering, including mechano signal transduction, pathophysiology, tissue engineering and regeneration, medical implants, surgical intervention. Structural-mechanical properties of specific tissues, such as heart valves, cardiac tissues, blood vessels, tendon/ligament, skeletal muscles, cartilage, and meniscus will be discussed in great details. This course integrates the concepts of biomechanics, the underlying structural and biological mechanisms, illustrates how experimental, analytical and computational methods have been used to address clinical needs in enhancing the quality of health care delivery. Preferred background: satisfactory completion of BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4314. BIOMEDICAL IMPLANTS. 3 Hours.
A comprehensive course covers the essential knowledge in biomedical implants. The goal is to provide students with the knowledge and skills to understand the clinical needs, the engineering principles, methodologies used in implant design, the resulting host-implant interaction, and the constraints, limitations on engineering design optimization, as well as the evaluation and assessment of the implant performance and clinical outcomes. Case studies include mechanical, bio-prosthetic and trans-catheter heart valves, vascular grafts, stents, pacemakers, orthopedic implants, dental implants, etc. The course also covers topics on regulatory issues, patent protection, design validation in animal models and clinical trials, IACUC, IRB, Good Manufacture Practice (GMP), and FDA regulations and approvals. Students are expected to be able to apply the learning to solve problems in the rapidly growing field of biomedical engineering. Preferred background: satisfactory completion of BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4318. MEDICAL DEVICE PROTOTYPING. 3 Hours.
This course introduces students to fundamental skills for prototyping medical devices and tissue engineering implants using 3D printing and supporting software. The lectures and exercises provide in depth understanding of the software. Students will learn to build simple 3D parts, move towards designing medical implants and devices for bioengineering applications as well as practice running mechanical simulations on the prototypes. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate adviser.

BE 4324. BIOMEDICAL OPTICS LABORATORY. 3 Hours.
The primary objective of this course is to provide students hands-on experience with fundamental optical techniques and instrumentation used in modern biomedical research and applications. The skills learned will be valuable to anyone who intends to work in an experimental setting that requires working knowledge of optical instrumentation and techniques. The course is divided into ten core lab modules that cover topics ranging from basic optical techniques to advanced imaging and spectroscopy techniques. Preferred background: satisfactory completion of BE 3320. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4325. FUNDAMENTALS OF BIOENGINEERING. 3 Hours.
Topics cover fundamentals of biosensors, bio-signal processing, and bioinstrumentation. An introduction to various imaging modalities such as ultrasound, magnetic resonance, optical tomography, and x-ray radiography is also presented. Other bioengineering topics may be included as time allows or as is appropriate. Preferred background: satisfactory completion of BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4326. TISSUE ULTRASOUND-OPTICAL IMAGING. 3 Hours.
This course will introduce the fundamental principles of ultrasound and optical related imaging techniques, such as ultrasonic, tissue optical, and photoacoustic imaging techniques. Some topics related to the new progresses and applications in the related fields will be introduced. Students are expected to know the principles of these imaging techniques, and use mathematical, numerical simulation and experimental methods to understand these technologies and their biomedical applications. Preferred background: satisfactory completion of PHYS 1443, PHYS 1444 and BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4329. NEURAL ENGINEERING. 3 Hours.
This course consists of both lecture/discussion and laboratory. Lecture topics include central and peripheral nervous system injury and regeneration, brain/machine interfacing, primary culture of neural cells, neuroinflammatory and neurodegenerative disease. Laboratories include embryonic and neonatal rat derived neuronal culturing, immunostaining and quantitative analysis. Preferred background: satisfactory completion of BE 3367 and BE 3380. Prerequisites: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4330. MEDICAL IMAGE PROCESSING. 3 Hours.
Principles and computational methods in digitally processing medical images are presented. Topics include image reconstruction, two and three dimensional visualization, image registration, quantitative image analysis, image enhancement, and statistical processing methods including Monte Carlo methods. Prerequisites: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4331. BIOPOLYMERS AND BIOCOMPATIBILITY. 3 Hours.
This is a foundation course in polymeric biomaterial design, synthesis, characterization, and processing. The topics include design, surface-engineering, functionalization, characterization, as well as micro- and nano-fabrication of polymeric biomaterials. The biomedical applications of the polymeric biomaterials and their interaction with cell/tissue is discussed. Preferred background: basic understanding of general chemistry and successful completion of BE 3415. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4333. NANO BIOMATERIALS AND LIVING-SYSTEMS INTERACTION. 3 Hours.
Synthesis, fabrication, characterization, and biomedical applications of nanobiomaterials. Topics include synthetic nanobiomaterials, biological nanobiomaterials (DNA nanomaterials, protein and peptide nanomaterials, etc.), biofunctionalization of nanobiomaterials, and use of nanobiomaterials in tissue engineering, drug delivery, gene delivery. Preferred background: basic understanding of general chemistry and successful completion of BE 3415. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4337. TRANSPORT PHENOMENA IN BIOMEDICAL ENGINEERING. 3 Hours.
Principles of momentum, mass and heat transfer; description of blood flow, trans-capillary, interstitial, lymphatic fluid transport and pulmonary gas exchange. Applications in the design of blood oxygenator, dialysis devices, and strategies in drug delivery, hyperthermia treatment. Preferred background: basic understanding of general physics, biology and calculus, and successful completion of BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4345. BIOSENSORS. 3 Hours.
The course will cover major classes of bio-sensing technologies currently used in practice and the emerging ones that are currently being evaluated. The basic operating principle behind bio-sensing technologies will be explained and its implementation in medical devices will be discussed. Explanation of biosensor operation will involve understanding the mechanism of bio-signal transduction (bio-parameter to biomechanical, electrical, optical or chemical signal), detection method, and their analysis. Methodology for device calibration and data interpretation of physiological parameters will be discussed. The course material will be derived from book chapters and review papers. Course includes hand-on learning experience in laboratory by deconstructing commercially available biosensors and using experimental bio-sensing instruments. Students will be required to design and implement a point-of-care biosensor. Preferred background: satisfactory completion of EE 2440 or CSE 2440. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4350. SENIOR DESIGN PROJECT I. 3 Hours.
First of two courses in design of biomedical systems and processes. Major design project in biomedical engineering, incorporating engineering standards and realistic design constraints. This course prepares students through a major design experience incorporating engineering principles and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, and social consideration. Prerequisite: C or better in BE 3317, BE 3380 and BE 4382; accepted into the BE Professional Program, and consent of the BE undergraduate advisor.

BE 4355. SENIOR DESIGN PROJECT II. 3 Hours.
Second in two courses in design of biomedical systems. Proposals approved in BE 4350 will be completed. Teams will address, resolve limitations in the design and present final results through an oral presentation. Teams are required to submit a final project report with their design notebooks to the course instructors. Prerequisite: C or better in BE 4350.

BE 4360. FUNDAMENTALS OF ULTRASOUND IN BIOENGINEERING. 3 Hours.
This course instructs the students in the physics of ultrasound transducers, their operation, and their biomedical applications. The material includes modeling of the interaction of acoustic waves with various types of tissue and cells. Mathematical methods for analyzing the reflected and refracted waves as well as constructing images from the waves will be covered. Prerequisite: Accepted into the BE Professional Program and EE 2440 or CSE 2440, BE 3344, or consent of the BE undergraduate advisor.

BE 4364. TISSUE ENGINEERING LECTURE. 3 Hours.
Fundamentals of cell/extracellular matrix interactions in terms of cell spreading, migration, proliferation and function; soft and hard tissue wound healing and nerve regeneration; polymer scaffolding materials and fabrication methods; cell-polymer interactions; in vitro and in vivo tissue culture and organ replacement. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4365. TISSUE ENGINEERING LABORATORY. 3 Hours.
Each student will be given the opportunity to perform the techniques commonly used in tissue engineering and biomaterial research. These techniques are culture media preparation, cell culture/subculture, degradable scaffold preparation, scaffold modification, histological sections and staining, and cell imaging analyses. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4366. PROCESS CONTROL IN BIOTECHNOLOGY. 3 Hours.
Principles and methods and measurement, data acquisition, and analysis. Application of control theory in biological systems and in biotechnology processes; control of pressure, flow, temperature, and pH. Prerequisite: Accepted into the Professional Program and BE 3317 (or equivalent course) or consent of the BE undergraduate advisor.

BE 4368. AN INTRODUCTION TO TISSUE ENGINEERING AND DRUG DELIVERY. 3 Hours.
Topics include fundamentals of cell-ECM interactions, cell spreading, migration, proliferation and function; soft and hard tissue wound healing and nerve regeneration; polymer scaffolding materials and fabrication methods; cell-polymer interactions; in vitro and in vivo tissue culture and organ replacement. Students will be introduced to basic principles of pharmacokinetics and pharmacodynamics. Topics also include design and development of targeted and controlled drug delivery systems, including transdermal, inhalation, drug-eluting stents, stimulated-drug, as well as encapsulated nano and micro-particles for controlled release. Underlying principles of drug delivery, targeting, modification, distribution and diffusive transport will be discussed. Preferred background: satisfactory completion of BE 3380 (or co-requisite). Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4372. DRUG DELIVERY SYSTEMS. 3 Hours.
This class focuses on the development, design, and application of controlled and targeted drug delivery systems including transdermal, inhalation, drug eluting stents, stimulation-drug, as well as microparticles and nanoparticles for controlled drug delivery. Principles of drug delivery, targeting, modification, distribution and diffusion will be discussed. Preferred background: satisfactory completion of BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4373. FORMULATION AND CHARACTERIZATION OF DRUG DELIVERY SYSTEMS. 3 Hours.
This class will provide students with hands-on experience in the development of drug delivery systems such as hydrogels, scaffolds, microparticles and/or nanoparticles that can be loaded with and release pharmaceutical agents to treat various diseases. The emphasis is synthesis, characterization and pharmacokinetic studies of these drug delivery systems. Preferred background: satisfactory completion of BE 4372. Prerequisite: Accepted into the BE Engineering Professional Program or consent of the BE undergraduate advisor.

BE 4382. LABORATORY PRINCIPLES. 3 Hours.
Introduction to fundamental biomedical engineering laboratory procedures including human studies and animal surgery; includes clinical laboratory projects, data collection, analysis, and interpretation. Preferred background: satisfactory completion of BE 3320 and BE 3380. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4385. STEM CELL TISSUE ENGINEERING. 3 Hours.
Students will gain experience and expertise in stem cell culture and differentiation, and engineering stem cell-based 2D and 3D tissue constructs. Using phenotypic markers and appropriately integrating with biocompatible scaffolds, the engineered tissue constructs will be differentiated to several tissue types and functionally validated. Lectures will cover stem cells, designing scaffolds and multimodal imaging techniques. The final projects may include acquisition of big data images, data mining and development of pattern recognition algorithms. Prerequisite: Accepted into the BE Professional Program and BE 3380, BE 3301, BE 3367, or consent of the undergraduate advisor.

BE 4388. MEDICAL PRODUCT DESIGN AND DEVELOPMENT. 3 Hours.
This course aims to provide, 1) A comprehensive knowledge of biomedical product design and development life cycle, 2) Basic knowledge on developing business plan, securing funding, designing product and process, conducting preclinical and clinical studies, 3) Basic training and classroom exercises on various biomedical product design and development tools, 4) Basic knowledge of FDA regulation and quality control, 5) Basic training on intellectual property and industrial project management. Prerequisite: Accepted into the BE Professional Program or consent of the BE undergraduate advisor.

BE 4390. UNDERGRADUATE RESEARCH PROJECT. 3 Hours.
Student works on an independent, individual research or development project under supervision of faculty instructor. A final project report is required. Prerequisite: Permission from Instructor.

BE 4391. DIRECTED RESEARCH IN BIOENGINEERING. 3 Hours.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 5101. SEMINAR IN BIOENGINEERING. 1 Hour.
University and guest lecturers speak on topics of current interest in the field of bioengineering.

BE 5191. DIRECTED RESEARCH IN BIOENGINEERING. 1 Hour.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 5193. MS COMPREHENSIVE EXAMINATION. 1 Hour.
Individual instruction, directed study, consultation, and comprehensive examination over coursework leading to the Thesis-Substitute Master of Science degree in bioengineering. Graded P/F/R. Required of all Thesis-Substitute MS students.

BE 5201. SEMINAR IN BIOENGINEERING. 2 Hours.
University and guest lecturers speak on topics of current research interest in the field of bioengineering. Students are expected to write a report for each topic to summarize the presentation and to offer critiques. Prerequisite: Graduate admission to the BE MS program.

BE 5281. BEST PRACTICES IN TEACHING AND LEARNING. 2 Hours.
Introduction to approaches and activities that can facilitate learning. Students gain insight into specific challenges of teaching, basics of designing a course, role of assessments and evaluations, good presentation skills and comparisons of various engagement levels. Students teach mock lessons and are given feedback.

BE 5291. DIRECTED RESEARCH IN BIOENGINEERING. 2 Hours.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 5293. MASTERS COMPREHENSIVE EXAMINATION. 2 Hours.
Individual instruction, directed study, consultation, and comprehensive examination over coursework leading to the Master of Science degree in bioengineering. Required of all MS students.

BE 5300. SELECTED TOPICS IN BIOENGINEERING. 3 Hours.
Material may vary from semester to semester. May be repeated for credit if different topics are covered for each registration. Prerequisite: permission of the instructor.

BE 5301. CELL PHYSIOLOGY FOR BIOENGINEERS. 3 Hours.
This course will cover principles of molecular omics (i.e., genomics, transcriptomics, proteomics and synthetic biology). The field of Molecular bioengineering and processes involving inducible transcription and chimeric proteins. The composition of cell membranes, ion transport and the application of optogenetics in cell physiology regulation. The way cells communicate and integrate signals and translated them in intracellular metabolic cascades through the understanding of phosphoproteomics, energy metabolism, metabolomics, cellular motility, and molecular motors. The processes involved in cell proliferation, abnormal cell division dysregulation in cancer, and nanotechnology techniques for tumor treatment. Prerequisite: Graduate Level or Instructor Permission.

BE 5309. HUMAN PHYSIOLOGY IN BIOENGINEERING. 3 Hours.
An introduction to human physiology emphasizing biomedical engineering related topics. The course focuses on understanding basic function with the relationships on the cellular as well as organ level both in healthy and diseased states.

BE 5310. BIOMECHANICS AND FLUID FLOW WITH COMPUTATIONAL LAB. 3 Hours.
Follow an introduction to the basics of solid, fluid mechanics, student learn the fundamental behavior of various biological materials, flow properties of blood, viscoelastic properties of cells, tissue matrix, as well as their roles in human physiology at normal and disease states. Examples also include the design aspects of medical prosthetic devices. The course will cover biomechanics across a wide range of scales from organism, organ, tissue, cell and to protein levels. Students learn computational modeling to formulate and solve bioengineering problems. Prerequisite: Undergraduate solid and fluid mechanics courses or consent of the instructor.

BE 5312. TISSUE BIOMECHANICS AND BIOENGINEERING. 3 Hours.
This course introduces biomechanics as a means to describe mechanical behavior of biological tissues. A comprehensive course, it covers the fundamental concepts, experimental and theoretical approaches of biomechanics, and their applications in modern bioengineering, including mechano signal transduction, pathophysiology, tissue engineering and regeneration, medical implants, surgical intervention. Structural-mechanical properties of specific tissues, such as heart valves, cardiac tissues, blood vessels, tendon/ligament, skeletal muscles, cartilage, and meniscus will be discussed in great details. This course integrates the concepts of biomechanics, the underlying structural and biological mechanisms, illustrates how experimental, analytical and computational methods have been used to address clinical needs in enhancing the quality of health care delivery.

BE 5314. BIOMEDICAL IMPLANTS. 3 Hours.
A comprehensive course covers the essential knowledge in biomedical implants. The goal is to provide students with the knowledge and skills to understand the clinical needs, the engineering principles, methodologies used in implant design, the resulting host-implant interaction, and the constraints, limitations on engineering design optimization, as well as the evaluation and assessment of the implant performance and clinical outcomes. Case studies include mechanical, bio-prosthetic and trans-catheter heart valves, vascular grafts, stents, pacemakers, orthopedic implants, dental implants, etc. The course also covers topics on regulatory issues, patent protection, design validation in animal models and clinical trials, IACUC, IRB, Good Manufacture Practice (GMP), and FDA regulations and approvals. Students are expected to be able to apply the learning to solve problems in the rapidly growing field of biomedical engineering.

BE 5315. FUNDAMENTALS OF BIOMOLECULAR ENGINEERING. 3 Hours.
The course will introduce the principles of engineering living systems at the atomic, molecular, and cellular levels. Fundamentals covered in the course will include topics such as chemical bonding and reactions; synthesis, structure and function of carbohydrates, polypeptides, nucleic acids, and lipids; as well as analytical and engineering tools for characterization, design, and production of synthetic biological systems.

BE 5316. FUNDAMENTAL MATH AND PHYSICS FOR BIOENGINEERING. 3 Hours.
This course introduces the basic physics concepts such as introduction to electromagnetism, Maxwell's equations, computation of Fresnel coefficients, interference and diffraction of light, waveguides and optical fibers, photon counting statistics, and Beer-Lambert law. It also covers basic mathematical concepts such as curvilinear coordinates, vector calculus, Stokes theorem and solving differential equations with initial conditions and the diffusion equation.

BE 5318. MEDICAL DEVICE PROTOTYPING. 3 Hours.
This course introduces students to fundamental skills for the prototyping medical devices and tissue engineering implants using 3D printing and supporting software. The lectures and exercises provide in depth understanding of the software. Students will learn to build simple 3D parts, move towards designing medical implants and devices for bioengineering applications, as well as practice running mechanical simulations on the prototypes.

BE 5323. INTRODUCTION TO BIOPHOTONICS. 3 Hours.
Introduction to properties of light, light-cell/tissue interactions, optical techniques, and optical instrumentation, in the context of biophotonic medical applications. Topics that will be covered include fundamental properties of optical wave fields, basic properties and characterization of laser sources and detectors used in modern biomedicine, interferometry, linear and nonlinear light-tissue interactions exploited for biomedical imaging and sensing applications, and spectroscopy.

BE 5324. BIOMEDICAL OPTICS LABORATORY. 3 Hours.
The primary objective of the Biomedical Optics Laboratory course is to provide students hands-on experience with fundamental optical techniques and instrumentation used in modern biomedical research and applications. The skills learned will be valuable to anyone who intends to work in an experimental setting that requires working knowledge of optical instrumentation and techniques. The course is divided into ten core lab modules that cover topics ranging from basic optical techniques to advanced imaging and spectroscopy techniques.

BE 5325. FLUORESCENCE MICROSCOPY. 3 Hours.
Introduction to the anatomy of a fluorescence microscope and the physical principles of its operation. Confocal and multi-photon microscopy. Molecular imaging applications based on Forster Resonance Energy Transfer (FRET), Fluorescence Lifetime Imaging (FLIM), Fluorescence Correlation Spectroscopy (FCS), Fluorescence Recovery After Photobleaching (FRAP) and Total Internal Reflection Fluorescence (TIRF) Microscopy.

BE 5326. TISSUE ULTRASOUND OPTICAL IMAGING. 3 Hours.
This course will introduce the fundamental principles of ultrasound and optical related imaging techniques, such as ultrasound, tissue optical, photo-acoustic and ultrasound-modulated optical imaging techniques. Lectures, laboratories, simulations, and paper presentations and discussion will be adopted in this course. Some topics related to the new progresses and applications in the related fields will be introduced. Prerequisite: Graduate level or instructor permission.

BE 5327. TISSUE OPTICS. 3 Hours.
Introduction to the science and technology behind tissue optical imaging systems and their design requirements for different clinical applications. Diffuse optical tomography, fluorescence tomography, bioluminescence tomography, multi-modality imaging.

BE 5329. NEURAL ENGINEERING. 3 Hours.
This course consists of both lecture/discussion and laboratory. Lecture topics include central and peripheral nervous system injury and regeneration, brain/machine interfacing, primary culture of neural cells, neuroinflammatory and neurodegenerative disease. Laboratories include embryonic and neonatal rat derived neuronal culturing, immunostaining and quantitative analysis.

BE 5331. POLYMERS AND BIOCOMPATIBILITY. 3 Hours.
This is a foundation course in polymeric biomaterial design, synthesis, characterization, and processing. The topics include design, surface-engineering, functionalization, characterization, as well as micro- and nano-fabrication of polymeric biomaterials. The biomedical applications of the polymeric biomaterials and their interaction with cell/tissue is discussed.

BE 5333. NANO BIOMATERIALS AND LIVING-SYSTEMS INTERACTION. 3 Hours.
Synthesis, fabrication, characterization, and biomedical applications of nanobiomaterials. Topics include synthetic nanobiomaterials, biological nanobiomaterials (DNA nanomaterials, protein and peptide nanomaterials, etc.), biofunctionalization of nanobiomaterials, use of nanobiomaterials in tissue engineering, drug delivery, gene delivery.

BE 5335. BIOLOGICAL MATERIALS, MECHANICS, & PROCESSES. 3 Hours.
Typical functional behavior of various biological materials, flow properties of blood, bioviscoelastic fluids and solids, mass transfer in cardiovascular and pulmonary systems.

BE 5337. TRANSPORT PHENOMENA IN BIOMEDICAL ENGINEERING. 3 Hours.
Principles of momentum, mass and heat transfer; description of blood flow, trans-capillary, interstitial, lymphatic fluid transport and pulmonary gas exchange. Applications in the design of blood oxygenator, dialysis devices, and strategies in drug delivery, hyperthermia treatment. Prerequisite: undergraduate courses in CE 2312 Statics/Dynamics, MAE 2314 Fluid Mechanics I or CE 3305 and MAE 3310 Thermodynamics I or CHEM 3321.

BE 5340. FINITE ELEMENT APPLICATIONS IN BIOENGINEERING. 3 Hours.
The course describes the fundamental principles of the finite element method and various numerical modeling techniques. Topics include variational and Galerkin formulations, linear and Hermitian elements, accuracy and convergence. Applications in biological systems and to the design of prosthetic devices are emphasized. Topic areas include linear elasticity, fluid dynamics, heat transfer, and mass transport processes.

BE 5343. IMAGE PROCESSING WITH MATLAB: APPLICATIONS IN MEDICINE AND BIOLOGY. 3 Hours.
This course focuses on introduction to image processing for applications in medicine and biology. After a review of how to use MATLAB arrays, files, functions, and to write MATLAB programs for quantitative computation and graphing, students will learn the fundamental tools in image processing, image analysis, and two-dimensional Fourier transform, using MATLAB functions available in the textbook. Topics also include image segmentation. Real-world research-based examples will be presented, and discussed in the course. With hands-on exercises, students will learn the basic skills, knowledge on MATLAB usage and the problem-solving techniques required for medical image processing.

BE 5344. BIOINSTRUMENTATION I. 3 Hours.
Fundamental principles of bioinstrumentation, including operational amplifiers and instrumentation amplifiers; measurements of biopotentials; signals and noise in biological systems; mechanical transducers; resistive, inductive, capacitive transducers; measurement of temperature, blood pressure and flow; electrical safety.

BE 5345. BIOSENSOR. 3 Hours.
The course will cover major classes of bio-sensing technologies currently used in practice and the emerging ones that are currently being evaluated. The basic operating principle behind bio-sensing technologies will be explained and its implementation in medical devices will be discussed. Explanation of biosensor operation will involve understanding the mechanism of bio-signal transduction (bio-parameter to biomechanical, electrical, optical or chemical signal), detection method, and their analysis. Methodology for device calibration and data interpretation of physiological parameters will be discussed. The course material will be derived from book chapters and review papers. Course includes hand-on learning experience in laboratory by deconstructing commercially available biosensors and using experimental bio-sensing instruments. Students will be required to design and implement a point-of-care biosensor. Prerequisite: Undergraduate instrumentation courses or consent of the instructor.

BE 5346. MEDICAL IMAGING. 3 Hours.
This course introduces basic medical imaging modalities, including X-ray Computed Tomography (CT), Nuclear Medicine Imaging (PET and SPECT), Magnetic Resonance Imaging (MRI), and image-guided interventions. Through this course, the students will learn fundamental knowledge on how medical images are obtained and how they can be used for diagnosis, therapy, and surgery.

BE 5347. PRINCIPLES OF FUNCTIONAL MAGNETIC RESONANCE IMAGING. 3 Hours.
This course introduces basic principles of Magnetic Resonance Imaging (MRI) and functional MRI (fMRI) for brain functional imaging. After taking this course, the students will gain basic knowledge on how functional brain images are obtained from MRI and fMRI as well as how they can be used for diagnosis, therapy, and surgery. The emphasis in this course is on fMRI . This course will include lecture and some laboratory exercises involving actual fMRI measurement data.

BE 5350. MODELING AND CONTROL OF BIOLOGICAL SYSTEMS. 3 Hours.
Introduction to fundamental methods of modeling, analysis and control of biological systems. Linear system modeling, state space modeling, stability analysis, basic identification techniques. Examples from cardiopulmonary, visual, and motor control systems. Prerequisite: an undergraduate course in linear systems, control theory, or consent of the instructor.

BE 5352. DIGITAL PROCESSING OF BIOLOGICAL SIGNALS. 3 Hours.
Fundamental techniques for extraction of useful information from signals acquired from biological systems. Topics include time and frequency domain analysis, cross correlation, spectrum analysis, and convolution. Design of FIR and IIR filters for processing biological signals are described. Examples include cardiac, respiratory, and biomechanical movements. Prerequisite: an undergraduate engineering course in signals and systems analysis or consent of the instructor.

BE 5360. DESIGN AND APPLICATION OF ARTIFICIAL ORGANS. 3 Hours.
Fundamental principles of fluid mechanics, mass transfer and chemical reaction in engineered biological systems. Simple solutions are developed for the design of artificial ventricular assist devices, total artificial hearts, lungs and kidneys.

BE 5361. BIOMATERIALS AND BLOOD COMPATIBILITY. 3 Hours.
This course is an introduction to polymer structure and fabrication methods. Blood and tissue interactions with materials, and methods to improve the biocompatibility of materials are discussed.

BE 5364. TISSUE ENGINEERING LECTURE. 3 Hours.
Fundamentals of cell/extracellular matrix interactions in terms of cell spreading, migration, proliferation and function. Soft and hard tissue wound healing and nerve regeneration. Polymer scaffolding materials and fabrication methods. Cell-polymer interactions. In vitro and in vivo tissue culture and organ replacement.

BE 5365. TISSUE ENGINEERING LAB. 3 Hours.
Each student will be given the opportunity to perform the techniques commonly used in tissue engineering and biomaterial research. These techniques are culture media preparation, cell culture/subculture, degradable scaffold preparation, scaffold modification, histological sections and staining, and cell imaging analyses.

BE 5366. PROCESS CONTROL IN BIOTECHNOLOGY. 3 Hours.
Principles and methods of measurement, data acquisition and analysis. Application of control theory in biological systems and in biotechnology processes; control of pressure, flow, temperature, and pH. Prerequisite: an undergraduate course in control theory or consent of the instructor.

BE 5370. BIOMATERIAL - LIVING SYSTEMS INTERACTION. 3 Hours.
This course describes current developments in molecular structure and organization at synthetic material interfaces with tissues and the subsequent influences on cells and cell membranes. It is designed to lay the groundwork for an improved understanding of events at the biomaterial-living system interface.

BE 5372. DRUG DELIVERY. 3 Hours.
This class focuses on the development, design and application of controlled and targeted drug delivery systems including transdermal, inhalation, drug eluting stents, stimulated-drug as well as microparticles and nanoparticles for controlled drug delivery. Principles of drug delivery, targeting, modification, distribution and diffusion will be discussed.

BE 5373. FORMULATION AND CHARACTERIZATION OF DRUG DELIVERY SYSTEMS. 3 Hours.
This class will provide the students with hands-on experience for developing drug delivery systems such as microparticles and nanoparticles that deliver pharmaceutical agents to treat various diseases. The emphasis is on understanding the principles of pharmacokinetics and drug delivery systems to improve the clinical efficacy and reduce side effects.

BE 5382. LABORATORY PRINCIPLES. 3 Hours.
Introduction to fundamental biomedical engineering laboratory procedures including human studies and animal surgery; includes clinical laboratory projects; data collection, analysis, and interpretation. Prerequisite: permission of the instructor.

BE 5385. STEM CELL TISSUE ENGINEERING. 3 Hours.
Students will gain experience and expertise in stem cell culture and differentiation, and engineering stem cell-based 2D and 3D tissue constructs. Using phenotypic markers and appropriately integrating with biocompatible scaffolds, the engineered tissue constructs will be differentiated to several tissue types and functionally validated. Lectures will cover stem cells, designing scaffolds and multimodal imaging techniques. The final projects may include acquisition of big data images, data mining and development of pattern recognition algorithms.

BE 5386. MEDICAL PRODUCT DESIGN CONTROL AND RISK MANAGEMENT. 3 Hours.
This course presents a thorough description of the design control for medical device development, starting with documenting the product requirements and concluding with design verification and validation that the design output meets the design meets product specifications and user needs. The role and scope of standard operating procedures (SOP) and representative content of an SOP are described. The students are introduced to elements of design history file and documentation.

BE 5387. MEDICAL DEVICE PROTOTYPE DEVELOPMENT. 3 Hours.
Students in this course are grouped in small teams to practice the design and development of a medical device that strictly adheres to the needed controls for regulatory affair approval of the product. The teams will be provided with a typical medical device manufacturer's standard operating procedure (SOP) and will be asked to apply that to their design. The teams demonstrate their understanding and implementation of design input, history file documentation, verification, and validation.

BE 5388. MEDICAL PRODUCT DESIGN AND DEVELOPMENT. 3 Hours.
This course aims to provide 1) A comprehensive knowledge of biomedical product design and development life cycle, 2) Basic knowledge on developing business plan, securing funding, designing product and process, conducting preclinical and clinical studies, 3) Basic training and classroom exercises on various biomedical product design and development tools, 4) Basic knowledge of FDA regulation and quality control, 5) Basic training on intellectual property and industrial project management.

BE 5390. RESEARCH PROJECT. 3 Hours.
Taken by students enrolled in the non-thesis option for the MS degree. Individual instruction in research and/or instrumentation development and evaluation conducted under supervision of the instructor. A final report required. Prerequisite: Permission of the instructor.

BE 5391. DIRECTED RESEARCH IN BIOENGINEERING. 3 Hours.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 5395. INTERNSHIP IN BIOENGINEERING. 3 Hours.
Students receive training in a Bioengineering company or a hospital to gain firsthand industrial or clinical engineering experience. The company or hospital assigns projects, and a faculty member monitors the student's progress. Prerequisite: Completion of at least 9 graduate credit hours in BE with good standing in the graduate program. International students need to complete at least 2 full semesters and comply with OIE/CPT rules to enroll. Prerequisite: Completion of at least 9 graduate credit hours in BE with good standing in the graduate program. Permission of Graduate Academic Advisor.

BE 5398. THESIS. 3 Hours.
Prerequisite: graduate standing in biomedical engineering.

BE 5691. DIRECTED RESEARCH IN BIOENGINEERING. 6 Hours.
Student participates in a research project under the individual instruction of a faculty supervisor.

BE 5698. THESIS. 6 Hours.
Graded P/F/R. Prerequisite: Graduate standing in Biomedical Engineering.

BE 6101. PhD SEMINAR IN BIOENGINEERING. 1 Hour.
University and guest lecturers speak on topics of current research interests in the field of bioengineering. Prerequisite: Graduate admission to BE PhD program.

BE 6102. PhD SEMINAR IN BIOENGINEERING. 1 Hour.
University and guest lecturers speak on topics of current research interests in the field of bioengineering. Prerequisite: Graduate admission to BE PhD program.

BE 6103. PhD SEMINAR IN BIOENGINEERING. 1 Hour.
This course serves as a forum to present recent scientific and technological topics in Bioengineering and as a practical guide to organize and deliver proper and effective scientific oral presentations. Prerequisite: PhD student status.

BE 6194. DOCTORAL DIAGNOSTIC EXAMINATION. 1 Hour.
Individual instruction, directed study, consultation, and diagnostic examination. Required of all doctoral students in the semester when they take any portion of the diagnostic examination.

BE 6195. DOCTORAL COMPREHENSIVE EXAMINATION. 1 Hour.
Individual instruction, directed study, consultation, and comprehensive examination on a detailed prospectus of proposed dissertation research as well as an oral examination. Required of all doctoral students in the semester when they take the comprehensive examination. Prerequisite: BE 6194.

BE 6197. RESEARCH IN BIOENGINEERING. 1 Hour.
Individually approved research projects leading to a doctoral dissertation in the area of biomedical engineering.

BE 6297. RESEARCH IN BIOENGINEERING. 2 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of biomedical engineering.

BE 6395. INTERNSHIP IN BIOENGINEERING. 3 Hours.
Students receive training in a bioengineering company or a hospital to gain firsthand industrial or clinical engineering experience. The company or hospital assigns projects, and a faculty member monitors the student's progress. Prerequisite: Completion of at least 9 graduate credit hours in BE with good standing in the graduate program. International students need to complete at least 2 full semesters and comply with OIE/CPT rules to enroll. Prerequisite: Completion of at least 9 graduate credit hours in BE and good standing in the graduate program.

BE 6397. RESEARCH IN BIOENGINEERING. 3 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of bioengineering.

BE 6399. DISSERTATION. 3 Hours.
Preparation and submission of a doctoral dissertation in an area of bioengineering. Graded R/F only. Prerequisite: Admission to candidacy for the Ph.D. in Biomedical Engineering.

BE 6499. DISSERTATION. 4 Hours.
Preparation and submission of a doctoral dissertation in an area of bioengineering. This course is only to be taken by students preparing a dissertation for submission that is supervised primarily by a University of Texas Southwestern Medical School faculty member and must be taken concurrently with a 5-hour dissertation course at that institution. To satisfy requirement that a P be awarded in a 9-hour dissertation course in their final semester of enrollment, a student must be concurrently enrolled in this course and the 5-hour dissertation course at the University of Texas Southwestern Medical School and receive a P in both courses at the end of that semester. If a P is not awarded in both classes, the two classes must be repeated until P grades are concurrently awarded.

BE 6695. INTERNSHIP IN BIOENGINEERING. 6 Hours.
Students receive training in a bioengineering company or a hospital to gain firsthand industrial or clinical engineering experience. The company or hospital assigns projects, and a faculty member monitors the student's progress. Prerequisite: Completion of at least 9 graduate credit hours in BE with good standing in the graduate program. International students need to complete at least 2 full semesters and comply with OIE/CPT rules to enroll. Prerequisite: Completion of at least 9 graduate credit hours in BE and good standing in the graduate program.

BE 6697. RESEARCH IN BIOENGINEERING. 6 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of bioengineering.

BE 6699. DISSERTATION. 6 Hours.
Preparation and submission of a doctoral dissertation in an area of bioengineering. Graded R/F only. Prerequisite: Admission to candidacy for the Ph.D. in Biomedical Engineering.

BE 6995. INTERNSHIP IN BIOENGINEERING. 9 Hours.
Students receive training in a bioengineering company or a hospital to gain firsthand industrial or clinical engineering experience. The company or hospital assigns projects, and a faculty member monitors the student's progress. Prerequisite: Completion of at least 9 graduate credit hours in BE with good standing in the graduate program. International students need to complete at least 2 full semesters and comply with OIE/CPT rules to enroll. Prerequisite: Completion of at least 9 graduate credit hours in BE and good standing in the graduate program.

BE 6997. RESEARCH IN BIOENGINEERING. 9 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of bioengineering.

BE 6999. DISSERTATION. 9 Hours.
Preparation and submission of a doctoral dissertation in an area of bioengineering. Graded P/R/F. Prerequisite: admission to candidacy for the Ph.D. in Biomedical Engineering.

BE 7399. DOCTORAL DEGREE COMPLETION. 3 Hours.
This course may be taken during the semester in which a student expects to complete all requirements for the doctoral degree and graduate. Enrolling in this course meets minimum enrollment requirements for graduation, for holding fellowships awarded by The Office of Graduate Studies and for full-time GTA or GRA positions. Students should verify that enrollment in this course meets other applicable enrollment requirements. To remain eligible in their final semester of study for grants, loans or other forms of financial aid administered by the Financial Aid Office must enroll in a minimum of 5 hours as required by the Office of Financial Aid. Other funding sources may also require more than 3-hours of enrollment. Additional hours may also be required to meet to requirements set by immigration law or by the policies of the student's degree program. Students should contact the Financial Aid Office, other sources of funding, Office of International Education and/or their graduate advisor to verify enrollment requirements before registering for this course. This course may only be taken twice. Students who do not complete all graduation requirements while enrolled in this course must enroll in a minimum of 6 dissertation hours (6699 or 6999) in their graduation term. Graded P/F/R.

COURSES

CE 1000. FRESHMAN UNDERGRADUATE RESEARCH. 0 Hours.
Freshman level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

CE 1105. INTRODUCTION TO CIVIL ENGINEERING. 1 Hour.
Introduction to basic civil engineering practice. There are several writing assignments and an oral presentation. Use of spreadsheet and word processor software in solving civil engineering problems and presenting solutions. Professional engineering licensure and the various specializations within civil engineering are covered.

CE 1252. COMPUTER TOOLS - AUTOCAD. 2 Hours.
Introduction to computer aided design, using AutoCAD. Creation of precise two-and/or three- dimensional engineering drawings and solid models. Prerequisite: Grade of C or better in MATH 1302.

CE 1353. INTRODUCTION TO COMPUTER AIDED DESIGN TOOLS IN CIVIL ENGINEERING. 3 Hours.
An introduction to computer aided design using AutoCAD interface built in Civil 3D. Students will be taught CAD commands, tools, 2D drawing objects, multi-view drawing, layer management, linetypes, object snap, polar tracking, and annotation. Civil 3D concepts and essential functions for creating, designing, and analyzing civil engineering drawings will be covered. Prerequisite: Grade of C or better in MATH 1421 (or concurrent enrollment) or MATH 1426 (or concurrent enrollment).

CE 2000. SOPHOMORE UNDERGRADUATE RESEARCH. 0 Hours.
Sophomore level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

CE 2152. COMPUTER TOOLS - MATHCAD. 1 Hour.
Introduction to computer aided mathematics, using Mathcad. Solution of engineering problems involving systems of simultaneous linear and nonlinear equations and elementary calculus, use of the tools for visualization. Prerequisite: Grade of C or better in PHYS 1443.

CE 2153. COMPUTER TOOLS - CIVIL 3D. 1 Hour.
Introduction to civil engineering construction documentation and building information modeling (BIM) using AutoCAD Civil 3D. Prerequisite: Grade of C or better in CE 1252.

CE 2191. PROBLEMS IN CIVIL ENGINEERING. 1 Hour.
Selected problems in civil engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: permission of the chair of the department and sophomore classification in civil engineering.

CE 2221. DYNAMICS. 2 Hours.
Planar and spatial kinematics and kinetics of particles and rigid bodies utilizing Newton's Laws of Motion, the principle of work and energy, and the principle of impulse and momentum; introduction to single degree of freedom vibration. Prerequisite: Grade of C or better in CE 2311; grade of C or better in MATH 2425.

CE 2291. PROBLEMS IN CIVIL ENGINEERING. 2 Hours.
Selected problems in civil engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: permission of the chair of the department and sophomore classification in civil engineering.

CE 2311. STATICS. 3 Hours.
Vector algebra; composition and resolution of forces; equivalence of force couple systems; equilibrium of force systems acting on particles, and force - couple systems acting on rigid bodies, and systems of rigid bodies; internal forces in rigid bodies; shear and moment diagrams; centroids and moments of inertia; frictional forces. Prerequisite: Grade of C or better in PHYS 1443.

CE 2312. STATICS AND DYNAMICS FOR NON-CE MAJORS. 3 Hours.
Principles of forces and force systems, resultants and components of force systems, forces due to friction, condition of equilibrium, forces acting on members of trusses and frame structures, centroids and moments of inertia, review of kinematics and kinetics of particle motion, and two-dimensional motion of rigid bodies. CE 2312 cannot be substituted for CE 2221 and CE 2311. Prerequisite: PHYS 1443 and MATH 2425 or concurrent enrollment.

CE 2313. MECHANICS OF MATERIALS I. 3 Hours.
Concepts of stress and strain; stress-strain relationships. Behavior of members subjected to tension, compression, shear, bending, torsion, and combined loading. Deflections and elastic curves, shear and bending moment diagrams for beams, and column theory. Prerequisite: Grade of C or better in CE 2311; Grade of C or better in MATH 2425.

CE 2331. ENGINEERING MEASUREMENT AND COMPUTER MODELING. 3 Hours.
Principles and theories of physical measurements of spatial quantities; the use of surveying instruments; introduction to engineering using computer modeling programs; and organization and programming for computer solutions. Prerequisite: Grade of C or better in CE 2153.

CE 2391. PROBLEMS IN CIVIL ENGINEERING. 3 Hours.
Selected problems in civil engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the chair of the department.

CE 3000. JUNIOR UNDERGRADUATE RESEARCH. 0 Hours.
Junior level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

CE 3131. ENVIRONMENTAL ANALYSIS. 1 Hour.
Laboratory examinations of water, wastewater, and air. Water and air quality parameters and their significance. Sources and types of pollutants and their effects. Prerequisite: Concurrent enrollment in CE 3334 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3142. APPLIED FLUID MECHANICS LAB. 1 Hour.
Fluid flow measurements studied by means of performed laboratory experiments and/or digital computer programming of relevant equations. Prerequisite: Concurrent enrollment in CE 3305 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3143. PROPERTIES AND BEHAVIOR OF SOILS. 1 Hour.
An introduction to determination of civil engineering properties of soil and their behavior, identification, grain size analysis, Atterberg limits, compaction, permeability, consolidation, and shear strength. Also an introduction to sampling of soil materials. Prerequisite: Concurrent enrollment in CE 3343 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3210. CIVIL ENGINEERING COMMUNICATIONS. 2 Hours.
Technical writing, oral communication, professional presentations, and other related topics. Prerequisite: Grade of C or better in COMS 2302 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3253. APPLICATIONS OF COMPUTER-BASED DESIGN PROGRAMS IN CIVIL ENGINEERING. 2 Hours.
Applications of computer-based design programs including AutoCAD Civil 3D in civil engineering projects. Prerequisite: Grade of C or better in CE 2153 and CE 2331, and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3300. INTRODUCTION TO SUSTAINABLE ENGINEERING. 3 Hours.
Introduction to key sustainability concepts and challenges. The engineering design process and consideration of sustainability. Techniques for generating creative and innovative alternative solutions to sustainability problems. Use of life cycle assessment to quantify environmental, economic, and social impacts of various alternatives. Methods to incorporate life cycle assessment into alternatives evaluation. Case study project. Prerequisite: Admission to an Engineering Professional Program or Junior Level Standing.

CE 3301. STOCHASTIC MODELS FOR CIVIL ENGINEERING. 3 Hours.
Basic theory of probability and statistics with practical applications to civil and environmental engineering problems. Emphasis on sampling, distribution functions, tests of significance, and regression modeling. Prerequisite: Grade of C or better in MATH 2425; Permission of the CE Chair or Admission to the CE Professional Program.

CE 3302. TRANSPORTATION ENGINEERING. 3 Hours.
Planning, design, and operation of transportation facilities. Characteristics of vehicle movement; basic geometric design of highways; traffic flow relations in traffic streams; highway capacity; traffic engineering; and procedures for transportation planning. Prerequisite: Grade of C or better in CE 2331; and Grade of C or better in either CE 3301 or IE 3301 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3305. BASIC FLUID MECHANICS. 3 Hours.
Fundamentals of fluid statics, kinematics of fluid flow, fluid energy, fluid forces, similitude, and dimensional analysis. Related to steady flow of incompressible fluids in confined and free surface systems. Prerequisite: Grade of C or better in CE 2311; Grade of C or better in MATH 3319 or concurrent enrollment; Permission of the CE Chair or Admission to the CE Professional Program.

CE 3311. CONSTRUCTION ENGINEERING. 3 Hours.
Principles of construction engineering and the project management process, value engineering, specifications, different construction contracts and delivery methods, estimating and scheduling fundamentals and project control, and management of construction process. Prerequisite: Grade of C or better in IE 2308 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3334. PRINCIPLES OF ENVIRONMENTAL ENGINEERING. 3 Hours.
Physical, chemical, and biological unit operations and processes in an air, water, and land environment. Prerequisites: Grade of C or better in CHEM 1465 or CHEM 1442; Grade of C or better in CE 3305; concurrent enrollment in CE 3131 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3341. STRUCTURAL ANALYSIS. 3 Hours.
Structural analysis/design process, structural forms, and basic structural elements. Analysis of statically determinate structures including beams, trusses, frames, and composite structures, shear and moment diagrams, influence lines, and moving loads. Methods to compute deflections including double integration, moment area, and virtual work. Methods of analysis for statically indeterminate structures including consistent deformation, slope deflection and moment distribution. Use of structural analysis programs. Prerequisite: Grade of C or better in CE 2313 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3342. WATER RESOURCES ENGINEERING. 3 Hours.
Hydrologic cycle, precipitation, evapotranspiration, water budget, rainfall-runoff, hydrograph, reservoir and streamflow routing, groundwater flow, catchment hydrology, probability concepts in design, hydrologic modeling, open channel and pipe network hydraulics, pumps, urban stormwater drainage. Prerequisite: Grade of C or better in CE 3301; grade of C or better in CE 3305; concurrent enrollment in CE 3142 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3343. SOIL MECHANICS. 3 Hours.
An introduction to the significant geophysical and soil science properties and behavior of materials making up the earth's crust as they apply to civil engineering, sources of materials, classification, plasticity, permeability, stress distribution, consolidation, shear strength, and settlement. Also an introduction to basic foundation engineering concepts. Prerequisite: Grade of C or better in CE 2313; concurrent enrollment in CE 3143 and Permission of the CE Chair or Admission to the CE Professional Program.

CE 3361. PROPERTIES & BEHAVIOR OF CIVIL ENGINEERING MATERIALS. 3 Hours.
The nature and properties of materials used in civil engineering such as structural metals, concrete, timber, and bituminous materials. The engineering application and performance of materials are emphasized. Laboratory experimentation is also used to investigate properties and behavior of civil engineering materials. Prerequisite: Grade of C or better in CE 2313; Grade of C or better in CE 3143; Permission of the CE Chair or Admission to the CE Professional Program.

CE 4000. SENIOR UNDERGRADUATE RESEARCH. 0 Hours.
Senior level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

CE 4191. PROBLEMS IN CIVIL ENGINEERING. 1 Hour.
Selected problems in civil engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: permission of the chair of the department and sophomore standing in civil engineering.

CE 4291. PROBLEMS IN CIVIL ENGINEERING. 2 Hours.
Selected problems in civil engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: permission of the department chairperson and sophomore standing in civil engineering.

CE 4300. ADVANCED TOPICS IN CIVIL ENGINEERING. 3 Hours.
Advanced topics of current interest in any one of the various fields of civil engineering. The subject title to be listed in the class schedule. May be repeated for credit when topic changes. Prerequisite: changes with topic; consent of instructor required and Admission to the CE Professional Program.

CE 4301. ADVANCED TOPICS IN CIVIL ENGINEERING WITH LAB. 3 Hours.
Advanced topics of current interest in any one of the various fields of civil engineering. The subject title to be listed in the class schedule. May be repeated for credit when topic changes. Prerequisite: Changes with topic; Consent of instructor required and Admission to the CE Professional Program.

CE 4302. ADVANCED CONCRETE MATERIALS. 3 Hours.
Providing a practical understanding of design and characterization of advanced concrete materials, this course is intended for graduate and senior undergraduate students who want to advance their knowledge in new concepts of materials in construction. Topics include the study of properties at the nanoscale and how they affect the material's properties at the macro level. Lectures will focus on the advances in the design and technology of cement based materials, with particular emphasis on the evolution of nanotechnology in construction. Prerequisite: Grade of C or better in CE 3361 and admission to the CE Professional Program.

CE 4303. CONSTRUCTION PROJECT ADMINISTRATION. 3 Hours.
Topics in construction management and project administration, such as project delivery system, documentation and specification, electronic project administration, construction safety, risk allocation and liability sharing, changes and extra work, claims and disputes, and project closeout. Credit not granted for CE 4303 and CE 5342. Prerequisite: Grade of C or better in CE 3311 and admission to the CE Professional Program.

CE 4304. CONSTRUCTION CONTRACTS, SPECIFICATIONS, & ADMINISTRATION. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Credit not granted for both CE 4304 and CE 5378. Prerequisite: Grade of C or better in CE 3311 and admission to the CE Professional Program.

CE 4305. TRENCHLESS TECHNOLOGY METHODS. 3 Hours.
Pipeline and utility design, construction and renewal. Topics include pipeline infrastructure structural considerations, planning and construction considerations, pipe materials, and trenchless technologies. Prerequisite: Grade of C or better in CE 3311 and admission to the CE Professional Program.

CE 4306. INFRASTRUCTURE ASSET MANAGEMENT. 3 Hours.
Infrastructure inventory, inspection, and life cycle costs. Topics include pipeline deterioration parameters, asset management technologies, risk assessment, government regulations and case studies. Prerequisite: Grade of C or better in CE 3311 and admission to the CE Professional Program.

CE 4307. CONSTRUCTION SUSTAINABILITY. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Credit not granted for both CE 4307 and CE 5382. Prerequisite: Grade of C or better in CE 3311 and admission to the CE Professional Program.

CE 4308. TEMPORARY STRUCTURES. 3 Hours.
Analysis and design of temporary structures. Topics include loads on temporary structures, shoring, formwork, falsework, scaffolding, bracing, soldier beam and lagging, sheet piling, equipment bridges, and support of existing structures. Prerequisite: Grade of C or better in CE 3341 and CE 3343; Admission to the CE Professional Program.

CE 4310. SYSTEM EVALUATION IN CIVIL ENGINEERING. 3 Hours.
Techniques necessary to perform economic and multi-criteria evaluations of civil engineering projects. These will be used to assess the strengths and weaknesses of different decision-making strategies and analyze contemporary topics and case studies in making civil engineering decisions. Prerequisite: Grade of C or better in IE 2308; Grade of C or better in CE 3301.

CE 4311. URBAN TRANSPORTATION INFRASTRUCTURE PLANNING. 3 Hours.
Urban transportation system design, planning, transportation modeling, economic theory, travel demand and travel estimation techniques. Prerequisite: Grade of C or better in CE 3302 and Admission to the CE Professional Program.

CE 4312. STREET AND HIGHWAY DESIGN. 3 Hours.
The geometric design concepts for urban and rural roadways. Consideration of vehicle and road user characteristics in roadway design, including horizontal and vertical alignments, intersections, interchanges, and roadway cross-section and right-of-way considerations. Prerequisite: Grade of C or better in CE 3302 and Admission to the CE Professional Program.

CE 4313. TRAFFIC ENGINEERING. 3 Hours.
Design and control of fixed-time, actuated, and computer-controlled traffic signals; optimization of traffic flow at intersections; capacity analysis of intersections, legal requirements and traffic studies for installation of traffic control devices; characteristics of signs, signals, and markings; traffic laws. Prerequisite: Grade of C or better in CE 3302 and Admission to the CE Professional Program.

CE 4314. INTRODUCTION TO RAILROAD ENGINEERING. 3 Hours.
Overview of the railroad industry in the United States; structure of track, base, and foundation; drainage, railroad structures (bridges and retaining walls); geometric design; communications and signaling; maintenance. Credit not granted for both CE 4314 and CE 5334. Prerequisite: Grade of C or better in CE 3302 and Admission to the CE Professional Program.

CE 4320. EARTH STRUCTURES DESIGN. 3 Hours.
Study of the states of stress and analysis/design techniques associated with cuts, fills, and retaining structures. Includes slope stability, conventional and reinforced earth retaining walls, excavation bracing, and sheet pile wharf structures. Prerequisite: Grade of C or better in CE 3343 and Admission to the CE Professional Program.

CE 4321. FOUNDATION ENGINEERING. 3 Hours.
Aspects of design and construction considerations for all types of foundation systems in most soil/rock support conditions, interactions between soils and structures, bearing capacity theories, consolidation, shrink-swell, and settlement. Numerical analyses of design are applied to most of the situations. Prerequisite: Grade of C or better in both CE 3341 and CE 3343 and Admission to the CE Professional Program.

CE 4322. APPLICATIONS WITH GEOSYNTHETICS. 3 Hours.
Definitions and properties of geotextiles, geogrids, geonets, geocomposites and geomembranes; reinforcement design applications in rigid and flexible pavements, foundations, embankments, slopes and retaining walls; drainage and filtration application designs, AASHTO design criteria; construction methods. Prerequisite: Grade of C or better in CE 3343 and Admission to the CE Professional Program.

CE 4323. LANDFILL DESIGN. 3 Hours.
Introduction and types of landfills, landfill site selection, siting and configuration, compacted and geosynthetic clay liners, final cover design, landfill settlement and slope stability, post closure uses of landfills, leachate and gas generation, collection and removal system, bioreactor landfills and future trends. Prerequisite: Grade of C or better in CE 3343 and Admission to the CE Professional Program.

CE 4324. MECHANICS OF MATERIALS II. 3 Hours.
Theories of stress and deformation, stress-strain tensors, stress and strain relationships, stresses due to various loading conditions, theories of failure, energy methods, shear-center, unsymmetrical bending, curved beams, torsion in closed and open cell cross-sections and buckling analysis. Prerequisite: Grade of C or better in CE 2313 and Admission to the CE Professional Program.

CE 4325. FUNDAMENTALS OF FINITE ELEMENT METHOD. 3 Hours.
Stiffness method using basic equations and virtual work; element equations using shape functions for axial, beam, frame, two dimensional elements; stiffness methods for three dimensional structures. Flexibility method; finite elements modeling and optimization of idealized structures. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4326. GIS/HYDROLOGIC AND HYDRAULIC MODELING. 3 Hours.
Use of Geographic Information Systems (GIS) and design of GIS-developed hydrologic/hydraulic models commonly applied in the water resources field. The course will have three main areas of emphasis including: principles and operations of ArcGIS, design and implementation of standard hydrologic and hydraulic models, and the linkage of these models to engineering analysis of current water resources problems including flooding, water quality and water supply. Prerequisite: Grade of C or better in CE 3342 and Admission to the CE Professional Program.

CE 4327. SITE REMEDIATION ENGINEERING. 3 Hours.
This course provides practical understanding of the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. In-situ and ex-situ treatment processes will be covered, including unit operations, coupled processes, and complete systems within the context of community implementation. Case studies with focus on developing communities will be used and computerized tools for process selection and design will be presented. Prerequisite: Grade of C or better in CE 3334 and Admission to the CE Professional Program.

CE 4328. WATER SYSTEM DESIGN. 3 Hours.
Hydraulic/hydrologic analysis and design of municipal water distribution, stormwater collection, and wastewater collection systems. Prerequisite: Grade of C or better in CE 3342 and Admission to the CE Professional Program.

CE 4330. HYDRAULIC DESIGN. 3 Hours.
Design methods for appurtenances of water conveyance systems under open channel and pressure flow conditions. Prerequisite: Grade of C or better in CE 3342 and Admission to the CE Professional Program.

CE 4332. CONSTRUCTION EQUIPMENT, METHODS, & MANAGEMENT. 3 Hours.
Introduction to the construction industry and the methods, equipment, and management techniques used. Topics include equipment operating characteristics, underground construction, job site safety, and field management. Credit not granted for both CE 4332 and CE 5344. Prerequisite: Grade of C or better in CE 3311 and Admission to the CE Professional Program.

CE 4334. DRONES & ADVANCED CONSTRUCTION TECHNOLOGY. 3 Hours.
A practical course for technologies and their applications used on construction job sites. Topics include drones (also known as sUAS, or small unmanned aircraft systems), robotics, extended reality, artificial intelligence, blockchain, wearables, etc. Practical sessions are included to train students to operate drones for various construction applications. Credit not granted for both CE 4334 and AREN 4334. Prerequisite: Grade of C or better in CE 2331; Grade of C or better in CE 3311; Admission to the CE Professional Program.

CE 4335. GEOTECHNICAL ASPECTS OF CONSTRUCTION. 3 Hours.
Review of engineering geology and soil mechanics; interpretation of geotechnical reports; site preparation; ground improvement; excavation including supports and dewatering; foundations including consideration of deep foundations and expansive soils; tunneling in soils and rock. Prerequisite: Grade of C or better in CE 3343 and admission to the CE Professional Program.

CE 4336. HOT MIX ASPHALT DESIGN & CONSTRUCTION. 3 Hours.
An in-depth study of the properties of constituent materials for asphalt concrete mixtures. Design methods for Hot-Mixes Asphalt (HMA) and Stone Matrix Asphalt (SMA). Theory and practice of asphalt concrete mix for pavements, including specifications and construction methods for hot-mix asphalt and surface treatments. Maintenance and rehabilitation of flexible pavements. Relationships of material engineering properties to pavement design and performance. Prerequisites: Grade of C or better in CE 3361 and Admission to the CE Professional Program.

CE 4337. PORTLAND CEMENT CONCRETE PAVEMENTS. 3 Hours.
Portland cement concrete mix design and production. Paving operations. Saw and seal operations. Subgrade preparation. Base selection. Drainage selection, design and construction. Bonded and unbonded concrete overlays. Whitetopping and Ultra-Thin Whitetopping. Concrete pavement restoration; Quality Assurance and Quality Control in Concrete Pavement Construction. Prerequisite: Grade of C or better in CE 3361 and Admission to the CE Professional Program.

CE 4347. REINFORCED CONCRETE DESIGN. 3 Hours.
An analysis, design and synthesis course for concrete structures, emphasizing strength design method. Topics include strength and serviceability requirements, design of one way slabs, rectangular beams, flanged sections and columns, for strength, shear, bond, bearing, and serviceability. Building codes, American Concrete Institute (ACI) specifications, material specifications, test methods, and recommended practice documents are involved. Prerequisite: Grade of C or better in CE 3341 and admission to the CE Professional Program.

CE 4348. STRUCTURAL DESIGN IN STEEL. 3 Hours.
A design synthesis course for structural steel structures using Allowable Strength Design and Load Resistance Factor Design. Topics include tension members, compression members, flexural members and simple connections. Building codes, American Institute of Steel Construction (AISC) specs, material specs, test methods, and recommended practice documents. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4350. INTRODUCTION TO AIR POLLUTION. 3 Hours.
An introduction to the air pollution field, including: pollutant types, sources, effects; atmosphere and basic calculations; emission estimates; Clean Air Act; dispersion modeling; air pollution reduction strategies. Prerequisite: Grade of C or better in CE 3334 and Admission to the CE Professional Program.

CE 4351. PHYSICAL UNIT PROCESSES. 3 Hours.
Principles of unit process modeling using reactor and kinetic theory, and theory and design of mixing, mass transfer, flocculation, sedimentation, filtration, and gas transfer. Prerequisite: Grade of C or better in both CE 3131 and CE 3334 and Admission to the CE Professional Program.

CE 4352. PROFESSIONAL PRACTICE. 3 Hours.
Professional practice issues in the private and public sector are addressed by visiting practitioners. Topics include project management, teamwork, obtaining work, regulatory requirements, specifications, issues in design/build, design alternatives, cost estimation, design and construction drawings, contract and construction law, legal issues, ethics and professionalism, design reports, licensure, lifelong learning, ethical and engineering practice organizations. Learning principles of engineering practice by working as a team is emphasized. Oral and written presentations are required. Prerequisites: Grade of C or better in CE 3210 and CE 3311 and Admission to the CE Professional Program.

CE 4353. WATER CHEMISTRY. 3 Hours.
Principles of water chemistry applied to the theory and design of unit processes including coagulation, precipitation, corrosion, oxidation-reduction, and membrane processes. Prerequisites: Grade of C or better in both CE 3334 and CE 3131 and Admission to the CE Professional Program.

CE 4354. INTRODUCTION TO SOLID WASTE ENGINEERING. 3 Hours.
This course provides an overview of the various aspects of integrated municipal solid waste management (with the exception of landfilling, covered in CE 4323). Topics covered include waste generation, characterization, and collection; source reduction; waste processing; design of facilities for materials recovery (recycling centers) and energy recovery (combustors and anaerobic digesters); life cycle analysis of solid waste management facilities; case study project. Prerequisite: Grade of C or better in CE 3334 and Admission to the CE Professional Program.

CE 4355. DESIGN OF WATER AND WASTEWATER TREATMENT FACILITIES. 3 Hours.
Design of facilities commonly used in water and wastewater treatment plants including pumps, pipelines, channels, flow measurement and control devices, screens, grit removal, mixing, sludge removal, aeration equipment, and chemical feed and storage. Materials of construction, process control interface, and operation and maintenance factors are also discussed. Prerequisite: Grade of C or better in both CE 3334 and CE 3142 and Admission to the CE Professional Program.

CE 4356. ADVANCED STEEL DESIGN. 3 Hours.
Covers torsional design of beams, beams with web holes, composite design of beams, lateral-torsional buckling of beams, plate buckling, column design and behavior, frame stability, bracing requirements for compression members. Prerequisite: CE 4348 and Admission to the CE Professional Program.

CE 4357. INTRODUCTION TO BIOLOGICAL WASTEWATER TREATMENT SYSTEMS. 3 Hours.
Basic understanding of biological processes used in water quality control and to show how theoretical concepts can be applied in a practical design. The course will include a discussion of the theory, design, and operation of biological systems used for water and wastewater treatment. Credit is not granted for both CE 4357 and CE 5325. Prerequisite: Grade of C or better in CE 3334 and CE 3131; Admission to the CE Professional Program.

CE 4358. OPEN CONDUIT SYSTEM. 3 Hours.
Non-pressure conduit and channel flow, surface profiles, steady and gradually varied flow, hydraulic jumps, and specific energy. Prerequisite: Grade of C or better in CE 3342 and Admission to the CE Professional Program.

CE 4360. DESIGN OF STRUCTURAL MASONRY. 3 Hours.
Covers masonry unit types and mortar types, reinforcing and connections. Design of beams, columns, pilasters, and walls. Structural behavior and construction practices. Includes plain and reinforced masonry. Building Codes, Masonry Standards Joint Committee (MSJC) specifications, material specifications, test methods, and recommended practice documents. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4361. ADVANCED REINFORCED CONCRETE DESIGN. 3 Hours.
Advanced topics on structural design of concrete structures. Topics include slender columns, shear walls, torsion, deep beams, brackets, retaining walls, strut and tie model for shear torsion, two-way slabs, and shear friction. Building codes, American Concrete Institute (ACI) specifications, material specifications, test methods, and recommended practice documents are involved. Prerequisite: Grade of C or better in CE 4347 and Admission to the CE Professional Program.

CE 4363. FUNDAMENTALS OF PRESTRESSED CONCRETE. 3 Hours.
Introduction to pre-tensioned and post-tensioned concrete structures, bonded and unbonded constructions, hardware, stress calculations, section proportioning, flexural design, shear design, prestress losses, deflections, allowable stress, load-balancing, and ultimate strength, design/analysis methods, including: partially prestressed systems shear design, analysis and design of composite beams, design of prestressed concrete bridges. Both American Concrete Institute (ACI-318) and American Association of State Highway and Transportation Officials (AASHTO-LRFD) provisions will be discussed. Prerequisite: Grade of C or better in CE 4347 and Admission to the CE Professional Program.

CE 4365. STRUCTURAL WOOD DESIGN. 3 Hours.
Covers material grade and properties of wood, design criteria using structural lumber, glue laminated lumber and structural panels. Design of bending and compression members, trusses and diaphragms. Building codes, National Design Specification for Wood Construction (NDS) specifications, material specifications, test methods, and recommended practice documents. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4366. FUNDAMENTALS OF FIBER REINFORCED COMPOSITES. 3 Hours.
Introduction to basic analysis, design and manufacture of composite materials for engineered structures. Fiber materials, tapes, cloths, resin system, elastic constants, matrix formulation, theory of failure. The course will also cover an introduction to design with composites, preliminary design, optimization, processing variables, product design. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4368. ADVANCED STRUCTURAL ANALYSIS. 3 Hours.
Advanced analysis of indeterminate beams, frames, trusses, arches, and cables. Credit will not be granted for both CE 5351 and CE 4368. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4369. LOADS ON STRUCTURES. 3 Hours.
Structural analysis of structures under gravity and lateral loads, emphasizing the logical reasoning process of analysis, synthesis and design. Use of recommended practice documents and commercial structural and mathematical software will assist in providing insight and understanding of load requirements, structural behavior and analysis tools. Prerequisite: Grade of C or better in CE 3341 and Admission to the CE Professional Program.

CE 4383. SENIOR PROJECT. 3 Hours.
Planning, analysis of alternatives, and designs of selected projects that cross various civil engineering disciplines, and include engineering standards and multiple realistic constraints. Application of computer-aided engineering in analysis and design. A final oral presentation and written report that presents pros and cons of alternative solutions, application of engineering standards and multiple realistic constraints are required. A team approach is emphasized. Prerequisite: Grade of C or better in CE 4352; Grade of C or better in CE 4328 or CE 4347; Completion of all required 3000 level courses and Admission to the CE Professional Program.

CE 4391. PROBLEMS IN CIVIL ENGINEERING. 3 Hours.
Selected problems in civil engineering on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the chair of the department.

CE 4393. INDUSTRIAL INTERNSHIP. 3 Hours.
Student to experience industrial internship under supervision of an industrial mentor and internship committee. May not be repeated for credit. Credit not granted for both CE 4393 and CE 4394. Prerequisite: Grade of C or better in CE 3341; Grade of C or better in CE 3342; Admission to the CE Professional Program.

CE 4394. RESEARCH INTERNSHIP. 3 Hours.
Student to experience research internship under supervision of a CE faculty. May not be repeated for credit. Credit not granted for both CE 4393 and CE 4394. Prerequisite: Grade of C or better in CE 3341; Grade of C or better in CE 3342; Admission to the CE Professional Program.

CE 4395. SUSTAINABLE ENGINEERING DESIGN PROJECT. 3 Hours.
Following the engineering design process, students will brainstorm, evaluate, and select among engineering alternatives. Students will evaluate the alternatives based on sustainability criteria, including environmental, economic, and social impacts. Life cycle assessment will be used to quantify environmental and economic impacts of the design alternatives. Students will use a decision-making matrix in selecting among alternatives. Prerequisite: Grade of C or better in CE 3300, Grade of C or better in Societal Context Elective, ECON 2305 or IE 2308 (or concurrent enrollment), Grade of C or better in 6 credit hours of Sustainable Engineering Electives (or concurrent enrollment).

CE 5191. ADVANCED STUDIES IN CIVIL ENGINEERING. 1 Hour.
Individual studies of advanced topics under the supervision of a professor or professors. Prerequisite: consent of instructor.

CE 5300. TOPICS IN CIVIL ENGINEERING. 3 Hours.
Topics of current interest in the field of civil engineering. The subject title is listed in the class schedule and in the student's record. Topics vary. May be repeated for credit when topic changes. Prerequisite: consent of instructor.

CE 5301. TOPICS IN CIVIL ENGINEERING WITH LAB. 3 Hours.
Topics of current interest in the field of civil engineering. The subject title is listed in the class schedule and in the student's record. Topics vary. May be repeated for credit when topic changes. Prerequisite: Consent of instructor.

CE 5302. ADVANCED CONCRETE MATERIALS. 3 Hours.
Providing a practical understanding of design and characterization of advanced concrete materials, this course is intended for graduate and senior undergraduate students who want to advance their knowledge in new concepts of materials in construction. Topics include the study of properties at the nanoscale and how they affect the material's properties at the macro level. Lectures will focus on the advances in the design and technology of cement based materials, with particular emphasis on the evolution of nanotechnology in construction. Prerequisite: CE 3361.

CE 5303. INTRODUCTION TO FINITE ELEMENT. 3 Hours.
Stiffness method using basic equations and virtual work; element equations using shape functions for axial, beam, frame, two dimensional elements; stiffness method for three dimensional structures. Flexibility method; finite element modeling and optimization of idealized structures. Credit not granted for both CE 4325 and CE 5303. Prerequisite: CE 3341.

CE 5304. POST-TENSIONED CONCRETE DESIGN. 3 Hours.
Overview of Post-tensioned Concrete Structures; Allowable Stresses, Ultimate Flexural Strength, and One-Way Shear Design according to ACI 318 and ACI 320; Equivalent Load and Load Balancing Method in Determinate Systems; Equivalent Load, Load Balancing Method, and Secondary Effects in Indeterminate Systems; Idealized and Actual Tendon Layouts in Indeterminate Systems; Post-tensioned Continuous Beams and Intermediate Structures; Post-tensioned One-Way Slabs; Equivalent Frame Method and Computer-Aided Analysis of Equivalent Frames; Post-tensioned Two-Way Slabs; Punching Shear and Design of Headed Shear Stud Reinforcement; Anchorage Zone; Post-tensioned Slabs-on-Ground. Prerequisite: CE 4347.

CE 5305. FIBER REINFORCED COMPOSITE DESIGN. 3 Hours.
Introduction to basic analysis, design and manufacture of composite materials for engineered structures. Fiber materials, tapes, cloths, resin systems, elastic constants, matrix formulation, theory of failure. The course will also cover an introduction to design with composites, preliminary design, optimization, processing variables, product design. Credit not granted for both CE 4366 and CE 5305. Prerequisite: CE 3341.

CE 5306. STRUCTURAL STEEL DESIGN. 3 Hours.
The basic design course for steel structures emphasizing Load Resistant Factor Design Method. Topics include tension members, compression members, flexural members, and simple connections. Building codes, American Institute of Steel Construction (AISC) specifications, material specifications, test methods, and recommended practice documents. Credit not granted for both CE 4348 and CE 5306. Prerequisite: CE 3341.

CE 5307. STRUCTURAL TIMBER DESIGN. 3 Hours.
Covers material grade, properties of wood, design criteria using structural lumber, glue laminated lumber and structural panels. Design of bending and compression members, trusses and shear diaphragms. Building codes, National Design Specifications (NDS) , material specifications, test methods, and recommended practice documents. Credit not granted for both CE 4365 and CE 5307. Prerequisite: CE 3341.

CE 5308. STRUCTURAL MASONRY DESIGN. 3 Hours.
Covers masonry unit type and grades of mortar types, reinforcing and connectors. Design of beams, columns, pilasters, and walls. Structural behavior and construction practices. Includes plain and reinforced masonry. Building codes, Masonry Standard Joint Committee (MSJC) specifications, material specifications, test methods, and recommended practice documents. Credit not granted for both CE 4360 and CE 5308. Prerequisite: CE 3341.

CE 5309. PRESTRESSED CONCRETE. 3 Hours.
Introduction to pre-tensioned concrete structures for bridge and building applications, bonded and unbonded construction, hardware, stress calculations, section proportioning, flexural design, shear design, prestress losses, deflections, allowable stress, ultimate flexural strength design/analysis methods, shear design, analysis and design of composite beams, live load distribution factors for prestressed beams and girders in concrete bridges, compression and tension members. Both American Concrete Institute (ACI 318 and ACI 319) and American Association of State Highway and Transportation Officials Load and Resistance Factor Design (AASHTO LRFD) provisions will be discussed. Credit not granted for both CE 4363 and CE 5309. Prerequisite: CE 4347.

CE 5310. PLASTIC ANALYSIS AND DESIGN OF STRUCTURES. 3 Hours.
Behavior of structural members beyond elastic range; plastic analysis of steel and concrete members and framed structures; stepwise incremental load and mechanism methods; yield/failure mechanisms for various types of frames. Use of nonlinear structural analysis programs and design code provisions. Application to earthquake resistant design. Prerequisite: CE 4347 and CE 4348; or equivalent.

CE 5311. ADVANCED STEEL DESIGN I. 3 Hours.
Covers torsional design of beams, beams with web holes, composite design of beams, lateral-torsional buckling of beams, plate buckling, column design and behavior, frame stability, bracing requirements for compression members. Prerequisite: CE 4348 or CE 5306.

CE 5312. ADVANCED CONCRETE DESIGN I. 3 Hours.
Advanced topics on structural design of concrete structures. Topics include slender columns, shear walls, torsion, deep beams, brackets, retaining walls, strut and tie model for shear torsion, two-way slabs, and shear friction. Building codes, American Concrete Institute (ACI) specifications, material specifications, test methods, and recommended practice documents are involved. Credit not granted for both CE 4361 and CE 5312. Prerequisite: CE 4347.

CE 5313. GEOTECHNICAL ASPECTS OF CONSTRUCTION. 3 Hours.
Review of engineering geology and soil mechanics and teaching of the foundation and underground excavation construction solely to graduate students specializing in construction engineering & management. Topics include interpretation of geotechnical reports, embankment construction, foundations on expansive soils, excavation supports, excavation dewatering, deep foundation construction, tunneling in soft ground as well as in soft/hard rock, and trenchless technology piping. Credit not granted for both CE 4335 and CE 5313. Prerequisite: CE 5378.

CE 5314. ADVANCED STEEL DESIGN II. 3 Hours.
Covers structural design of beam columns and building connections. Rigid frame and multi-story building design issues. Building codes, American Institute of Steel Construction (AISC) specifications, and recommended practice documents. Prerequisite: CE 4348 or CE 5306.

CE 5315. ADVANCED MECHANICS OF MATERIALS. 3 Hours.
Analysis of stresses and strains at a point, stress-strain relationships, stresses due to various leading conditions, theories of failure, energy methods, shear center, unsymmetrical bending, curved beams, torsion in closed and open cell cross-sections, principles of plastic analysis, and buckling analysis. Credit not granted for both CE 4324 and CE 5315. Prerequisite: CE 2313.

CE 5316. MACHINE LEARNING FOR SMART BUILDINGS. 3 Hours.
Applying machine learning in building engineering would generate innovative opportunities for smart buildings and cities (e.g., human-building interaction, building-to-grid integration, building energy management). This course will cover basic data science skills and machine learning algorithms (e.g., supervised, unsupervised, reinforcement learning). The main objective is to teach how to apply machine learning techniques for advanced building systems. Prerequisite: AREN 3301 or CE 3301.

CE 5317. ENVIRONMENTAL ENGINEERING PROCESS AND ANALYSIS LAB. 3 Hours.
The course meets for 2 hours of lecture and 3 hours of lab each week. Lectures will cover advanced analytical procedures for the analyses of air, liquid, and other wastes, including optical, Chromatographic, electrical, and other instrumental methods of analysis. Lectures will also review the basics of physical/chemical processes. In the laboratory, students will demonstrate and analyze basic reactor types (CSTR, plug flow, and reactors in series) and treatment of contaminants, including gas transfer, adsorption, advanced oxidation processes, and membrane separation.

CE 5318. PHYSICAL-CHEMICAL PROCESSES I. 3 Hours.
Principles of unit process modeling using reactor and kinetic theory, theory and design of mixing, mass transfer, flocculation, sedimentation, filtration and gas transfer. Credit not granted for both CE 4351 and CE 5318. Prerequisite: CE 3131 and CE 3334; or consent of instructor.

CE 5319. PHYSICAL-CHEMICAL PROCESSES II. 3 Hours.
Principles of water chemistry applied to the theory and design of unit processes including coagulation, precipitation, corrosion, oxidation-reduction, and membrane processes. Credit not granted for both CE 4353 and CE 5319 Prerequisite: CE 3131 and CE 3334; or consent of instructor.

CE 5320. TEMPORARY STRUCTURES. 3 Hours.
Analysis and design of temporary structures. Topics include loads on temporary structures, shoring, formwork, falsework, scaffolding, bracing, soldier beam and lagging, sheet piling, equipment bridges, and support of existing structures. Prerequisite: CE 3341 and CE 3343.

CE 5321. ENGINEERING FOR ENVIRONMENTAL SCIENTISTS. 3 Hours.
Fundamental principles of engineering science applicable to the comprehension and design of engineered environmental systems. Includes water and air quality indices; kinetic and reactor theory; mass and energy balances; fluid system theory; and applications of physical, chemical and biological processes in the design of engineered environmental systems. May not be used to satisfy any of the requirements for a graduate degree in Civil Engineering. Prerequisite: PHYS 1441, CHEM 1442, and MATH 2425.

CE 5322. ADVANCED PHYSICAL-CHEMICAL PROCESSES. 3 Hours.
The course represents the fundamentals and applications of various advanced physical and chemical unit operations and processes for controlling drinking water quality. The course will cover 1) general overview on the standard, regulations, and goals of drinking water quality, 2) detailed discussion of the theory, design, and operation of advanced physical and chemical unit processes, including but not limited to, sorption, centrifugation, osmotic pressure, membrane separation, chemical oxidation and advanced oxidation, UV technology, and disinfection, and 3) post treatment issues. Prerequisites: CE 5318.

CE 5323. SUSTAINABLE ENGINEERING. 3 Hours.
Introduction to sustainability concepts and challenges through evaluation of case studies. The engineering design process and consideration of sustainability. Techniques for generating creative and innovative alternative solutions to sustainability problems. Training on Simapro software for life cycle assessment of environmental impacts. Evaluation of economic and social impacts of alternatives and decision-making.

CE 5324. INFRASTRUCTURE DURABILITY & MONITORING. 3 Hours.
Durability and total cost of ownership for infrastructure; the physical, mechanical and chemical characteristics of deterioration and degradation for steel and other metals, Portland cement concrete, and organic materials; practical aspects of identification and remediation; a research literature review related to material durability.

CE 5325. BIOLOGICAL PROCESSES FOR WASTEWATER TREATMENT. 3 Hours.
Biological processes used in water quality control. Includes principles from microbiology and biochemistry applied to suspended and attached growth systems. Prerequisite: CE 5318.

CE 5326. WATER AND WASTEWATER TREATMENT FACILITIES DESIGN. 3 Hours.
Design of facilities commonly used in water and wastewater treatment plants including pumps, pipelines, channels, flow measurement and control devices, screens, grit removal, mixing, sludge removal, aeration equipment, and chemical feed and storage. Materials of construction, process control interface, and operation and maintenance factors are also discussed. Credit not granted for both CE 4355 and CE 5326. Prerequisite: CE 3131, CE 3142, and CE 3334.

CE 5327. ADVANCED PROJECT CONTROL. 3 Hours.
Fundamentals of construction estimating and scheduling, earned value, value engineering, risk allocations, jobsite management, safety and closeout.

CE 5328. FUNDAMENTALS OF AIR POLLUTION. 3 Hours.
An introduction to the air pollution field including: pollutant types, sources, effects; atmosphere and basic calculations; emission estimates; Clean Air Act; dispersion modeling; air pollution reduction strategies. Credit not granted for both CE 4350 and CE 5328. Prerequisite: concurrent enrollment in CE 3334 or CE 5321 or consent of instructor.

CE 5329. ENVIRONMENTAL RISK BASED CORRECTIVE ACTION. 3 Hours.
Process for the assessment and response to contamination; integrating risk and exposure practices to ensure protection of human health and environment. Includes characterization, EPA tier approach, general aspects of toxicology, dose exposure, pathways, receptors, migration and risk assessment. Prerequisite: consent of instructor.

CE 5330. CHARACTERISTICS OF TRAFFIC. 3 Hours.
The fundamental elements of traffic - the driver, the vehicle, and the roadway - are considered and then extended into studies of streams of traffic flow. Techniques of conducting traffic engineering studies, including methods of measuring speed, volume, and density, are covered along with methods for the determination of capacity on freeways and rural highways (uninterrupted flow facilities). Parking and accident studies are also included. Prerequisite: CE 3302; and CE 3301 or concurrent registration therein.

CE 5331. TRAFFIC ENGINEERING OPERATIONS. 3 Hours.
Methods of traffic regulation and control optimization. Traffic laws, motorist communication by means of traffic control devices, and the design and operation of both fixed time and actuated traffic signals at intersections. Analysis and design techniques for intersections using capacity and level of service concepts. Credit will not be granted for both CE 4313 and CE 5331. Prerequisite: CE 3302; and CE 3301 or concurrent registration therein.

CE 5332. HIGHWAY DESIGN. 3 Hours.
Geometric considerations necessary for the design of city streets, highways, and freeways such as the cross sections, vertical and horizontal alignment, sight distances and stopping distances. Includes the design of maneuver areas, channelization, ramps, intersections, and interchanges. Credit will not be granted for both CE 4312 and CE 5332. Prerequisite: CE 3302.

CE 5333. TRAFFIC CONTROL SYSTEMS. 3 Hours.
Control algorithms and optimization of splits, offsets, and cycle lengths for arterial progression and traffic signals in networks; computer simulation techniques; problem solving with computer simulation and optimization packages; freeway control using ramp meters and dynamic motorist communications. Prerequisite: CE 4313 or CE 5331 or Equivalent or Consent of Instructor.

CE 5334. INTRODUCTION TO RAILROAD ENGINEERING. 3 Hours.
Overview of railroad industry in the United States; structure of track, base, and foundation; drainage; railroad structures (bridges and retaining walls); geometric design; communications and signaling; maintenance. Credit not granted for CE 4314 and CE 5334. Prerequisite: CE 3302.

CE 5335. AIRPORT ENGINEERING. 3 Hours.
Airport master planning, for forecasting air travel demand, airside capacity, passenger terminal design, air traffic control, land access planning and design, landside operations, air cargo facility design. Prerequisite: CE 3302.

CE 5336. PAVEMENT DESIGN. 3 Hours.
Principles and theoretical concepts of rigid and flexible pavements for highways and airfields; effects of traffic loads, natural forces, and material quality; current design practices; and live cycle cost analysis. Prerequisite: CE 3302 and CE 3343.

CE 5337. URBAN TRANSPORTATION PLANNING. 3 Hours.
Theory and application of a comprehensive urban transportation planning methodology. Basic studies of population dynamics, urban growth, land use, forecasting trip generation and distribution, traffic assignment, mode split, evaluation, simulation models, characteristics of mass transit and other non-auto modes, and system design and evaluation. Credit will not be granted for both CE 4311 and CE 5337. Prerequisite: CE 3301 and CE 3302; or consent of instructor.

CE 5338. SYSTEM EVALUATION. 3 Hours.
Techniques necessary to perform economic and multi-criteria evaluations of civil engineering projects. These will be used to assess the strengths and weaknesses of different decision-making strategies and analyze contemporary topics and case studies in making civil engineering decisions. Prerequisite: IE 2308 and CE 3301 or IE 3301 or equivalents, or consent of instructor.

CE 5339. STATISTICS FOR CONSTRUCTION. 3 Hours.
Point estimation, interval estimation, sample size determination, tests of hypothesis, analysis of variance, linear regression, matrix methods for multiple linear regression, polynomial regression, transformations, non-linear regression. Prerequisite: CE 3301.

CE 5340. CONSTRUCTION PROJECT ACQUISITION. 3 Hours.
Fundamentals of acquiring the required goods and services necessary to fulfill the obligations of the construction contract. Service and subcontractor contracts, negotiating tactics and strategies, material pricing; and dispute resolution. The course includes negotiation practice based on typical construction acquisition situations to help prepare the student with experience of negotiating in the real world of construction and business. Prerequisite: consent of instructor.

CE 5341. PAVEMENT EVALUATION, REHABILITATION AND MANAGEMENT SYSTEMS. 3 Hours.
Pavement inventory; condition and structural evaluation techniques; serviceability concepts; deterioration modeling; maintenance vs. rehabilitation vs. reconstruction; economic considerations, selection of project alternatives and life cycle cost analysis. Prerequisite: CE 5336 or equivalent.

CE 5342. CONSTRUCTION PROJECT ADMINISTRATION. 3 Hours.
Topics in construction management and project administration, such as project delivery system, documentation and specification, electronic project administration, construction safety, risk allocation and liability sharing, changes and extra work, claims and disputes, and project closeout. Credit not granted for CE 4303 and CE 5342.

CE 5343. ADVANCED BUILDING INFORMATION MODELING. 3 Hours.
Introduction to current Building Information Modeling (BIM); Discussion of the role of BIM in the Construction Engineering and Management; Revit Architecture, Structure, and MEP; Creating sets, building elements, structural systems, and MEP systems; BIM and clash detection; BIM and Construction Cost Estimating and Scheduling.

CE 5344. CONSTRUCTION METHODS: FIELD OPERATIONS. 3 Hours.
Introduction to the methods, equipment, and management techniques used in the construction industry. Topics include equipment operating characteristics, job site safety, and field management. Credit not granted for CE 4332 and CE 5344.

CE 5345. INFRASTRUCTURE EVALUATION, MAINTENANCE, AND RENEWAL. 3 Hours.
This course is designed for engineers and managers involved in infrastructure development, sustainability, and replacement. Topics include asset management, inspection, evaluation, maintenance, and renewal alternatives for waste collection and water distribution systems, surface and subsurface drainage, pavements, bridges, culverts, buildings, and other structures. Prerequisite: Consent of instructor.

CE 5346. OPEN CHANNEL FLOW. 3 Hours.
Open channel hydraulic principles, flow classification, backwater curves, transitions, obstructions, bends, flood flow computations, and urban watershed applications. Credit not granted for both CE 4358 and CE 5346. Prerequisite: CE 3305 and CE 4328; or consent of instructor.

CE 5347. ADVANCED HYDROLOGY. 3 Hours.
Elements of hydrometeorology, infiltration, soil moisture, hydrographs, rainfall runoff relationships, and effects of these factors with regard to water resources, urban watersheds, flood control, and environmental issues. Prerequisite: CE 3342 and CE 4328 or equivalent.

CE 5348. GROUNDWATER HYDROLOGY. 3 Hours.
Hydrology and hydrogeology of groundwater to include aquifer and vadose properties and measurements, basic flow systems and solutions, well systems, elementary contaminate transport, water quality, recharge, subsidence, flow system analysis, flow nets, and leaky aquifers. Prerequisite: CE 3342 or consent of instructor.

CE 5349. ADVANCED GIS AND HYDROLOGIC AND HYDRAULIC MODELING. 3 Hours.
Use of Geographic Information Systems (GIS) and design of GIS developed hydrologic/hydraulic models commonly applied in the water resources field. The course will have three main areas of emphasis including: principles and operations of ArcGIS, design and implementation of standard hydrologic and hydraulic models, the linkage of these models to engineering analysis of current water resources problems including flooding, water quality and water supply.

CE 5350. RISK MANAGEMENT. 3 Hours.
The risk management process including risk identification, monitoring, and control; integrated quantitative cost and schedule risk analysis.

CE 5351. ADVANCED STRUCTURAL ANALYSIS I. 3 Hours.
Advanced analysis of indeterminate beams, frames, trusses, arches, and cables. Credit will not be given for both CE 5351 and CE 4368. Prerequisite: CE 3341.

CE 5352. REMOTE SENSING-HYDROMETEOROLOGY. 3 Hours.
Atmospheric composition, radiative fluxes, thermodynamics, water vapor, stability, circulation, precipitation processes, fronts, thunderstorms and tropical storms; basics of remote sensing; observing precipitation using weather radar and satellite-borne sensors; prediction of precipitation by numerical weather models. The class will be a combination of lectures and in-class computer-based laboratory exercises. Prerequisite: CE 3342 and CE 4328.

CE 5353. ADVANCED HYDRAULICS. 3 Hours.
Flow resistance, St. Venant equations, solution of St. Venant by finite difference methods, dam break problem, water hammer intro to finite elements to open channel flow. Credit will not be granted for both CE 4330 and CE 5353. Prerequisite: CE 5346 and CE 5347; or consent of instructor.

CE 5354. WATER RESOURCES PLANNING. 3 Hours.
Historical and current water development concepts. Administrative and allocation concerns. General principles and procedures of water resource planning includes regional, multipurpose, economic and systems considerations. Prerequisites: CE 3301, CE 3342, and IE 2308; or consent of instructor.

CE 5355. CONSTRUCTION MATERIALS. 3 Hours.
Principles of construction related to construction regulations and standards, loads, fire safety, acoustics, joints and sealants. Systems of construction involving concrete, steel, wood, masonry, sealants, and soil, and including excavations, below grade construction, formwork, cladding, joints, windows, doors, roofing, and ceilings.

CE 5356. SURFACE WATER QUALITY MODELING. 3 Hours.
Contaminant transport and fate in surface water. Engineering methods assessing surface water and transport for water and sediment quality. Modeling dissolved oxygen, chemicals and waterborne substances. Prerequisite: CE 5346.

CE 5357. HYDROLOGIC TECHNIQUES. 3 Hours.
A study of current hydrologic techniques and methods for the analysis of hydrologic variables necessary in the design of projects such as bridges, culverts, reservoirs. Techniques involve extreme value statistics, model hydrographs, deterministic and stochastic methods for data analysis. Prerequisite: CE 5347 or consent of instructor.

CE 5358. SOLID WASTE ENGINEERING. 3 Hours.
This course provides an overview of the various aspects of integrated municipal solid waste management (with the exception of landfilling, covered in CE 5375). Topics covered include waste generation, characterization, and collection; source reduction; waste processing; design of facilities for materials recovery (recycling centers) and energy recovery (combustors and anaerobic digesters); life cycle analysis of solid waste management facilities; case study project. Credit not granted for both CE 4354 and CE 5358. Prerequisite: CE 3334 or CE 5321 or consent of instructor.

CE 5359. HUMAN INTERACTION IN THE BUILT ENVIRONMENT. 3 Hours.
Understanding human interaction in the built environment is critical for assessing comfort levels and system performance. This course would cover theories of human computer interaction, environmental monitoring, and advanced data analytics. Students would be given a hands-on opportunity to build their own data acquisition system to collect and model human behavior. This course meets the emerging trend in a nexus of computer science and facility management. Credit not granted for both AREN 4343 and CE 5359.

CE 5360. BUILDING SCIENCE II. 3 Hours.
Building science is critical for accessing human comfort and energy efficiency. In this course, students will be able to understand the basic concepts of thermodynamics (heat transfer, energy balance, psychrometric chart) and apply to building engineering (human comfort, building enclosures, HVAC systems). As a term project, students will learn energy simulation tools. There will be additional tasks to learn EnergyPlus for graduate students. Credit not granted for both AREN 4314 and CE 5360. Prerequisite: AREN 3213.

CE 5361. DESIGN AND CONSTRUCTION OF ASPHALT CONCRETE. 3 Hours.
An in-depth study of the properties of constituent materials for asphalt concrete mixtures. Design methods for Hot-Mixes Asphalt (HMA) and Stone Matrix Asphalt (SMA). Theory and practice of asphalt concrete mix for pavements, including specifications and construction methods for hot-mix asphalt and surface treatments. Maintenance and rehabilitation of flexible pavements. Relationships of material engineering properties to pavement design and performance. Credit not granted for both CE 4336 and CE 5361. Prerequisite: CE 3361 or equivalent.

CE 5362. RIGID PAVEMENTS. 3 Hours.
Portland cement concrete mix design and production. Paving operations. Saw and seal operations. Subgrade preparation. Base selection. Drainage selection, design and construction. Bonded and unbonded concrete overlays. Whitetopping and ultra-thin whitetopping. Concrete pavement restoration; quality assurance and quality control in concrete pavement construction. Credit not granted for both CE 4337 and CE 5362. Prerequisite: CE 3361 or equivalent.

CE 5363. CONSTITUTIVE MODELING OF SOILS. 3 Hours.
Fundamental aspects of elasto-plastic behavior of soils along axisymmetric stress paths, shear strength of soils in light of critical state soil mechanics, and constitutive models to predict soil response under saturated conditions, including Cam Clay and modified Cam Clay models. Prerequisite: CE 3343 or consent of instructor.

CE 5364. FOUNDATION ANALYSIS AND DESIGN. 3 Hours.
The design, construction, and performance of footings, rafts, and piles founded on or in sands, clays, silts, stratified soils, and weak rock. Includes the influence of various geologic terrain on selecting foundation type and constructability, in-situ investigations to determine material design parameters, bearing capacity, and settlement of foundations. Credit not granted for both CE 4321 and CE 5364. Prerequisite: CE 3343.

CE 5365. THEORETICAL SOIL MECHANICS. 3 Hours.
Theory of consolidation, magnitude, time rate, pore pressure dissipation with variable construction rate and layered soils. Secondary compression, preconsolidation, and preloading. Shear strength of soil. Critical state soil mechanics, dilation and strain-softening in drained shear, pore pressure response in undrained shear, including static liquefaction. Prerequisite: CE 3343 or consent of instructor.

CE 5366. SOIL DYNAMICS. 3 Hours.
Fundamental aspects of mechanical behavior and characterization of soils and earth structures subjected to dynamic loads, including wave propagation in soils, dynamic soil properties, liquefaction of soils, dynamic bearing capacity of shallow foundations, seismic design of retaining walls, and seismic slope stability. Prerequisites: CE 2221 and CE 3343; or consent of instructor.

CE 5367. DESIGN OF EARTH STRUCTURES. 3 Hours.
Study of the states of stress and analysis techniques associated with cuts, fills, and retaining structures. Includes slope stability, embankment reinforcement, conventional and reinforced earth retaining walls, excavation bracing, and sheet pile wharf structures. Credit not granted for both CE 4320 and CE 5367. Prerequisite: CE 3343 or consent of instructor.

CE 5368. UNSATURATED SOIL MECHANICS. 3 Hours.
Fundamental aspects of the mechanical behavior of unsaturated soils, including stress and volumetric state variables, matrix suction measurements and soil-water characteristic curves, shear-strain-strength and volume change responses, suction-controlled laboratory testing techniques and constitutive modeling. Prerequisite: CE 3343; or consent of instructor.

CE 5369. COMPUTATIONAL GEOTECHNICS. 3 Hours.
Introduction to analytical, finite differences, and finite element modeling, analyses of embankments, earth dams, slopes, excavation support systems including soldier pile and diaphragm walls, shallow and deep foundation systems, and other geostructures using different geotechnical software. Prerequisite: CE 3343 or consent of instructor.

CE 5370. EXPERIMENTAL SOIL MECHANICS. 3 Hours.
Fundamentals of experimental studies of soil behavior, soil properties and their laboratory test methods which include consolidation, direct shear, static triaxial, cyclic triaxial, resonant column, bender elements and other advanced geotechnical laboratory tests, instrumentation and measurement techniques. Prerequisite: CE 3343 or consent of instructor.

CE 5371. SOIL BEHAVIOR. 3 Hours.
Fundamental aspects of soil behavior, bonding, crystal structure, surface characteristics, clay mineralogy, soil-water movement, fabric, effective stress concepts, conduction phenomena, consolidation, and shear strength. Prerequisite: CE 3343 or consent of instructor.

CE 5372. GEOSYNTHETICS. 3 Hours.
Geosynthetics properties and testing, design of geotextiles, geogrids, geonets, and geomembranes for applications in separation, pavement, embankment and retaining wall reinforcement, soil stabilization, filtration, drainage and liquid barrier, construction guidelines and case histories. Credit not granted for both CE 4322 and CE 5372. Prerequisite: CE 3343 or consent of instructor.

CE 5373. ENVIRONMENTAL GEOTECHNOLOGY. 3 Hours.
Physical and chemical principles of clays, clay mineralogy, coupled flow, hydraulic conductivity, in situ and laboratory tests, chemical transport, adsorption of chemicals, risk assessment and soil remediation technologies, bioremediation, phytoremediation, electrokinetics and soil washing, waste containment. Prerequisite: CE 5371 or consent of instructor.

CE 5374. GROUND IMPROVEMENT. 3 Hours.
Introduction and types of ground improvement for different problem soils including soft and expansive soils, shallow and deep soil densification, sand drains and wick drains, chemical modification, chemical binders and mechanisms of ground improvement, different types of grouting, deep mixing, stone columns, soil nailing, ground anchors, geosynthetics, MSE walls, reinforced slopes. Prerequisite: CE 3343 or consent of instructor.

CE 5375. GEOTECHNICAL ASPECTS OF LANDFILLS. 3 Hours.
Introduction and types of landfills, landfill site selection, siting and configuration, compacted and geosynthetic clay liners, final cover design, landfill settlement and slope stability, post closure uses of landfills, leachate and gas generation, collection and removal system, bioreactor landfills and future trends. Credit not granted for both CE 4323 and CE 5375. Prerequisite: CE 3343 or consent of instructor.

CE 5376. GIS IN GEOTECHNICS. 3 Hours.
Introduction to (GIS,Geographical Information Systems, ArcInfo/ArcView) based applications in geotechnical engineering, including bore-log database management and profiling, spatial analyses and assessment of liquefaction, ground motion amplification, landslide, and groundwater contamination hazard potentials. Prerequisite: CE 3343 or consent of instructor.

CE 5377. CONSTRUCTION FINANCE. 3 Hours.
Financial aspects and job costing of a construction project. Includes project management principles, budgets, cost codes, cost-to-complete, and financial reports specific to the management of a construction company and project control.

CE 5378. CONSTRUCTION CONTRACTS, SPECIFICATIONS, & ADMINISTRATION. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Credit not granted for CE 4304 and CE 5378. Prerequisite: Consent of instructor.

CE 5380. MANAGEMENT OF INFRASTRUCTURE ASSETS. 3 Hours.
Overview of an infrastructure management system. Infrastructure asset development and management. Optimization of infrastructure asset procurement and preservation through good data input and the use of economic models, benefit cost studies, and good maintenance and rehabilitation practices to protect assets investments.

CE 5381. PUBLIC PRIVATE PARTNERSHIP FOR INFRASTRUCTURE PROJECTS. 3 Hours.
Public-private partnership (P3) arrangements as an innovative approach to deliver public infrastructure projects. Topics include P3 benefits, limitations, contracting and implementation strategies. Prerequisite: CE 3311 or IE 2308; or consent of instructor.

CE 5382. CONSTRUCTION SUSTAINABILITY. 3 Hours.
Introduction to International Code Council's 2012 International Building Code and USGBC's LEED® New Construction Guidelines v.3 for constructing sustainable/green buildings. Review of building occupancy categories, construction types, allowable height and area, life safety requirements, rated building assemblies, and egress. Site selection, energy and water efficiency, material reuse and indoor air quality. Credit not granted for CE 4307 and CE 5382.

CE 5383. EXPERIMENTAL STRESS ANALYSIS. 3 Hours.
Introduction to experimental stress-analysis techniques. Theory and application of mechanical strain gages, electrical strain gages, introduction to photoelastic and thermal techniques, and brittle coatings. Prerequisite: CE 2313.

CE 5384. CONCRETE BRIDGE DESIGN AND EVALUATION. 3 Hours.
Analysis, design and evaluation of concrete highway bridges using AASHTO specifications. Analysis and design topics include bridge type selection, preliminary design, AASHTO LRFD bridge design philosophy, design loads, deck design, shear design, barrier design and substructure design. Evaluation topics include bridge inspection, non-destructive evaluation (NDE), load testing and load rating, using the AASHTO procedures. Prerequisite: CE 4363 or CE 5309.

CE 5385. STRUCTURAL DYNAMICS. 3 Hours.
Equation of motion for single degree of freedom systems including: free vibration; harmonic and periodic excitations; arbitrary, step and pulse excitations. Dynamic response of multi degree of freedom systems including: free vibration; computation of vibration properties of structures; damping in structures; modal analysis; and response history analysis. Dynamic analysis of systems with distributed mass. Prerequisite: CE 5303 or concurrent registration.

CE 5386. BUILDING HVAC SYSTEMS & ENERGY SIMULATION. 3 Hours.
This course will introduce the fundamental principles and engineering procedures for basic building science; design of heating, ventilating, and air conditioning (HVAC) systems; system and equipment selection; and duct design and layout. This course will also include energy conservation techniques and computer applications, including building energy modeling.

CE 5387. CONSTRUCTION PRODUCTIVITY. 3 Hours.
Evaluation of construction project management's effectiveness. An investigation of the advanced techniques required for improvement of construction projects including time, cost, quality management, preplanning, field evaluation techniques, time-lapse photograph, safety, human factors, and communications. Prerequisite: CE 5327.

CE 5388. PIPELINE CONSTRUCTION AND TRENCHLESS TECHNOLOGY. 3 Hours.
Pipeline and utility design, construction and renewal. Topics include pipeline infrastructure structural considerations, planning and construction considerations, pipe materials, and trenchless technologies. Credit not granted for both CE 4305 and CE 5388. Prerequisite: graduate standing and consent of instructor.

CE 5389. PIPELINE SYSTEMS ASSET MANAGEMENT. 3 Hours.
Pipeline systems asset management, inventory, inspection, and life cycle costs. Topics include pipeline deterioration parameters, asset management technologies, risk assessment, government regulations, renewal technologies, and case studies. Credit not granted for both CE 4306 and CE 5389. Prerequisite: graduate standing and consent of instructor.

CE 5390. UNSATURATED SOIL MECHANICS II. 3 Hours.
Advanced principles of unsaturated soil behavior in light of critical state based soil mechanics. Topics: Cam-Clay model for saturated soils, Cam-Clay model for unsaturated soils, and calibration/programming of Barcelona Basic Model for unsaturated soils. Prerequisite: CE 5368 or consent of instructor.

CE 5391. ADVANCED STUDIES IN CIVIL ENGINEERING. 3 Hours.
Individual studies of advanced topics under the supervision of a professor or professors. Graded F, P, R. Prerequisite: consent of instructor.

CE 5392. SPECIAL TOPICS IN AIR POLLUTION. 3 Hours.
Sources, transport, fate, characteristics, and control of air contaminants. May be repeated for credit when topics vary. Topics include: Topic 1 - Air Quality Modeling. Mathematical models for predicting air pollutant transport and transformation in the atmosphere, to evaluate health impacts and potential control strategies. The course covers 4 types of air quality models: box models, photochemical grid models (for ozone and particulate matter), Gaussian dispersion models (major emphasis), and receptor models. Use of Gaussian dispersion modeling software. Topic 2 - Air Pollution Control System Design. Design of air pollution control systems for stationary sources, including particle control technologies (cyclones, electrostatic precipitators, fabric filters and wet scrubbers) and gaseous control technologies (incinerators, adsorption systems, absorption systems, biofilters, nitrogen oxide controls, mercury controls, and carbon dioxide controls). Topic 3 - Air Pollution Chemistry and Meteorology. Designed to give students an understanding of how pollutants react and travel in the atmosphere. Chemistry of ground-level ozone formation, ozone layer depletion, acid deposition, fine particle formation, and climate change; meteorological variables impacting pollutant transport in the atmosphere, such as atmospheric stability, turbulence and wind speed. Prerequisite: Graduate standing and consent of instructor.

CE 5393. ENVIRONMENTAL ORGANIC CHEMISTRY. 3 Hours.
Introduction to chemical structures, reactions, and transformations. Disposition of compounds of environmental significance utilizing sorption, bioaccumulation, acid-base reactions, hydrolysis reactions, biodegradation, and biotransformation. Prerequisite: CE 3334 or consent of instructor.

CE 5394. EARTHQUAKE DESIGN OF REINFORCED CONCRETE BUILDINGS. 3 Hours.
Design of earthquake resistant reinforced concrete (RC) building structures. ACI 318, ASCE 7, earthquake loads effects on buildings and related structural damage, properties of concrete and steel beyond the elastic range, development and anchorage, confined concrete, inelastic behavior of RC members under large load reversals, design of RC beams, columns, beam-column joints, special moment frames, coupling beams, special structural walls, and other structural systems. Prerequisite: CE 4347.

CE 5395. MASTER'S PROJECT. 3 Hours.
Non-thesis master's degree candidates with approval to include a project in their program. Graded F, P, R. Prerequisite: consent of instructor and approval of Civil Engineering Graduate Advisor.

CE 5396. SITE REMEDIATION ENGINEERING. 3 Hours.
This course provides practical understanding of the engineering principles and practices associated with the characterization and remediation of contaminated sites. Methods for site characterization and risk assessment will be highlighted while the emphasis will be on remedial action screening processes and technology principles and conceptual design. In-situ and ex-situ treatment processes will be covered, including unit operations, coupled processes, and complete systems within the context of community implementation. Case studies with focus on developing communities will be used and computerized tools for process selection and design will be presented. Prerequisite: CE 3334; or consent of instructor.

CE 5398. THESIS. 3 Hours.
Research and preparation pertaining to the master's thesis. Graded F, P, R.

CE 5695. MASTER'S PROJECT. 6 Hours.
Non-thesis master's degree candidates with approval to include a project in their program. Graded F, P, R. Prerequisite: consent of instructor and approval of Civil Engineering Graduate Advisor.

CE 5698. THESIS. 6 Hours.
Research and preparation pertaining to the master's thesis. Graded F, P, R.

CE 6197. RESEARCH IN CIVIL ENGINEERING. 1 Hour.
Individual supervised research projects. May be repeated for credit. Graded F, P, R. Prerequisite: consent of instructor and approval of Supervising Committee Chair.

CE 6297. RESEARCH IN CIVIL ENGINEERING. 2 Hours.
Individual supervised research projects. May be repeated for credit. Graded F, P, R. Prerequisite: consent of instructor and approval of Supervising Committee Chair.

CE 6300. ADVANCED TOPICS IN CIVIL ENGINEERING. 3 Hours.
Topics of current interest in the field of civil engineering. The subject title is listed in the class schedule and in the student's record. Topics vary. May be repeated for credit when topic changes. Prerequisite: consent of instructor.

CE 6306. PUBLIC TRANSIT PLANNING & OPERATIONS. 3 Hours.
Theory and application of technologies used for transit demand analysis, routing, scheduling, evaluation, crew assignment, maintenance strategies, and management. Land-use impact on public transit policy and operation is also introduced. Prerequisite: CE 4311 or CE 5337 or equivalent.

CE 6308. ANALYTICAL MODELS IN TRANSPORTATION. 3 Hours.
Development and analysis of mathematical models in transportation. Topics include travel demand, trip generation, distribution, mode choice, assignment, plan evaluation, spatial distribution, traffic control and flow models; principles of behavioral, econometric, deterministic, probabilistic, and chaotic simulation models, and their applications. Prerequisite: CE 4311 or CE 5337.

CE 6309. TRAFFIC FLOW THEORY. 3 Hours.
Speed, density relationships of vehicular traffic flow; statistical aspects of traffic events and queuing processes; deterministic models and simulation models of traffic flow behavior; applications of flow theory to traffic problem solutions. Prerequisite: CE 5330 or equivalent.

CE 6311. ADVANCED FOUNDATION DESIGN. 3 Hours.
Subsurface investigations; advanced design of mat foundations, retaining walls, reinforced retaining walls, anchor tiebacks, driven piles, and piers; destructive and nondestructive tests on deep foundations; group piles, laterally loaded piles, and design of foundations in expansive soils. Prerequisite: CE 4321 or CE 5364.

CE 6312. IN-SITU TESTING. 3 Hours.
Site characterization, in-situ testing procedures, and soil property interpretation methods for standard penetration tests, cone penetration tests utilizing friction cone, piezocone, and seismic cone, dilatometer, vane shear, pressure meter, and bore hole shear tests, non-destructive tests for pavement subgrade characterization. Prerequisite: CE 3143 or CE 5370 or consent of instructor.

CE 6313. DESIGN OF EARTH DAMS. 3 Hours.
Introduction to dams and levees, failure and damage analysis, erosion, seepage, filter, drainage design, foundation preparation for problematic subsoil conditions, seepage induced slope stability issues, desiccation crack and erosion control, numerical modeling and case studies, seismic issues. Prerequisite: CE 5367 or consent of instructor.

CE 6314. STORMWATER MODELING. 3 Hours.
Hydrologic modeling methods and issues, urban watershed modeling, methods of system analysis; analysis of hydrologic components as linear and nonlinear systems, watershed response, kinematic wave; and model parameters optimization. Prerequisite: CE 5346 and CE 5347; or consent of instructor.

CE 6315. ADVANCED GEOTECHNICAL MODELING. 3 Hours.
This course covers two numerical simulation methods: discrete element method (DEM) and finite element method (FEM). The four basic elements in DEM: initialization, search, contact models, velocity and displacement calculations will be introduced. This course will use FORTRAN as the coding language. A basic Fortran code will be provided. Students will learn how to make modifications to the basic code for their own applications. A term project will be required that consists of a numerical experiment. Fundamentals of FEM will be introduced including: basic elements, formulation methods, coordinate transformation, and boundary conditions. CAM clay model will be introduced and implemented in ABAQUS as a class exercise. Usage of ABAQUS will be introduced. Applications of FEM including pile soil interaction and simple beam simulation. Prerequisite: Grade of C or better in CE 5363; Grade of C or better in CE 5369; Programming language (FORTRAN, C, or MATLAB); and numerical analyses; or consent of instructor.

CE 6316. SEDIMENT TRANSPORT. 3 Hours.
Sourcing the sediment influx, the settling velocity, Shields critical shear stress, design with critical shear, bedload transport equations, suspended load transport, total transport equation, regime theory as index of stability. Prerequisite: CE 4358 or CE 5346; and CE 5347.

CE 6350. ADVANCED CONCRETE DESIGN II. 3 Hours.
Detailing of connections for ductility demands, modified compression field theory, strut and tie modeling of systems and areas, and design of shear walls and hybrid construction. Behavior of reinforced concrete structures, with emphasis on ductility and detailing. Prerequisite: CE 5312.

CE 6354. REPAIR AND REHABILITATION OF STRUCTURES. 3 Hours.
Causes of distress, evaluation methods for condition, strength, serviceability; repair materials, repair techniques, and quality control methods for repair of concrete. Criteria for rehabilitation; retrofit techniques for change in function, loading, and seismic forces. Prerequisite: CE 5311 and CE 5312.

CE 6355. EARTHQUAKE ENGINEERING. 3 Hours.
Earthquake characteristics; design of structures to resist earthquakes. Characterization of earthquakes for design. Development of design criteria for elastic and inelastic structural response. Seismic performance of various structural systems. Prediction of nonlinear seismic behavior. Basis for code design procedures. Preliminary design of steel and reinforced concrete structures. Evaluation of earthquake vulnerability of existing structures and rehabilitation of seismic deficiencies. Prerequisite: CE 5385.

CE 6356. ENERGY METHODS. 3 Hours.
Principles of mechanics; elastic beams and frames; variational method: curved cantilever beams; Rayleigh Ritz method; special form of Euler equation; differential equation for beam; variation of double integral; first variation of triple integral. Deformable bodies using indicial notation; buckling using energy method; Lagrange and Hamilton Principles; theory and analysis of plates; theory and buckling; and theory of vibration. Prerequisite: CE 5315.

CE 6357. STRUCTURAL STABILITY. 3 Hours.
Buckling of columns; approximate method of analysis for buckling problems; beam columns; structural system stability (buckling of frames); lateral torsional buckling; buckling of plates; and buckling of axially compressed cylindrical shells. Prerequisite: CE 5303 or concurrent registration therein.

CE 6358. THEORY OF ELASTICITY & ADVANCED MECHANICS. 3 Hours.
Introduction to matrices; vector spaces and calculus; tensor algebra, Eigenvalue problems. Solution to discrete systems: steady state problems and propagation problems. Solution of continuous systems: differential formulation; variational method; and weighted residual methods. Solution of linear and nonlinear static equilibrium equations. Theory of deformation; strain displacement relations in orthogonal curvilinear coordinate systems. Theory of stress; differential equation of equilibrium in curvilinear spatial coordinates; three dimensional equations of elasticity; nonlinear constitutive relationship; plane theory of elasticity; and plane elasticity in polar coordinates. Prerequisite: CE 5315 and MATH 3319.

CE 6360. THEORY OF ELASTICITY. 3 Hours.
Introductory mathematical concepts: vector calculus; tensor algebra. Theory of deformation; strain displacement relations in orthogonal curvilinear coordinate systems. Theory of stress; differential equation of equilibrium in curvilinear spatial coordinates; three dimensional equations of elasticity; nonlinear constitutive relationship; plane theory of elasticity; and plane elasticity in polar coordinates. Prerequisite: CE 5315.

CE 6391. ADVANCED PROJECTS IN CIVIL ENGINEERING. 3 Hours.
Projects related to advanced topics in graduate area. Graded F, P, R. Prerequisite: consent of instructor and approval of Civil Engineering Graduate Advisor.

CE 6397. RESEARCH IN CIVIL ENGINEERING. 3 Hours.
Individual supervised research projects. May be repeated for credit. Graded F, P, R. Prerequisite: consent of instructor and approval of Supervising Committee Chair.

CE 6399. DISSERTATION. 3 Hours.
Preparation of a doctoral dissertation in civil engineering. Graded F, R. Prerequisite: admission to candidacy for the Doctor of Philosophy degree.

CE 6697. RESEARCH IN CIVIL ENGINEERING. 6 Hours.
Individual supervised research projects. May be repeated for credit. Graded F, P, R. Prerequisite: consent of instructor and approval of Supervising Committee Chair.

CE 6699. DISSERTATION. 6 Hours.
Preparation of a doctoral dissertation in civil engineering. Graded F, R. Prerequisite: admission to candidacy for the Doctor of Philosophy degree.

CE 6997. RESEARCH IN CIVIL ENGINEERING. 9 Hours.
Individual supervised research projects. May be repeated for credit. Graded F, P, R. Prerequisite: consent of instructor and approval of Supervising Committee Chair.

CE 6999. DISSERTATION. 9 Hours.
Preparation of a doctoral dissertation in civil engineering. Graded F, P, R. Prerequisite: admission to candidacy for the Doctor of Philosophy degree.

CE 7399. DOCTORAL DEGREE COMPLETION. 3 Hours.
This course may be taken during the semester in which a student expects to complete all requirements for the doctoral degree and graduate. Enrolling in this course meets minimum enrollment requirements for graduation, for holding fellowships awarded by The Office of Graduate Studies and for full-time GTA or GRA positions. Students should verify that enrollment in this course meets other applicable enrollment requirements. To remain eligible in their final semester of study for grants, loans or other forms of financial aid administered by the Financial Aid Office must enroll in a minimum of 5 hours as required by the Office of Financial Aid. Other funding sources may also require more than 3-hours of enrollment. Additional hours may also be required to meet to requirements set by immigration law or by the policies of the student's degree program. Students should contact the Financial Aid Office, other sources of funding, Office of International Education and/or their graduate advisor to verify enrollment requirements before registering for this course. This course may only be taken twice. Students who do not complete all graduation requirements while enrolled in this course must enroll in a minimum of 6 dissertation hours (6699 or 6999) in their graduation term. Graded P/F/R.

COURSES

CM 1311. CONSTRUCTION DRAFTING. 3 Hours.
Introduction to computer aided drafting, using AutoCAD.

CM 1331. CONSTRUCTION SURVEYING. 3 Hours.
Introduction to surveying including distance measurement, corrections, leveling, measurement of angles and directions, traverse adjustment, volumes, cross section and area computations, and error theory. Methods and technologies such as Excel, MathCAD, global positioning system and geographic information systems used to manage data in surveying. Emphasis on the use of total stations. Prerequisite: Grade of C or better in CM 1311.

CM 2311. INTRODUCTION TO CONSTRUCTION MANAGEMENT. 3 Hours.
Characteristics of the construction industry; types of construction companies, contracts, people involved in a project, their responsibilities and interrelationships; ethical conduct; evolution of a project; interpreting working drawings; construction bonds; contract documents.

CM 2313. CONSTRUCTION MATERIALS AND METHODS. 3 Hours.
Materials, methods and sequences of the construction process; emphasis on design, specification, purchase and use of concrete, steel, masonry and wood. An understanding of the uses of construction materials. Prerequisite: Grade of C or better in CM 2311.

CM 2315. INTRODUCTION TO MECHANICS FOR CONSTRUCTION. 3 Hours.
Structural behavior in buildings; forces, moments, support reactions; free-body diagrams, equilibrium; internal forces in columns and beams; deflection; buckling. Prerequisite: Grade of C or better in MATH 1303 and PHYS 1441.

CM 2331. CONSTRUCTION DOCUMENTS. 3 Hours.
Introduction to construction documents and applicable software for use in communicating building design intentions to field personnel, including an understanding of how to interpret, explain, quantify and use construction documents to bid, construct and manage construction projects. Prerequisite: Grade of C or better in CM 2311.

CM 2391. PROBLEMS IN CONSTRUCTION MANAGEMENT. 3 Hours.
Selected problems in construction management on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the chair of the department.

CM 3313. CONSTRUCTION ESTIMATING I. 3 Hours.
Systems approach to determining required quantities of construction materials; quantification of various types of foundation systems, structural systems and building envelope systems; excerpts of contract documents from a variety of different building projects and materials; plan reading. Prerequisite: Grade of C or better in CM 2311 and CM 2331; Permission of the CE Chair or admission to the CM Professional Program.

CM 3315. CONSTRUCTION LAW AND ETHICS. 3 Hours.
Introduction to basic contract and tort issues and their application in the construction industry; delineation of the various types of contracts and remedies available to parties involved in a construction project; additional related topics including bidding, delays, mechanics liens, site conditions, warranties and the Uniform Commercial Code as it relates to the construction industry. Prerequisite: Grade of C or better in CM 2311 and CM 2313; Permission of the CE Chair or admission to the CM Professional Program.

CM 3331. MECHANICAL AND ELECTRICAL SYSTEMS. 3 Hours.
Mechanical and electrical systems with a major emphasis on estimating and installation, design and control of the electrical, heating, ventilation and cooling system, site planning and acoustical treatments. Prerequisite: Grade of C or better in PHYS 1442; Permission of the CE Chair or admission to the CM Professional Program.

CM 3333. CONSTRUCTION DESIGN I. 3 Hours.
The principles flexure and shear, deflections, buckling are used to consider design/build construction including building systems, building codes, criteria and selection, economic feasibility, value engineering, customer control, and value-added construction services as well as an introduction to Building Information Modeling BIM. Prerequisite: Grade of C or better in CM 2315; Permission of the CE Chair or admission to the CM Professional Program.

CM 3335. SOILS AND FOUNDATION IN CONSTRUCTION. 3 Hours.
Introduction to soil types found on construction projects; properties and classification of soil, embankment control, dewatering, excavation supports, foundations, piers, and pilings. Prerequisite: Grade of C or better in CM 2315; Permission of the CE Chair or admission to the CM Professional Program.

CM 3337. CONSTRUCTION ADMINISTRATION AND ECONOMICS. 3 Hours.
Project planning, cost controls, and construction related financial documents including: schedule of values, labor and operations cost reports, income statements, balance sheets and construction budgets; emphasis on the development of techniques required to ethically and effectively monitor the financial aspects of a construction project. Prerequisite: Grade of C or better in CM 2331 and MATH 1303; Permission of the CE Chair or admission to the CM Professional Program.

CM 3339. CONSTRUCTION SAFETY. 3 Hours.
Examines the application of OSHA 29CFR 1926 for the construction industry along with applicable state and federal construction safety laws pertaining to construction, altercations, or repair work at a construction site. Prerequisite: Grade of C or better in CM 2331; Permission of the CE Chair or admission to the CM Professional Program.

CM 3341. CONSTRUCTION DESIGN. 3 Hours.
Application of statics and strength of materials for design and construction of concrete, masonry, steel, and timber building structures. Prerequisite: Grade of C or better in CM 2313 and CM 2315.

CM 4111. CONSTRUCTION MANAGEMENT CAPSTONE I. 1 Hour.
This course is the first in the Construction Management capstone series and provides project definition, project planning, scheduling, and results in a presentation and plan for implementing during Capstone II. Prerequisite: Grade of C or better in CM 3333; Permission of the CE Chair or admission to the CM Professional Program.

CM 4300. ADVANCED TOPICS IN CONSTRUCTION MANAGEMENT. 3 Hours.
Advanced topics of current interest in any one of the various fields of construction management. The subject title to be listed in the class schedule. May be repeated for credit when topic changes. Prerequisite: Admission to the professional program and consent of the department chair.

CM 4301. ADVANCED TOPICS IN CONSTRUCTION MANAGEMENT WITH LAB. 3 Hours.
Advanced topics of current interest in any one of the various fields of construction management. The subject title to be listed in the class schedule. May be repeated for credit when topic changes. Prerequisite: Admission to the professional program and permission of the chair of the department.

CM 4304. CONSTRUCTION CONTRACTS. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Prerequisite: Grade of C or better in CM 3315 and CM 3337; Admission to the CM Professional Program.

CM 4306. BUILDING CONSTRUCTION CONTRACTS. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Prerequisite: Grade of C or better in CM 3315; Grade of C or better in CM 3337; Admission to the CM Professional Program.

CM 4313. CONSTRUCTION DESIGN II. 3 Hours.
Application of statics and strength of materials for construction of steel buildings with computer analysis and design. Prerequisite: Grade of C or better in CM 3333 and Admission to the CM Professional Program.

CM 4315. CONSTRUCTION ESTIMATING II. 3 Hours.
Quantification and pricing of direct field costs and general condition costs from construction documents; the preparation of complete lump sum bid package ready for project execution; utilization of complete set of contract documents required; plan reading. Prerequisite: Grade of C or better in ACCT 2301 and CM 3313 and Admission to the CM Professional Program.

CM 4317. CONSTRUCTION SCHEDULING. 3 Hours.
An introduction to construction project management scheduling covering concepts of project selection and scheduling, utilizing the estimate to predict the schedule, scheduling subcontracting, cost controls, project documentation, construction bonds, insurance, payments and the elements of close out; development of professional communication skills through student prepared multi-media presentations. Prerequisite: Grade of C or better in CM 3313 and Admission to the CM Professional Program.

CM 4331. CONSTRUCTION MANAGEMENT CAPSTONE. 3 Hours.
Utilize information from all previous courses to give an understanding of the construction management profession culminating in a semester project and presentation. A response to an RFP announcement or bid will be prepared for each team project. Prerequisite: Grade of C or better in CM 4315, CM 4317, CM 4351, and CM 4357; Completion of all required 3000 level CM courses; Admission to the CM Professional Program.

CM 4332. CONSTRUCTION FIELD OPERATIONS. 3 Hours.
Introduction to the construction industry and the methods, equipment, and management techniques used. Topics include equipment operating characteristics, underground construction, job site safety, and field management. Prerequisite: Grade of C or better in CM 2313 and CM 3335; Admission to the CM Professional Program.

CM 4335. GEOTECHNICAL ASPECTS OF CONSTRUCTION. 3 Hours.
Review of engineering geology and soil mechanics; interpretation of geotechnical reports; site preparation; ground improvement; excavation including supports and dewatering; foundations including consideration of deep foundations and expansive soils; tunneling in soils and rock. Prerequisite: Grade of C or better in CM 3335 and admission to the CM Professional Program.

CM 4337. LAND AND SITE DEVELOPMENT. 3 Hours.
Introduction to site planning and its process. This course covers important characteristics of Site Planning involved in a construction project including land features, uses, buildings, regulations, local community cultures, and site analysis and planning. Students will work on developing a site plan for the end of semester project. Prerequisite: Grade of C or better in CM 1331 and CM 3335; Admission to the CM Professional Program.

CM 4351. BUILDING INFORMATION MODELING FOR CONSTRUCTION MANAGEMENT. 3 Hours.
Introduction to techniques used in development and management of Building Information Models. Emphasis on constructability and management. Prerequisite: Grade of C or better in CM 3341 and admission to the CM Professional Program.

CM 4353. RESIDENTIAL AND COMMERCIAL CONSTRUCTION. 3 Hours.
A senior course for students preparing to enter the project management of residential and commercial construction projects, including: aspects of design, bidding/estimating, presentation, value engineering, contracts/negotiation, subcontractor relations, cost controls, management during construction, close out, and post-construction requirements. Prerequisite: Admission to the CM Professional Program.

CM 4357. SUSTAINABLE BUILDING PRACTICE. 3 Hours.
Ethics and application of environmental sustainability practice in building construction. Introduction to U.S. Green Building Council LEED program standards, methods, and procedures as applied to construction documents interpretation and construction. Prerequisite: Admission to the CM Professional Program.

CM 4359. INDUSTRIAL INTERNSHIP I. 3 Hours.
Program provides for a learning experience in a construction management environment appropriate to the undergraduate level of work with a minimum of 150 hours of work. A written report of the experience and a presentation are required. Prerequisite: Permission of instructor and admission to the CM Professional Program.

CM 4360. INDUSTRIAL INTERNSHIP II. 3 Hours.
Student to experience industrial internship under supervision of an industrial mentor and internship instructor. Prerequisite: CM 4359; Admission to the CM Professional Program.

CM 4391. PROBLEMS IN CONSTRUCTION MANAGEMENT. 3 Hours.
Selected problems in construction management on an individual or group basis. Reference material is assigned and progress conferences are held frequently, by arrangement, with a faculty supervisor. Prerequisite: Permission of the chair of the department and admission to the CM Professional Program.

CM 5300. TOPICS IN CONSTRUCTION MANAGEMENT. 3 Hours.
Topics of current interest in the field of construction management. The subject title is listed in the class schedule and in the student's record. Topics vary. May be repeated for credit when topic changes. Prerequisite: Consent of instructor.

CM 5301. TOPICS IN CONSTRUCTION MANAGEMENT WITH LAB. 3 Hours.
Topics of current interest in the field of construction management. The subject title is listed in the class schedule and in the student's record. Topics vary. May be repeated for credit when topic changes. Prerequisite: Consent of instructor.

CM 5313. GEOTECHNICAL ASPECTS OF CONSTRUCTION. 3 Hours.
Review of engineering geology and soil mechanics and teaching of the foundation and underground excavation construction solely to graduate students specializing in construction engineering & management. Topics include interpretation of geotechnical reports, embankment construction, foundations on expansive soils, excavation supports, excavation dewatering, deep foundation construction, tunneling in soft ground as well as in soft/hard rock, and trenchless technology piping. Prerequisite: CM 5378.

CM 5339. STATISTICS FOR CONSTRUCTION. 3 Hours.
Point estimation, interval estimation, sample size determination, tests of hypothesis, analysis of variance, linear regression, matrix methods for multiple linear regression, polynomial regression, transformations, non-linear regression. Prerequisite: Grade of C or better in CE 3301.

CM 5340. CONSTRUCTION PROJECT ACQUISITION. 3 Hours.
Fundamentals of acquiring the required goods and services necessary to fulfill the obligations of the construction contract. Service and subcontractor contracts, negotiating tactics and strategies, material pricing; and dispute resolution. The course includes negotiation practice based on typical construction acquisition situations to help prepare the student with experience of negotiating in the real world of construction and business. Prerequisite: Consent of instructor.

CM 5342. CONSTRUCTION PROJECT ADMINISTRATION. 3 Hours.
Topics in construction management and project administration, such as project delivery system, documentation and specification, electronic project administration, construction safety, risk allocation and liability sharing, changes and extra work, claims and disputes, and project closeout. Credit not granted for CE 4303 and CM 5342.

CM 5343. BUILDING INFORMATION MODELING. 3 Hours.
Introduction to current Building Information Modeling (BIM); Discussion of the role of BIM in Construction Engineering and Management; Revit Architecture, Structure, and MEP; Creating sets, building elements, structural systems, and MEP systems; BIM and clash detection; BIM and Construction Cost Estimating and Scheduling.

CM 5344. CONSTRUCTION METHODS: FIELD OPERATIONS. 3 Hours.
Introduction to the methods, equipment, and management techniques used in the construction industry. Topics include equipment operating characteristics, job site safety, and field management. Credit not granted for CE 4332 and CM 5344.

CM 5345. INFRASTRUCTURE EVALUATION, MAINTENANCE, AND RENEWAL. 3 Hours.
This course is designed for engineers and managers involved in infrastructure development, sustainability, and replacement. Topics include asset management, inspection, evaluation, maintenance, and renewal alternatives for waste collection and water distribution systems, surface and subsurface drainage, pavements, bridges, culverts, buildings, and other structures. Prerequisite: Consent of instructor.

CM 5350. RISK MANAGEMENT. 3 Hours.
The risk management process including risk identification, monitoring, and control; integrated quantitative cost and schedule risk analysis.

CM 5355. CONSTRUCTION MATERIALS. 3 Hours.
Principles of construction related to construction regulations and standards, loads, fire safety, acoustics, joints and sealants. Systems of construction involving concrete, steel, wood, masonry, sealants, and soil, and including excavations, below grade construction, formwork, cladding, joints, windows, doors, roofing, and ceilings.

CM 5377. CONSTRUCTION FINANCE. 3 Hours.
Financial aspects and job costing of a construction project. Includes project management principles, budgets, cost codes, cost-to-complete, and financial reports specific to the management of a construction company and project control.

CM 5378. CONSTRUCTION CONTRACTS, SPECIFICATIONS, & ADMINISTRATION. 3 Hours.
Types of construction contracts, contractual relationship between general contractor and owner, contractual relationship between general contractor and subcontractors, legal issues in construction administration, insurance, and concepts in value engineering. Reading and evaluating specifications, CSI Master Format. Credit not granted for CE 4304 and CM 5378. Prerequisite: Consent of instructor.

CM 5379. CONSTRUCTION COST ESTIMATING. 3 Hours.
Types of estimates, development of unit costs, quantity takeoff, cost estimating using manual methods and computerized cost estimating, budgets, and costs.

CM 5381. PUBLIC PRIVATE PARTNERSHIP FOR INFRASTRUCTURE PROJECTS. 3 Hours.
Public-private partnership (P3) arrangements as an innovative approach to deliver public infrastructure projects. Topics include P3 benefits, limitations, contracting and implementation strategies. Prerequisite: Grade of C or better in CE 3310 or IE 2308, or consent of instructor.

CM 5382. CONSTRUCTION SUSTAINABILITY. 3 Hours.
Introduction to International Code Council's 2012 International Building Code and USGBC's LEED® New Construction Guidelines v.3 for constructing sustainable/green buildings. Review of building occupancy categories, construction types, allowable height and area, life safety requirements, rated building assemblies, and egress. Site selection, energy and water efficiency, material reuse and indoor air quality. Credit not granted for CE 4307 and CM 5382.

CM 5386. CONSTRUCTION PLANNING & SCHEDULING. 3 Hours.
Construction productivity, planning, & scheduling of operations, flow charts, linear programming, critical path method (CPM), program evaluation review techniques (PERT), precedence networks. Computer methods.

CM 5387. CONSTRUCTION PRODUCTIVITY. 3 Hours.
Evaluation of construction project management's effectiveness. An investigation of the advanced techniques required for improvement of construction projects including time, cost, quality management, preplanning, field evaluation techniques, time-lapse photograph, safety, human factors, and communications. Prerequisite: CM 5379.

CM 5388. PIPELINE CONSTRUCTION AND TRENCHLESS TECHNOLOGY. 3 Hours.
Pipeline and utility design, construction and renewal. Topics include pipeline infrastructure structural considerations, planning and construction considerations, pipe materials, and trenchless technologies. Credit not granted for CE 4305 and CE 5388. Prerequisite: Consent of instructor.

CM 5389. PIPELINE SYSTEMS ASSET MANAGEMENT. 3 Hours.
Pipeline systems asset management, inventory, inspection, and life cycle costs. Topics include pipeline deterioration parameters, asset management technologies, risk assessment, government regulations, renewal technologies, and case studies. Credit not granted for CE 4306 and CE 5389. Prerequisite: Consent of instructor.

COURSES

EE 1000. FRESHMAN UNDERGRADUATE RESEARCH. 0 Hours.
Freshman level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

EE 1101. INTRODUCTION TO ELECTRICAL ENGINEERING. 1 Hour.
After an introduction to different branches of Engineering, we focus on Electrical Engineering to illustrate concepts, methods, problem solving approach, and tools common to all Engineering, and those unique to Electrical Engineering. Various areas within Electrical Engineering will be introduced, with examples from analog and digital electronic circuits, control and robotics, microwave and optical engineering, telecommunication, energy systems, and biosensors. Students will be introduced to skills they need to succeed in subsequent Engineering courses, and ethical responsibilities. The emphasis is to engage students in active learning through exercises, mini-projects, and team activities. Selected speakers from across the College of Engineering will make presentations and emphasize the interdisciplinary nature of Engineering. Some College of Engineering requirements are satisfied by the content of this course.

EE 1106. ELECTRICAL ENGINEERING FRESHMAN PRACTICUM. 1 Hour.
A hands-on lab course focusing on basic methods for manipulating voltages and currents to achieve specific application objectives. Introduction to lab equipment and safety. Basic theory includes circuit elements and abstractions, circuit topology and analysis methods. Students will engage in laboratory experiments and learn how to conduct measurements including voltage, current, impedance, waveform, and frequency/spectrum analysis. Prerequisite: Grade of C or better in EE 1201 (concurrent enrollment with EE1201 is recommended).

EE 1201. INTRODUCTION TO ELECTRICAL ENGINEERING. 2 Hours.
An introduction to Electrical Engineering to illustrate concepts, methods, problem solving approaches, and tools unique to Electrical Engineering. Students will be introduced to skills they need to succeed in all subsequent Engineering courses. Students will learn about laws and rules related to academic integrity and professional ethical responsibilities. Five areas within Electrical Engineering will be highlighted with examples from analog and digital electronic circuits, control and robotics, microwave and optical engineering, telecommunication/signal processing, and energy systems. Selected speakers will make presentations to highlight the five areas and emphasize the interdisciplinary nature of Engineering. Ideally this will help the student make decisions about areas of interest to pursue as elective courses later in the curriculum. Computer access is required (laptop preferred) and general computer skills are expected. Prerequisite: Grade C or better in MATH 1426 (or concurrent enrollment). Concurrent enrollment with EE 1106 is recommended.

EE 1311. COMPUTING SYSTEM AND ALGORITHMIC SOLUTIONS. 3 Hours.
This course focuses on algorithmic problem solving and implementation of the algorithm using C or Python Programming Language. Fundamental concepts covered in this course include computing system architecture, operating systems, program execution, algorithm and flowchart, data structure, numerical methods, and hardware interfacing. Prerequisite: Grade C or better in MATH 1426 (or concurrent enrollment).

EE 2000. SOPHOMORE UNDERGRADUATE RESEARCH. 0 Hours.
Sophomore level undergraduate research course. Prerequisites: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

EE 2181. CIRCUIT ANALYSIS LABORATORY. 1 Hour.
Circuits laboratory for non-electrical engineering majors. This is identical to the laboratory portion of EE 2440. Prerequisite: Grade C or better in MATH 2425. Corequisite: EE 2320 and PHYS 1444.

EE 2240. SOPHOMORE PROJECT LABORATORY. 2 Hours.
A project based course encompassing design and implementation that provides an opportunity for students to explore and develop comprehensive applications of electrical engineering concepts and technologies to address real-world needs. Students will work in teams and engage in project planning, management, presentation, reporting, and outcome assessment. Prerequisite: Grade of C or better in each of the following: EE 1311, EE 2315, EE 2303 (or concurrent enrollment), EE 2341 (or concurrent enrollment), and EE 2347 (or concurrent enrollment).

EE 2301. MODELING AND ANALYSIS METHODS IN ELECTRICAL ENGINEERING. 3 Hours.
Modeling and analysis with emphasis on solution techniques of dynamic problems arising in electrical engineering applications. Problem formulation and solution of first and second order ordinary differential equations (ODEs). Use of Laplace Transform and numerical solution methods to solve initial and boundary value problems. Systems of ODEs. Vectors and matrices. Linear equations and inverse matrices. Vector spaces, Eigenvalues and Eigenvectors. First and second order partial differential equations (PDEs). Solutions to boundary value problems for Laplace's equation and other PDEs. Prerequisite: MATH 2326 and an academic history that includes a Linear Algebra and Matrix Theory Course or consent of the instructor.

EE 2302. PRINCIPLES OF ACTIVE AND PASSIVE DEVICES. 3 Hours.
This course covers electric and magnetic properties of solid materials with applications in the design and fabrication of active and passive devices. Topics include charge carriers, drift and diffusion currents, electrostatics, magnetostatics, dielectric/conductor/semiconductor properties, magnetic domain, Hall effects, passive circuit elements, electronic energy band diagrams, p-n junction, diode, FET, LED, semiconductor lasers, sensor and device applications. Prerequisite: Grade of C or better in both CHEM 1465 and PHYS 1444.

EE 2303. ELECTRONICS I. 3 Hours.
Review of semiconductors, drift and diffusion current, and p-n junction. Electrical characteristics of diodes, bipolar junction transistors (BJTs), and field-effect transistors (FETs). Circuit applications: switches, square-law detector, and amplifier. Digital and analog electronic circuits. Logic circuits. Single and multistage electronic circuit analysis and design. Amplifier operating point and frequency response. Low frequency and high frequency analysis and design. Prerequisite: Grade C or better in each of the following EE 2302 (or concurrent enrollment), EE 2315 and MATH 3319.

EE 2315. CIRCUIT ANALYSIS I. 3 Hours. (TCCN = ENGR 2305)
This course covers fundamental concepts and applications in manipulating voltage and current using passive and active circuit elements. Circuit models for passive (lumped) elements (resistor, capacitor, and inductor); independent and dependent sources; switches and active elements (diode and transistor). Circuit topology, governing laws (KCL and KVL), and node and mesh analysis methods. Time-varying and time-harmonic analyses of 1st order and 2nd order passive circuits. Steady-state alternating-current (AC) phasor analysis. Frequency domain analysis and Bode plots. Properties and applications of diode and transistor. Rectifier and switches. Higher level abstractions: Thevenin and Norton equivalents, and op-amps. Properties and applications of op-amps. Computer-assisted circuit analysis and design. Prerequisite: Grade C or better in each of the following: EE 1106, MATH 2425, MATH 3319 (or concurrent enrollment) and PHYS 1444 (or concurrent enrollment).

EE 2320. CIRCUIT ANALYSIS. 3 Hours.
For non-electrical engineering majors. Basic principles of R, L, and C components. Kirchhoff's laws, network analysis, loop and node equations, basic network theorems. Steady-state Alternating Current (AC) phasor analysis, operational amplifiers, filtering, and digital circuits. Prerequisite: Grade of C or better in each MATH 2425 or HONR-SC 2425 and PHYS 1444.

EE 2341. DIGITAL CIRCUITS AND SYSTEMS. 3 Hours.
An introduction to digital system design with hands-on projects. Number systems and codes. Boolean algebra; combinatorial logic and arithmetic. Digital electronics; CMOS logic gates; digital signals and noise margin; logic gates; and combinatorial logic circuits. Timing hazard and delay. Programmable logic devices; VHDL. State machines; sequential logic elements; counters and shift registers; sequential logic circuits. Arithmetic and computer logic circuits. Prerequisite: Grade C or better in each of the following: EE 1311 and EE 2315 (or concurrent enrollment).

EE 2347. MATHEMATICAL FOUNDATIONS OF ELECTRICAL ENGINEERING. 3 Hours.
This course focuses on mathematical modeling and algorithmic thinking to solve electrical engineering problems and interpret the results. Concepts covered in this course include mathematical representation of electrical signal and system behavior, complex analysis, Fourier series and Fourier transformations, computational modeling using MATLAB or Python, data processing and analysis. Prerequisite: Grade of C or better in each of EE 1311, MATH 2425, and MATH 3319.

EE 2403. ELECTRONICS I. 4 Hours.
Introduction to semiconductors, carrier statistics, drift and diffusion, semiconductor diodes, bipolar junction transistors (BJTs), and field-effect transistors (FETs). Circuit applications of diodes. Direct Current (DC) biasing and stability of circuits containing diodes, BJTs, and FETs. Introduction to mid-band single stage small signal analysis of BJT and FET circuits. Laboratory experiments to complement concepts learned in class. Prerequisite: Grade C or better in both EE 2415 and MATH 2326.

EE 2415. CIRCUIT ANALYSIS I. 4 Hours.
Basic circuit concepts of resistor, inductor, and capacitor (RLC) components. Kirchhoff's laws, resistive network analysis, power calculations, loop and node equations, topology, basic network theorems. Dependent sources and operational amplifiers. Computer-assisted solution of circuit problems. Elementary transient time-domain analysis. Introduction to frequency domain analysis and Bode plots. Steady state A-C phasor analysis, including element laws and phasor diagrams. Problems and experimental demonstrations will be covered during recitation and laboratory sessions. Prerequisite: Grade C or better in EE 1106 and MATH 2425. Co-requisite: MATH 3319 and PHYS 1444.

EE 2440. CIRCUIT ANALYSIS WITH LAB. 4 Hours. (TCCN = ENGT 1401)
For non-electrical engineering majors. Basic principles of R, L, and C components. Kirchhoff's laws, network analysis, loop and node equations, basic network theorems. Steady-state AC phasor analysis, operational amplifiers, filtering, and digital circuits. Concurrent laboratory experiments complement lecture topics. Prerequisite: Grade C or better in MATH 2425 and PHYS 1444.

EE 2441. DIGITAL DESIGN AND PROGRAMMABLE MICROCONTROLLERS. 4 Hours.
Theory and design of digital logic circuits. Number systems and binary arithmetic. Boolean algebra theorems. Optimization by algebraic and mapping methods. Logic gates, arithmetic logic units, decoders, analysis and synthesis of combinatorial logic circuits, sequential circuits. Synchronous and asynchronous state machines, hazards and races conditions with sequential circuits. Introduction of hardware description language (VHDL). Laboratory consists of "proof of concept" experiments using digital components. Prerequisite: Grade C or better in CSE 1311.

EE 3000. JUNIOR UNDERGRADUATE RESEARCH. 0 Hours.
Junior level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

EE 3140. JUNIOR PROJECT LABORATORY. 1 Hour.
Introduction to electrical engineering design concepts and strategies. Students must complete semester long projects from the areas of sensors, analog, digital, and mixed signal circuits, modules, and systems. Students are expected to use knowledge and skills previously obtained from lecture and laboratory courses (electronics, digital logic and microprocessors, and circuit analysis II) to complete their projects. The project must be well planned with clear performance objectives and constraints. Students are expected to show competency in technical writing and presentation. Prerequisite: Must be in the professional EE program. Grade of C or better in EE 2403, EE 2441. Prerequisite or concurrent enrollment: EE 3446.

EE 3240. JUNIOR PROJECT LABORATORY. 2 Hours.
Introduction to electrical engineering design concepts and strategies, engineering ethics, professional responsibility and safety. Students must complete semester long projects from the areas of sensors, analog, digital, and mixed signal circuits, modules, and systems. Students are expected to use knowledge and skills previously obtained from lecture and laboratory courses to complete their projects. The project must be well planned with clear performance objectives, specifications, consideration of constraints, timeline, public health, accessibility and environmental impact. Students are expected to show competency in technical writing and presentation. Prerequisite: Must be in the professional EE program and Grade of C or better in each of the following: EE 2303, EE 2341, and EE 3346 (or concurrent enrollment).

EE 3301. COMPUTER SOLUTIONS AND CODING FOR ELECTRICAL ENGINEERING. 3 Hours.
Introduction to computer architecture and operating systems. Python programming. Programming constructs and strategies. Design and analysis of algorithms and data structures. Applications of searching, sorting, numerical, and simulation algorithms. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 1311, EE 2341, and EE 3330 (or concurrent enrollment).

EE 3302. FUNDAMENTALS OF POWER SYSTEMS. 3 Hours.
Introduction to power systems, three-phase circuit analysis, symmetrical components, transformer, polyphase induction motors, synchronous generators, synchronous motors, diode and diode circuits, thyristor and thyristor circuits, DC-DC switching converters, and DC-AC switching converters, Renewable energy sources. Concurrent laboratory experiments complement the course lecture topics. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 3346 and EE 3407 (or concurrent enrollment).

EE 3310. ADVANCED MICROCONTROLLERS. 3 Hours.
Principles of operation for microcontroller, including assembly language programming, internal architecture of microcontroller, timing analysis, and interfacing techniques. Special emphasis will be placed on hardware-software interactions, design of memory systems for microcontroller and utilization of programmable peripheral devices. Prerequisite: Grade of C or better in EE 2441 and EE 2403.

EE 3314. FUNDAMENTALS OF EMBEDDED CONTROL SYSTEMS. 3 Hours.
Analyses of open-loop and closed loop systems using frequency domain and state variable techniques. Analog and digital control design methods. System design requirements and specifications. Design and implementation of control system using programmable devices. Principles of operation for microcontroller, internal architecture, programming tools and techniques, timing analysis, interfacing with sensors and actuators. Real-time control applications. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2341, EE 3316, and EE 3318 (or concurrent enrollment).

EE 3316. CONTINUOUS AND DISCRETE SIGNALS AND SYSTEMS. 3 Hours.
Time-domain and frequency-domain analyses of periodic, aperiodic, continuous, and discrete time signals. Energy and power signals. System abstraction, signal flow and block diagrams. Linear systems, time invariance, causality, stability, and state-space. Laplace transforms. Impulse and frequency responses of LTI systems. LTI system specification and design. Filters and equalizers. Continuous time and discrete time (DT) signal conversion, sampling theorem, aliasing, and quantization error. Discrete-Time Fourier Transform (DTFT). Time and frequency responses of LTI system to DT signals. Interpolation and low-pass filter. Time and frequency domain analyses of DT LTI systems. z-transform. Causality and stability of DT LTI systems. Applications of DT LTI systems, FIR and IIR filters. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347 and EE 2315.

EE 3317. LINEAR SYSTEMS. 3 Hours.
For non-electrical engineering majors. Time-domain transient analysis, convolution, Fourier Series and Transforms, Laplace Transforms and applications, transfer functions, signal flow diagrams, Bode plots, stability criteria, and sampling. Prerequisite: Grade C or better in MATH 3318, MATH 3330, and EE 2440 (or equivalent).

EE 3318. ANALOG AND DIGITAL SIGNAL PROCESSING. 3 Hours.
Time and frequency domain analyses of continuous-time (CT) and discrete-time (DT) signals and systems. CT and DT Convolution. DTFT, DFT, and z-transforms of signals. Phase shifting, frequency shifting, and group delay. Modeling of stationary random signals utilizing filtered white noise. Power spectral density and SNR. Improving SNR through filtering. Amplitude, phase, and stability of causal and non-causal digital filters. FIR and IIR digital filter design. Applications of discrete time systems. Program assignments in Matlab. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 3316 and EE 3330 (or concurrent enrollment).

EE 3330. PROBABILITY AND STATISTICAL METHODS. 3 Hours.
Probability, random variables, functions of random variables, moments, random signals, noise, stochastic models and power spectral density. Data and statistics. Random sampling. Statistical analysis, hypothesis testing, goodness of fit test, and regression. Response of LTI systems to random signals. Rigorous mathematical concepts will be tied to engineering system issues such as characterizing uncertainty due to measurement error, component and system tolerances, and noise sources such as device noise, quantization noise, communication channel noise, and thermal noise. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347 and EE 3316 (or concurrent enrollment).

EE 3346. CIRCUIT ANALYSIS II. 3 Hours.
Time-harmonic single-phase and poly-phase voltages and currents. Instantaneous, time average, and complex powers. Power factor and maximum power transfer. Independent and dependent sources. Time and frequency domain analyses of open-loop and closed-loop circuits. Feedback configurations, poles and zeros, stability analysis. Oscillators and filters. Two-port networks and network parameters. Network theorems and analyses, superposition, reciprocity. Characteristics and applications of operation amplifiers. Amplifiers and active filters. Power distribution networks and transmission lines. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347, EE 2303, and EE 2315.

EE 3407. ELECTROMAGNETICS. 4 Hours.
Time varying electric and magnetic fields; electromagnetic (EM) sources. Laws governing EM fields and sources. Circuit and transmission line circuits. Wave propagation on transmission line. Power flow and impedance matching. Applications of EM theory in energy conversion. Antenna concept, EM wave radiation and polarization. Applications of EM theory in energy conversion. Waves in unbounded medium. Wave reflection, transmission, and scattering. Fundamentals and applications of rectangular waveguides. Fundamentals of antenna. Friis' transmission formula. Applications of EM theory in optical transmission, wireless communications, and radar. A designated lab provides experiences using modern RF and EM tools to re-enforce abstract concepts. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347, PHYS 1444, and EE 3346 (or concurrent enrollment).

EE 3444. ELECTRONICS II. 4 Hours.
Low and high frequency characteristics and circuit models for diodes, bipolar junction transistors (BJTs), and field effect transistors (FETs). Analysis and design of full spectrum small signal BJT and FET circuits. Analysis and transistor level design of active filters, oscillators, feedback configurations, and multistage differential and operational amplifiers. Concurrent laboratory exercises in support of the topics covered in class. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2303 and EE 3346.

EE 3446. CIRCUIT ANALYSIS II. 4 Hours.
Analysis and design of filters, oscillators, feedback configurations, and operational amplifiers. Dependent sources, device models, two-port networks, and mutual inductance and transformers. Network response functions, poles and zeros, network theorems, resonance, and the analysis and design of active filters. Application of phasors in steady-state circuit analysis. Introduction to distributed networks and transmission lines. Introduction to single-phase and three-phase balanced and unbalanced power networks, complex power, power factor correction, and maximum power transfer. Concurrent laboratory experiments complement lecture topics. Prerequisite: Must be in the professional EE program. Grade C or better in EE 2347 and EE 2415.

EE 4000. UNDERGRADUATE RESEARCH. 0 Hours.

EE 4149. ENGINEERING DESIGN PROJECT. 1 Hour.
A practicum resulting in the design, construction, and evaluation of a device or system, building on electrical or electronic knowledge and skills acquired in earlier course work, and incorporating appropriate engineering standards. The application of project management techniques in order to meet design specifications through the effective allocation of team resources, scheduling, and budgetary planning. The demonstration of the finished product/prototype through both oral presentation and a written project report. Mode of Instruction: Practicum. Prerequisite: Must be in the professional EE program and Grade of C or better in EE 4240. Grade of C or better in all prior 3000 and 4000 level EE coursework.

EE 4240. CONCEPTS & EXERCISES IN ENGINEERING PRACTICE. 2 Hours.
Integration of technical knowledge and skills with project planning, project execution, teamwork, and communication skills (written and oral) are utilized to begin the capstone design experience. Student teams are given a project description with requirements and constraints and they design, construct, and evaluate a technical solution to that meets them. It builds on electrical or electronic knowledge and skills acquired in earlier course work while incorporating appropriate engineering standards. Project management techniques are applied in order to meet design specifications through the effective allocation of team resources, scheduling, and budgetary planning. By the end of this course, students are expected to deliver a final project design that is ready to be built and experimentally tested in the second semester 4149 course. Must be taken in the semester prior to EE 4149. An EE Proficiency Test is administered during the class. Prerequisite: Must be in the professional EE program and grade of C or better in each of the following: COMS 2302, EE 3240, EE 3314, EE 3318, EE 3330, and EE 3407. Co-requisite ECON 2305.

EE 4301. POWER SYSTEMS ANALYSIS AND CONTROL. 3 Hours.
This course includes an introduction to synchronous machines, power flow analysis, short circuit analysis, power system controls, and the fundamentals of transient stability analysis. Prerequisite: Grade of C or better in EE 3302.

EE 4302. ENGINEERING ENTREPRENEURSHIP. 3 Hours.
Topics include special problems of newly formed firms, planning, start-up business considerations, business strategy, management basics, and business plan design. Students will engage in business and entrepreneurship training and discussion, become aware of basic business operations, and learn about inventions, intellectual property, and the patenting process. Other topics include assessment of possible markets, venture feasibility, teambuilding, and leadership. Opportunities in university environments will be discussed including incubation centers and patent licensing. We address legal issues, Small Business Innovation Research (SBIR) proposal design, SBIR funding from the National Science Foundation (NSF), National Institutes of Health (NIH), and others. Additional topics include the proposal review process, grant reporting, local high-tech business accelerators, angel-group funding, venture plans, and venture capital. Classes will feature lectures from engineering and business faculty as well as presentations by successful entrepreneurs. Course taught as EE 4302, ENGR 4302 and ENGR 5302; credit will be granted only once. Prerequisite: Student must be in an engineering professional program.

EE 4308. POWER SYSTEM MODELING AND ANALYSIS. 3 Hours.
Fundamental concepts for modeling transmission lines, distribution lines, power system generators, power transformers and power system load. The method of symmetrical components is discussed. Simulation of power systems during normal and abnormal conditions are presented. The philosophy of deregulation regarding separation of power systems into generation, transmission and distribution companies is introduced. Prerequisite: Grade of C or better in EE 3302.

EE 4310. MICROPROCESSOR SYSTEMS. 3 Hours.
Hardware/software development techniques for microprocessors with emphasis on asynchronous and synchronous memory interfaces, optimizing data throughput, and modern bus architectures. Topics include DMA controller design, SDRAM controller design, and real-world interfacing. Prerequisite: Grade of C or better in EE 3314.

EE 4311. EMBEDDED MICROCONTROLLER SYSTEMS. 3 Hours.
Hardware/software development techniques for microcontroller systems with an emphasis on hardware-software interactions, programming internal peripherals, interfacing with external sensors and devices, and real-time control applications. Prerequisite: Grade of C or better in EE 3314.

EE 4312. ADVANCED MICROPROCESSOR SYSTEMS. 3 Hours.
Study of the advanced microprocessor architectures including 32/64-bit RISC and CISC families of microprocessors will be compared based on detailed architectural analysis of the selected devices. This course may also include: address/instruction pipelines, burst cycles, memory caching and cache coherency issues, register renaming, speculative instruction execution and other performance-oriented techniques. Prerequisite: EE 4311.

EE 4313. CONTROL SYSTEMS FOR NON-EE MAJORS. 3 Hours.
For non-electrical engineering majors. Analyses of closed loop systems using frequency response, root locus, and state variable techniques. Analog and digital control design methods. System modeling, identification, and control design based on analytic and computer methods. Classes meet at the same time as EE 4314. Prerequisite: Grade of C or better in either EE 3317 or MAE 3319.

EE 4314. CONTROL SYSTEMS. 3 Hours.
Analyses of closed loop systems using frequency response, root locus, and state variable techniques. Analog and digital control design methods. System modeling, identification, and control design based on analytic and computer methods. Use of laboratory experiments with mechatronic systems to complement the course lectures. Prerequisite: Grade of C or better in EE 3316. Co-requisite EE 3318.

EE 4315. INTRODUCTION TO ROBOTICS. 3 Hours.
Overview of industrial robots. Study of principles of kinematics, dynamics, and control as applied to industrial robotic systems; robotic sensors and actuators; path planning; programming of industrial robot in the laboratory; survey of robotic applications in various modern and traditional fields; and guidelines to robot arm design and selection. Prerequisite: Grade C or better in EE 4314.

EE 4316. OP AMPS IN ANALOG SIGNAL PATHS. 3 Hours.
The course covers fundamental concepts involved in the analysis and design of a wide variety of linear and non-linear circuits that use bipolar and CMOS integrated circuit operational amplifiers (op-amps). Applications of these components in practical circuit designs are emphasized. Prerequisite: Grade of C or better in EE 3446.

EE 4317. ANALOG CMOS IC DESIGN. 3 Hours.
Analysis and design of CMOS analog integrated circuits; MOS device structure and models; single-state and differential amplifiers; current mirror and Operational Amplifier design; noise analysis and feedback; comparators and voltage references. Prerequisite:Must be in the professional EE program and C or better in each of the following: EE 2303 and EE 3444.

EE 4318. DIGITAL SIGNAL PROCESSING. 3 Hours.
Discrete time convolution. Fast convolution using the fast Fourier transform (FFT). Amplitude and phase of digital filters. Stability analyses using the Z-transform. Design of finite impulse response (FIR) digital filters through windowing and optimization approaches. Infinite Impulse Response (IIR) digital filter design approaches using transformation and optimization. Prerequisite: Grade of C or better in EE 3316 and EE 3318.

EE 4320. DIGITAL VLSI DESIGN. 3 Hours.
Introduction to Very Large Scale Integration circuit design and fabrication technology. Metal-Oxide Semiconductor (MOS) device models and digital integrated circuit design with Metal-Oxide Semiconductor Field-Effect Transistor (MOSFETs). Computer Aided Drafting (CAD) tools for VLSI design. Processing models and process flow. MOS integrated circuits for logic gates and digital systems. Prerequisite: Grade of C or better in EE 3444.

EE 4327. THEORY AND DESIGN OF ANTENNAS. 3 Hours.
Basic theory of antennas with emphasis on design and engineering application. Prerequisite: Grade of C or better in EE 3407.

EE 4328. CURRENT TOPICS IN ELECTRICAL ENGINEERING. 3 Hours.
To introduce current topics into the curriculum prior to the creation of permanent course numbers. A notice listing a descriptive course title, a course description, and the name of the instructor will be posted on the departmental webpage each time the course contents are changed. Prerequisite: Consent of instructor.

EE 4329. SEMICONDUCTOR DEVICES. 3 Hours.
Introduction to semiconductors in terms of atomic bonding and electron energy bands. Equilibrium statistics of electrons and holes. Carrier dynamics; continuity, drift, and diffusion currents; generation and recombination processes, including important optical processes. Introduction to P-N junctions, metal-semiconductor junctions; bipolar junction transistors, junction and Metal-Oxide Semiconductor Field-Effect Transistors (MOSFETs). Introduction to optoelectronic devices, including LEDs, lasers, detectors, solar cells, modulators, etc. Prerequisite: Grade of C or better in EE 3407.

EE 4330. FUNDAMENTALS OF TELECOMMUNICATIONS SYSTEMS. 3 Hours.
Examines analog and digital communication techniques including amplitude modulation, frequency modulation, phase modulation and pulse code modulation. Probabilistic telecom signals introduced. Time domain and frequency domain multiplexing. Analog and digital noise analysis, practical pulse shaping for Digital Telecom transmission. Design of communications systems. Prerequisite: Grade of C or better in EE 3316 and EE 3330. Co-requisite EE 3318.

EE 4331. DATA COMMUNICATIONS ENGINEERING. 3 Hours.
Layered approach to data communications and networking will be presented. Network models such as TCP/IP and OSI will be introduced. Protocols and technologies related to each layer will be studied in depth. For physical layer, analog and digital signaling, modulation, bandwidth, multiplexing as well as line and block coding techniques. For data link layer, various MAC layer protocols involving multiple access, error detection (CRC), wired (Ethernet) versus wireless (Wi-Fi) LANs, switching. For network layer, internet protocol (IP) and routing principle. Underlying technologies learned from this course are applicable to wide range of traditional and current data communication protocols. Performance analysis of well-known protocols using probabilistic model will also be studied. Prerequisite: Grade of C or better in each of the following: EE 3316, EE 3330, and EE 3318 (or concurrent enrollment).

EE 4333. WIRELESS COMMUNICATIONS AND IoT. 3 Hours.
Fundamental principles of radio system design and propagation. Basics of cellular systems, environment, propagation models, traffic models and spectral capacity. Multiple-access techniques including FDMA (frequency division multiple access), TDMA (time division multiple access), CDMA (code division multiple access). Internet of Things (IoT) system architecture, IoT enabling technologies such as sensors and sensor networks, IoT communication and networking protocols, IoT services and applications. IoT demands, impacts, and implications on sensors technologies, big data management, and future internet design for various IoT use cases, such as smart cities, smart environments, smart homes, etc. Prerequisite: Grade of C or better in EE 3316 and EE 3330. Prerequisite or concurrent enrollment in EE 3318.

EE 4334. PROGRAMMABLE LOGIC DESIGN. 3 Hours.
Design of digital systems using programmable logic devices and high-level techniques. The course emphasizes the understanding of state-of-the-art hardware devices as well as design and simulation tools. Hardware description language will be taught and used for digital system design. Various design options and compromises will be explored for typical tasks. Projects will be assigned to develop design proficiency. Prerequisite: Grade of C or better in EE 2341.

EE 4336. FOUNDATIONS OF MEDICAL IMAGING. 3 Hours.
This course introduces the engineering, physics, mathematics, and signal processing methods fundamental to medical image acquisition and processing. X-ray projection, X-ray computed tomography, magnetic resonance imaging, and ultrasound imaging. Brief introduction to optical and infrared imaging and nuclear imaging (SPECT/PET) will be included. Open to students in an engineering or science professional program. Prerequisite: EE 3316 or equivalent.

EE 4339. RADIO FREQUENCY CIRCUIT DESIGN. 3 Hours.
Analysis of waves on ideal transmission lines, assorted practical transmission line systems, and hollow waveguides. Circuit theory for transmission line systems involving scattering parameters and the Smith chart. Microwave impedance matching techniques. Design of lumped element amplifiers from VHF to microwave frequencies. Real world microwave characterization techniques. Prerequisite: Grade of C or better in EE 3444 and EE 3407.

EE 4340. CONCEPTS & EXERCISES IN ENGINEERING PRACTICE. 3 Hours.
Integration of technical knowledge and skills with project planning, teamwork, and communication skills (written and oral). A project-oriented approach is used including the preparation of literature-based research reports, research proposals, product development proposals, and project management plans. Supporting topics: technical information resources, ethics, safety, intellectual property. Students will begin their engineering capstone design experience, including team formation, project selection, background research, and preparation of preliminary project plan. Must be taken in the semester prior to EE 4349 (Engineering Design Project). An EE Proficiency Test will be administered on first day of class. Prerequisite: Grade of C or better in each of COMS 2302, EE 3330, EE 3446, and EE 3407. Corequisite ECON 2305.

EE 4344. INTRODUCTION TO MEMS AND DEVICES. 3 Hours.
Develops the basics for microelectromechanical devices and systems including microsensors, and micromotors, principles of operation, different micromachining techniques, and thin-film technologies as they apply to MEMS. Prerequisite: EE 3407.

EE 4349. ENGINEERING DESIGN PROJECT. 3 Hours.
A practicum resulting in the design, construction, and evaluation of a device or system, building on electrical or electronic knowledge and skills acquired in earlier course work, and incorporating appropriate engineering standards. The application of project management techniques in order to meet design specifications through the effective allocation of team resources, scheduling, and budgetary planning. The demonstration of the finished product/prototype through both oral presentation and a written project report. Mode of Instruction: Practicum. Prerequisite: Grade of C or better in EE 4340. Grade of C or better in all prior 3000 and 4000 level EE coursework.

EE 4357. INTRODUCTION TO MACHINE LEARNING. 3 Hours.
The course presents fundamental principles and techniques on detecting meaningful patterns in data. Supervised learning techniques with applications in regression and classification will be presented, as well as support vector machines in classification. Further, the toolbox of neural networks will be detailed with applications in classification problems. Unsupervised learning will be studied on clustering problems. Feature extraction and dimensionality reduction will also be covered. Boosting methods will also be covered. Prerequisite: Grade of B or better in EE 3330, EE 2347, MATH 2326, and MATH 3319.

EE 4362. DIGITAL COMMUNICATIONS. 3 Hours.
Fundamental principles underlying the transmission of digital data over noisy channels. Basics of source coding techniques including entropy coding, Lempel-Ziv. Channel capacity. Spectral analysis of digital modulation techniques. Optimum receiver design and error probability performance of commonly used modulation schemes. Applications to lightwave and wireless systems. Prerequisite: Grade of C or better in EE 3318 and in EE 4330.

EE 4364. INFORMATION THEORY FOR DATA SCIENCE. 3 Hours.
Entropy, conditional entropy, relative entropy, mutual information, transfer entropy, entropy rates of stochastic process, data compression, Huffman coding, Shannon coding, compressive sensing, encoding of correlated data, source coding with side information, channel capacity, differential entropy, rate distortion, information theoretical foundations for data science, Bayesian inference, probabilistic reasoning, stock market and portfolio theory. Prerequisite: Must be in the professional EE program and grade C or better in EE 3330.

EE 4370. ELECTRIC MOTOR DRIVES. 3 Hours.
Fundamentals of electromechanical energy conversion devices and systems; Principles of inductors, transformers, force/torque formulation, and reference frame transformation; induction motors and permanent magnet machines; Inverter topologies and switching strategies; Scalar and vector control methods for machine drive systems. Prerequisite: Must be in the professional EE program and grade of C or better in EE 3407.

EE 4371. POWER SYSTEM PROTECTIVE RELAYING. 3 Hours.
Fundamental understanding of symmetrical components, applications of symmetrical components in system protection, philosophy of power system protection, various protective relay systems, and the special considerations in applying the microprocessor-based relays are covered. Experiments utilizing the Power System Simulation Laboratory are required. Prerequisite: Must be in the professional EE program and grade of C or better in EE 3346.

EE 4372. POWER SYSTEM DISTRIBUTION. 3 Hours.
The basic functions of a Distribution Company are presented. Load representation, distribution load flow and the philosophy of simulation for a distribution system are discussed in detail. Prerequisite: Must be in the professional EE program and grade of C or better in EE 3346.

EE 4373. POWER QUALITY. 3 Hours.
Principles of harmonics and filtering, source of voltage surges and surge protection, causes of voltage sags, flickers, and interruptions, and voltage supporting devices, and utility and end-user strategies for improving power quality are covered. Prerequisite: Must be in the professional EE program and grade of C or better in EE 3318 (or concurrent enrollment).

EE 4375. INTRODUCTION TO POWER ELECTRONICS. 3 Hours.
This course discuses conceptualization, analysis, and design of power electronics components, circuits, and systems. It discusses different classes of switching converters (dc-dc, ac-dc, dc-ac) and elements of power electronics (magnetic design, loads, and capacitors). Applications of power electronics in renewable energy systems and vehicular electronics are discussed. Prerequisite: Grade of C or better in EE 2403 and EE 3446.

EE 4378. INTRODUCTION TO UNMANNED VEHICLE SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty.

EE 4379. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: EE 4378.

EE 4380. PRINCIPLES OF PHOTONICS AND OPTICAL ENGINEERING. 3 Hours.
Optical fields with applications to laser, optical fibers, and photonic signal processing. Encoding, manipulating, transmitting, storing, and retrieving information using light. Light propagation including isotropic and birefringent optical media, dielectric interfaces, interference and diffraction, Gaussian beams, optical cavities and principles of laser action, optical waveguides and fibers, electro- and acousto-optic modulation. Design, analysis and application of optical devices in communications and signal processing. Prerequisite: Must be in the professional EE program and grade of C or better in EE 3407.

EE 4382. OPTICAL BIOSENSORS. 3 Hours.
Introduction to modern biological and chemical sensing for in-vivo and in-vitro disease diagnosis. Photonics and nanotechnologies for biomolecular analysis. Bio/chemical sensor principle, instrumentation, and applications. Prerequisite: Grade of C or better in EE 3407, or PHYS 3445, or PHYS 4324.

EE 4391. ADVANCED PROBLEMS IN ELECTRICAL ENGINEERING. 3 Hours.
A research project under the direction of a faculty supervisor. May be taken as a technical elective with the permission of the department.

EE 5190. ELECTRICAL ENGINEERING GRADUATE SEMINAR. 1 Hour.
Topics vary from semester to semester. May be repeated for credit. Graded F, P. Prerequisite: graduate standing or consent of the department.

EE 5191. ADVANCED STUDY IN ELECTRICAL ENGINEERING. 1 Hour.
Individual research projects in electrical engineering. Prior approval of the EE Graduate Advisor is required for enrollment. A written report is required. Graded F, I, P.

EE 5302. RANDOM SIGNALS AND NOISE. 3 Hours.
Probability, random variables, and stochastic processes in physical systems. Topics include probability space, discrete and continuous random variables, density and conditional density functions, functions of random variables, mean-square estimation, random signals, system response, optimum system design, and Markov processes.

EE 5304. CYBER-PHYSICAL SYSTEMS. 3 Hours.
Cyber-physical system fundamentals; model-based designs; data-driven analytics; co-design techniques of integrated communication, control, and computing components; implementation considerations; and applications, such as internet of things, intelligent transportation, and robot networking. Topics include but are not limited to hybrid systems, stochastic networks, uncertainty quantification, experimental design, data fusion techniques, stochastic optimal control, networking and edge computing, network control, and related software, hardware, and middleware issues.

EE 5305. ANALOG INTEGRATED CIRCUIT DESIGN. 3 Hours.
Analysis and design of basic analog integrated circuits; device physics; single-stage and differential amplifiers; current mirror and biasing technique; feedback and operational amplifier; noise analysis.

EE 5306. ELECTROMAGNETIC THEORY. 3 Hours.
Advanced study of electromagnetic theory, its content, methods, and applications. Topics include theorems in electromagnetic theory, cylindrical and spherical wave functions, waveguides, integral equation methods, scattering and diffraction.

EE 5307. LINEAR SYSTEMS ENGINEERING. 3 Hours.
Topics include state-space description of dynamic systems, analysis and design of linear systems, similarity transformation, state feedback, state observers, and matrix characterization of multivariable systems.

EE 5308. POWER SYSTEM MODELING AND ANALYSIS. 3 Hours.
Fundamental concepts for modeling transmission lines, distribution lines, power system generators, power transformers and power system load. The method of symmetrical components is discussed. Simulation of power systems during normal and abnormal conditions are presented. The philosophy of deregulation regarding separation of power systems into generation, transmission and distribution companies is introduced.

EE 5309. TOPICS IN ELECTRICAL ENGINEERING. 3 Hours.
Material may vary from semester to semester. Topics are selected from current areas of electrical engineering interest. May be repeated when topic changes.

EE 5310. DIGITAL VLSI DESIGN. 3 Hours.
Introduction of VLSI digital circuit design methodology and processing technology. Application of various design software packages for circuit analysis and layout. Design of basic CMOS digital logic circuits. Implementation of digital logic design at the transistor level.

EE 5311. VLSI SIGNAL PROCESSING ARCHITECTURES. 3 Hours.
Design and synthesis of DSP and telecommunication systems using integrated modeling, design, and verification tools. Exploration of high-level architectural transformations that can be used to design families of DSP architectures for a given signal processing algorithm. Prerequisite: EE 5350.

EE 5312. CMOS RFIC DESIGN. 3 Hours.
Basic concept of RF design; CMOS transceiver architectures for wireless communications; low noise amplifiers; mixers; oscillators; phase-locked loops; frequency synthesizer; power amplifier. Prerequisite: EE 5305.

EE 5313. MICROPROCESSOR SYSTEMS. 3 Hours.
Hardware/software development techniques for microprocessors with emphasis on asynchronous and synchronous memory interfaces, optimizing data throughput, and modern bus architectures. Topics include DMA controller design, SDRAM controller design, and real-world interfacing.

EE 5314. EMBEDDED MICROCONTROLLER SYSTEMS. 3 Hours.
Hardware/software development techniques for microcontroller systems with an emphasis on hardware-software interactions, programming internal peripherals, interfacing with external sensors and devices, and real-time control applications.

EE 5315. SYSTEM ON CHIP (SOC) DESIGN. 3 Hours.
Programming and implementation of FPGA-based system on chip solutions, including processor subsystems, FPGA fabric, processor to FPGA bridges, and device drivers. Prerequisite: EE 5314.

EE 5316. CMOS MIXED SIGNAL IC DESIGN. 3 Hours.
Design of CMOS mixed signal ICs with emphasis on full custom chip design. Comparators, switched-capacitor circuits, converter architectures, analog-to-digital converters, digital-to-analog converters, integrator-based filters. A project is required, including design, simulation and layout using an IC design tool. Prerequisite: EE 5305 or EE 5318.

EE 5317. ADVANCED DIGITAL VLSI DESIGN. 3 Hours.
Design of logical gates using CMOS technologies; static and dynamic circuit techniques; advanced techniques in logic circuits; general VLSI system components design; arithmetic circuits in VLSI; low power design; chip layout strategies. A design project using computer tools is required. Prerequisite: EE 5310.

EE 5319. TOPICS IN DIGITAL SYSTEMS. 3 Hours.
Formal instruction in selected topics in digital systems and microcomputers. May be repeated when topic changes.

EE 5321. OPTIMAL CONTROL. 3 Hours.
Design of optimal control systems. Topics include optimization under constraints, linear quadratic regulators, Riccati's equation, suboptimal control, dynamic programming, calculus of variations, and Pontryagin's minimum principle. A prior introductory systems course, such as EE 5307, is desirable.

EE 5322. INTELLIGENT CONTROL SYSTEMS. 3 Hours.
Principles of intelligent control including adaptive, learning, and self-organizing systems. Neural networks and fuzzy logic systems for feedback control. Mobile robots. Discrete event systems and decision-making supervisory control systems. Manufacturing work-cell control. Advanced sensor processing including Kalman filtering and sensor fusion. A prior introductory systems course, such as EE 5307, is desirable.

EE 5323. NONLINEAR SYSTEMS. 3 Hours.
Analysis and design of nonlinear systems. A general course in nonlinear systems with examples from multiple engineering and science disciplines. Topics include phase planes, Lyapunov's theory, describing functions, iterative maps, chaos and fractals, and nonlinear optimization methods. A prior introductory systems course, such as EE 5307, is desirable.

EE 5325. ROBOTICS. 3 Hours.
Principles of kinematics, dynamics, and control of robot manipulators and mobile robots. Analysis of dynamical equations and design of robot control systems using modern nonlinear systems techniques. Computer simulation of robotic and mobile robot systems. Path planning, workcell coordination and control. Also listed as ME 5337.

EE 5327. SYSTEM IDENTIFICATION AND ESTIMATION. 3 Hours.
Introduction to parametric and non-parametric modeling and identification and estimation methods for linear and nonlinear systems. Methods covered include linear and non-linear least squares, LTI (linear time-invariant) black-box models, empirical transfer function estimate, state-space and frequency domain model reduction methods, Kalman filtering and self-tuning adaptive control. Introductory systems and signals courses, such as EE 5302 and EE 5307, are desirable.

EE 5329. TOPICS IN SYSTEMS ENGINEERING. 3 Hours.
Formal instruction in selected topics in systems engineering, such as advanced controls, systems performance, manufacturing, graphics subsystems design, stochastic control, decision and information theory, hierarchical or distributed parameter control. May be repeated when topic changes.

EE 5330. DISTRIBUTED DECISION AND CONTROL. 3 Hours.
Topics include cooperative decision and control algorithms for networked teams of dynamical agents on communication graphs. Included are multi-agent local decision protocols that yield global team behavior, synchronization of dynamics including coupled oscillators and chaotic systems, analysis of stability and consensus convergence behaviors, and group decision and adversarial games on graphs. Applications are to engineering systems such as dynamical systems on communications networks, networked teams of autonomous systems and vehicles, and formation flight.

EE 5331. RF SYSTEMS ENGINEERING. 3 Hours.
Topics include design and performance analysis of transmitter and receiver systems for communications and radar, including digital and analog modulators, transmit lineups, power amplifiers and linearization techniques, feedline structures, antennas, RF propagation channels, receiver lineups, and demodulation techniques. Additional topics include frequency planning, noise and interference mitigation, and regulatory and compliance issues.

EE 5332. ANTENNA SYSTEM ANALYSIS. 3 Hours.
Fundamental study of antennas and antenna design techniques, directed toward applications. Topics include electromagnetic basis of antenna radiation and reception; antenna characterization and measurements; analysis and simulation of wire antennas, aperture antennas, patch antennas, horns and reflector antennas; antenna elements in arrays; system architectures for beamsteering, beamforming, and MIMO; and introduction to antenna array processing.

EE 5333. WAVE PROPAGATION AND SCATTERING. 3 Hours.
Fundamentals of electromagnetic wave propagation and scattering in radar and wireless communications. Propagation over irregular terrain, in built-up areas, and inside buildings. Scattering from objects and area extensive targets. Propagation and scattering modeling and their applications in wireless communications and remote sensing. Signal statistics. Prerequisites: EE 5302 and EE 5306.

EE 5334. FUNDAMENTALS OF RADAR REMOTE SENSING. 3 Hours.
Active and passive remote sensing systems, platforms for remote sensing, radar equation, interaction of electromagnetic waves with matter, radar cross section, scattering from area extensive targets, surface scattering, volume scattering, radiative transfer theory, radar data collection and analysis, retrieval of target parameters, and subsurface sensing.

EE 5335. FUNDAMENTALS OF RADAR IMAGING. 3 Hours.
Radar system, electromagnetic waves scattering from targets, radar signal and noise, detection and extraction of signal from noise or clutter, range and Doppler profiles, ambiguity function, radar image formation, real aperture radar imaging, SAR imaging, ISAR imaging, and superresolution radar imaging techniques.

EE 5336. FOUNDATIONS OF MEDICAL IMAGING. 3 Hours.
This course introduces the engineering, physics, mathematics, and signal processing methods fundamental to medical image acquisition and processing: X-ray projection, X-ray computed tomography, magnetic resonance imaging, and ultrasound imaging. Brief introduction to optical and infrared imaging and nuclear imaging (SPECT/PET) will be included. Open to graduate students in College of Engineering or College of Science.

EE 5338. COMPUTATIONAL METHODS IN ELECTRICAL ENGINEERING. 3 Hours.
Mathematical and computational methods to analyze physical phenomena in electrical engineering, including Fourier transformation, finite difference method, finite element method, and integral equation method.

EE 5339. TOPICS IN ELECTROMAGNETICS. 3 Hours.
Formal instruction in selected topics in electromagnetics. May be repeated when topic changes.

EE 5340. SEMICONDUCTOR DEVICE THEORY. 3 Hours.
Quantum mechanics applicable to semiconductor theory. Energy band theory, density of states and effective mass theory. Intrinsic and extrinsic semiconductors, equilibrium statistics for electrons and holes. Transport, generation and recombination of excess carriers. Device equations and physics. Theory and performance of p-n and Schottky diodes, bipolar and MOS transistor electronic devices, and optoelectronic devices.

EE 5341. ELECTRONIC MATERIALS: FUNDAMENTALS AND APPLICATIONS. 3 Hours.
Fundamental theory required for the study of electronic materials: waves and particles, quantum mechanics, crystal structures, chemical bonds, and band theory. Materials and properties considered will be metals, semiconductors, and dielectrics including effective mass, doping, and carrier statistics, and electronic, dielectric, magnetic, and optical properties of materials as applied to integrated circuits, wireless communication, optoelectronics, optical communication, and data storage.

EE 5342. SEMICONDUCTOR DEVICE MODELING AND CHARACTERIZATION. 3 Hours.
Device models and characterization procedures for the pn junction and Schottky diodes, the BJT, JFET, MOSFET, HBT, and optical sources and detectors. SPICE derived and higher level circuit simulator models will be presented. Prerequisite: EE 5340 or EE 5341.

EE 5343. SILICON INTEGRATED CIRCUIT FABRICATION TECHNOLOGY. 3 Hours.
Basic integrated circuit fabrication processes: crystal growth (thin film and bulk), thermal oxidation, dopant diffusion/implantation, thin film deposition/etching, and lithography. Introduction to process simulators, such as SUPREM. Fabrication and characterization of resistors, MOS capacitors, junction diodes and MOSFET devices. Prerequisite: Pass the NanoFAB Safety and Clean Room Protocol test.

EE 5344. INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS (MEMS) AND DEVICES. 3 Hours.
Develops the basics for microelectromechanical devices and systems including microsensors, and micromotors, principles of operation, different micromachining techniques, and thin-film technologies as they apply to MEMS.

EE 5345. INTRODUCTION TO BIO-NANOTECHNOLOGY. 3 Hours.
Introduction to the area of bio-nanotechnology. Basics of nanotechnology as applicable to biological and biomedical sensing, therapy and diagnostics. Theory, fabrication, techniques and uses of nano-scale devices and objects in biomedical and biology.

EE 5346. MICROWAVE DEVICES. 3 Hours.
Device physics and applications of microwave semiconductor devices and vacuum tubes. Topics include operation, modeling and characterization of MESFETs and HEMTs, microwave diodes, and microwave vacuum tubes. Prerequisite: EE 5340 and EE 5341.

EE 5348. RADIO-FREQUENCY CIRCUIT DESIGN. 3 Hours.
Design of lumped- and distributed-element radio-frequency circuits; scattering parameters; impedance-matching circuits; transmission line theory and design; low noise amplifiers; power amplifiers; resonant circuits; noise analysis; RF filter design. Prerequisite: EE 5305.

EE 5349. TOPICS IN INTEGRATED CIRCUIT TECHNOLOGY. 3 Hours.
Formal instruction in selected topics in integrated circuit technology. May be repeated when topic changes.

EE 5350. DIGITAL SIGNAL PROCESSING. 3 Hours.
Time and frequency domain analyses of linear time invariant systems. Stability analyses of causal and non-causal systems using the Z-transform. FIR digital filter design. Design of frequency selective IIR digital filters using frequency transformations and the bilinear transform. Design of infinite and finite impulse response filters.

EE 5351. DIGITAL VIDEO CODING. 3 Hours.
Fundamentals, principles, concepts and techniques of data compression such as Huffman, Lempel-Ziv, Arithmetic, Facsimile, Transform, DPCM, VQ, and Hybrid coding and applications in ITU, ISO, and IEC standards related to audio, video, and image compression.

EE 5352. STATISTICAL SIGNAL PROCESSING. 3 Hours.
Estimation of correlation functions, power spectra, and probability density functions using training data. Algorithm development using maximum likelihood and Bayes approaches. Lower bounds on estimates of error variance. Optimal feature extraction. Design of approximate Bayes discriminants for classification using training data. Feature selection using subsetting and transformation approaches. Branch and bound. Applications in bioengineering, remote sensing, and telecom.

EE 5353. NEURAL NETWORKS AND DEEP LEARNING. 3 Hours.
First and second order training algorithms for both shallow and deep neural networks. Initialization lemmas. Approximation of continuous functions and Bayes discriminants using feedforward networks. Structure and training of convolutional networks, and their relationship to conventional pattern recognition systems. Analyses of drop out and mini-batches. Methods for evaluating network performance. Applications in pattern recognition, estimation and forecasting.

EE 5354. MACHINE LEARNING. 3 Hours.
Fundamental principles and techniques on detecting meaning patterns in data. Supervised learning with applications in regression and classification. Kernel methods and nonlinear spaces along with support vector machines in classification and training of neural networks. Clustering techniques in unsupervised learning. Feature extraction and dimensionality reduction. Graphical models and Hidden Markov models for sequential data and latent variables. Advanced boosting methods, recommended systems as well as online and reinforcement learning techniques.

EE 5355. DISCRETE TRANSFORMS AND THEIR APPLICATIONS. 3 Hours.
Principles and properties of discrete transforms such as discrete Fourier, discrete cosine, Walsh-Hadamard, slant, Haar, discrete sine, discrete Hartley, LOT and Wavelet transforms, and their applications in signal and image processing.

EE 5356. DIGITAL IMAGE PROCESSING. 3 Hours.
Digital image processing as applied to image sampling and quantization, image perception, image enhancement, image restoration, image reconstruction from projections, and filtering and image coding.

EE 5357. STATISTICAL PATTERN RECOGNITION. 3 Hours.
Theories of optimal feature extraction for statistical pattern recognition. Feature extraction using transform based methods, convolutional and other block based approaches. The relationships of Bayes discriminants to neural net, nearest neighbor, SVM, and deep classifiers. Sensor fusion in conventional and convolutional systems. Feature selection using transformation and subsetting approaches.

EE 5358. COMPUTER VISION. 3 Hours.
Techniques for the interpretation, analysis, and classification of digital images. Methods for segmentation, feature extraction, object recognition, stereo vision and 3-D modeling. A research project will be assigned.

EE 5359. TOPICS IN SIGNAL PROCESSING. 3 Hours.
Formal instruction in selected topics in signal processing. May be repeated when topic changes.

EE 5360. DATA COMMUNICATIONS ENGINEERING. 3 Hours.
Layered approach to data communications and networking will be presented. Network models such as TCP/IP and OSI will be introduced. Protocols and technologies related to each layer will be studied in depth. For physical layer, analog and digital signaling, modulation, bandwidth, multiplexing as well as line and block coding techniques. For data link layer, various MAC layer protocols involving multiple access, error detection (CRC), wired (Ethernet) versus wireless (Wi-Fi) LANs, switching. For network layer, internet protocol (IP) and routing principle. Underlying technologies learned from this course are applicable to wide range of traditional and current data communication protocols. Performance analysis of well-known protocols using probabilistic model will also be studied.

EE 5362. DIGITAL COMMUNICATIONS. 3 Hours.
The course presents fundamental principles underlying the transmission and reception of digital information, and studies the different parts of a modern digital communication system. Specifically, the course will touch upon different digital modulation schemes, as well as the design and performance analysis of optimum receivers for additive white Gaussian noise (AWGN) channels. Some concepts of information theory and channel coding will also be studied. Further, techniques for carrier and symbol synchronization will be presented. Communication over bandlimited channels will also be explored, and the effects of intersymbol interference (ISI), as well as channel equalization techniques will be considered.

EE 5364. INFORMATION THEORY FOR DATA SCIENCE. 3 Hours.
Entropy, conditional entropy, relative entropy, mutual information, transfer entropy, data compression, Huffman coding, Shannon coding, compressive sensing, encoding of correlated data, source coding with side information, channel capacity, differential entropy, rate distortion, information theoretical foundations for data science, Bayesian inference, probabilistic reasoning, stock market and portfolio theory.

EE 5365. FIBER OPTIC TRANSMISSION SYSTEMS. 3 Hours.
Propagation in optical fibers, characteristics and manufacture of fibers, semiconductor lightwave sources and detectors, optical transmitters and receivers, lightwave transmission systems for wide area and local area networks.

EE 5368. WIRELESS COMMUNICATION AND IoT. 3 Hours.
Fundamental principles of radio system design and propagation. Basics of cellular systems, environment, propagation models, traffic models and spectral capacity. Multiple-access techniques including FDMA (frequency division multiple access), TDMA (time division multiple access), CDMA (code division multiple access). Machine learning for wireless communications. Internet of Things (IoT) system architecture, IoT enabling technologies such as sensors and sensor networks, IoT communication and networking protocols, IoT services and applications. IoT demands, impacts, and implications on sensors technologies, big data management, and future internet design for various IoT use cases, such as smart cities, smart environments, smart homes, etc.

EE 5369. TOPICS IN COMMUNICATIONS. 3 Hours.
Formal instruction in selected topics in communications. May be repeated when topic changes.

EE 5370. ELECTRIC MOTOR DRIVES. 3 Hours.
Fundamentals of electromechanical energy conversion devices and systems; Principles of inductors, transformers, force/torque formulation, and reference frame transformation; induction motors and permanent magnet machines; Inverter topologies and switching strategies; Scalar and vector control methods for machine drive systems.

EE 5371. POWER SYSTEM PLANNING, OPERATION, AND CONTROL IN A DEREGULATED ENVIRONMENT. 3 Hours.
Current market structure and practices are discussed. The issues of system planning, operation, and control in a deregulated environment are addressed. Prerequisite: EE 5308.

EE 5372. CONGESTION MANAGEMENT. 3 Hours.
Phenomena of congestion and transmission pricing are presented. Thermal related congestion, such as power flow, and stability related congestion, such as voltage stability, transient stability, and dynamic stability, are covered. The effects of reactive power are discussed. Reliability and security issues of power transmission systems are presented. Congestion management and congestion relief measures are discussed. Prerequisite: EE 5308.

EE 5373. UNBUNDLING SERVICES OF A DEREGULATED POWER SYSTEM. 3 Hours.
The fundamental operating functions of a deregulated power system are presented. Unbundling of these functions and cost allocations are discussed. Topics of ancillary services, power marketing, price forecasting, and load forecasting are covered. Prerequisite: EE 5308.

EE 5374. POWER SYSTEM PROTECTIVE RELAYING. 3 Hours.
Fundamental understanding of symmetrical components, applications of symmetrical components in system protection, philosophy of power system protection, various protective relay systems, and the special considerations in applying the microprocessor based relays are covered. Experiments utilizing the Power System Simulation Laboratory are required.

EE 5375. POWER SYSTEM DISTRIBUTION. 3 Hours.
The basic functions of a Distribution Company are presented. Load representation, distribution load flow and the philosophy of simulation for a distribution system are discussed in detail.

EE 5376. POWER SYSTEM RELIABILITY IN PLANNING AND OPERATION. 3 Hours.
Loss of Load indices, Loss of Energy indices, Frequency and Duration methods, Interconnected Reliability methods, and Composite Generation and Transmission Reliability methods will be covered.

EE 5377. PROGRAMMABLE LOGIC CONTROLLERS IN INDUSTRIAL AUTOMATION. 3 Hours.
The application of Programmable Logic Controllers (PLC) in industrial automation and energy systems monitoring will be covered. Transducers, Supervisory Control and Data Acquisition (SCADA) systems, and Distributed Control Systems (DCS) will be discussed. Material covered is also applicable to various mechanical and civil engineering fields, thus enrollment of graduate engineering students from other disciplines is welcome. Experiments utilizing the Power System Simulation Laboratory are required.

EE 5378. POWER QUALITY. 3 Hours.
Principles of harmonics and filtering, source of voltage surges and surge protection, causes of voltage sags, flickers, and interruptions, and voltage supporting devices, and utility and end-user strategies for improving power quality are covered.

EE 5379. TOPICS IN POWER SYSTEM ENGINEERING. 3 Hours.
Formal instruction in selected topics in power system engineering. May be repeated when topic changes.

EE 5380. PRINCIPLES OF PHOTONICS AND OPTICAL ENGINEERING. 3 Hours.
Optical fields with applications to laser, optical fibers, and photonic signal processing. Encoding, manipulating, transmitting, storing, and retrieving information using light. Light propagation including isotropic and birefringent optical media, dielectric interfaces, interference and diffraction, Gaussian beams, optical cavities and principles of laser action, optical waveguides and fibers, electro- and acousto- optic modulation. Design, analysis and application of optical devices in communications and signal processing.

EE 5381. FOUNDATIONS IN SEMICONDUCTORS. 3 Hours.
Electronic properties of semiconductors affecting semiconductor devices: quantum behavior; Kronig-Penny model; energy bands; carrier statistics; density of states; one, two, and three dimensional systems; carrier transport; thermoelectric effects; surface and bulk generation-recombination statistics; continuity equations and their solutions; optical properties; semiconductor characterization techniques.

EE 5382. OPTICAL DETECTORS AND RADIATION. 3 Hours.
Basic principles of optical detectors used in imaging and communications. The course focuses on infrared detectors. Geometric optics, blackbody radiation, radiometry, photon detection mechanisms, thermal detection mechanisms, noise in optical detectors, figures of merit for detectors, photovoltaic detectors, photoconductive detectors, bolometers, pyroelectric detectors, and quantum well detectors.

EE 5383. SOLAR ELECTRICITY & PHOTOVOLTAICS. 3 Hours.
Solar radiation and other forms of renewable energy: wind, tide, biomass and hydropower. Fundamental theory of photovoltaics: crystal structures, band theory, semiconductors, doping, carrier statistics, optical absorption, and p-n junctions. Status of solar cell, including cost, optical design, system engineering, silicon solar cells and thin film solar cells. Prospects of solar cells, regarding low-cost and high-efficiency solar cells. Prerequisite: EE 5340 or EE 5341.

EE 5384. OPTOELECTRONIC DEVICES FOR COMMUNICATION. 3 Hours.
Electronic and optical processes in semiconductors. Light emitting diodes. Laser diodes: structures, properties and operating principles. Photodetectors and solar cells. Noise and the photoreceiver. Optoelectronic modulators and switching devices. Systems needs and new device challenges.

EE 5385. NONLINEAR OPTICS. 3 Hours.
Nonlinear optical processes and applications in crystals, optical fibers and waveguides. Second- and third- order nonlinear susceptibility, symmetry properties, coupled-wave propagation,phase-matching techniques, sum- and difference-frequency generation, parametric amplification, four-wave mixing, self- and cross-phase modulation, soliton propagation, and Raman scattering.

EE 5386. INTEGRATED OPTICS. 3 Hours.
Theory and techniques of integrated optics including optical waveguiding, coupling, modulation, grating diffraction, detection and integrated systems.

EE 5387. FOURIER OPTICS AND HOLOGRAPHY. 3 Hours.
Theory of Fourier optics and holography including scalar diffraction theory, Fresnel and Fraunhofer diffraction, Fourier transforming properties of lenses, optical imaging systems, spatial filtering, and the theory and applications of holography. Prerequisite: EE 5306.

EE 5388. LASERS. 3 Hours.
Propagation of optical rays and waves, Gaussian laser beams, laser resonators, atomic systems, lasing and population inversion, laser amplifiers, practical gas and solid-state lasers including continuous-wave and pulsed lasers, mode locking, Q-switching, frequency doubling, tunable lasers, semiconductor lasers, vertical-cavity lasers and applications of lasers.

EE 5389. TOPICS IN OPTICS. 3 Hours.
Formal instruction in selected topics in optics. May be repeated when topic changes.

EE 5391. ADVANCED STUDY IN ELECTRICAL ENGINEERING. 3 Hours.
Individual research projects in electrical engineering. Prior approval of the EE Graduate Advisor is required for enrollment. A written report is required. Graded F,P,R.

EE 5392. PROJECT IN ELECTRICAL ENGINEERING. 3 Hours.
Individual research projects performed for fulfilling the requirements of the thesis substitute option. Prior approval of the EE graduate advisor is required for enrollment. A written and oral report is required. Graded F, P, R.

EE 5398. THESIS. 3 Hours.
Graded F, P, R. Prerequisite: Graduate standing in electrical engineering.

EE 5698. THESIS. 6 Hours.
Graded F, P, R. Prerequisite: Graduate standing in electrical engineering.

EE 6313. ADVANCED MICROPROCESSOR SYSTEMS. 3 Hours.
Study of the advanced microprocessor architectures including 32/64-bit RISC and CISC families of microprocessors will be compared based on detailed architectural analysis of the selected devices. Topics include: address/instruction pipelines, burst cycles, memory caching and cache coherency issues, register renaming, speculative instruction execution and other performance-oriented techniques. Prerequisite: EE 5313.

EE 6314. ADVANCED EMBEDDED MICROCONTROLLER SYSTEMS. 3 Hours.
Study of advanced microcontroller system designs with an emphasis on multi-tasking, real-time control of devices. Topics include: design of real-time control systems, design of bootloaders, USB peripherals, and Ethernet applications. Prerequisite: EE 5314.

EE 6321. INTRODUCTION TO UNMANNED VEHICLE SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty.

EE 6322. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: EE 6321.

EE 6342. ADVANCED QUANTUM DEVICES. 3 Hours.
Advanced concepts in quantum theory of semiconductors. Epitaxial growth and characterization of heterostructures, quantum wells, and superlattices including strained layers; electronic and optical properties of these structures; electronic and optoelectronic devices based on quantum wells and superlattices. Prerequisite: Graduate standing.

EE 6343. QUANTUM WELL LASERS. 3 Hours.
Introduction to semiconductor heterostructures and quantum wells. Quantum theory of optical processes and laser operation. Threshold, spectral, and dynamical behavior. Modern laser structures and technologies, including strained-layer and surface emitting lasers. Prerequisite: EE 5340 and EE 5341.

EE 6344. NANOSYSTEMS AND QUANTUM ELECTRONIC DEVICES. 3 Hours.
Design, analysis, and techniques for conceptualizing and fabricating nanoscale systems. Role of quantum confinement and mesoscopic behavior, phase coherence, quantum transport, single electron devices, semiconductor heterostructures, self-assembly and molecular electronic schemes, lithographic methods, atomic epitaxy, and surface analysis techniques. Prerequisite: EE 5340 and EE 5341.

EE 6345. ADVANCED MEMS -- MICROELECTROMECHANICAL SYSTEMS. 3 Hours.
Microelectromechanical systems (MEMS) and devices including micro-actuators and optical MEMS. Application strategy of MEMS; fabrication and design; actuation mechanism and architectures; optical sensor and communication applications. Mask layout and hands-on design, fabrication procedures, design rules, demonstrated examples, and integration architectures. Prerequisite: EE 5344.

EE 6353. CONVEX OPTIMIZATION FOR ENGINEERS. 3 Hours.
This course presents an overview of standard methods in convex optimization with applications to real-world problems from multiple areas of engineering and sciences including, signal processing, machine learning, control, networks, power system analysis, mechanical and aerospace, and circuit design. Course materials include advanced linear algebra, numerical algorithms, constrained and unconstrained optimization, duality theory, semidefinite programming, nonlinear and mixed-integer optimization, convex algebraic geometry, and several engineering applications.

EE 6356. IMAGE AND VIDEO CODING. 3 Hours.
Fundamentals, principles, concepts, and techniques of data (image/video/audio) compression such as Huffman coding, arithmetic coding, Lempel-Ziv coding, facsimile coding, scalar and vector quantization, DPCM, PCM, sub-band coding, transform coding, hybrid coding and their applications. Prerequisite: EE 5350.

EE 6364. ADVANCED DATA NETWORKS. 3 Hours.
Network performance analysis, link and upper layer. Internet and ATM protocols, Internet routing and traffic management, ATM switch design and ATM traffic management. Prerequisite: EE 5360.

EE 6365. ADVANCED FIBER OPTICS SYSTEMS. 3 Hours.
Course reviews the modern WDM systems and methods of their design. Topics include architecture of state-of-the-art WDM systems; design of optical amplifiers; signal-to-noise-ratio budget; estimation of various system impairments; popular modulation formats; transmitter and receiver design issues; balancing optical nonlinearity and dispersion; optical networking; and characterization of WDM system's performance. Familiarity with fiber optics and telecommunications is desirable.

EE 6367. ADVANCED AND NEXT-G WIRELESS COMMUNICATIONS. 3 Hours.
Performance analysis of wireless communication systems with multiple input multiple output (MIMO). Space time coding design criteria, space time trellis codes, space time block codes. The next-G wireless communications including mm-wave communications, advanced channel coding, BCJR decoding, Turbo codes, Polar codes, and selected topics in Next-G wireless communications.

EE 6373. RENEWABLE ENERGY SYSTEMS. 3 Hours.
Wind energy harvest, solar energy sources and harvesting, hydropower resources, geothermal, fuel cell and hydrogen economy, power grid interface and distributed generation, microscopic energy harvest from vibration and thermal, role of power electronics in integration of renewable energy systems. Familiarity with the principles of power electronics and electric power recommended.

EE 6375. POWER ELECTRONICS ENGINEERING. 3 Hours.
The course presents selected topics in modeling and analysis of power electronics devices and systems, including dc-dc and dc-ac converters, studies different converter topologies, and investigates various control techniques. The course content helps graduate students to develop and/or improve their research skills in power and energy systems.

EE 6381. NANOPHOTONICS. 3 Hours.
Introduction to nanophotonic materials, devices, systems integration, and applications. Principles of nanoscale structures, quantum dots, photonic crystals, near field optics, plasmonics and metamaterials. Design, modeling, synthesis and fabrication of nano-structures and devices. Scaling of photonic components and optoelectronic integration.

EE 6382. OPTICAL BIOSENSORS: INSTRUMENTATION AND TECHNIQUES. 3 Hours.
Introduction to modern biological and chemical sensing for in-vivo and in-vitro disease diagnosis. Photonics and nanotechnologies for biomolecular analysis. Bio/chemical sensor principle, instrumentation, and applications.

EE 6397. RESEARCH IN ELECTRICAL ENGINEERING. 3 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of electrical engineering. Graded F, P, R.

EE 6399. DISSERTATION. 3 Hours.
Graded F, R.

EE 6697. RESEARCH IN ELECTRICAL ENGINEERING. 6 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of electrical engineering. Graded F, P, R.

EE 6699. DISSERTATION. 6 Hours.
Graded F, R, P, W.

EE 6997. RESEARCH IN ELECTRICAL ENGINEERING. 9 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of electrical engineering. Graded F, P, R.

EE 6999. DISSERTATION. 9 Hours.
Graded F, P, R.

EE 7399. DOCTORAL DEGREE COMPLETION. 3 Hours.
This course may be taken during the semester in which a student expects to complete all requirements for the doctoral degree and graduate. Enrolling in this course meets minimum enrollment requirements for graduation, for holding fellowships awarded by The Office of Graduate Studies and for full-time GTA or GRA positions. Students should verify that enrollment in this course meets other applicable enrollment requirements. To remain eligible in their final semester of study for grants, loans or other forms of financial aid administered by the Financial Aid Office must enroll in a minimum of 5 hours as required by the Office of Financial Aid. Other funding sources may also require more than 3-hours of enrollment. Additional hours may also be required to meet to requirements set by immigration law or by the policies of the student's degree program. Students should contact the Financial Aid Office, other sources of funding, Office of International Education and/or their graduate advisor to verify enrollment requirements before registering for this course. This course may only be taken twice. Students who do not complete all graduation requirements while enrolled in this course must enroll in a minimum of 6 dissertation hours (6699 or 6999) in their graduation term. Graded P/F/R.

COURSES

ENGR 0251. PROBLEM SOLVING IN ENGINEERING PRACTICUM. 2 Hours.
Supplementary material to ENGR 1251, and student success activities, including Peer-Led Team Learning. Corequisite: ENGR 1251.

ENGR 1099. UNDERGRADUATE INDEPENDENT STUDY. 0 Hours.
Independent study related to Engineering.

ENGR 1101. ENTRANCE TO ENGINEERING FOR TRANSFER STUDENTS. 1 Hour.
Entrance to Engineering for Transfer Students welcomes transfer students to the College of Engineering. Topics include engineering student life, fields of study, ethics, design, and preparing for a successful career.

ENGR 1191. UNDERGRADUATE SPECIAL TOPICS IN ENGINEERING. 1 Hour.
Topics in the field of engineering. Topic may vary from semester to semester. May be repeated for credit when topic changes. Departmental approval required in advance to use for degree credit. Prerequisite: consent of instructor.

ENGR 1199. ENGINEERING PROBLEM SOLVING BRIDGE. 1 Hour.
Expanding on prior knowledge of engineering topics, this course enhances problem solving skills in preparation for subsequent engineering courses. Prerequisite: permission of instructor.

ENGR 1204. ENGINEERING FIRST YEAR SEMINAR. 2 Hours.
Introduction to basic engineering concepts, engineering and its many subfields, ethical responsibilities, creativity and design. Self-management and academic skills necessary for academic and professional success.

ENGR 1250. PROBLEM SOLVING IN ENGINEERING. 2 Hours.
Broad introduction to engineering through the process of applying the principles of mathematics to solve real-life engineering problems. Math topics are presented within the context of engineering applications and reinforced through examples from engineering courses. Also introduces algorithm development through the use of the engineering analysis software MATLAB. Prerequisite: C or better in MATH 1426 (or concurrent enrollment), or C or better in (or concurrent enrollment in) a subsequent mathematics course (MATH 2425, MATH 2326, MATH 3319, HONR-SC 1426, HONR-SC 2425), or a qualifying score on the Math Placement Test (MPT).

ENGR 1251. PROBLEM SOLVING IN ENGINEERING FOR PRECALCULUS STUDENTS. 2 Hours.
Broad introduction to engineering through the process of applying the principles of mathematics to solve real-life engineering problems. Math topics are presented within the context of engineering applications and reinforced through examples from engineering courses. Also introduces algorithm development through the use of the engineering analysis software MATLAB. Available only to students taking Math 1421 (Preparation for Calculus) in the same semester. Additional student success activities will be required. Corequisite: ENGR 0251, and concurrent enrollment in Math 1421.

ENGR 1291. UNDERGRADUATE SPECIAL TOPICS IN ENGINEERING. 2 Hours.
Topics in the field of engineering. Topic may vary from semester to semester. May be repeated for credit when topic changes. Departmental approval required in advance to use for degree credit. Prerequisite: consent of instructor.

ENGR 1300. ENGINEERING PROBLEM SOLVING. 3 Hours.
Broad introduction to the profession of engineering and its different disciplines, through the process of applying the principles of mathematics to solve real-life engineering problems and technical writing assignments. Math topics are presented within the context of engineering applications and reinforced through examples from engineering courses. Also introduces algorithm development through the use of the engineering analysis software MATLAB. Prerequisite: C or better in MATH 1421 (or concurrent enrollment), or C or better in (or concurrent enrollment in) a subsequent mathematics course (Math 1426, Math 2425, Math 2326, Math 3319, HONR-SC 1426, HONR-SC 2425), or a qualifying score on the Math Placement Test (MPT).

ENGR 1391. UNDERGRADUATE SPECIAL TOPICS IN ENGINEERING. 3 Hours.
Topics in the field of engineering. Topic may vary from semester to semester. May be repeated for credit when topic changes. Departmental approval required in advance to use for degree credit. Prerequisite: consent of instructor.

ENGR 2100. SUPERVISED ENGINEERING WORK EXPERIENCE. 1 Hour.
Course is for cooperative education students in engineering to be taken in the semester or summer they are employed. Each student will prepare a technical report based upon their work experience. Students who complete the cooperative program will receive certificates and this will be entered on their transcript. Prerequisite: acceptance into and continuance in the Engineering Cooperative Education Program.

ENGR 3000. SUPERVISED ENGINEERING WORK EXPERIENCE. 0 Hours.
Course is for cooperative education students in engineering to be taken in the semester or summer they are employed. Each student will prepare a technical report based upon their work experience. Students who complete the cooperative program will receive certificates and this will be entered on their transcript. Prerequisite: acceptance into and continuance in the Engineering Cooperative Education Program. May be repeated.

ENGR 3100. SUPERVISED ENGINEERING WORK EXPERIENCE. 1 Hour.
Course is for cooperative education students in engineering to be taken in the semester or summer they are employed. Each student will prepare a technical report based upon their work experience. Students who complete the cooperative program will receive certificates and this will be entered on their transcript. Prerequisite: acceptance into and continuance in the Engineering Cooperative Education Program.

ENGR 4100. SUPERVISED ENGINEERING WORK EXPERIENCE. 1 Hour.
Course is for cooperative education students in engineering to be taken in the semester or summer they are employed. Each student will prepare a technical report based upon their work experience. Students who complete the cooperative program will receive certificates and this will be entered on their transcript. Prerequisite: acceptance into and continuance in the Engineering Cooperative Education Program.

ENGR 4302. ENGINEERING ENTREPRENEURSHIP. 3 Hours.
Topics include special problems of newly formed firms, planning, start-up business considerations, business strategy, management basics, and business plan design. Students will engage in business and entrepreneurship training and discussion, become aware of basic business operations, and learn about inventions, intellectual property, and the patenting process. Other topics include assessment of possible markets, venture feasibility, teambuilding, and leadership. Opportunities in university environments will be discussed including incubation centers and patent licensing. We address legal issues, Small Business Innovation Research (SBIR) proposal design, SBIR funding from the National Science Foundation (NSF), National Institutes of Health (NIH), and others. Additional topics include the proposal review process, grant reporting, local high-tech business accelerators, angel-group funding, venture plans, and venture capital. Classes will feature lectures from engineering and business faculty as well as presentations by successful entrepreneurs. Course taught as EE 4302, ENGR 4302 and ENGR 5302; credit will be granted only once. Prerequisite: Student must be in an engineering professional program.

ENGR 4395. SUSTAINABLE ENGINEERING DESIGN PROJECT. 3 Hours.
Following the engineering design process, students will brainstorm, evaluate, and select among engineering alternatives. Students will evaluate the alternatives based on sustainability criteria, including environmental, economic, and social impacts. Life cycle assessment will be used to quantify environmental and economic impacts of the design alternatives. Students will use decision-making methods and optimization in selecting among alternatives. Prerequisites: ENGR 2300, IE 3315, ECON 2305 or IE 2308.

ENGR 5302. ENGINEERING ENTREPRENEURSHIP. 3 Hours.
Topics include special problems of newly formed firms, planning, start-up business considerations, business strategy, management basics, and business plan design. Students will engage in business and entrepreneurship training and discussion, become aware of basic business operations, and learn about inventions, intellectual property, and the patenting process. Other topics include assessment of possible markets, venture feasibility, teambuilding, and leadership. Opportunities in university environments will be discussed including incubation centers and patent licensing. We address legal issues, Small Business Innovation Research (SBIR) proposal design, SBIR funding from the National Science Foundation (NSF), National Institutes of Health (NIH), and others. Additional topics include the proposal review process, grant reporting, local high-tech business accelerators, angel-group funding, venture plans, and venture capital. Classes will feature lectures from engineering and business faculty as well as presentations by successful entrepreneurs.

COURSES

IE 1104. INTRODUCTION TO ENGINEERING. 1 Hour.
Introduction to basic engineering concepts. Students will become familiar with engineering and its many sub-fields, ethical responsibilities, creativity and design.

IE 1110. FIRST SEMESTER INDUSTRIAL ENGINEERING SEMINAR. 1 Hour.
This class focuses on creating a collaborative and inclusive environment for both freshmen and transfer students to the Industrial Engineering program at UTA. This course uses team building exercises, introduces faculty to students through presentations about their classes and research, and presents the curriculum within the "big picture" of how the courses fit together to prepare students for a successful career. This course is intended to provide students the opportunity to form productive study groups and to meet and interact with their professors.

IE 1205. INTRODUCTION TO INDUSTRIAL ENGINEERING AND COMPUTING. 2 Hours.
Introduction to basic industrial engineering concepts and industrial engineering as a field. Microsoft Excel skills are stressed and the software is used to analyze collected data. Some College of Engineering requirements are satisfied by the content of this course.

IE 1325. INTRODUCTION TO DATA ANALYSIS. 3 Hours.
This course is an introduction to organizing, manipulating, analyzing, and visualizing data. Students will become proficient in using Microsoft Excel functions, pivot tables, advanced analytics modules, visualization tools and external data sources. This class will prepare students for success in future industrial engineering classes. Prerequisite: IE 1110 or concurrent enrollment.

IE 2000. UNDERGRADUATE RESEARCH. 0 Hours.
Sophomore level undergraduate research. May be taken a maximum of three times. Prerequisite: Departmental good standing and permission of instructor.

IE 2305. COMPUTER APPLICATIONS IN INDUSTRIAL ENGINEERING. 3 Hours.
An overview of Industrial Engineering concepts and issues important to the design and operation of industrial and service systems. Students will learn the use of software tools developed to enhance the Industrial Engineer's ability such as database management, high level programming languages, electronic spreadsheets, and computer graphics. Prerequisite: IE 1325 (or IE 1205).

IE 2308. ECONOMICS FOR ENGINEERS. 3 Hours.
Methods used for determining the comparative financial desirability of engineering alternatives. Provides the student with the basic tools required to analyze engineering alternatives in terms of their worth and cost, an essential element of engineering practice. The student is introduced to the concept of the time value of money and the methodology of basic engineering economy techniques. The course will provide the student with the background to enable them to pass the Engineering Economy portion of the Fundamentals of Engineering exam. Prerequisites: MATH 1426 or concurrent enrollment.

IE 3000. UNDERGRADUATE RESEARCH. 0 Hours.
Junior level undergraduate research. May be taken a maximum of three times. Prerequisite: Departmental good standing and permission of instructor.

IE 3301. ENGINEERING PROBABILITY. 3 Hours.
Topics in engineering that involve random processes. Applications and backgrounds for topics in reliability, inventory systems, and queuing problems, including absolute and conditional probabilities, discrete and continuous random variables, parameter estimation, hypothesis testing, and an introduction to linear regression, experimental design, and analysis of variance. Prerequisite: MATH 2425.

IE 3312. ECONOMICS FOR ENGINEERS. 3 Hours.
Tools and methods used for determining the comparative financial desirability of engineering alternatives. Prerequisite: MATH 1426 or concurrent enrollment.

IE 3314. ENGINEERING RESEARCH METHODS. 3 Hours.
A continuation of IE 3301. Simple and multiple linear regression analysis, design of experiments, analysis of variance, and quality control statistics. Emphasis on the application of these methods to engineering data, with computerized data analysis. Prerequisite: IE 3301 and MATH 2326.

IE 3315. OPERATIONS RESEARCH I. 3 Hours.
An introduction to the major deterministic quantitative techniques of operations research and their application to decision problems. These techniques include linear programming, integer programming, network analysis, and nonlinear programming. Modeling with these techniques is emphasized. Appropriate solvers are used. Prerequisite: MATH 2326 or concurrent enrollment.

IE 3343. METRICS AND MEASUREMENT. 3 Hours.
This course presents methods for determining the most effective utilization of effort in the man-machine environment as well as systems and methods to measure enterprise performance. Prerequisite: MATH 2326, IE 2308 or concurrent enrollment, and IE 3301 or concurrent enrollment.

IE 4000. UNDERGRADUATE RESEARCH. 0 Hours.
Senior level undergraduate research. May be taken a maximum of three times. Prerequisite: Departmental good standing and permission of instructor.

IE 4191. SPECIAL PROBLEMS IN INDUSTRIAL ENGINEERING. 1 Hour.
The investigation of special individual problems in industrial engineering under the direction of a faculty member. Prerequisite: Consent of instructor and undergraduate advisor.

IE 4291. SPECIAL PROBLEMS IN INDUSTRIAL ENGINEERING. 2 Hours.
The investigation of special individual problems in industrial engineering under the direction of a faculty member. Prerequisite: Consent of instructor and undergraduate advisor.

IE 4300. TOPICS IN INDUSTRIAL ENGINEERING. 3 Hours.
A study of selected topics in industrial engineering. May be repeated when topics vary. Prerequisite: consent of instructor and undergraduate advisor.

IE 4302. ENGINEERING ADMINISTRATION AND ORGANIZATION. 3 Hours.
A survey of administration, control and organization of engineering and research activities. Strategic planning as well as project planning and control are discussed. Prerequisite: accepted in an UTA engineering professional program.

IE 4303. PRODUCTION AND INVENTORY CONTROL. 3 Hours.
Fundamental theory and design of systems for the control of production, inventories and their economic interaction, particularly in cases involving uncertainty of demand, of supply availability, and of production rates. Prerequisite: IE 2305, IE 3301 and IE 3315.

IE 4304. ENTERPRISE SYSTEMS. 3 Hours.
An extension of Production and Inventory Control (IE 4303), this course covers enterprise resource planning systems (ERP) in manufacturing, E-Commerce and supply chain environments. ERP software and case studies are reviewed. Prerequisite: IE 4303.

IE 4305. ENGINEERING DECISION MAKING WITH DATA USING PYTHON. 3 Hours.
This course utilizes statistical tools using Python to analyze real world data on engineering applications. Students explore file handling, database access, and various case studies using Machine Learning techniques. Machine Learning topics include Regression, Classification, Clustering, Dimensionality Reduction, Ensemble Methods, Neural Networks and Deep Learning. Some programming experience is required. Prerequisite: IE 3301 and accepted into an UTA engineering professional program.

IE 4308. QUALITY SYSTEMS. 3 Hours.
A comprehensive coverage of modern quality systems techniques to include the design of statistical process control systems, acceptance sampling, and process analysis and design. Prerequisite: IE 3301 or concurrent enrollment.

IE 4310. INDUSTRIAL AND PRODUCT SAFETY. 3 Hours.
Scientific, managerial, and legal aspects of safety hazard control and elimination in the industrial workplace. Methods for enhancing product safety. Prerequisite: accepted in an UTA engineering professional program.

IE 4314. DATA MINING AND ANALYTICS. 3 Hours.
This course provides an introduction to data mining and pattern recognition. The basic theories, algorithms, key technologies in data analytics and machine learning will be discussed. Topics include data processing and visualization methods, supervised learning methods (parametric/non-parametric algorithms, KNN, decision tree, discriminant functions, Bayesian classification models, support vector machines, neural networks), unsupervised learning methods (clustering, dimensionality reduction, recommender systems), ensemble learning methods (random forests and adaptive boosting), feature selection methods, and deep learning methods. Prerequisite: IE 3301 and accepted into an UTA engineering professional program.

IE 4315. OPERATIONS RESEARCH II. 3 Hours.
A continuation of IE 3315 that includes probabilistic techniques of operations research and their application to decision problems. Topics include Markov chains, game theory, decision analysis, multiple-objective decision making, and queuing theory. Modeling with these techniques is emphasized. Appropriate solvers are used. Projects are required. Prerequisite: IE 3301, IE 3315, and MATH 3319 (or concurrent enrollment).

IE 4318. ENTERPRISE DESIGN. 3 Hours.
This course provides students with an introduction to enterprise systems. Students will be exposed to the technology and analysis methodologies for enterprise resource planning, system design, supply chain management. Also, modern and next-generation enterprise systems will be introduced and basic data mining and machine learning methods will be covered. Prerequisite: Accepted in an UTA engineering professional program.

IE 4322. ENTERPRISE SIMULATION. 3 Hours.
The design and analysis of complex manufacturing and service systems using computer-based discrete event simulation techniques. Topics include an introduction to simulation methods, and the design, construction and analysis of discrete-event simulation models, as well as their computer applications. The course also covers the execution and management of simulation projects and the formal presentation of their findings. Prerequisite: IE 3314 and IE 4315.

IE 4323. AGENT-BASED MODELING AND SIMULATION. 3 Hours.
A series of agent-based modeling topics will be covered including the fundamental concepts of agent-based modeling approach, when to apply, and how to design and implement agent-based simulation to represent complex systems and solve decision problems. Some programming experience and Excel basic knowledge is required. Prerequisite: IE 3301 and accepted into an UTA engineering professional program.

IE 4325. AUTOMATION AND ROBOTICS I. 3 Hours.
Study of the use of industrial automation and robotics technologies in manufacturing industries. The course introduces the major classes of industrial automation. Issues associated with the successful deployment of automation are presented. Laboratory exercises focus on a practical introduction to various automation technologies. Prerequisite: IE 4303 or concurrent enrollment.

IE 4335. COGNITIVE SYSTEMS ENGINEERING. 3 Hours.
This course will discuss applications of psychological principles and computer and information sciences related to human-centered designs for both simple and complex systems. Emphasis will be placed on the design of advanced technological systems to support both individual and larger distributed work systems. In this class, you will learn about theories of human-machine systems, human perceptual and cognitive abilities/limitations, the role of technology and techniques in supporting decision-making and problem solving, and various interface evaluation methods that help to identify issues with how people interact with work and technologies. Prerequisite: Must be in a College of Engineering or College of Science professional program or approval of advisor.

IE 4339. MANUFACTURING PROCESS & SYSTEM ANALYSIS. 3 Hours.
This course provides students with an introduction to manufacturing systems and processes such as machining, welding, and the emerging technology of additive manufacturing. Students will learn to quantify and measure variabilities in the manufacturing system, describe the system's behavior, and improve the system's performance. The impact of quality and reliability on overall system performance sustainability will be explored. Prerequisite: Accepted in an UTA engineering professional program.

IE 4340. ENGINEERING PROJECT MANAGEMENT. 3 Hours.
Introduces engineering project management concepts and tools needed to form, develop and manage cross-disciplinary engineering design teams. Topics include: Understanding R&D organizations, teams and work groups, job design, organizational effectiveness, and leading technical professionals. Prerequisite: Admitted into an Engineering Professional Program.

IE 4343. FACILITIES PLANNING AND DESIGN. 3 Hours.
The course covers strategic facilities planning through detailed facilities layout design. Considerations include product flow, space and activity relationships, personnel requirements, material handling, and layout. Traditional and contemporary issues in manufacturing and their impact on facilities design including receiving, shipping, warehousing, and integration with manufacturing and supporting operations are explored. Facilities planning models and the process of evaluating, selecting, preparing, presenting, and implementing the facilities plan are covered. Prerequisite: IE 4303 or concurrent enrollment.

IE 4344. HUMAN FACTORS ENGINEERING. 3 Hours.
Study of the interactions between people and their work, workplace, and the environment. Involves identification, measurement, analysis, and evaluation of interactions via human physical and mental capacities and limitations, and social interactions. Prerequisite: IE 3301, IE 2308, and IE 3343.

IE 4345. DECISION ANALYSIS IN SYSTEM DESIGN. 3 Hours.
Application of decision theory principles and tools to evaluate alternative hardware/software system architectures based on technical design requirements such as mass, reliability, power and life cycle costs. Systems engineering trade study approaches are presented with applications in defense, aerospace, energy and related areas. Methods for dealing with technical data risk and uncertainty are presented. Prerequisite: Accepted into an engineering professional program at UTA.

IE 4349. INDUSTRIAL AUTOMATION. 3 Hours.
Project oriented course focusing on the design, implementation, and operation of technology. An in-depth study of the design and deployment of industrial technology to meet the needs of high-precision, multi-product environments. The laboratory activities associated with the course provide practical experience. Prerequisite: IE 4325.

IE 4350. INDUSTRIAL ENGINEERING CAPSTONE DESIGN. 3 Hours.
This course provides an open-ended design experience through the planning and design of an enterprise in which the student must demonstrate the ability to perform design, analysis, operation, and improvement of integrated systems that produce or supply products or services in an effective, efficient, sustainable and socially responsible manner. Contemporary project management techniques are utilized. The design experience project includes submittal of several written and oral presentations culminating in a written project report and oral presentation at the end of the semester. IE 4350 is the capstone design course and draws on material from the total industrial engineering curriculum. The impact of engineering design on society is discussed. Prerequisite: all required 4000 level IE courses or concurrent enrollment.

IE 4351. FUNDAMENTALS OF SYSTEMS ENGINEERING. 3 Hours.
This course includes a survey of concepts, principles and processes required to engineer complex systems throughout the life-cycle from concept through disposal. Topics include systems thinking, technical and management processes, life cycle models, sustainability, and model-based systems engineering. Prerequisite: Accepted into an engineering professional program at UTA.

IE 4378. INTRODUCTION TO UNMANNED VEHICLES SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty. Prerequisite: Admission to a professional engineering or science program.

IE 4379. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: B or better in IE 4378 and admission to the UVS certificate program.

IE 4391. SPECIAL PROBLEMS IN INDUSTRIAL ENGINEERING. 3 Hours.
The investigation of special individual problems in industrial engineering under the direction of a faculty member. Prerequisite: Consent of instructor and undergraduate advisor.

IE 5191. ADVANCED STUDIES IN INDUSTRIAL ENGINEERING. 1 Hour.
Individually approved research projects and reading courses in industrial engineering. Such individual studies will be graded A, B, C, D, F or X. Subject to the approval of the Graduate Advisor, IE 5191, IE 5291 and IE 5391 may be repeated as the topics change. In addition, work on a thesis substitute will be performed under IE 5391. In this case, IE 5391 is graded P/F/R.

IE 5291. ADVANCED STUDIES IN INDUSTRIAL ENGINEERING. 2 Hours.
Individually approved research projects and reading courses in industrial engineering. Such individual studies will be graded A, B, C, D, F or X. Subject to the approval of the Graduate Advisor, IE 5191, IE 5291 and IE 5391 may be repeated as the topics change. In addition, work on a thesis substitute will be performed under IE 5391. In this case, IE 5391 is graded P/F/R.

IE 5300. TOPICS IN INDUSTRIAL ENGINEERING. 3 Hours.
A study of selected topics in industrial engineering. May be repeated when topics vary. Prerequisite: consent of instructor and Graduate Advisor.

IE 5301. INTRODUCTION TO OPERATIONS RESEARCH. 3 Hours.
An introduction to the major quantitative techniques of operations research and their application to decision problems. These techniques include linear programming, integer programming, network analysis, nonlinear programming, game theory, Markov Chains, and queuing theory. Modeling with these techniques is emphasized. Appropriate solvers are used. Prerequisite: IE 3301 or equivalent, or IE 5317 concurrent, or DASC 5302 concurrent.

IE 5302. INTRODUCTION TO INDUSTRIAL ENGINEERING. 3 Hours.
An introduction to the fundamental principles of Industrial Engineering. Topics include Human Factors Engineering, Metrics and Measurement, Production and Inventory Control, Quality Systems, Simulation and Optimization, and Facilities Planning and Design. Prerequisite: Graduate standing.

IE 5303. QUALITY SYSTEMS. 3 Hours.
Principles and practices of industrial quality control. Topics include the Deming philosophy, process improvements, statistical process control, process capability analysis and product acceptance. Prerequisite: IE 3301, or IE 5317, or DASC 5302, or equivalent.

IE 5304. ADVANCED ENGINEERING ECONOMY. 3 Hours.
Analysis of capital investments in engineering and technical projects. Topics include decision analysis methods, cash flows, revenue requirements, activity-based analysis, multi-attribute decisions, probabilistic analysis and sensitivity/risk analysis. Prerequisite: graduate standing.

IE 5305. LINEAR OPTIMIZATION. 3 Hours.
Theory and applications of linear programming including linear programming formulation, the simplex method, duality, revised simplex, general linear programs, infeasibility, the dual simplex method, column generation, and network flow problems. Prerequisite: IE 3315, or IE 5301, or equivalent.

IE 5306. DYNAMIC OPTIMIZATION. 3 Hours.
Dynamic optimization methods including dynamic programming, the calculus of variations, and optimal control theory. Emphasis is on the modeling and solution of practical problems using these techniques. Prerequisites: IE 5317 or equivalent or IE 5318 concurrent.

IE 5307. QUEUEING THEORY. 3 Hours.
The fundamentals of queueing theory including Markovian birth-death models, networks of queues, and general arrival and service distributions. Prerequisites: IE 3301, or IE 5317, or equivalent.

IE 5309. STOCHASTIC PROCESSES. 3 Hours.
The study of probabilistic model building including the fundamentals of both discrete and continuous Markov chains, queueing theory and renewal theory. Prerequisite: IE 3301, IE 5317, or equivalent.

IE 5310. PRODUCTION SYSTEMS DESIGN. 3 Hours.
Methods for the design and analysis of manufacturing and logistics systems. Emphasis is placed on reducing cycle time, increasing throughput, lowering variation, and improving both quality and customer responsiveness through modeling techniques. Prerequisites: IE 3301, or IE 5317, or equivalent; IE 5301 current or equivalent; IE 5329 concurrent or equivalent.

IE 5311. DECISION ANALYSIS. 3 Hours.
A survey of methods for making optimal decisions. Topics include decision models, formal logic, fuzzy controls, statistical decision theory, game theory, multiobjective decisions, stochastic programming, information theory and qualitative aspects of the decisions. Prerequisites: IE 3301, or IE 5301, or equivalent.

IE 5312. PLANNING AND CONTROL OF ENTERPRISE SYSTEMS. 3 Hours.
A continuation of IE 5329 covering enterprise resource planning systems (ERP) and other advanced production control techniques. Computer modeling is emphasized. Prerequisite: Graduate standing.

IE 5313. RELIABILITY AND ADVANCED QUALITY CONTROL TOPICS. 3 Hours.
Includes advanced quantitative topics in reliability design and quality control. Management of reliability and quality control functions are also included. Prerequisites: IE 4308, or IE 5303, or equivalent.

IE 5314. SAFETY ENGINEERING. 3 Hours.
Methods to identify, measure, analyze, and evaluate safety hazards in the workplace. Scientific and managerial methods to prevent or control safety hazards. Prerequisite: graduate standing.

IE 5315. DATA SCIENCE PROJECT MANAGEMENT. 3 Hours.
Management and control of multifaceted science and engineering projects. Coordination and interactions between client and various service organizations. Project management selection. Typical problems associated with various phases of project life cycle. Case studies illustrate theories and concepts. Students will be expected to demonstrate an understanding of communication and collaboration, including workflow, reproducibility, codebase management, collaboration tools, oral and written communication, presentation, storytelling, and team management, as well as ethics, such as understanding bias, fairness, credibility and misinformation, security, privacy and codes of conduct. Prerequisite: Graduate standing.

IE 5317. INTRODUCTION TO PROBABILITY AND STATISTICS. 3 Hours.
Topics include descriptive statistics, set theory, combinatorics, mathematical expectation, probability distributions, confidence interval estimation, regression analysis, analysis of variance, and design of experiments. Prerequisite: Graduate standing in any program.

IE 5318. APPLIED REGRESSION ANALYSIS. 3 Hours.
An in-depth study of one predictor variable followed by the matrix approach to multiple linear regression. Topics include estimation, prediction, analysis of variance, residual analysis, transformations, multicollinearity, model selection, weighted least squares, ridge regression, and robust regression. Prerequisite: IE 3301, or IE 5317, or DASC 5302, or equivalent.

IE 5319. ADVANCED STATISTICAL PROCESS CONTROL AND TIME SERIES ANALYSIS. 3 Hours.
Design of control schemes for statistical monitoring and control of modern manufacturing systems. Topics include charts for process control, effect of autocorrelation on SPC charts, and sampling plans for acceptance inspection. Prerequisite: IE 3301 and IE 5303 or equivalent.

IE 5320. ENTERPRISE ENGINEERING METHODS. 3 Hours.
A survey of enterprise engineering methods. Topics include system development methodology, discussion of enterprise architectures, activity modeling, business modeling, activity-based performance analysis, and process improvement. Prerequisite: Graduate standing.

IE 5321. ENTERPRISE ANALYSIS AND DESIGN. 3 Hours.
An in-depth study of techniques useful for the analysis and design of the manufacturing enterprise. This course presents an advanced process description technique that is used, with simulation and activity based costing, to facilitate analysis and design. Prerequisites: Graduate standing.

IE 5322. SIMULATION AND OPTIMIZATION. 3 Hours.
An in-depth study of discrete event simulation theory and practice. Optimization and search techniques used in conjunction with simulation experiments are introduced. A commercial simulation software application is used. Prerequisite: IE 5317, DASC 5302, or equivalent, or IE 5318 concurrent.

IE 5323. AGENT BASED SIMULATION. 3 Hours.
Topics include the fundamental concepts of agent-based modeling and implementing agent-based simulation. Students are expected to be proficient in programming and Excel. Prerequisite: IE 3301, or IE 5317, or DASC 5302 or equivalent.

IE 5326. INDUSTRIAL BIOMECHANICS. 3 Hours.
The development and application of biomechanical models of physical work tasks, especially manual materials handling and hard-arm work activities. Prerequisite: Graduate Standing.

IE 5327. ADVANCED STATISTICS. 3 Hours.
Continuation of IE 5317. Topics include multiple linear regression analysis, design of experiments, analysis of variance, and quality control statistics. Prerequisite: IMSE advisor approval.

IE 5329. PRODUCTION AND INVENTORY CONTROL SYSTEMS. 3 Hours.
The fundamentals of production and inventory control systems. The economic impacts of fluctuating demand, supply availability and production rates are examined. Prerequisite: IE 3301, or IE 5317, or equivalent, or IE 5318 or equivalent; IE 5301 concurrent or equivalent.

IE 5330. AUTOMATION AND ADVANCED MANUFACTURING. 3 Hours.
The design of automated and advanced production processes for manufacturing. Topics include numerical control, robotics, group technology, just-in-time, automated inspection and flexible manufacturing systems. Prerequisite: Graduate standing in IMSE or permission of IMSE advisor.

IE 5331. INDUSTRIAL ERGONOMICS. 3 Hours.
The analysis and design of physical work, workplace, and hand tools using ergonomic principles for enhancing performance, health, and safety. Work refers mainly to whole body and hand-arm activities, while workplace refers to industrial and computerized office environments. Applications focus on people's anthropometric, musculoskeletal and psychological characteristics. Prerequisite: Graduate standing in IMSE or permission of IMSE advisor.

IE 5332. NONLINEAR PROGRAMMING. 3 Hours.
Methods for nonlinear optimization including classical theory; gradient methods; sequential unconstrained methods; convex programming; genetic algorithms; simulated annealing; and separable, quadratic, and geometric programming. Prerequisite: Graduate standing.

IE 5333. LOGISTICS TRANSPORTATION SYSTEMS DESIGN. 3 Hours.
The design and analysis of domestic and international transportation systems of people, processes, and technology. Topics include the role of transportation in the extended enterprise, transportation modeling and optimization techniques, value-added supply chain issues, and financial performance measures. Prerequisites: IE 3301, or IE 5317, or equivalent or IE 5318; IE 5301 concurrent or equivalent.

IE 5334. LOGISTICS DISTRIBUTION SYSTEMS DESIGN. 3 Hours.
The design and analysis of distribution systems of people, processes and technology. The focus is on distribution, warehousing and material handling. Topics include the role of the warehouse in the extended enterprise, warehouse planning, process design, layout, equipment selection, workforce and workplace issues, and financial performance measures. Prerequisites: IE 3301, or IE 5317, or equivalent, or IE 5318 or equivalent; IE 5301 concurrent or equivalent.

IE 5335. COGNITIVE SYSTEMS ENGINEERING. 3 Hours.
This course will discuss applications of psychological principles and computer and information sciences related to human-centered designs for both simple and complex systems. Emphasis will be placed on the design of advanced technological systems to support both individual and larger distributed work systems. Topics include theories of human-machine systems, human perceptual and cognitive abilities/limitations, the role of technology and techniques in supporting decision-making and problem solving, and various interface evaluation methods that help to identify issues with how people interact with work and technologies. Prerequisite: IE 3301, or IE 5317, or DASC 5302, or equivalent. Some introductory programming knowledge is recommended.

IE 5338. HUMAN ENGINEERING. 3 Hours.
Human structural, physiological, psychological, and cognitive capacities and limitations in the workplace, and their effects on the design of work systems to enhance productivity, and maintain health and safety. Prerequisite: IE 3301, or IE 5317, or equivalent.

IE 5339. PRODUCT DESIGN, DEVELOPMENT, PRODUCIBILITY, AND RELIABILITY DESIGN. 3 Hours.
This course covers product development and engineering design process with a focus on collaborative design. Software, manufacturing, reliability, testing, logistical and product support considerations are emphasized. Prerequisite: graduate standing.

IE 5342. METRICS AND MEASUREMENT. 3 Hours.
Work measurement, methods improvements, and performance measurement. A survey of enterprise and management measurement systems is presented. Prerequisite: IE 3301, or IE 5317 or equivalent.

IE 5343. HEALTHCARE SYSTEMS ENGINEERING. 3 Hours.
Application of continuous process improvement tools in the analysis of healthcare systems. Plan and execute studies that impact healthcare quality and costs. Evaluates the effectiveness of healthcare and administrative processes and procedures. Prerequisite: graduate standing.

IE 5345. MANAGEMENT OF KNOWLEDGE AND TECHNOLOGY. 3 Hours.
Review of contemporary issues in knowledge management, databases, decision support systems, and intelligent systems. Topics include knowledge acquisition, intelligent database design, decision support systems, data mining, knowledge transfer, and collaborative development. Prerequisite: Graduate standing.

IE 5346. TECHNOLOGY DEVELOPMENT AND DEPLOYMENT. 3 Hours.
Review of management issues in developing and implementing new technologies and methodologies into an organization. Topics include technology forecasting, management of technology based projects, technological competitiveness, technology alliances, and collaboration. Prerequisite: Graduate standing.

IE 5350. GRADUATE DESIGN CAPSTONE. 3 Hours.
Practicum consisting of professional level experience in a relevant company, agency, or institution. Students will be expected to demonstrate an understanding of communication and collaboration, including workflow, reproducibility, management, collaboration tools, oral and written communication, presentation and storytelling, and team management, as well as ethics, such as understanding bias, fairness, credibility and misinformation, security, privacy, and codes of conduct. Prerequisite: 9 hours of graduate work.

IE 5351. INTRODUCTION TO SYSTEMS ENGINEERING. 3 Hours.
This course includes a survey of concepts, principles and processes required to engineer complex systems throughout the life-cycle from concept through disposal. Topics include systems thinking, technical and management processes, life cycle models, sustainability, and model-based systems engineering. Prerequisite: Graduate standing.

IE 5352. REQUIREMENTS ENGINEERING. 3 Hours.
This course focuses on system requirements engineering and related processes and methods. System verification will also be covered. Students will be introduced to model-based systems engineering related to the processes covered in the class. Prerequisite: graduate standing in engineering or consent of instructor.

IE 5353. SYSTEMS ARCHITECTURE & DESIGN. 3 Hours.
This course focuses on systems architecting and design for complex systems. Topics covered include logical and physical system architecture analysis, system design, implementation, transition to use, and enabling products. Students will be introduced to model-based systems engineering related to the processes covered in the class. Prerequisite: graduate standing in engineering or consent of instructor.

IE 5354. MANAGEMENT OF COMPLEX SYSTEMS. 3 Hours.
This course focuses on the management of the engineering of complex systems including key systems engineering management processes. Prerequisite: graduate standing in engineering or consent of instructor. Prerequisite: graduate standing in engineering or consent of instructor.

IE 5361. OPERATIONS RESEARCH FOR LOGISTICS. 3 Hours.
Quantitative techniques of operations research and their application to decision problems in logistics are explored via techniques such as linear programming, integer programming, network analysis, and applied simulation. Modeling with these techniques is emphasized. Prerequisite: Graduate standing.

IE 5362. LOGISTICS & PRODUCTION PLANNING. 3 Hours.
The economic impacts of fluctuating demand, supply availability and production rates are examined via design and analysis of manufacturing and logistics systems. Emphasis is placed on reducing cycle time, increasing throughput, lowering variation, and improving both quality and customer responsiveness through modeling techniques. Prerequisite: Graduate standing.

IE 5363. DISTRIBUTION & TRANSPORTATION SYSTEMS. 3 Hours.
The role of distribution centers and transportation in the extended enterprise are explored via transportation modeling and optimization techniques, value-added supply chain issues, distribution center process design, layout, equipment selection, workforce and workplace issues, and financial performance measures. Prerequisite: Graduate standing.

IE 5378. INTRODUCTION TO UNMANNED VEHICLE SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty. Prerequisite: Permission of instructor.

IE 5379. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: Permission of instructor.

IE 5391. ADVANCED STUDIES IN INDUSTRIAL ENGINEERING. 3 Hours.
Individually approved research projects and reading courses in industrial engineering. Such individual studies will be graded A, B, C, D, F or X. Subject to the approval of the Graduate Advisor, IE 5191, IE 5291 and IE 5391 may be repeated as the topics change. In addition, work on a thesis substitute will be performed under IE 5391. In this case, IE 5391 is graded P/F/R.

IE 5398. THESIS. 3 Hours.
Supervised research projects directed toward the thesis. Graded P, R, F, or W.

IE 5698. THESIS. 6 Hours.
Graded P, F, R.

IE 6197. RESEARCH IN INDUSTRIAL ENGINEERING. 1 Hour.
Supervised research projects directed toward the dissertation. Graded P, R, F.

IE 6297. RESEARCH IN INDUSTRIAL ENGINEERING. 2 Hours.
Supervised research projects directed toward the dissertation. Graded P, R, F.

IE 6301. ENTERPRISE ARCHITECTURES AND FRAMEWORKS. 3 Hours.
A survey of enterprise architectures and analysis frameworks that have been proposed for the integration of large complex enterprise systems. Emphasis is placed on state-of-the-art approaches. Prerequisite: IE 5320.

IE 6302. FACILITIES PLANNING AND DESIGN. 3 Hours.
Facilities planning through layout design. Product flow, space-activity relationships, personnel requirements, and material handling are considered, as well as receiving, shipping, warehousing, and integration with manufacturing. Facilities planning models are explored. Prerequisite: IE 3301, or IE 5317, or equivalent; IE 5301 concurrent or equivalent.

IE 6303. COMBINATORIAL OPTIMIZATION. 3 Hours.
A survey of problems and algorithms in combinatorial optimization. Topics include integer programming formulation, branch-and-bound and cutting plane algorithms, computational complexity, and polyhedral theory. Prerequisite: IE 5301 or consent of instructor.

IE 6305. ENGINEERING MANAGEMENT I. 3 Hours.
The management of the engineering function in high-technology industry with principal emphasis on the historical development of industrial management principles, decision-making and planning. Prerequisite: Graduate standing.

IE 6306. ENGINEERING MANAGEMENT II. 3 Hours.
The management of the engineering function in high-technology industry with principal emphasis on human resources and staffing, directing and leading, and controlling. Prerequisite: IE 6305.

IE 6308. DESIGN OF EXPERIMENTS. 3 Hours.
Introduction to statistical design and analysis of experiments with applications from engineering, health care and business. Analysis includes analysis of variance, multiple comparisons and model adequacy. Designs include complete factorial, complete block, incomplete block, Latin square, Youden, two-level fractional factorial and hierarchically nested. Prerequisite: IE 3301, or IE 5317, or equivalent, and IE 5318.

IE 6309. RESPONSE SURFACE METHODOLOGY AND COMPUTER EXPERIMENTS. 3 Hours.
Empirical model building and process optimization using experimental design and statistical modeling. The first half of the course covers first and second order models and designs, multiresponse experiments and mixture experiments. The second half introduces designs based on Latin hypercubes, orthogonal arrays, and number-based theoretic methods, plus models using kriging, multivariate adaptive regression splines and neural networks. Prerequisite: IE 6308.

IE 6310. INDUSTRIAL APPLICATIONS. 3 Hours.
Project oriented course focusing on the requirements and selection criteria for the integration of technology into simple and complex industrial activities. Prerequisite: IE 5330 or equivalent.

IE 6318. DATA MINING & ANALYTICS. 3 Hours.
An in-depth introduction to data mining and pattern recognition. Basic theories, algorithms, and key technologies in data analytics will be discussed. Case studies and real-world applications will be presented. Prerequisite: IE 3301, or IE 5317, or DASC 5302, or equivalent, and IE 5318.

IE 6397. RESEARCH IN INDUSTRIAL ENGINEERING. 3 Hours.
Supervised research projects directed toward the dissertation. Graded P, R, F.

IE 6399. DISSERTATION. 3 Hours.
Graded F, R.

IE 6697. RESEARCH IN INDUSTRIAL ENGINEERING. 6 Hours.
Supervised research projects directed toward the dissertation. Graded P, R, F.

IE 6699. DISSERTATION. 6 Hours.
Supervised research projects directed toward the dissertation. Graded P, R, F, or W.

IE 6997. RESEARCH IN INDUSTRIAL ENGINEERING. 9 Hours.
Supervised research projects directed toward the dissertation. Graded P, R, F.

IE 6999. DISSERTATION. 9 Hours.
Supervised research projects directed toward the thesis. Graded P, R, F, or W.

IE 7399. DOCTORAL DEGREE COMPLETION. 3 Hours.
This course may be taken during the semester in which a student expects to complete all requirements for the doctoral degree and graduate. Enrolling in this course meets minimum enrollment requirements for graduation, for holding fellowships awarded by The Office of Graduate Studies and for full-time GTA or GRA positions. Students should verify that enrollment in this course meets other applicable enrollment requirements. To remain eligible in their final semester of study for grants, loans or other forms of financial aid administered by the Financial Aid Office must enroll in a minimum of 5 hours as required by the Office of Financial Aid. Other funding sources may also require more than 3-hours of enrollment. Additional hours may also be required to meet to requirements set by immigration law or by the policies of the student's degree program. Students should contact the Financial Aid Office, other sources of funding, Office of International Education and/or their graduate advisor to verify enrollment requirements before registering for this course. This course may only be taken twice. Students who do not complete all graduation requirements while enrolled in this course must enroll in a minimum of 6 dissertation hours (6699 or 6999) in their graduation term. Graded P/F/R.

COURSES

MAE 1104. INTRODUCTION TO ENGINEERING. 1 Hour.
Introduction to basic engineering concepts. Students will become familiar with engineering and its many sub-fields, ethical responsibilities, creativity, and design.

MAE 1105. INTRODUCTION TO MECHANICAL AND AEROSPACE ENGINEERING. 1 Hour.
Introduction to basic engineering concepts. Opportunities are provided to develop skills in oral and written communication and department specific material. Case studies are presented and analyzed. Prerequisite: C or better in ENGR 1250 (or concurrent enrollment), or C or better in ENGR 1300 or MAE 1104.

MAE 1106. INTRODUCTION TO AEROSPACE ENGINEERING. 1 Hour.
An introduction to human flight and to the field of aerospace engineering through a combined theoretical and hands-on approach. Topics covered include history of flight and aerospace engineering and introductions to aerostatics and aerodynamics, aerospace structures, stability and control, and propulsion. Some College of Engineering requirements are satisfied by the content of this course. Prerequisite: C or better in MATH 1426 (or concurrent enrollment) or MATH 1426 qualifying score in Math Placement Test; or student group.

MAE 1107. INTRODUCTION TO MECHANICAL ENGINEERING. 1 Hour.
Introduction to basic engineering concepts. Opportunities are provided to develop skills in oral and written communication, in engineering design teamwork, as well as in department-specific material. Some College of Engineering requirements are satisfied by the content of this course. Prerequisite: C or better in MATH 1426 (or concurrent enrollment) or MATH 1426 qualifying score in Math Placement Test; or student group.

MAE 1140. PROBLEMS IN MECHANICAL AND AEROSPACE ENGINEERING. 1 Hour.
This course introduces students to units, 2D and 3D coordinate geometry, vector algebra and scientific problem solving, in preparation for higher level courses. Prerequisite: C or better in MATH 1426 (or concurrent enrollment); or student group.

MAE 1312. ENGINEERING STATICS. 3 Hours. (TCCN = ENGR 2301)
A study of forces and force systems, resultants and components of force systems, forces due to friction, conditions of equilibrium, forces acting on members of trusses and frame structures, centroids and moments of inertia. Vector and index notation introduced. Prerequisite: C or better in each of the following, MAE 1140 (or ENGR 1250 or REE 1301), MATH 1426 (or HONR-SC 1426), and PHYS 1443; or student group.

MAE 1351. INTRODUCTION TO ENGINEERING DESIGN. 3 Hours.
Foundational course in product design and manufacturing using computer-based methodologies. 3D parametric solid modeling of parts and assemblies. Technical sketching, and ASME Y14 engineering drawing standards. Industrial practices for product design and fabrication. Introduction to 3D product analysis tools. Prerequisite: C or better in MATH 1426 (or concurrent enrollment) or HONR-SC 1426 (or concurrent enrollment) or MATH 1426 qualifying score in Math Placement Test; or student group.

MAE 2000. UNDERGRADUATE RESEARCH. 0 Hours.
Sophomore level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

MAE 2010. AUTOMOTIVE ENGINEERING PRACTICUM I. 0 Hours.
Practical design experience as full team member of automotive design competition team. Prerequisite: Permission of Director of the Arnold E. Petsche Center for Automotive Engineering.

MAE 2312. SOLID MECHANICS. 3 Hours.
The relationship between stresses and strains in elastic bodies and the tension, compression, shear, bending, torsion, and combined loadings which produce them. Deflections and elastic curves, shear and bending moment diagrams for beams, and column theory. Prerequisite: C or better in each of the following, MAE 1140 (or ENGR 1250 or REE 1301) and MAE 1312; or student group.

MAE 2315. FLUID DYNAMICS. 3 Hours.
Introduction to Fluid Dynamics and low speed aerodynamics; fluid properties; dimensional analysis; conservation equations in integral and differential form; potential flow theory and viscous flow. Prerequisites: C or better in each of the following, MAE 1106, MAE 2323 (or concurrent enrollment), MAE 3309 (or concurrent enrollment) or MAE 3310 (or concurrent enrollment), and MAE 3360 (or concurrent enrollment); or student group.

MAE 2323. DYNAMICS. 3 Hours. (TCCN = ENGR 2302)
The relation between forces acting on particles, systems of particles and rigid bodies, and the changes in motion produced. Review of kinematics and vector analysis, Newton's Laws, energy methods, methods of momentum, inertia tensor and Euler's equations of motion. Prerequisite: C or better in each of the following, MAE 1140 (or ENGR 1250 or REE 1301), MAE 1312 and MATH 2425 (or HONR-SC 2425); or student group.

MAE 2360. NUMERICAL ANALYSIS & PROGRAMMING. 3 Hours.
Utilization of digital computers in mechanical and aerospace engineering. Computational algorithms and their representation in FORTRAN, C, and Matlab. Introduction to linear algebra and numerical methods. Prerequisite: C or better in MATH 1426; or student group.

MAE 2381. EXPERIMENTAL METHODS AND MEASUREMENTS. 3 Hours.
Introduction to data analysis, incorporating statistics and probability, design and planning of engineering experiments for error prediction and control. Measurement and instrumentation, basic instruments, their calibration and use. Prerequisite: C or better in each of the following, MAE 1351 and MATH 2425 (or HONR-SC 2425) and PHYS 1443 (or HONR-SC 1443); or student group.

MAE 2391. SPECIAL PROBLEMS IN MECHANICAL AND AEROSPACE ENGINEERING. 3 Hours.
Special problems in mechanical and aerospace engineering for preprofessional students in mechanical or aerospace engineering. Prerequisite: Instructor permission.

MAE 3000. UNDERGRADUATE RESEARCH. 0 Hours.
Junior level undergraduate research. Prerequisite: Departmental good academic standing and permission of instructor. May be taken a maximum of 3 times.

MAE 3181. MATERIALS AND STRUCTURES LAB. 1 Hour.
Experiments to study materials behavior and deformation of structural elements. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 2381 and C or better in MAE 3315 (or concurrent enrollment) or MAE 3242 (or concurrent enrollment); or student group.

MAE 3182. AERODYNAMICS AND FLUIDS LAB. 1 Hour.
Wind tunnel experiments to study flow phenomena of aerodynamics interest, including scale testing of airfoils, wings, and aircraft. Prerequisite: C or better in each of the following, MAE 2381, MAE 3302 (or concurrent enrollment), and MAE 3303 (or concurrent enrollment); or student group.

MAE 3183. MEASUREMENTS LABORATORY II. 1 Hour.
Fundamental measurement techniques and experimental data analysis in mechanical engineering in the fields of thermal, fluid, structures, design, and dynamic systems. Introduction to sensor calibration, digital data acquisition, uncertainty analysis, and report writing. Prerequisite: Must be in the professional ME program and C or better in each of the following, MAE 2381, MAE 3314, and MAE 3319; or student group.

MAE 3185. INTRODUCTION TO MECHATRONICS. 1 Hour.
Project based introduction to the application of software and hardware required to build functioning electromechanical systems. Integrates the theory of electrical circuits, electromechanics, electronics, mechanics, and mechanical devices, along with computer and microprocessor programming and the software-hardware interface, for practical applications. Prerequisite: Professional AE or ME program and C or better in each of MAE 2360, MAE 2381, MAE 3360 and EE 2320; or student group.

MAE 3242. MECHANICAL DESIGN I. 2 Hours.
The overall nature of design as a process is presented along with various models, methods, techniques, and tools for the various phases of the process provide the student with an excellent understanding of how to design. Students learn to design mechanical components based on stress/deflection and the associated failure theories. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2312, MAE 2323, and MAE 3324; or student group.

MAE 3302. INCOMPRESSIBLE AERODYNAMICS. 3 Hours.
Introduction to and application of the methods used to determine the low speed aerodynamic forces on aerodynamic components such as wings and airfoils. Topics include potential flow theory for lifting flows; airfoil and finite wing theory; panel and vortex-lattice methods. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2315, MAE 2323, MAE 3309 (or MAE 3310), and MAE 3360; or student group.

MAE 3303. COMPRESSIBLE FLOW. 3 Hours.
Fundamental thermodynamic concepts of compressible flow, isentropic flow, normal and oblique shock waves; expansion waves; quasi-one dimensional flows within nozzles and diffusers, linearized compressible flow theory, the method of characteristics and supersonic nozzle design. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following MAE 2315, MAE 2323, MAE 3309 (or MAE 3310), and MAE 3360; or student group.

MAE 3304. ASTRONAUTICS I. 3 Hours.
Introduction to astronautics, the solar system, and the two-body problem. Orbit shaping and orbit transfers. Patched conic approximations for interplanetary transfers. Introduction to the three-body problem and relative motion. Rigid spacecraft equation of motion. Active and passive attitude stabilization techniques for spacecraft. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following: MAE 2323, MAE 2360, and MAE 3360; or student group.

MAE 3306. FLIGHT PERFORMANCE, STABILITY & CONTROL. 3 Hours.
Review of aerodynamics. Introduction to aircraft performance and the assessment of aircraft static stability and control characteristics. Performance topics covered include cruise, climb, gliding flight, turns, range and endurance. Static stability and control topics covered include longitudinal, lateral and directional stability and control power calculations. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following: MAE 3302 and MAE 3303.

MAE 3309. THERMAL ENGINEERING. 3 Hours.
Basic concepts and definitions, properties of pure substances, work and heat, first law of thermodynamics, second law of thermodynamics, entropy, and introduction to conductive, convective, and radiative transfer. Prerequisite: Must be in an EE or MAE department degree program and C or better in each of the following, CHEM 1465 or both CHEM 1441 and CHEM 1442; MATH 2425 (or HONR-SC 2425) and PHYS 1444; or student group.

MAE 3310. THERMODYNAMICS I. 3 Hours.
Basic concepts and definitions, properties of pure substances, work and heat, first law of thermodynamics, second law of thermodynamics, entropy, thermodynamics of gases, vapors, and liquids in various nonflow and flow processes, and irreversibility and availability. Prerequisite: Must be in an MAE department degree plan and C or better in each of the following, CHEM 1465 or both CHEM 1441 and CHEM 1442; MATH 2425 (or HONR-SC 2425), and PHYS 1444; or student group.

MAE 3311. THERMODYNAMICS II. 3 Hours.
Availability, power, refrigeration and heat pump cycles (both gas and vapor), property relations and equations of state, ideal gas mixtures, mixtures of gases and vapors, psychrometrics, adiabatic flame temperature, thermochemical equilibrium, and compressible flow. Emphasis is on applying these topics to thermal systems design. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3313 (or concurrent enrollment) and MAE 3310; or student group.

MAE 3313. FLUID MECHANICS. 3 Hours.
Fundamental concepts of fluid mechanics leading to the development of both the integral and differential forms of the basic conservation equations. Application of the integral conservation equations to engineering problems in fluid dynamics including buoyancy and other hydrostatics problems. Dimensional analysis and similitude are also discussed. Prerequisite: Must be in the professional ME program and C or better in each of the following, MAE 2323, MAE 2360, MAE 3360, and MAE 3310 (or concurrent enrollment); or student group.

MAE 3314. HEAT TRANSFER. 3 Hours.
Topics cover the fundamental laws of heat and mass transfer, including steady and unsteady conduction, forced and free convection, and radiation as well as heat transfer in phase change. Applications of heat transfer to thermal systems design are included. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3313 or C or better in MAE 3302.

MAE 3315. AEROSPACE STRUCTURAL STATICS. 3 Hours.
Overview of aircraft basic structural elements and materials; introduction to elasticity; equations of equilibrium; constitutive equations of isotropic solids; bending and torsion analysis of thin-walled beams; flexure shear of thin-walled beams with stringer reinforcement; introduction to fatigue and fracture analysis; failure criteria; energy method to find strain energy release rate; elastic column buckling. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 2312; or student group.

MAE 3316. AEROSPACE STRUCTURAL DYNAMICS. 3 Hours.
Harmonic and periodic motion including both damped and undamped free and forced vibration. Single-and multi-degree-of-freedom discrete systems. Vibration of continuous systems. Introduction of finite element method for structural dynamics. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2312, MAE 2323, MAE 3360, and MATH 3330; or student group.

MAE 3318. KINEMATICS AND DYNAMICS OF MACHINES. 3 Hours.
The motion and interaction of linkage and mechanisms. Fundamental concepts of kinematics and dynamics applied to the determination of degree of freedom mechanisms and forces acting on joints of mechanisms. Specific mechanisms and applications such as multi-body mechanisms, linkage synthesis, cam design, and balancing. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 2323, or student group.

MAE 3319. DYNAMIC SYSTEMS MODELING AND SIMULATION. 3 Hours.
Introduction to modeling and prediction of behavior of engineering systems. Analytic and numerical simulation, state-space differential equations, and Laplace transform methods. Effects of physical characteristics of system elements on system design and dynamic performance. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3314 (or concurrent enrollment), EE 2320, and MATH 3330; or student group.

MAE 3324. STRUCTURE & MECHANICAL BEHAVIOR OF MATERIALS. 3 Hours.
Crystal structure and defects in materials. Diffusion, phase diagrams and phase transformations in metallic systems. The inter relationships between processing, structure, and properties of engineering materials with emphasis on the mechanical behavior of metals, polymers, and composite materials. Prerequisites: Must be in an MAE department degree program and C or better in each of the following, CHEM 1465 (or CHEM 1441 and CHEM 1442), MAE 2312 (or concurrent enrollment), and PHYS 1444; or student group.

MAE 3344. INTRODUCTION TO MANUFACTURING ENGINEERING. 3 Hours.
Introduction to casting, forming, machining, and joining processes for metals and nonmetals. Prerequisite: Must be in the professional ME program and C or better in each of the following, MAE 2312 and MAE 3324; or student group.

MAE 3360. ENGINEERING ANALYSIS. 3 Hours.
Mathematical analysis with emphasis on solution techniques and engineering applications. Topics include: ordinary differential equations (ODE), Laplace Transform, numerical solutions of ODE, boundary value problems, Fourier series, Sturm-Liouville problem and vector calculus. Prerequisite: Must be in an MAE department degree program and C or better in each of the following, MATH 2326 and MAE 2360 (or concurrent enrollment); or student group.

MAE 3405. FLIGHT DYNAMICS. 4 Hours.
Derivation of equation of motion (EOM) of a flight vehicle. Trimmed flight condition analysis based on the nonlinear EOM. Linearization of EOM for a given trimmed flight condition. State-space and transfer-function representations of the linear EOM. Aircraft stability and dynamic performance analysis based on the linear EOM. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3306 and MATH 3330; or student group.

MAE 4000. UNDERGRADUATE RESEARCH. 0 Hours.
Senior level undergraduate research. Prerequisite: Departmental good academic standing and permission of instructor. May be taken a maximum of 3 times.

MAE 4010. AUTOMOTIVE ENGINEERING PRACTICUM II. 0 Hours.
Practical design experience as full team member of automotive design competition team. Prerequisite: Permission of Director of the Arnold E. Petsche Center for Automotive Engineering.

MAE 4151. AEROSPACE VEHICLE DESIGN II. 1 Hour.
Analysis and design of an aerospace system such as a complete flight vehicle, a propulsion system, a structural system, or a control system; market analysis, operating studies, mission specification, civil and military certification requirements; design process, methods and tools; configuration concept selection, harmonization of individual design disciplines (aerodynamics, performance, flight mechanics, structures, cost, systems, etc.). Prerequisite: Must be in the professional ME or AE program and C or better in MAE 4350.

MAE 4188. DESIGN PROJECT LABORATORY II. 1 Hour.
The design project from MAE 4287 continued. The design is finalized, a physical model (prototype) is manufactured and tested. Redesign and retest is accomplished as desired. The final design is documented by written report and oral presentation. Exit survey forms and exit essays must be submitted to complete the requirements of this course. Prerequisite: Must be in the professional ME program and C or better in MAE 4287.

MAE 4191. SPECIAL PROBLEMS IN MECHANICAL AND AEROSPACE ENGINEERING. 1 Hour.
Special problems in mechanical and aerospace engineering for students of professional program standing. Prerequisite: Must be in the professional ME or AE program.

MAE 4287. DESIGN PROJECT I. 2 Hours.
Team engineering approach to a design project that integrates engineering knowledge from several courses. Problem definition and creative synthesis of prospective design solutions. Engineering proposals, feasibility studies, trade-off studies, systems models and analysis, decision making, and engineering reports and presentations. Professionalism, ethics, and societal impact issues. Prerequisite: Must be in the professional ME program and C or better in MAE 4344 (or concurrent enrollment) and must be within two calendar semesters of graduation (possibly including an 11-week summer session). MAE 4287 and MAE 4188 must be taken in consecutive semesters.

MAE 4291. SPECIAL PROBLEMS IN MECHANICAL AND AEROSPACE ENGINEERING. 2 Hours.
Special problems in mechanical and aerospace engineering for students of professional program standing. Prerequisite: Must be in the professional ME or AE program.

MAE 4301. SPECIAL TOPICS IN MECHANICAL AND AEROSPACE ENGINEERING. 3 Hours.
Topics will vary from semester to semester depending on student interest and the availability of faculty. May be repeated, provided topics are different. Prior approval by the student's advisor required. Prerequisite: Must be in the professional ME or AE program and others that vary by topic.

MAE 4302. INTRODUCTION TO BEARING DESIGN AND LUBRICATION. 3 Hours.
The course introduces 1) selection principles and design guidelines for various rolling element bearings, 2) theory of liquid and gas lubrication, 3) various novel fluid film bearings used in modern high speed turbomachinery and energy systems, and 4) fundamental principles of rotordynamics. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3313.

MAE 4304. ASTRONAUTICS II. 3 Hours.
The restricted three-body problem, the n-body problem, and approximations. Interplanetary transfers. Design considerations for both manned and unmanned interplanetary vehicles. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3304.

MAE 4305. FUNDAMENTALS OF ELECTRONIC PACKAGING. 3 Hours.
An introductory treatment of electronic packaging, from single chip to multichip, including materials, electrical design, thermal design, mechanical design, package modeling and simulation, processing considerations, reliability, and testing. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3314 or MAE 3309; or student group.

MAE 4306. COMPUTATIONAL TECHNIQUES FOR ELECTRONIC PACKAGING. 3 Hours.
Characterization of the thermo/mechanical reliability of microelectronics devices using commercial computational heat transfer codes (Icepack, Flotherm, and ANSYS). Industry related problems ranging from first level packages through system level packages analyzed. Formulate and model contemporary problems using commercial CFD codes. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3314 or MAE 3309; or student group.

MAE 4307. FINITE ELEMENT METHODS. 3 Hours.
Static response of complex structures and continua; application to field problems; mesh generation; error estimation and adaptive refinement. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3242.

MAE 4310. INTRODUCTION TO AUTOMATIC CONTROL. 3 Hours.
Block diagram algebra, transfer functions, and stability criteria. The use of transient response, frequency response, and root locus techniques in the performance analysis, evaluation, and design of dynamic systems. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, (MAE 3314 and MAE 3319) or (MAE 3405 and EE 2320); or student group.

MAE 4312. CONTROL SYSTEMS COMPONENTS. 3 Hours.
The components used in mechanical, electronic, and fluid power control systems are studied. Modeling and performance analysis are used to help in the understanding of system behavior. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 4310.

MAE 4314. MECHANICAL VIBRATIONS. 3 Hours.
Harmonic and periodic motion including both damped and undamped free and forced vibration. Single and multi-degree-of-freedom discrete systems. Vibration of continuous systems. Introduction of finite element method for structural dynamics. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2312, MAE 2323, MAE 3360, and MATH 3330; or student group.

MAE 4315. INTRODUCTION TO COMPOSITES. 3 Hours.
Composite classification, laminate coding, fiber and weight fractions of composite lamina; lamina constitutive equations; structural characteristics of [A], [B], [D] matrices; lamination theory; thermal and moisture induced load and moment; lamina stress analysis and failure prediction; issues in composite structural design. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 2312 (or CE 2313); or student group.

MAE 4320. HYDRAULIC AND PNEUMATIC SYSTEMS. 3 Hours.
The fundamentals of fluid mechanics as applied to hydraulic and pneumatic hardware. Mathematical models of pumps, motors, pistons, accumulators, valves, and transmission lines. Design and analysis procedures for implementing total fluid power systems with high operating efficiencies and adequate dynamic response characteristics. Theory is supported by laboratory demonstrations. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3313, MAE 4310, and MAE 3310; or student group.

MAE 4321. AEROSPACE PROPULSION. 3 Hours.
Introduction to rocket and air-breathing propulsion systems. Development of thrust and efficiency relations, mission requirements, rocket and gas turbine engine cycle analysis, off-design performance, component design and performance analysis, advanced propulsion system concepts. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3303 or C or better in each of MAE 3313 and MAE 3311.

MAE 4322. ROCKET PROPULSION. 3 Hours.
Examines chemical, nuclear, and electrical propulsion concepts. Development of design and performance analysis methods. Flight performance of rocket powered vehicles. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3303 (or MAE 3311).

MAE 4323. ENERGY CONVERSION. 3 Hours.
Thermodynamics as applied to thermo-mechanical systems such as power cycles, engines, turbines, refrigeration, and air-conditioning systems. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3311 and MAE 3314.

MAE 4324. POWER PLANT ENGINEERING. 3 Hours.
Fundamental thermodynamics and heat transfer principles behind design and optimization of power generation systems with significant emphasis on component and system design. This class will cover a number of power plant types, including coal/gas fired, hydroelectric, nuclear, and solar. Concepts learnt in this class prepare students for an engineering career in power plants, oil, gas and related industries. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3310 (or MAE 3309); or student group.

MAE 4325. COMBUSTION. 3 Hours.
Fundamental treatment of problems involving simultaneous occurrence of chemical reaction and transfer of heat, mass and momentum. Topics include kinetically controlled combustion phenomena; diffusion flames in liquid fuel combustion; combustion of solids; combustion of gaseous fuel jets; flames in premixed gasses. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3311 or MAE 3303.

MAE 4326. COMPUTATIONAL AERODYNAMICS I. 3 Hours.
Solution of engineering problems by finite-difference methods, emphasis on aerodynamic problems characterized by single linear and non-linear equations, introduction to and application of major algorithms used in solving aerodynamics problems by computational methods. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3314 or MAE 3303.

MAE 4327. HEATING, VENTILATION, AND AIR CONDITIONING. 3 Hours.
Application of engineering sciences to design of heating, venting, and air conditioning (HVAC) systems. Humidification and dehumidification, psychrometric charts, heat load, cooling load, degree-days, comfort zones, and air distribution systems. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3311 and MAE 3314.

MAE 4328. METAL ADDITIVE MANUFACTURING. 3 Hours.
This course will provide students with essential knowledge and technical skills for metal additive manufacturing (AM), providing a solid foundation for a future career in the field. Primary areas of focus include: metal AM processes and their capabilities, process fundamentals, part design and analysis, build preparation and machine set-up, fabrication and post-processing, inspection and monitoring, microstructure analysis and mechanical testing, and process optimization. Prerequisite: Must be in the professional ME or AE program.

MAE 4329. ADDITIVE MANUFACTURING. 3 Hours.
The range of technologies and processes, both physical and digital, used to translate virtual solid model data into physical models using additive layering methods. Emphasis is given to application of these technologies to manufacture end use components and assemblies but rapid prototyping is also discussed. Metal, polymer, ceramic, and composite material applications of additive manufacturing (AM) are included. Discussion includes advantages and limitations of additive methods with respect to subtractive methods and to each other. Principles of design for AM are covered along with discussion of applications. Students complete a project to design and build an engineering component or assembly for additive manufacture. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 1351 and MAE 3324; or student group.

MAE 4331. DESIGN FOR MANUFACTURING. 3 Hours.
The interaction between design and manufacturing stressed in terms of the design process, customer-focused quality, design specifications versus process capability and tolerances, and redesign for producibility. Topics include material and manufacturing process selection, tolerancing, quality function deployment (QFD), design for assembly (DFA), quality control techniques, reliability, and robust design. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3242 and MAE 3344.

MAE 4335. ANALYTICAL & COMPUTATIONAL DYNAMICS. 3 Hours.
The course focuses on developing the equations of motion for dynamic systems composed of multiple, connected and unconnected, rigid bodies using Kane's method and the Lagrangian approach. The resulting model is used to simulate and visualize the predicted motion. Topics include: kinematics, Euler parameters, kinematic constraints, virtual work, the calculus of variations, energy, momentum, contact, impact, and checking functions. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3318.

MAE 4336. ADVANCED MECHANICAL BEHAVIOR OF MATERIALS. 3 Hours.
Concept of stress and strain; elementary dislocation theory. Deformation of single crystals; strengthening mechanisms including solid solution strengthening, and precipitation hardening. Fracture mechanics; microscopic aspects of fracture, fatigue, and creep of materials; design and processing of materials for improved mechanical properties. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2312 and MAE 3324; or student group.

MAE 4338. FAILURE ANALYSIS. 3 Hours.
Theory and practice of techniques for determining modes of failure and fracture of engineering materials. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2312 and MAE 3324; or student group.

MAE 4339. FRACTURE MECHANICS. 3 Hours.
Theory and applications of fracture mechanics. Stress analysis of cracks, crack-tip plasticity, fatigue crack growth, and stress corrosion cracking. Applicability to materials selection, structural design, failure analysis, and structural reliability. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3242.

MAE 4342. MECHANICAL DESIGN II. 3 Hours.
Analysis for the design and manufacture of basic mechanical elements, and their role in the design of machines. A brief review of relevant topics including stress/deflection, failure theories, and contact stress is initially conducted. It is then extended to the design of fundamental mechanical components including shafts, gears, springs, bearings, fasteners, and clutches/brakes. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3242 and MAE 3318 (or concurrent enrollment).

MAE 4344. COMPUTER-AIDED ENGINEERING. 3 Hours.
A study of the principles of computer-aided engineering in mechanical and aerospace engineering. Applications in mechanical, structural, and thermal systems. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 3242, MAE 3314 (or concurrent enrollment), and MAE 3318.

MAE 4345. INTRODUCTION TO ROBOTICS. 3 Hours.
Overview of industrial robots. Study of principles of kinematics, dynamics, and control as applied to industrial robotic systems; robotic sensors and actuators; path planning; guidelines to robot arm design and selection; introduction to mechatronics; laboratory exercise in designing, building, and controlling a 3D-printed robotic manipulator. Prerequisite: Must be in the professional ME or AE program.

MAE 4347. HEAT EXCHANGER DESIGN. 3 Hours.
Design procedure system evaluation; design parameters in heat exchangers. The course considers various heat exchanger configurations and includes student design projects. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3314.

MAE 4348. COOLING OF ELECTRONIC PACKAGES. 3 Hours.
The calculation of heat loads and temperature fields using different cooling techniques. Includes parameter evaluation and design studies. Prerequisite: Must be in the professional ME or AE program and C or better in, MAE 3314 (or MAE 3309); or student group.

MAE 4350. AEROSPACE VEHICLE DESIGN I. 3 Hours.
Analysis and design of an aerospace system such as a complete flight vehicle, a propulsion system, a structural system, or a control system; market analysis, operating studies, mission specification, civil and military certification requirements; design process, methods and tools; configuration concept selection, integration of design disciplines (aerodynamics, performance, flight mechanics, structures, cost, systems, etc.). Prerequisite: Must be in the professional ME or AE program and C or better in each of the following: MAE 3405 (or concurrent enrollment) and MAE 3306.

MAE 4351. AEROSPACE VEHICLE DESIGN II. 3 Hours.
Analysis, design, and synthesis of an aerospace system such as a complete flight vehicle, a propulsion system, a structural system, or a control system; market analysis, operating studies, mission specification, civil and military certification requirements; design process, methods and tools; configuration concept selection, integration of individual design disciplines (aerodynamics, performance, flight mechanics, structures, cost, systems, etc.). Also included will be economic, environmental, sustainability, manufacturability, safety, social and political considerations. Formal written and oral reports are required. Exit survey forms and exit essays must be submitted to complete the requirements of this course. Prerequisite: Must be in the professional AE program and C or better in MAE 4350.

MAE 4352. SPACE VEHICLE AND MISSION DESIGN. 3 Hours.
Space vehicle design; influence of space environment, astrodynamics, and atmospheric reentry. Space vehicle sub system design; propulsion, attitude determination and control, structural design, thermal control, power and telecommunications. Investigation into mission design concepts and considerations. Prerequisite: Must be in the professional ME or AE program and C or better in each of the following, MAE 2323 and MATH 2326; or student group.

MAE 4357. AUTOMOTIVE ENGINEERING. 3 Hours.
Introduction to automotive engine types and performance, drive train modeling and vehicle loading characteristics, fueling requirements, fuel injection systems, tire characteristics and modeling, suspension characteristics and handling, braking systems and requirements. Course taught through lecture, student presentations and student design projects. Prerequisite: Must be in the professional ME, AE or EE program and C or better in each of the following, MAE 3360 (or MATH 3319) and MAE 2312 (or EE 3346); or student group.

MAE 4358. RACECAR ENGINEERING. 3 Hours.
This course is intended for Formula SAE team members and other interested students to develop new systems or analyze concepts for the Formula SAE or Formula Electric racecar and related equipment. The students will form teams and perform research and development on projects related to automotive or racecar engineering. Prerequisites: Must be in the professional ME, AE or EE program and C or better in each of the following, MAE 3360 (or Math 3319) and MAE 2312 (or EE 3346); or student group.

MAE 4362. INTRODUCTION TO MICRO AND NANOFLUIDICS. 3 Hours.
As going down to micro scales, the basic hypothesis in the macro scale fluid mechanics may not be applicable in such scales. The objectives of this course are: to identify dominant forces and their effects in micro scale fluid systems that are different from those in the macro scales; to understand the fundamentals of micro fluidic phenomena; to discuss various microfluidic applications in research and commercial levels; and to explore new possible microfluidic applications in the emerging fields. Topics include overview of microfluidics, scaling laws, violation limit of the Navier-Stokes equations, surface force, surface tension, electrowetting, electrokinetics, dielectrophoresis, and soft lithography. Prerequisite: Must be in the professional ME or AE program and C or better in MAE 3313 and MAE 3310; or student group.

MAE 4363. INTRODUCTION TO ROTORCRAFT ANALYSIS. 3 Hours.
History of rotorcraft. Behavior of the rotor blade in hover and forward flight. Rotor configurations, dynamic coupling with the fuselage, elastic and aeroelastic effects.

MAE 4378. INTRODUCTION TO UNMANNED VEHICLE SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty. Prerequisite: Admission to a professional engineering or science program.

MAE 4379. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: B or better in MAE 4378 and admission to the UVS certificate program.

MAE 4382. RESEARCH TRENDS IN RENEWABLE ENERGY TECHNOLOGIES. 3 Hours.
This course is offered to graduate and senior level undergraduate students with engineering and science background to introduce them to micro/nano research and development for energy conversion and storage. This course will include: Scaling laws, MEMS fabrication, Nanomaterial synthesis, Electrochemical energy storage/conversion (Batteries, Fuel Cells & Supercapacitors), Solar energy (photovoltaics and solar thermal energy), Energy harvesting and Solar water splitting and electrocatalysis. Prerequisite: Must be in the professional ME or AE program.

MAE 4386. WIND & OCEAN CURRENT ENERGY HARVESTING FUNDAMENTALS. 3 Hours.
A broad senior/graduate first course in wind/wave/ocean current energy harvesting systems, focused on fundamentals, and serving as the basis for subsequent MAE specialized follow-on graduate course offerings focused on structures (conventional and composite), aero/hydro-mechanical response and control, and tailoring and smart material actuation, respectively, as well as for non-MAE, specialized graduate courses. Prerequisite: Must be in the professional ME or AE program and C or better in EE 2320 and C or better in either MAE 3313 or MAE 2315, or student group.

MAE 4391. SPECIAL PROBLEMS IN MECHANICAL AND AEROSPACE ENGINEERING. 3 Hours.
Special problems in mechanical and aerospace engineering for students of professional program standing. Prerequisite: Must be in the professional ME or AE program.

COURSES

NE 3301. INTRODUCTION TO NUCLEAR ENGINEERING. 3 Hours.
Fundamentals of radiation, radiation decay, binding energy, nuclear reactions, radiation interactions , shielding, radiation detections and measurement of radiation, applications of nuclear science and engineering such as principles of nuclear reactors, reactor generations I, II, III, IV, fusion reactor, radiation therapy, food irradiation , radionuclide production, radiopharmaceuticals, principles of positron emission tomography (PET). Prerequisite: PHYS 1444; MATH 3319 or MAE 3360.

NE 4302. NUCLEAR REACTOR THEORY AND TECHNOLOGY OF THE NUCLEAR POWER PLANT. 3 Hours.
The course covers the theoretical aspect of reactor theory and analysis along with the complete understanding of the nuclear reactor systems, major components, operations, control and over all safety aspect of nuclear power plant technology. The theoretical topics in the course will include the neutronics behavior of fission reactors, primarily from a one-speed diffusion perspective. Reactor kinetics and dynamics, criticality, fission product poisoning, reactivity control, reactor stability and introductory concepts in fuel management, followed by slowing down and one-speed diffusion theory. Use of industry adopted software and power plant simulation for evaluating basic reactor parameters. Prerequisite: NE 3301 or PHYS 3446 or permission of instructor.

NE 4303. NUCLEAR POWER PLANT ENGINEERING. 3 Hours.
Thermal hydraulic processes involved in the transfer of power from the reactor core to the secondary systems of nuclear power plants. Major topics include an overview of nuclear heat generation, fluid dynamics with respect to the flow in reactor channels, steady state radial and axial temperature distribution, thermal analysis of fuel elements and subchannel flow, Hot channel factors, two-phase flow dynamics. Prerequisite: NE 3301 or MAE 3314 or MAE 3309 or permission of instructor.

NE 4391. SPECIAL TOPICS IN NUCLEAR ENGINEERING. 3 Hours.
Special topics in the field of nuclear engineering. Topic may vary from semester to semester. May be repeated for credit when topic changes. Departmental approval required in advance to use for degree credit. Prerequisite: NE 3301 or consent of instructor.

COURSES

GEOL 1301. EARTH SYSTEMS. 3 Hours. (TCCN = GEOL 1303)
An integrated study of the earth, emphasizing interactions between plate tectonics, the atmosphere, the oceans, the biosphere, and human activity. Formerly listed as GEOL 1425, credit will not be given for both.

GEOL 1302. EARTH HISTORY. 3 Hours. (TCCN = GEOL 1304)
History of the earth and evolution of life emphasizing the co-evolution of the atmosphere, oceans, and biosphere. Formerly listed as GEOL 1426, credit will not be given for both.

GEOL 1330. GLOBAL WARMING. 3 Hours.
Global environmental challenges confronting humanity such as pollution, depletion of natural resources, ecosystem deterioration, food production, and population growth. Offered as ENVR 1330 and GEOL 1330. Credit will not be given for both.

GEOL 1340. WEATHER AND CLIMATE. 3 Hours. (TCCN = GEOL 1347)
Nature and variability of weather and climate, including wind, temperature, clouds and precipitation, droughts and flooding. Storm systems, fronts, thunderstorms, tornadoes, hurricanes. Atmospheric chemistry and air pollution. Mean climate, seasonal variations and climatic change. Formerly listed as GEOL 2401, credit will not be given for both.

GEOL 1350. INTRODUCTION TO OCEANOGRAPHY. 3 Hours. (TCCN = GEOL 1345)
The study of ocean basins and their origin, ocean currents, waves and tides, properties of sea water, and marine ecosystems, emphasizing the role of the ocean in the Earth system. Discussion of weekly ocean news, and incorporation of web-delivered current oceanographic data into the course material. Formerly offered as GEOL 3301 and GEOL 3184 and GEOL 2412; credit will be granted only once. Formerly listed as GEOL 1450, credit will not be given for both.

GEOL 1360. GEOLOGIC HAZARDS. 3 Hours.
Processes producing earthquakes, floods, eruptions and landslides, and their effect on people. Formerly listed as GEOL 2404, credit will not be given for both.

GEOL 2406. NATURAL RESOURCES & SUSTAINABILITY. 4 Hours.
Energy, construction, agricultural, and hydrological resources are evaluated in terms of their production and use, including storage and disposal of waste. Emphasis is placed on the importance of preserving clean water, air and soils. The course will concentrate on what humans take from the Earth, the impacts it has on their environment, and what it takes to make the planet sustainable for human habitation.

GEOL 2445. MINERALOGY. 4 Hours.
Lectures discuss the physical and chemical principles governing the properties and formation of minerals. There are three major divisions of the subject matter: (a) geometric and optical crystallography; (b) crystal chemistry and properties of minerals, and (c) occurrence, origins, and pressure-temperature stabilities of the major rock-forming minerals. Laboratories are devoted to exercises in crystallography, X-ray diffraction, optical mineralogy and hand-specimen mineral identification. Prerequisite: GEOL 1301 or GEOL 3340, and CHEM 1442, or permission from instructor.

GEOL 3100. GEOSCIENCE PROFESSIONAL ORIENTATION. 1 Hour.
Review of various careers in the Geosciences, and how to prepare a resume, network, and interview. Principles to follow for on-the-job success. Class will involve field trips and guest lectures.

GEOL 3316. ASTROBIOLOGY I. 3 Hours.
This is an interdisciplinary course between astrophysics, biology and geology. Topics include properties of life, origin and evolution of life on Earth, terrestrial geology and habitability, environmental forcings, extremophiles, mass extinctions, meteorites, searches for life in the solar system. Offered as BIOL 3316, GEOL 3316 and PHYS 3316; credit will be granted only once. Prerequisite: PHYS 1441 & PHYS 1442 or equivalent and PHYS 2315 or PHYS 3315, or permission from instructor. Prerequisites for Biology majors: PHYS 1441 & PHYS 1442 or equivalent.

GEOL 3340. GEOLOGY FOR ENGINEERS. 3 Hours.
Introduction to geological materials and processes important to engineering. Includes processes forming minerals and rocks; mechanics and deformation of rocks, weathering, erosion and soils; soil hazards, land subsidence and mass movements; groundwater hydrology, geochemistry and contamination; and rivers. Labs will include introduction to geologic materials and use of GIS software to store, analyze and display geologic and engineering data. Prerequisites: PHYS 1443 and CHEM 1465 or CHEM 1442.

GEOL 3358. ASTROBIOLOGY II. 3 Hours.
This is an interdisciplinary course between astrophysics, biology and geology. Topics include basic properties of life, habitability of Earth, studies of possible life regarding Mars, Europa & Titan, space missions, exoplanets and exomoons, stellar habitable zones, multistellar systems, exoEarths, biomarkers, SETI, Fermi paradox, Drake equation, cosmology. Offered as BIOL 3358, GEOL 3358, and PHYS 3358; credit will be granted only once. Prerequisite: PHYS 1441 & PHYS 1442 or equivalent and PHYS 2315 or PHYS 3315, or permission from instructor. Prerequisites for Biology majors: PHYS 1441 & PHYS 1442 or equivalent. Note that Astrobiology I is strongly recommended to students to be taken prior to Astrobiology II, but is not a prerequisite.

GEOL 3387. FIELD GEOLOGY I. 3 Hours.
Stratigraphic and structural mapping and analysis of data collected in the field. Taught for three weeks only in the summer session. Special fee covers cost of transportation, room, and board while in the field. Prerequisite: GEOL 2445, GEOL 3442, GEOL 3443, and GEOL 3446.

GEOL 3388. FIELD GEOLOGY II. 3 Hours.
Mapping and analysis of igneous and metamorphic rock data as well as hydrologic, geochemical and mass wasting data collected in the field. Taught for three weeks after GEOL 3387 only in the summer session. Special fee covers cost of transportation, room, and board while in the field. Prerequisite: GEOL 2445, GEOL 3442, GEOL 3443, and GEOL 3387.

GEOL 3441. BIOSTRATIGRAPHY AND LIFE THROUGH TIME. 4 Hours.
Basic principles of bio- and chronostratigraphy including the classification of fossil groups, how index fossils are used to construct the geologic timescale and correlate strata. Prerequisite: GEOL 1302.

GEOL 3442. SEDIMENTOLOGY AND STRATIGRAPHY. 4 Hours.
An introduction to the description, origin, and historical interpretation of stratified rocks. Prerequisite: GEOL 2445.

GEOL 3443. STRUCTURAL GEOLOGY. 4 Hours.
The genesis, classification, and description of structural features resulting from deformation of the earth's crust. Prerequisite: GEOL 2445 and PHYS 1441 or PHYS 1443, or permission of instructor.

GEOL 3446. PETROLOGY AND GEOCHEMISTRY. 4 Hours.
Distribution, description, classification, plate-tectonic setting and origins of igneous and metamorphic rocks in the light of theoretical-experimental multicomponent phase equilibria studies; use of trace elements and radiogenic and stable isotopes as tracers in rock genesis; hand specimen and microscopic examinations of the major igneous-metamorphic rock types in the laboratory. Prerequisite: GEOL 2445.

GEOL 3454. STATISTICS FOR EARTH AND ENVIRONMENTAL SCIENTISTS. 4 Hours.
This course provides students with basic principles of statistics and helps students apply statistics to analyze data and interpret results from the perspective of Earth and environmental scientists. The course will first introduce basic concepts and then focus on applications to various examples in Earth and environmental sciences. Offered as ENVR 3454 and GEOL 3454, credit will not be given for both. Prerequisite: MATH 1426 or HONR-SC 1426.

GEOL 4081. RESEARCH IN EARTH & ENVIRONMENTAL SCIENCES. 0 Hours.
Research problems on an individual or group basis, conducted on a selected topic under the direction of a member of the Earth & Environmental Sciences faculty. May be repeated. This is a non-credit course so cannot be used to meet degree requirements. Prerequisite: Permission of the instructor.

GEOL 4181. TOPICS IN ENERGY AND EARTH RESOURCES. 1 Hour.
Lectures will discuss the historical evolution and current status of major research thrusts in the environment, energy, and resources studies, including Superfund and groundwater remediation, carbon sequestration, tight sands and coalbed methane, petroleum production in shale gas and oil reservoirs, geological repository of high-level nuclear waste, geothermal energy exploitation, mining of critical minerals, and gas (methane) hydrate. Prerequisite: GEOL 1301 or GEOL 3340 or equivalent.

GEOL 4189. RESEARCH IN GEOLOGY. 1 Hour.
Supervised undergraduate research in any one of the various fields of geology. May be repeated but will not meet Geology degree requirements. Prerequisite: permission from instructor.

GEOL 4190. GEOSCIENCE INTERNSHIP. 1 Hour.
Work in geoscience for a commercial concern at least 20 hours per week for three months. Requirements include: writing a resume, learning how to interview and function on the job, and a report describing the work. Prerequisite: 16 hours of Geology coursework.

GEOL 4199. TECHNICAL SESSIONS. 1 Hour.
Forum for presentation of results of undergraduate and graduate students and faculty research. Offered as ENVR 4199 and GEOL 4199. Credit will not be given for both. Prerequisite: For ENVR: ENVR 1301 or equivalent. For GEOL: GEOL 1301 or equivalent.

GEOL 4289. RESEARCH IN GEOLOGY. 2 Hours.
Supervised undergraduate research in any one of the various fields of geology. May be repeated but will not meet Geology degree requirements. Prerequisite: permission from instructor.

GEOL 4302. GEODYNAMICS. 3 Hours.
A comprehensive and quantitative study of fundamental aspects of plate tectonics. Introduction to heat flow, elasticity and flexure, fluid mechanics, faulting, gravity, and flow in porous media, with a wide range of geological applications. Includes collaborative problem solving. Prerequisite: GEOL 3443 and MATH 2425.

GEOL 4304. SOLID EARTH GEOMECHANICS. 3 Hours.
Application of continuum mechanics to understanding deformation in the earth, including mechanical analysis of natural geologic structures such as faults, folds, lava flows, and dikes, as well as practical problems related to reservoir geomechanics and mining applications. Prerequisites: GEOL 3443, MATH 2425, and PHYS 1444.

GEOL 4305. SELECTED TOPICS IN GEOLOGY. 3 Hours.
Geological topics not treated in the regular curriculum. Topic, format, and prerequisites to be determined by the instructor. May be repeated for Geology elective credit as different topics are offered.

GEOL 4307. SEQUENCE STRATIGRAPHY. 3 Hours.
This course introduces sequence stratigraphy within context of all stratigraphy and history of sequence stratigraphy. Includes overview of sequence stratigraphy principles. Review of basic fundamental concepts of surface- and facies-based physical stratigraphy. Review of architectural element analysis, sequence stratigraphic in seismic, borehole expression of sequences and overview of subsurface stratigraphic techniques. Prerequisite: GEOL 3442.

GEOL 4308. ENVIRONMENTAL GEOCHEMISTRY. 3 Hours.
The geochemistry of natural waters with emphasis on processes that control solute concentrations including complexation reactions, oxidation and reduction reactions, biogeochemistry, and chemical weathering reactions. Offered as ENVR 4308 and GEOL 4308. Credit will not be given for both. Prerequisite: CHEM 1442 or GEOL 2445.

GEOL 4323. ISSUES IN ENVIRONMENTAL HEALTH. 3 Hours.
An introduction to health issues of current concern resulting from environmental exposures. Topics include: environmental asthma, endocrine disruptors, climate change and health, emerging contaminants, nanotechnology and health, airborne particles and pediatric health. Offered as ENVR 4323 and GEOL 4323. Credit will not be given for both.

GEOL 4330. UNDERSTANDING GEOGRAPHIC INFORMATION SYSTEMS. 3 Hours.
A practical introduction to GIS and methods of creating, maintaining and displaying spatial data using the ArcGIS software. This course replaces GEOL 4352; credit will not be granted for both. This course is offered as GEOL 4330 and GEOG 4330. Prerequisite: Junior standing.

GEOL 4331. ANALYSIS OF SPATIAL DATA. 3 Hours.
Analyzing spatial data using ArcGIS, Spatial Analyst, and 3-D Analyst, topological surface analysis and modeling; 3-D visualization and viewscapes; spatial statistics and data quality management. Course taught as GEOL 4331 and GEOG 4331. Credit will be granted in only one department. Prerequisite: GEOL 4330 or GEOG 4330.

GEOL 4332. GLOBAL POSITIONING SYSTEM. 3 Hours.
Review of the NAVSTAR Global Positioning System and its segments: space, operational control, and GPS receivers. Mechanics of the satellite constellation; GPS signal structure; datums and coordinate systems; precision and accuracy; error factors; absolute (point) versus relative (differential) positioning. Various positioning techniques using several types of GPS receivers; field data collection and input into GIS programs for data analysis and presentation. Course taught as GEOL 4332 and GEOG 4332. Credit will be granted in only one department. Prerequisite: GEOL 4330 or GEOG 4330.

GEOL 4333. REMOTE SENSING FUNDAMENTALS. 3 Hours.
The electromagnetic spectrum and the interaction of EM waves with matter; various types of sensing devices; spectral and spatial resolution parameters; airborne and satellite sensor platforms; aerial photographs and false-color images. The sequence of data acquisition, computer processing, and interpretation; sources of data; the integration of remote sending data with other data types in GIS. Course taught as GEOL 4333 and GEOG 4333. Credit will be granted in only one department. Prerequisite: GEOL 4330 or GEOG 4330.

GEOL 4334. GEOGRAPHIC DATA ANALYSIS. 3 Hours.
Acquisition, processing and analysis of a set of spatial data selected by the student with approval of the instructor. A written report of the results is required. Course taught as GEOL 4334 and GEOG 4334. Credit will be granted in only one department. Prerequisite: GEOL 4330 or GEOG 4330; or cons. inst.

GEOL 4335. TECTONICS AND ISOTOPES. 3 Hours.
Fundamentals of global tectonics, and the application of isotope geochemistry in sedimentary rocks to understanding tectonic questions. Emphasis will be given to the mechanisms of mountain formation, isotope paleoaltimetry, detrital geochronology, and thermochronology. Prerequisite: GEOL 3442, GEOL 3446.

GEOL 4342. MICROFOSSILS AND CARBONATE ROCKS. 3 Hours.
Half of this course consists of an introduction to microfossil groups occurring in sedimentary rocks: foraminifers, conodonts, coccolithophorids and others, and their usefulness in regional and global correlation of Phanerozoic strata. The biostratigraphy of these groups will be discussed along with the principles used in the correlation of sedimentary rocks. The other half of the course consists of the analysis of the lithofacies and biofacies of carbonate rocks, their genesis, depositional environments, and diagenesis. Prerequisite: GEOL 1302, or cons. inst.

GEOL 4343. RESEARCH METHODS - UTEACH. 3 Hours.
The purpose of this course is to present UTeach students with the tools scientists use to solve scientific problems. These tools enable scientists to develop new knowledge and insights, the most important of which are eventually presented in textbooks and taught in more conventional science classes. These tools include: design of experiments to answer scientific questions; use of statistics to interpret experimental results and deal with sampling errors; mathematical modeling of scientific phenomena; finding and reading articles in the current scientific literature; applying scientific arguments in matters of social importance; writing scientific papers; reviewing scientific papers; oral presentation of scientific work; use of probes and computers to gather and analyze data; ethical treatment of human subjects; laboratory safety. Research Methods is primarily a laboratory course, and most of these topics are developed in connection with four independent inquiries UTeach students design and carry out. Written inquiries will be evaluated as examples of scientific writing. Prerequisite: C or better in SCIE 1201 or SCIE 1334, or concurrent enrollment; and junior or senior standing.

GEOL 4346. BASIN ANALYSIS. 3 Hours.
The classification and characteristics of sedimentary basins and the mechanisms forming them; and the tectonic, climatic, and eustatic controls on basin subsidence and the basin fill. Applications include the influence of basin evolution on petroleum generation, migration, and accumulation. Prerequisite: GEOL 3442 and MATH 1426.

GEOL 4350. STABLE ISOTOPE GEOCHEMISTRY. 3 Hours.
Principles governing the fractionation and distribution of stable isotopes (C, H, N, O, S) in nature, and application of stable isotope geochemistry to environmental problems and global climate change. Prerequisite: GEOL 2445 and CHEM 1442, or permission from instructor.

GEOL 4351. SUSTAINABLE ENERGY RESOURCES. 3 Hours.
The seminar will review literature of sustainable energy resources including critical minerals, subsurface storage and generation of hydrogen and hydrocarbons, geothermal energy, carbon capture and CO2 sequestration, waste management, and green energies. Prerequisite: GEOL 1301, or ENVR 1301, or GEOL 3340, or cons. inst.

GEOL 4352. ANALYTICAL METHODS IN GEOCHEMISTRY. 3 Hours.
Principles of geochemical analysis of waters, rocks and soils, and gases. Methods to be covered include x-ray fluorescence and diffraction, mass spectrometry, coulometry, inductively-coupled plasma, and gas/ion chromatography with various detection methods. Prerequisite: CHEM 1442.

GEOL 4356. ENVIRONMENTAL RISK ASSESSMENT. 3 Hours.
This course introduces the basic scientific components of environmental and occupational health risk assessment and describes the policy context in which decisions to manage environmental health risks are made. The course presents the quantitative methods used to assess the human health risks associated with exposure to toxic chemicals, focusing on the four major components of risk assessment-hazard identification, dose-response assessment, exposure assessment, and risk characterization.

GEOL 4357. MEDICAL GEOLOGY. 3 Hours.
Introduction to geoscience and health. Students will learn how the geologic and geochemical environment can impact health. The historic background to geoscience and health will be presented followed by discussions on the natural abundance of elements in the earth, and the nature of essential and toxic elements (dose-response). Students will then learn about health responses following exposures in specific geologic/geochemical situations. Prerequisite: GEOL 1301 or ENVR 1301, or equivalent.

GEOL 4360. GEOLOGICAL PROCESSES OF OCEANS. 3 Hours.
Sedimentation in the oceans, chemistry of seawater, geochemical cycles in the oceans, and physical and biological processes that relate to sediment production, origin of seafloor topography, and seafloor spreading. Prerequisite: GEOL 3442.

GEOL 4367. PALEO EARTH SYSTEMS. 3 Hours.
This course discusses the evolution of Earth's complex dynamic system that is controlled by feedback processes that are both non-linear and stochastic in nature. Prerequisite: GEOL 1301.

GEOL 4368. GEOLOGY OF THE PERMIAN BASIN. 3 Hours.
Overview of the geologic evolution of the Permian Basin of W Texas and SE New Mexico and its petroleum resources. Emphasis on student presentations and term paper. Prerequisite: GEOL 1301 or equivalent.

GEOL 4389. RESEARCH IN GEOLOGY. 3 Hours.
Supervised undergraduate research in any one of the various fields of geology. May be repeated but will not meet Geology degree requirements. Prerequisite: permission from instructor.

GEOL 4393. HONORS THESIS/SENIOR PROJECT. 3 Hours.
Required of all students in the University Honors College. During the senior year, the student must complete a thesis or project under the direction of a faculty member in the Earth and Environmental Sciences Department.

GEOL 4402. COMPUTER MODELING IN EARTH SCIENCE. 4 Hours.
An introduction to basic programming and computation in the earth sciences using Matlab®, with emphasis on development of univariate and bivariate statistical models, spatial and image analysis, time series analysis, and the development of basic deterministic physics-based models of geological processes. Prerequisite: MATH 2425.

GEOL 4405. METEOROLOGY AND CLIMATOLOGY. 4 Hours.
A quantitative approach to the study of the structure, energy, and motions of the atmosphere. Prerequisite: MATH 1426 and PHYS 1441, or permission of instructor.

GEOL 4420. HYDROGEOLOGY. 4 Hours.
Hydrologic cycle, Darcy's law, hydraulic properties, aquifer types and materials, groundwater flow to wells, fracture flow, vadose zone flow, groundwater chemistry, and groundwater modeling. Prerequisite: PHYS 1441 or PHYS 1443.

GEOL 4421. GEOCHRONOLOGY. 4 Hours.
Introduction to dating techniques, applied to understand past climate and tectonics. Prerequisite: GEOL 1301 or equivalent.

GEOL 4422. CONTAMINANT HYDROGEOLOGY. 4 Hours.
Sources and types of organic and inorganic contaminants; the physical, chemical, and biological factors and processes that affect the transport and fate of contaminants in the subsurface; non-aqueous phase liquids and multiphase flow; and various remedial techniques of contaminated sites. Prerequisite: GEOL 1301, ENVR 1301, or equivalent.

GEOL 4425. PALEOCLIMATE & CLIMATE CHANGE. 4 Hours.
Climate change throughout geologic time, especially the last 100 million years: models of the climate system, reconstruction and modeling of past climates, abrupt climate change, warm climates, paleoclimatology, climate change and mass extinctions. Prerequisite: GEOL 1301 or ENVR 1330 or GEOL 1330, or permission from instructor.

GEOL 4443. SEDIMENTARY SYSTEMS. 4 Hours.
Focuses on the processes transporting and archiving siliciclastic sediment, and the approaches using siliciclastic sedimentary rocks to reconstruct earth surface processes. This course includes a heavy component of student-led presentation and discussion. Prerequisite: GEOL 3442.

GEOL 4455. ENVIRONMENTAL DATA SCIENCE. 4 Hours.
This course focuses on acquisition, analysis, interpretation, and presentation of environmental data. Available datasets will be utilized to explore different models and case studies of the fate and transport of contaminants in multimedia environments, climate and health, toxicology prediction, water quality, environmental epidemiology, etc. The course includes practical exercises with Python and R. Offered as ENVR 4455 and GEOL 4455. Credit will not be given for both.

GEOL 4456. ENVIRONMENTAL RISK ASSESSMENT. 4 Hours.
This course introduces the basic scientific components of environmental and occupational health risk assessment and describes the policy context in which decisions to manage environmental health risks are made. The course presents the quantitative methods used to assess the human health risks associated with exposure to toxic chemicals, focusing on the four major components of risk assessment-hazard identification, dose-response assessment, exposure assessment, and risk characterization. Offered as ENVR 4456 and GEOL 4456. Credit will not be given for both.

GEOL 4458. MACHINE LEARNING FOR EARTH AND ENVIRONMENTAL SCIENTISTS. 4 Hours.
This course provides students with basic principles of machine learning and helps students apply machine learning to analyze data, predict outcomes and interpret results from the perspective of earth and environmental scientists. The course will first introduce basic concepts and then focus on applications to various examples in earth and environmental sciences. Offered as GEOL 4458 and ENVR 4458. Credit will be not given for both. Prerequisite: GEOL 3454 or ENVR 3454 or equivalent.

GEOL 4465. PHYSICAL OCEANOGRAPHY AND LIMNOLOGY. 4 Hours.
An introduction to physical processes in lakes and oceans. Changes in lakes and oceans influence heat, and momentum fluxes at the aquatic/oceanic and atmospheric interface. Topics include ocean/lake structure and circulation, and the impact of global climate change on lakes and oceans. Field excursions to nearby lakes combine theoretical knowledge and field measurements. Prerequisite: MATH 1426 and PHYS 1441 or PHYS 1443.

GEOL 5151. TOPICS IN ENERGY AND EARTH RESOURCES. 1 Hour.
This course will discuss the historical evolution and current status of major research thrusts in the environment, energy, and resources studies, including Superfund and groundwater remediation, carbon sequestration, tight sands and coalbed methane, petroleum production in shale gas and oil reservoirs, geological repository of high-level nuclear waste, geothermal energy exploitation, mining of critical minerals, and gas (methane) hydrate. Prerequisite: GEOL 1301 or GEOL 3340 or EVSE 5311 or equivalent.

GEOL 5180. PROFESSIONAL ORIENTATION AND BUSINESS ETHICS. 1 Hour.
A mentoring program using working professionals selected by the Earth and Environmental Sciences Department. Each participant meets at least once a month with a mentor who provides information on practices and skills necessary to succeed in the workplace. Course participants review business ethics statements provided by the mentor's company or other companies and write a critique based on materials from professional business ethics organizations such as the International Business Ethics Institute. Prerequisite: Prerequisite or concurrent enrollment GEOL 5345.

GEOL 5181. RESEARCH IN GEOLOGY. 1 Hour.
Independent study in various areas of research including paleontology, stratigraphy, tectonics, structural geology, sedimentology, geochemistry, petrology, geophysics, and volcanology. May be repeated for credit. Graded P/F/R/W.

GEOL 5190. GEOSCIENCE INTERNSHIP. 1 Hour.
Work in geoscience for a commercial concern at least 20 hrs/wk for 3 months. Requirements include writing a resume, learning how to interview and function on the job, and a report describing the work. Prerequisite: Cons. inst.

GEOL 5199. TECHNICAL SESSIONS. 1 Hour.
Forum for presentation of results of graduate students and faculty research. Required each semester of all graduate students.

GEOL 5265. TOPICS IN GEOL. 2 Hours.

GEOL 5281. RESEARCH IN GEOLOGY. 2 Hours.
Independent study in various areas of research including paleontology, stratigraphy, tectonics, structural geology, sedimentology, geochemistry, petrology, geophysics, and volcanology. May be repeated for credit. Graded P/F/R/W.

GEOL 5301. ENVIRONMENTAL GEOCHEMISTRY. 3 Hours.
Fundamentals of low-temperature aqueous geochemistry, and anthropogenic impacts on natural water systems. Topics include equilibrium thermodynamics, kinetics, aqueous complexation, and oxidation/reduction processes that affect metals and organic matter in natural waters.

GEOL 5302. GEODYNAMICS. 3 Hours.
A comprehensive and quantitative study of fundamental aspects of plate tectonics. Introduction to heat flow, elasticity and flexure, fluid mechanics, faulting, gravity, and flow in porous media, with a wide range of geological applications. Includes collaborative problem solving. Prerequisite: GEOL 3443 and MATH 2425.

GEOL 5303. ROCK FRACTURE MECHANICS. 3 Hours.
Principles and tools of fracture mechanics are applied to the origins and physical behaviors of faults, dikes, joints, veins, and other natural structures in rock. Special emphasis will be given to combining field observations of fractures in rock with the elastic theory of cracks in order to explore the role of natural fractures in brittle rock deformation in the earth's crust with applications to crustal deformation, structural geology, engineering geology, and induced hydraulic fracture, i.e. Fracking. Prerequisite: GEOL 3443 and MATH 2425; or GEOL 3340 and CE 2313.

GEOL 5304. SOLID EARTH GEOMECHANICS. 3 Hours.
Application of continuum mechanics to understanding deformation in the earth, including mechanical analysis of natural geologic structures such as faults, folds, lava flows, and dikes, as well as practical problems related to reservoir geomechanics and mining applications. Prerequisite: GEOL 3443, MATH 2325, PHYS 1441 or PHYS 1443.

GEOL 5309. GEOMORPHOLOGY & QUATERNARY STRATIGRAPHY OF SEDIMENTARY SYSTEMS. 3 Hours.
This course examines those physical processes that sculpt the surface of the Earth and result in deposition of sediments. Surface systems covered include weathering, mass wasting, rivers, shorelines, eolian processes, and glaciers. The course also examines the stratigraphic techniques used to decode the recent (2 million to present) stratigraphic record of these systems. Course is designed for geologists, biologists, and other fields concerned with interpreting and/or managing modern environments.

GEOL 5320. UNDERSTANDING GEOGRAPHIC INFORMATION SYSTEMS. 3 Hours.
A practical introduction to GIS and methods of creating, maintaining and displaying spatial data using the ArcGIS software.

GEOL 5321. ANALYSIS OF SPATIAL DATA. 3 Hours.
Analyzing spatial data using ArcGIS, Spatial Analyst, and 3D Analyst, topological surface analysis and modeling; 3D visualization and viewscapes; spatial statistics and data quality management. Prerequisite: GEOL 4330 or GEOL 5320.

GEOL 5322. GLOBAL POSITIONING SYSTEM. 3 Hours.
Review of the NAVSTAR Global Positioning System and its segments: space, operational control, and GPS receivers. Mechanics of the satellite constellation; GPS signal structure; data and coordinate systems; precision and accuracy; error factors; absolute (point) versus relative (differential) positioning. Various positioning techniques using several types of GPS receivers; field data collection and input into GIS programs for data analysis and presentation. Prerequisite: GEOL 4330 or GEOL 5320.

GEOL 5323. REMOTE SENSING FUNDAMENTALS. 3 Hours.
The electromagnetic spectrum and the interaction of EM waves with matter; various types of sensing devices; spectral and spatial resolution parameters; airborne and satellite sensor platforms; aerial photographs and false-color images. The sequence of data acquisition, computer processing and interpretation; sources of data; the integration of remote sensing data with other data types in GIS. Prerequisite: GEOL 4330 or GEOL 5320.

GEOL 5324. GEOGRAPHIC DATA ANALYSIS PROJECT. 3 Hours.
Acquisition, processing and analysis of a set of spatial data selected by the student with the approval of the instructor. A written report of the results is required. Offered as GEOL 5324 and GEOG 5334. Credit will not be given for both. Prerequisite: GEOL 5320, or GEOL 4330 or GEOG 4330, or cons. inst.

GEOL 5332. STABLE ISOTOPE GEOCHEMISTRY. 3 Hours.
Principals governing the fractionation and distribution of stable isotopes (C, H, N, O, S) in nature, and application of stable isotope geochemistry to environmental problems and global climate change.

GEOL 5333. FIELD METHODS. 3 Hours.

GEOL 5334. ANALYTICAL METHODS IN ENVIRONMENTAL SCIENCE. 3 Hours.
Principals of geochemical analysis of waters, rocks and soils, and gases. Methods to be covered include x-ray fluorescence and diffraction, mass spectrometry, coulometry, inductively-coupled plasma, and gas/ion chromatography with various detection methods.

GEOL 5335. ISOTOPES AND TECTONICS. 3 Hours.
An Introduction to the fundamentals of clumped isotopes, and major radiogenic and cosmogenic isotope systems and their applications to the study of earth system processes and Earth history; emphasis will be placed on applications to tectonics, geochronology, and thermochronology. Prerequisite: CHEM 1442 or GEOL 4302.

GEOL 5342. MICROFOSSILS AND CARBONATE ROCKS. 3 Hours.
Half of this course consists of an introduction to microfossil groups occurring in sedimentary rocks: foraminifers, conodonts, coccolithophorids and others, and their usefulness in regional and global correlation of Phanerozoic strata. The biostratigraphy of these groups will be discussed along with the principles used in the correlation of sedimentary rocks. The other half of the course consists of the analysis of the lithofacies and biofacies of carbonate rocks, their genesis, depositional environments, and diagenesis. Prerequisite: GEOL 1302 or permission of the instructor.

GEOL 5345. PETROLEUM GEOLOGY. 3 Hours.
Origin, generation and migration of petroleum; reservoirs, seals and traps; the subsurface environment; properties of petroleum; exploration and production methods; use of seismic lines and well logs; types of petroleum basins; reserves and resources. Prerequisite: GEOL 3442 and GEOL 3443.

GEOL 5351. SUSTAINABLE ENERGY RESOURCES. 3 Hours.
The seminar will review literature of sustainable energy resources including critical minerals, subsurface storage and generation of hydrogen and hydrocarbons, geothermal energy, carbon capture and CO2 sequestration, waste management, and green energies. Prerequisite: GEOL 1301, or ENVR1301, or GEOL 3340, or cons. inst.

GEOL 5365. TOPICS IN GEOLOGY. 3 Hours.
Topics offered depend on student and faculty interest. Such topics might include identification of fossil fragments in thin section; magmatic processes; plate tectonics and sedimentary basin evolution; stratigraphic paleontology; sedimentary or volcanogenic ore deposition; geostatistics; geophysical archeology; and various advanced subjects in sedimentology, stratigraphy, paleontology, geophysics, geochemistry, volcanology and petrology. May be repeated for credit when topic changes.

GEOL 5367. PALEO EARTH SYSTEMS. 3 Hours.
This course discusses the evolution of Earth's complex dynamic system that is controlled by feedback processes that are both non-linear and stochastic in nature. Prerequisite: GEOL 1301.

GEOL 5368. GEOLOGY OF THE PERMIAN BASIN. 3 Hours.
Overview of the geologic evolution of the Permian Basin of W Texas and SE New Mexico and its petroleum resources. Emphasis on student presentations and term paper.

GEOL 5369. SEQUENCE STRATIGRAPHY. 3 Hours.
This course introduces sequence stratigraphy within context of all stratigraphy and history of sequence stratigraphy. Includes overview of sequence stratigraphy principles. Review of basic fundamental concepts of surface- and facies-based physical stratigraphy. Review of architectural element analysis, sequence stratigraphic in seismic, borehole expression of sequences and overview of subsurface stratigraphic techniques. Prerequisite: GEOL 3442.

GEOL 5370. SEDIMENTARY SYSTEMS. 3 Hours.
Carbonate and clastic depositional systems, recognition of facies, systems tracts, diagenetic overprint, shelf to basin profiling, and sequence stratigraphic analysis.

GEOL 5371. BASIN ANALYSIS. 3 Hours.
Topics include: the classification and characteristics of of sedimentary basins and the mechanisms forming them; and the tectonic, climatic, and eustatic controls on basin subsidence and the basin fill. Applications include the influence of basin evolution on petroleum generation, migration, and accumulation. Prerequisite: GEOL 3442 (Sedimentology and Stratigraphy).

GEOL 5372. STRUCTURAL GEOMETRY AND TECTONICS OF PETROLEUM FIELDS. 3 Hours.
Structural styles of thin-skinned, basement involved and reactivated systems in shortening, extensional and strike-slip deformation. Use of structural modeling and restoration methods to test the reliability of structural interpretations. Prerequisite: GEOL 3443.

GEOL 5373. RESERVOIR CHARACTERIZATION. 3 Hours.
Principles, protocols, analysis and measurement of petrophysical properties (e.g., fluid content, porosity, permeability, pore size distribution, water retention curve, imbibition) of petroleum reservoir rocks.

GEOL 5374. SEISMIC INTERPRETATION. 3 Hours.
Introduction to the methods of acquisition and processing as they relate to the interpretation of seismic records. Structural and stratigraphic interpretation methods and pitfalls using two and three dimensional seismic data. Introduction to Seismic Interpretation Software such as the Kingdom Suite from Seismic Micro Technology, Inc. Prerequisite: GEOL 3442 and GEOL 3443.

GEOL 5375. INTRODUCTION TO WELL LOG INTERPRETATION AND MAPPING. 3 Hours.
Introduction to the various types of well logs used in the petroleum industry and their petrophysical interpretations, including evaluations of porosity, water saturation, shale volume, permeability, and lithology. Introduction to techniques of contouring data and use of mapping software such as PETRA. Prerequisite: GEOL 3442.

GEOL 5381. RESEARCH IN GEOLOGY. 3 Hours.
Independent study in various areas of research including paleontology, stratigraphy, tectonics, structural geology, sedimentology, geochemistry, petrology, geophysics, and volcanology. May be repeated for credit. Graded R.

GEOL 5395. MASTER'S PROJECT. 3 Hours.
May be used as elective for students in non-thesis program. Graded F,P,R,W. Prerequisite: GEOL 1301 or equivalent course.

GEOL 5398. THESIS. 3 Hours.
Graded F, R.

GEOL 5405. METEOROLOGY AND CLIMATOLOGY. 4 Hours.
A quantitative approach to the study of the structure, energy, and motions of the atmosphere. Prerequisite: MATH 1426 and PHYS 1441, or cons. inst.

GEOL 5421. GEOCHRONOLOGY. 4 Hours.
Introduction to dating techniques, applied to understand past climate and tectonics. Prerequisite: GEOL 1301 or equivalent.

GEOL 5425. PALEOCLIMATE AND CLIMATE CHANGE. 4 Hours.
Climate change throughout geologic time, especially the last 100 million years: models of the climate system, reconstruction and modeling of past climates, abrupt climate change, warm climates, paleoclimatology, climate change and mass extinctions. Prerequisite: GEOL 1301 or ENVR 1330 or GEOL 1330, or cons. inst.

GEOL 5428. HYDROGEOLOGY. 4 Hours.
Hydrologic cycle, Darcy's law, hydraulic properties, aquifer types and materials, groundwater flow to wells, fracture flow, vadose zone flow, groundwater chemistry, and groundwater modeling; a term paper about the relevant topics covered in the class is required. Prerequisite: GEOL 2446, MATH 2425.

GEOL 5450. CONTAMINANT HYDROGEOLOGY. 4 Hours.
Sources and types of organic and inorganic contaminants; the physical, chemical, and biological factors and processes that affect the transport and fate of contaminants in the subsurface; non-aqueous phase liquids and multiphase flow; and various remedial techniques of contaminated sites.

GEOL 5454. STATISTICS FOR EARTH AND ENVIRONMENTAL SCIENTISTS. 4 Hours.
This course provides students with basic principles of statistics and helps students apply statistics to analyze data and interpret results from the perspective of Earth and environmental scientists. The course will first introduce basic concepts and then focus on applications to various examples in Earth and environmental sciences. Offered as EVSE 5454 and GEOL 5454. Credit will not be given for both.

GEOL 5456. ENVIRONMENTAL RISK ASSESSMENT. 4 Hours.
This course introduces the basic scientific components of environmental and occupational health risk assessment and describes the policy context in which decisions to manage environmental health risks are made. The course presents the quantitative methods used to assess the human health risks associated with exposure to toxic chemicals, focusing on the four major components of risk assessment-hazard identification, dose-response assessment, exposure assessment, and risk characterization. Offered as EVSE 5456 and GEOL 5456, credit will not be given for both.

GEOL 5458. MACHINE LEARNING FOR EARTH AND ENVIRONMENTAL SCIENTISTS. 4 Hours.
This course provides students with basic principles of machine learning and helps students apply machine learning to analyze data, predict outcomes and interpret results from the perspective of earth and environmental scientists. The course will first introduce basic concepts and then focus on applications to various examples in earth and environmental sciences. Offered as GEOL 5458 and EVSE 5458. Credit will not be given for both. Prerequisite: ENVR 3454 or GEOL 3454 or EVSE 5454 or GEOL 5454 or equivalent.

GEOL 5465. PHYSICAL OCEANOGRAPHY AND LIMNOLOGY. 4 Hours.
An introduction to physical processes in lakes and oceans. Changes in lakes and oceans influence heat, and momentum fluxes at the aquatic/oceanic and atmospheric interface. Topics include ocean/lake structure and circulation, and the impact of global climate change on lakes and oceans. Field excursions to nearby lakes combine theoretical knowledge and field measurements. Prerequisite: PHYS 1441 or PHYS 1443; and MATH 1426.

GEOL 5698. THESIS. 6 Hours.
Graded F, P, R.

COURSES

PHYS 1181. PROBLEMS IN MECHANICS. 1 Hour.
Primarily an independent study course involving problem-solving in general technical mechanics. The objective is to prepare the student whose background in physics is of a non-technical nature to do advanced study in curricula requiring technical physics. This course in combination with PHYS 1441 shall serve as an equivalent to PHYS 1443. Prerequisite: MATH 1426 and a grade of B or better in PHYS 1441. Department consent may be granted to take this course with Physics B AP score of 4 or 5.

PHYS 1182. PROBLEMS IN ELECTRICITY AND MAGNETISM. 1 Hour.
Primarily an independent study course involving problem-solving in general technical electricity and magnetism. The objective is to prepare the student whose background in physics is of a non-technical nature to do advanced study in curricula requiring technical physics. This course in combination with PHYS 1442 shall serve as an equivalent to PHYS 1444. Prerequisite: MATH 2425 and a grade of B or better in PHYS 1442. Department consent may be granted to take this course with Physics B AP score of 4 or 5.

PHYS 1188. SPECIAL PROBLEMS IN GENERAL PHYSICS. 1 Hour.
Primarily laboratory work and/or problem-solving in general technical physics. Prerequisite: PHYS 1441 or PHYS 1443 lecture credit equivalent or PHYS 1442 or PHYS 1444 lecture credit equivalent.

PHYS 1288. SPECIAL PROBLEMS IN GENERAL PHYSICS. 2 Hours.
Primarily laboratory work and/or problem-solving in general technical physics. Prerequisite: PHYS 1441 and PHYS 1442 lecture credit equivalent or PHYS 1443 and PHYS 1444 lecture credit equivalent.

PHYS 1300. INTRODUCTION TO MUSICAL ACOUSTICS. 3 Hours.
An introduction, for the music major, to the nature of periodic motion and its relation to music, characteristics of sound waves, sources of sound used in music, musical scales and temperament, mechanics of hearing, recording and reproduction of sound. May not be used to satisfy any of the requirements for a degree in physics.

PHYS 1301. PHYSICS FOR NON SPECIALISTS I. 3 Hours. (TCCN = PHYS 1305)
PHYS 1301 and 1302 constitute a one-year introductory course for liberal arts and business majors. How physics plays a role in everyday life; explanations of how things work. Helps develop analytical thinking. The first semester explains motion and forces and heat.

PHYS 1302. PHYSICS FOR NON SPECIALISTS II. 3 Hours. (TCCN = PHYS 1307)
Follows PHYS 1301 and explains sound, light, electricity and magnetism. Prerequisite: PHYS 1301 or permission from instructor.

PHYS 1351. ENERGY AND ENVIRONMENT. 3 Hours.
This course explores the fundamental laws of nature and natural processes related to energy production, transport, storage, and uses. The objective of this course is to provide students with an in-depth understanding of the Physics of Energy and its relation to the Earth Environment. The course is designed for non-science major students with two one-hour lectures (or one two-hour lecture) and one 2-hour laboratory per week.

PHYS 1441. GENERAL COLLEGE PHYSICS I. 4 Hours. (TCCN = PHYS 1401)
The first half of a one-year, non-calculus introductory physics course taken by pre-medical, pre-dental, biology and architectural majors and others. The study of mechanics, elasticity, fluids, heat and waves is supplemented by laboratory experiments. Familiarity with high school algebra and trigonometry is required.

PHYS 1442. GENERAL COLLEGE PHYSICS II. 4 Hours. (TCCN = PHYS 1402)
The second half of a one-year, non-calculus introductory physics course. Subject matter includes electricity and magnetism, light and optics, and modern physics. Prerequisite: PHYS 1441 or equivalent, or permission of instructor or student group.

PHYS 1443. GENERAL TECHNICAL PHYSICS I. 4 Hours. (TCCN = PHYS 2425)
The first half of a one-year technical course. Required for many science and engineering majors, exceeds premedical requirement. The study of physical phenomena in the fields of mechanics, heat, and waves. Concurrent enrollment in MATH 1426 (per prerequisite) is not recommended if no prior background in calculus. Prerequisite: MATH 1426 or consent of instructor.

PHYS 1444. GENERAL TECHNICAL PHYSICS II. 4 Hours. (TCCN = PHYS 2426)
The second half of a one-year technical course. The study of physical phenomena including electricity, magnetism, circuit theory, light, and optics. Prerequisites: PHYS 1443 or equivalent and MATH 2425 or concurrent enrollment.

PHYS 2311. MATHEMATICAL METHODS OF PHYSICS. 3 Hours.
Harmonic oscillators, waves, vector description of particles and fields, coordinate transformations, eigenvalue problems, and systems of linear equations. Prerequisites: PHYS 1444 or equivalent and MATH 2425.

PHYS 2315. INTRODUCTORY ASTROPHYSICS. 3 Hours.
This course introduces Science and Engineering majors to astrophysics. Subject matter includes the solar system, stellar properties and evolution, the Milky Way galaxy, normal and active galaxies, and cosmology. Prerequisite: PHYS 1444 or permission of the instructor.

PHYS 2321. COMPUTATIONAL PHYSICS. 3 Hours.
Development of computational techniques, including simulation, through applications to physical problems. A survey of topics including the multi-body problem, celestial mechanics, scattering, chaos, percolation, fractals, random processes, Fourier techniques in wave phenomena, Monte Carlo methods, and image reconstruction techniques. Prerequisite: PHYS 1444 or equivalent.

PHYS 3183. MODERN PHYSICS LABORATORY. 1 Hour.
Supplements the topics covered in PHYS 3313. Prerequisite: PHYS 3313 or concurrent enrollment.

PHYS 3313. INTRODUCTION TO MODERN PHYSICS. 3 Hours.
A brief introduction to the theories of quantum mechanics and statistical mechanics followed by a survey of atomic physics, conductors, semiconductors and modern electronic devices, nuclear and sub-nuclear physics. Prerequisites: PHYS 1444 or equivalent and MATH 2425.

PHYS 3315. ASTROPHYSICS AND COSMOLOGY. 3 Hours.
Diverse concepts in theoretical physics are applied to a wide range of astrophysical problems. Topics include stellar properties, spectra, evolution, radiation transport, nuclear reactions, degenerate matter, orbital mechanics, galactic dynamics, introductory general relativity and cosmology. Prerequisite: PHYS 3313 and MATH 3318 or MATH 3319.

PHYS 3316. ASTROBIOLOGY I. 3 Hours.
This is an interdisciplinary course between astrophysics, biology and geology. Topics include properties of life, origin and evolution of life on Earth, terrestrial geology and habitability, environmental forcings, extremophiles, mass extinctions, meteorites, searches for life in the solar system. Offered as BIOL 3316, GEOL 3316 and PHYS 3316; credit will be granted only once. Prerequisite: PHYS 1441 & PHYS 1442 or equivalent and PHYS 2315 or PHYS 3315, or permission from instructor. Prerequisites for Biology majors: PHYS 1441 & PHYS 1442 or equivalent.

PHYS 3321. INTERMEDIATE ELECTRICITY AND MAGNETISM. 3 Hours.
Vector algebra and vector calculus applied to electrostatics, magnetostatics, the study of dielectric materials, and boundary value problems. Prerequisite: PHYS 2311 and MATH 3318 or MATH 3319.

PHYS 3341. INTRODUCTION TO BIOLOGICAL PHYSICS. 3 Hours.
This course will cover four parts: Part I - History of Biological Physics and the general introduction of Cell biology; Part II - Physics of Biomaterials including polymer Physics; DNA & RNA; Protein Structures, Functions and Physics; Part III - Physics of life genetics including molecular motors, ATP functions, Photosynthesis and Physics of genetic regulations; and Part IV - Physics of biological detection including Physics of Radiation diagnosis; Optical Imaging; Magnetic Resonance Imaging and Ultrasound imaging. Prerequisite: PHYS 1442 or PHYS 1444 or equivalent.

PHYS 3342. INTRODUCTION TO NANO-BIO PHYSICS. 3 Hours.
The objective of this course is to provide students with an in-depth understanding of the physics of nanotechnology and its biological applications. The course is composed of two parts: nanoparticle physics and nano-bio physics. In the first part, the physics of nanotechnology will be introduced. The second part is the biological applications of nanotechnology, for which the focus will be on how to understand the physics of these applications. The understanding of the physical objectives for these applications will be helpful for the exploration of nano-biotechnology. Key advances from the recent literature will be reviewed and introduced to students as supplemental topics. Prerequisite: PHYS 1442 or PHYS 1444 or equivalent.

PHYS 3358. ASTROBIOLOGY II. 3 Hours.
This is an interdisciplinary course between astrophysics, biology and geology. Topics include basic properties of life, habitability of Earth, studies of possible life regarding Mars, Europa & Titan, space missions, exoplanets and exomoons, stellar habitable zones, multistellar systems, exoEarths, biomarkers, SETI, Fermi paradox, Drake equation, cosmology. Offered as BIOL 3358, GEOL 3358, and PHYS 3358; credit will be granted only once. Prerequisite: PHYS 1441 & PHYS 1442 or equivalent and PHYS 2315 or PHYS 3315, or permission from instructor. Prerequisites for Biology majors: PHYS 1441 & PHYS 1442 or equivalent. Note that Astrobiology I is strongly recommended to students to be taken prior to Astrobiology II, but is not a prerequisite.

PHYS 3360. PHYSICS OF THE HUMAN BODY. 3 Hours.
This course will explore the fundamental laws and natural processes related to the mechanics, fluid dynamics, optics, and biophysics of the human body. It is designed for kinesiology pre-health, biology and nursing students seeking to understand the foundations and biophysical principles of human life. Note that Kinesiology students seeking to apply to science based graduate programs are advised to take PHYS 1441 and PHYS 1442 so the prerequisite requirement of these courses will not preclude the students for whom PHYS 3360 is intended from taking the course. Prerequisite: PHYS 1441.

PHYS 3366. SPECIAL TOPICS IN PRE-COLLEGE PHYSICAL SCIENCE INSTRUCTION. 3 Hours.
A laboratory oriented curriculum for teaching physical science and/or physics is developed and experienced. The developed curriculum is particularly appropriate for pre-college instruction. May be repeated for credit as the subject matter changes, but not more than six hours credit may be accumulated. Prerequisite: junior standing, six hours of science, three hours of education, and consent of the instructor.

PHYS 3445. OPTICS. 4 Hours.
Fundamental principles of physical and geometric optics, absorption and scattering, Planck's quantum theory of radiation, diffraction, interference, light sources, and spectra. Prerequisites: PHYS 1444 or equivalent and MATH 2425.

PHYS 3446. NUCLEAR AND PARTICLE PHYSICS. 4 Hours.
The study of atomic nuclei and the fundamental constituents of matter. Topics include nuclear structure, radioactivity, nuclear reactions, fission, fusion, particles and their interactions, the standard model of particle physics, experimental methods, accelerators, and examples from current research topics. Prerequisite: PHYS 3313.

PHYS 3455. ELECTRONICS. 4 Hours.
A study of electronic components and quantum devices and their application to circuits and instrumentation. Prerequisites: PHYS 3313 and MATH 2425.

PHYS 4081. UNDERGRADUATE RESEARCH IN PHYSICS. 0 Hours.
Independent research conducted on a selected topic under the supervision of a member of the Physics faculty. This course may be repeated. This is a non-credit course so cannot be used to meet degree requirements. Prerequisite: Permission of instructor.

PHYS 4117. INDIVIDUAL LEARNING BY SEMINAR. 1 Hour.
Individual instruction on using the seminar as a model of learning current topics in physics. An individual report is required. Prerequisite: 18 hours of physics and senior standing.

PHYS 4171. ADVANCED OPTICS LABORATORY. 1 Hour.
Special laboratory projects in advanced optics. Prerequisite: PHYS 3445 or permission of the instructor.

PHYS 4181. SPECIAL PROBLEMS. 1 Hour.
Selected projects in research or teaching laboratories, which may be repeated in any order for a total credit not to exceed four hours, unless authorized by the undergraduate advisor. Prerequisite: Permission from instructor and Physics undergraduate advisor.

PHYS 4185. ADVANCED ELECTRICITY AND MAGNETISM LABORATORY. 1 Hour.
Supplements the topics covered in PHYS 3321 and PHYS 4324. Prerequisite: PHYS 4324 or concurrent enrollment.

PHYS 4191. SPECIAL TOPICS IN PHYSICS. 1 Hour.
Selected topics arranged on an individual basis, which may be repeated with permission from instructor and Physics undergraduate advisor. Prerequisite: as determined for topic or permission from instructor.

PHYS 4271. ADVANCED OPTICS LAB. 2 Hours.
Special laboratory projects in advanced optics. Prerequisite: PHYS 3445 or permission of the instructor.

PHYS 4281. SPECIAL PROBLEMS. 2 Hours.
Selected projects in research or teaching laboratories, which may be repeated in any order for a total credit not to exceed four hours, unless authorized by the undergraduate advisor. Prerequisite: permission from the instructor and the Physics undergraduate advisor.

PHYS 4291. SPECIAL TOPICS. 2 Hours.
Selected topics arranged on an individual basis, which may be repeated with permission from instructor and Physics undergraduate advisor. Prerequisite: as determined for topic or permission from instructor.

PHYS 4315. THERMODYNAMICS AND STATISTICAL MECHANICS. 3 Hours.
Topics in classical thermodynamics include the laws of thermodynamics, Gibbs' and Helmholtz's free energies, the Maxwell relations, heat capacities, entropy change calculations, phase and chemical changes. Statistical mechanics centers on the partition function and its applications, such as the entropy of an ideal gas, the Maxwell velocity distribution, the heat capacity of a solid, photon statistics, and blackbody radiation. Fermi-Dirac and Bose-Einstein statistics. Prerequisite: PHYS 3313 and MATH 2326 or permission of the instructor.

PHYS 4319. ADVANCED MECHANICS. 3 Hours.
Coupled oscillators, central forces, Lagrange's equations, Hamilton's canonical equations, the moment of inertia tensor, and the application of Euler's angles to rotational motion. Prerequisite: PHYS 2311, PHYS 3321, and MATH 3318 or MATH 3319, or permission of the instructor.

PHYS 4324. ADVANCED ELECTRICITY AND MAGNETISM. 3 Hours.
Electromagnetic phenomena based on Maxwell's equations and particle-field interactions. Prerequisite: PHYS 3321 or permission of the instructor.

PHYS 4325. SOLID STATE PHYSICS. 3 Hours.
Classification of crystalline solids and elastic and thermal properties, electric and magnetic properties, and electronic properties of solids. An introduction to current research problems. Prerequisite: PHYS 4315 or permission of the instructor.

PHYS 4326. INTRODUCTION TO QUANTUM MECHANICS. 3 Hours.
Schrodinger equation and implications, the free particle, the one-electron atom, the potential barrier, and perturbation theory. Prerequisite: PHYS 3313, MATH 3318 or MATH 3319, or permission of the instructor.

PHYS 4327. INTRODUCTION TO QUANTUM MECHANICS II. 3 Hours.
This is a continuation of Introduction to Quantum Mechanics (PHYS 4326). The topics that will be covered will include: time-independent perturbation theory for non-degenerate states, degenerate perturbation theory, atoms with one or two electrons and molecules, Fermi and Bose gases, time-dependent perturbation theory, scattering theory, and introduction to relativistic quantum mechanics. Prerequisite: PHYS 4326 or permission from instructor.

PHYS 4343. RESEARCH METHODS - UTEACH. 3 Hours.
The purpose of this course is to present UTeach students with the tools scientists use to solve scientific problems. These tools enable scientists to develop new knowledge and insights, the most important of which are eventually presented in textbooks and taught in more conventional science classes. These tools include: design of experiments to answer scientific questions; use of statistics to interpret experimental results and deal with sampling errors; mathematical modeling of scientific phenomena; finding and reading articles in the current scientific literature; applying scientific arguments in matters of social importance; writing scientific papers; reviewing scientific papers; oral presentation of scientific work; use of probes and computers to gather and analyze data; ethical treatment of human subjects; laboratory safety. Research Methods is primarily a laboratory course, and most of these topics are developed in connection with 4 independent inquiries UTeach students design and carry out. Written inquiries will be evaluated as examples of scientific writing. Prerequisite: C or better in SCIE 1201 or SCIE 1334 or concurrent enrollment; junior or senior standing.

PHYS 4391. SPECIAL TOPICS. 3 Hours.
Selected topics arranged on an individual basis, which may be repeated with permission from instructor and Physics undergraduate advisor. Prerequisite: as determined for topic or permission from instructor.

PHYS 4392. MEDICAL PHYSICS 1. 3 Hours.
The study of the basic physics behind ionizing radiation therapy, radiation generation modalities, dose calculation, treatment planning, and modern radiation therapeutic techniques. Prerequisite: PHYS 1443, PHYS 1444, PHYS 2311 and MATH 3318 or MATH 3319.

PHYS 4393. HONORS THESIS IN PHYSICS. 3 Hours.
Required of all students in the University Honors College. During the senior year the honors physics major will perform a research project under the direction of a Physics Department faculty member.

PHYS 5193. READINGS IN PHYSICS. 1 Hour.
Conference course. May be repeated for credit.

PHYS 5194. RESEARCH IN PHYSICS. 1 Hour.
Conference course with laboratory. May be repeated for credit.

PHYS 5294. RESEARCH IN PHYSICS. 2 Hours.
Conference course with laboratory. May be repeated for credit.

PHYS 5305. CHAOS AND NONLINEAR DYNAMICS. 3 Hours.
Introduction to basic principles and concepts of chaos theory and their applications in diverse fields of research. Topics include chaotic and non-chaotic systems, stability analysis and attractors, bifurcation theory, routes to chaos and universality in chaos, iterated maps, Lyapunov exponents, fractal dimensions, multifractals, hamiltonian chaos, quantum chaos, controlling chaos, self-organized systems, and theory of complexity.

PHYS 5306. CLASSICAL MECHANICS. 3 Hours.
General principles of analytical mechanics, the kinematics of rigid bodies, canonical transformation, Hamilton-Jacobi theory.

PHYS 5307. QUANTUM MECHANICS I. 3 Hours.
Matrix formulation, theory of radiation, angular momentum, perturbation methods.

PHYS 5308. QUANTUM MECHANICS II. 3 Hours.
Approximate methods, symmetry and unitary groups, scattering theory. Prerequisite: PHYS 5307.

PHYS 5309. ELECTROMAGNETIC THEORY I. 3 Hours.
Boundary value problems in electrostatics and magnetostatics, Maxwell's equations.

PHYS 5310. STATISTICAL MECHANICS. 3 Hours.
Fundamental principles of statistical mechanics, Liouville theorem, entropy, Fermi-Dirac distribution, Bose-Einstein distribution, Einstein condensation, density matrix, quantum statistical mechanics, kinetic methods, and transport theory.

PHYS 5311. MATHEMATICAL METHODS IN PHYSICS I. 3 Hours.
Algebraic and analytical methods used in modern physics. Algebra: matrices, groups, and tensors, with application to quantum mechanics, the solid state, and special relativity. Analysis: vector calculus, ordinary and partial differential equations, with applications to electromagnetic and seismic wave propagation.

PHYS 5312. MATHEMATICAL METHODS IN PHYSICS II. 3 Hours.
Continuation of PHYS 5311 with a selection from the following topics. Algebra: matrix representations of the symmetric and point groups of solid state physics, matrix representations of the continuous groups O(3), SU(2), SU(3), SL(2,C), general covariance. Analysis: further study of analytic functions, Cauchy's theorem, Green's function techniques, orthogonal functions, integral equations. Prerequisite: PHYS 5311.

PHYS 5313. ELECTROMAGNETIC THEORY II. 3 Hours.
Modern tensorial treatment of classical electrodynamics, force on and field of a moving charge, derivation and application of 4-vector potential, Maxwell's equations in tensor form, field momentum and radiation. Prerequisite: PHYS 5309.

PHYS 5314. ADVANCED OPTICS. 3 Hours.
Electromagnetic wave equations, theory of diffraction, radiation scattering and dispersion, coherence and laser optics. Additional advanced topics of current interest.

PHYS 5315. SOLID STATE I. 3 Hours.
Crystal structure, lattice vibration, thermal properties, and band theory of solids.

PHYS 5316. SOLID STATE II. 3 Hours.
Electrical and magnetic properties of crystalline solids, magnetic resonance, and optical phenomena. Prerequisite: PHYS 5315.

PHYS 5317. STATISTICAL MECHANICS II. 3 Hours.
Methods in applied statistical mechanics. Topics may include fluctuations and critical phenomena, the Ising model, the master equation, transport in solids, and chaos. Prerequisite: PHYS 5310.

PHYS 5319. MATHEMATICAL METHODS IN PHYSICS III. 3 Hours.
Numerical methods for applied physics; computer techniques, numerical differentiation, integration, interpolation, extrapolation; differential equations, integral equations, statistical analysis; scientific computer library; artificial intelligence programming.

PHYS 5320. QUANTUM MECHANICS III. 3 Hours.
Quantum theory of radiation; relativistic equations; elements of quantum field theory; symmetries and gauge theories. Applications in elementary particle physics and solid-state physics. Prerequisite: PHYS 5308 and PHYS 5312.

PHYS 5325. INTRODUCTION TO ELEMENTARY PARTICLES I. 3 Hours.
An overview of particles and forces. Particle detectors and accelerators. Invariance principles and conservation laws. Standard model. Electromagnetic, weak, strong, and unified interactions.

PHYS 5326. INTRODUCTION TO ELEMENTARY PARTICLE PHYSICS II. 3 Hours.
Systematics of the quark model; the fundamental interactions of elementary particles; spin and relativistic kinematics; Dirac Equation; the standard electroweak model. Prerequisite: PHYS 5325.

PHYS 5328. SURFACE PHYSICS. 3 Hours.
Experimental and theoretical methods for the study of solid surfaces. Geometric and electronic structure of metals and semiconductors. Surfaces as model systems of reduced dimensionality. Adsorption phenomena and film growth.

PHYS 5330. PHYSICS OF SEMICONDUCTOR PROCESSING AND CHARACTERIZATION. 3 Hours.
Selection from the following topics: physics of crystal growth, lattice defects, impurity diffusion, ion-implantation, thin film growth and plasma etching. Physics of characterization techniques utilizing resistivity, carrier mobility and lifetimes, electrons, x-rays, ions, Rutherford backscattering, neutron activation analysis, positron annihilation spectroscopy, deep-level transient spectroscopy.

PHYS 5381. MECHANICS & HEAT FOR TEACHERS. 3 Hours.
This course is intended for students who wish to achieve a higher level of knowledge and effectiveness in fundamental physics (not available for M.S. or Ph.D. credit in Physics). Topics include: 1) Newton's laws of motion, gravitation, and planetary motion; 2) the basic laws of thermal and statistical physics; 3) oscillatory motion including waves and sound. Replaceable experiments will be demonstrated throughout the course.

PHYS 5382. ELECTROMAGNETISM FOR TEACHERS. 3 Hours.
This course is intended for students who wish to achieve a higher level of knowledge and effectiveness in fundamental physics (not available for M.S. or Ph.D. credit in Physics). Topics include: 1) Static charges, current flow, electric and magnetic fields; 2) simple DC/AC electrical circuits including examples from household circuit and practical electronic devices; 3) light and optics including examples such as cameras, microscopes and telescopes. Replaceable experiments will be demonstrated throughout the course.

PHYS 5383. MODERN PHYSICS FOR TEACHERS. 3 Hours.
This course is intended for students who wish to achieve a higher level of knowledge and effectiveness in fundamental physics (not available for M.S. or Ph.D. credit in Physics). Topics include: 1) Introduction to special relativity and quantum theory; 2) light and radiation; 3) applications to modern electrical devices; 4) nuclear and particle physics.

PHYS 5385. PHYSICS LAB TECHNIQUES FOR TEACHERS. 3 Hours.
This course is intended for students who wish to achieve a higher level of knowledge and effectiveness in fundamental physics (not available for M.S. or Ph.D. credit in Physics). Experiments demonstrating various topics are covered. Experiments include gravitational acceleration heat flow, harmonic motion, sound, electric magnetic fields, electric circuits, optic, x-rays and nuclear radiation.

PHYS 5391. SPECIAL TOPICS IN PHYSICS. 3 Hours.
Topics in physics, particularly from areas in which active research is being conducted, are assigned to individuals or small groups for intensive investigations. May be repeated for credit.

PHYS 5392. MEDICAL PHYSICS 2. 3 Hours.
This course is the second part of Medical Physics, which involves in depth learning of clinic medical imaging modalities, such as X-ray computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and nuclear medicine (gamma imaging, single photon emission computed tomography (SPECT) and positron emission tomography (PET)). Prerequisite: MATH 3318 or MATH 3319, PHYS 4392.

PHYS 5393. READINGS IN PHYSICS. 3 Hours.
Conference course. May be repeated for credit.

PHYS 5394. RESEARCH IN PHYSICS. 3 Hours.
Conference course with laboratory. May be repeated for credit.

PHYS 5398. THESIS. 3 Hours.

PHYS 5694. RESEARCH IN PHYSICS. 6 Hours.
Conference course with laboratory. May be repeated for credit.

PHYS 5698. THESIS. 6 Hours.

PHYS 6301. METHODS OF APPLIED PHYSICS I--ELECTRONICS. 3 Hours.
The analysis and design of electronic circuits for use in the laboratory. Transistors and integrated circuits in analog instrumentation. Digital logic. Information theory and signal processing.

PHYS 6302. METHODS OF APPLIED PHYSICS II--COMPUTERS IN PHYSICS. 3 Hours.
Applications of computers in physics. Acquisition and analysis of experimental data. Vector and parallel processing, image processing, simulation.

PHYS 6303. METHODS OF APPLIED PHYSICS III--SPECTROSCOPY. 3 Hours.
The principles (interactions, cross-sections, elastic and inelastic scattering, diffraction, coherence), the methodologies (sources, detectors, visualization), and applications (structure, dynamics, composition, excitations) of neutral and charged particle spectroscopies to condensed matter physics and materials science.

PHYS 6304. APPLIED PHYSICS INTERNSHIP. 3 Hours.
Applied physics and engineering research and training in industry or other science or engineering departments of U.T. Arlington or other institutions requiring applied physicists. Faculty supervision and submission of technical progress reports required.

PHYS 6391. SELECTED TOPICS IN APPLIED PHYSICS. 3 Hours.
Topics chosen from research areas in the Department of Physics or at one of the institutions or corporations participating in the traineeship program in applied physics; emphasis on industrial and engineering applications. May be repeated for credit.

PHYS 6399. DISSERTATION. 3 Hours.

PHYS 6604. APPLIED PHYSICS INTERNSHIP. 6 Hours.
Applied physics and engineering research and training in industry or other science or engineering departments of U.T. Arlington or other institutions requiring applied physicists. Faculty supervision and submission of technical progress reports required.

PHYS 6699. DISSERTATION. 6 Hours.

PHYS 6904. APPLIED PHYSICS INTERNSHIP. 9 Hours.
Applied physics and engineering research and training in industry or other science or engineering departments of U.T. Arlington or other institutions requiring applied physicists. Faculty supervision and submission of technical progress reports required.

PHYS 6999. DISSERTATION. 9 Hours.

PHYS 7399. DOCTORAL DEGREE COMPLETION. 3 Hours.
This course may be taken during the semester in which a student expects to complete all requirements for the doctoral degree and graduate. Enrolling in this course meets minimum enrollment requirements for graduation, for holding fellowships awarded by The Office of Graduate Studies and for full-time GTA or GRA positions. Students should verify that enrollment in this course meets other applicable enrollment requirements. To remain eligible in their final semester of study for grants, loans or other forms of financial aid administered by the Financial Aid Office must enroll in a minimum of 5 hours as required by the Office of Financial Aid. Other funding sources may also require more than 3-hours of enrollment. Additional hours may also be required to meet to requirements set by immigration law or by the policies of the student's degree program. Students should contact the Financial Aid Office, other sources of funding, Office of International Education and/or their graduate advisor to verify enrollment requirements before registering for this course. This course may only be taken twice. Students who do not complete all graduation requirements while enrolled in this course must enroll in a minimum of 6 dissertation hours (6699 or 6999) in their graduation term. Graded P/F/R.