

## Graduate Course Descriptions

Effective Fall 2019

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### Accounting

#### ACC 5000 - Accounting Foundations I

Introduction to basic theories, concepts, and practices to understand fundamental accounting principles and the resultant financial statements. Topics include the decisions-making environment, accounting cycle, financial measurement and reporting.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5050 - Accounting Foundations II

Continuation of ACC5000 with theories, concepts, and practices underlying financial measurement and reporting. Topics include income measurement, cash flows, allocation of costs, budgeting, and decision making.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5100 - Advanced Auditing and Fraud Examination

An in-depth study of auditing with a focus on fraud examination from an external auditor's perspective. The course utilizes problems, cases, and projects relating to fraud examination and forensic accounting.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
Pre-Requisite(s): ACC 4100

#### ACC 5200 - Financial Statement Analysis

Study of financial statement analysis and concepts of valuation utilizing accounting based financial information. Methods are applied to encompass decision making, communication, and judgment using problems, cases, and projects.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5300 - Financial Reporting and Control

This class covers the collection, reporting, and analysis of financial information with emphasis on the use of that information to support decision making.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Accounting

#### ACC 5500 - Strategic Cost Accounting

This course focuses on the use of managerial accounting information in making strategic business decisions. Topics include contemporary costing methods, advanced capital budgeting, profit center analysis, transfer pricing, and performance evaluation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5600 - Taxation for Decision Makers

This course focuses on how taxes impact management decision making. Advanced tax planning techniques are studied to develop analytical, research, and professional communication skills.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5700 - Accounting Analytical Methods

Statistical analysis of large datasets. Computer programming will be used to analyze and manipulate the data. Topics include fundamental analysis, fraud detection, default prediction on loans, and other contemporary accounting issues.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5800 - Advanced Accounting Systems

This course presents a comprehensive understanding of accounting information systems and advanced technology in the accounting environment. It emphasizes how to use these tools to enhance financial decision making. Topics include contemporary technology and applications.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
Pre-Requisite(s): ACC 4800

#### ACC 5900 - Current Issues in Accounting

This course examines current issues in the accounting profession. Designed as a capstone course to further understand concepts introduced through the analysis of contemporary accounting issues.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Major(s): Accounting; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

#### ACC 5990 - Special Topics in Accounting

Accounting topics of interest to students. Study is under the guidance of a faculty member.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Permission of instructor required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

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### Atmospheric Science

#### ATM 5100 - Atmospheric Sciences Research Discussion

A weekly discussion of recent literature in the atmospheric sciences. Often coordinated with atmosphere-related seminars in the Remote Sensing seminar series.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): ATM 5515(C) or ATM 5640(C) or ATM 5680(C) or ENVE 5515 or PH 5640 or PH 5680 or CEE 5515

#### ATM 5200 - Special Topics in Atmospheric Sciences

Advanced study of topics in the atmospheric sciences. The subject matter may vary from term to term depending on the needs and interests of students.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

#### ATM 5512 - Applied Boundary Layer Meteorology

Study of how forcing phenomena affect transport of water and chemicals in the atmospheric boundary layer and how this transport is measured in the field, including relevant aspects of fluid dynamics, boundary layer structure, surface energy balance, and flux measurement.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

#### ATM 5515 - Atmospheric Chemistry

Study of the photochemical processes governing the composition of the troposphere and stratosphere, with application to air pollution and climate change. Covers radical chain reaction cycles, heterogeneous chemistry, atmospheric radiative transfer and measurement techniques for atmospheric gases.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): CH 3510 or CH 3520 or ENVE 4504 or CEE 4504

**ATM 5516 - Aerosol and Cloud Chemistry**

This course is focused on the chemistry of atmospheric aerosols and cloud processes. Students will learn about methods for chemical characterization, the chemical composition of aerosol and the chemical reactions pertinent to secondary aerosol and cloud composition.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): ATM 5515(C)

**ATM 5519 - Atmospheric Biogeochemistry**

Study of the relationship between atmospheric composition, global change, and the circulation of major elements through the Earth system. Responses of ecosystem emissions to changes in land use, biodiversity, nutrient supply, plant stressors, and climate change are discussed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CH 1150

**ATM 5640 - Atmospheric Physics**

Essential elements of atmospheric physics, including thermodynamics (e.g. adiabatic processes, phase transformations, stratification), aerosol and cloud physics (e.g. nucleation, Kohler theory, growth by condensation and collection), and radiative transfer (e.g. Beer's law, transfer equations with and without scattering).

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2008-2009 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 3530 and PH 2300

**ATM 5680 - Geophysical Fluid Dynamics**

Fundamentals forces and conservation laws that govern fluid flow; applications to the atmosphere and ocean, including balanced flow (pressure gradient and Coriolis Force), vorticity dynamics, turbulence, waves, and boundary layers.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): MA 3530 and PH 2300

**ATM 6999 - Doctoral Research**

Independent research conducted in partial fulfillment of the requirements of the Atmospheric Sciences doctoral degree.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BA 5400 - Financial Risk Management and Decision Making**

Explores the theory and practice of finance and capital markets. Topics include role of the financial manager and goals of the firm, financial mathematics, valuation of assets, cost of capital, project evaluation, capital structure, forecasting, financing vehicles, special topics in finance.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

Pre-Requisite(s): BA 5300

**BA 5610 - Operations Management**

Applications and case studies focusing on contemporary issues in operations and quality management to include lean manufacturing practices, ERP, quality and environmental management systems/standards, Six Sigma, statistical process control, and other current topics.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Data Science, Applied Natural Resource Econ., Accounting, Business Administration

Pre-Requisite(s): MA 2710 or MA 2720 or MA 3710 or EET 2010 or CEE 3710

**BA 5650 - Project Management**

Focuses on project definition, selection, planning, scheduling, implementation, performance monitoring, evaluation and control. Emphasis will be on product, service and process development and emerging concepts related to development on the internet. Some advanced concepts in resource constraint management and design matrix are included.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 2710 or MA 2720 or MA 3710 or EET 2010 or CEE 3710 or BUS 2100

**BA 5700 - Managing Behavior in Organizations**

Discusses managing effectively within the environmental context of the organization. Topics include corporate culture, managing in a global environment, planning and strategy, organizational structure, human resources management, managing change, leadership, motivation, communication, conflict management, and teamwork.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

**BA 5710 - Business and Corporate Strategies**

Introduces students to a repertoire of strategies that have been found useful in the creation of competitive advantage: cost leadership, business model differentiation, vertical integration, diversification, globalization, mergers and acquisitions, tacit collusion, alliance, and flexibility-agility-adaptability strategies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

Pre-Requisite(s): BA 5300 and BA 5400(C) and BA 5700 and BA 5800

**BA 5720 - Launching Entrepreneurial Ventures**

Focuses on the development of new technology-based businesses. Topics include creativity, screening technological opportunities, analyzing markets, testing business concepts, protecting intellectual property, strategy development, entrepreneurial team selection, securing financing, and developing a business plan.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

**BA 5740 - Managing Innovation and Technology**

An evolutionary strategic perspective is taken viewing how technology strategy evolves from underlying technological competencies, patterns of innovation, sources of external technological knowledge and modes of transfer.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Data Science, Applied Natural Resource Econ., Accounting, Business Administration

**Business Administration****BA 5200 - Information Systems Management and Data Analytics**

Focuses on management of IS/IT within the business environment. Topics include IT infrastructure and architecture, organizational impact of innovation, change management, human-machine interaction, and contemporary management issues involving data analytics. Class format includes lecture, group discussion, and integrative case studies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Data Science, Applied Natural Resource Econ., Accounting, Business Administration

**BA 5300 - Financial Reporting and Control**

This class covers the collection, reporting, and analysis of financial information with emphasis on the use of that information to support decision making.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

**BA 5770 - Managing Change**

This course focuses on theory, research, and practice of both 'planned' and 'unplanned' change. The course considers the dynamics of change in complex organizations, variables which facilitate or impede change, and how to lead change and motivate others to change.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

Pre-Requisite(s): BA 5700

**BA 5780 - Managing in the Global Environment**

Course topics may include the following: impact of international political, economic, technological, and social environment forces, currency risks, cross-cultural management issues, strategic challenges for multinational companies, and international joint ventures and alliances.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

Pre-Requisite(s): BA 5700 and BA 5400(C)

**BA 5800 - Marketing, Technology, and Globalization**

The course facilitates students' improvement of analytical skills, information processing techniques, and cultural competence in the globalized marketing environment. Focuses are placed on strategic marketing management, high-tech product marketing, global consumer behavior, branding, and online marketing.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Data Science, Applied Natural Resource Econ., Accounting, Business Administration

**BA 5900 - MBA Internship**

An opportunity to apply the business principles and skills learned in the MBA program to an organizational environment. The guided experience is integrated with coursework to achieve personalized learning objectives.

Credits: variable to 3.0; Repeatable to a Max of 3

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Applied Natural Resource Econ., Business Administration

**BA 5990 - Special Topics**

Business topics of interest to students. Study is under the guidance of a faculty member.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Applied Natural Resource Econ., Business Administration

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**Biomedical Engineering****BE 5000 - Biomedical Masters Research**

Includes the study of an acceptable biomedical engineering problem and the preparation of a report or thesis.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5115 - Finite Element Modeling**

The course teaches both fundamentals of finite element theory and hands-on experience for bio-engineers.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5200 - Cellular and Molecular Biology II**

Covers, at an advanced level, the general principles and engineering applications of science and biology, including cell biology, physiology, molecular biology, genetics, and biotechnology.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5230 - Stem Cell and Tissue Engineering**

This course will introduce basic concepts of tissue engineering; scaffold materials and biotechnologies for tissue engineering; basic concept of stem cells; review of stem cell sources and related policies; current progress in stem cell research, and application of stem cells in tissue engineering and regenerative medicine.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5250 - Biomedical Optics**

Light plays a significant role in modern clinical diagnostics and in the clinical treatment of disease. Examples include non-invasive surgery, optical biopsy, and cancer therapy. This course will focus on the study of how light propagates through biological tissue.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5300 - Polymeric Biomaterials**

A specialized study of polymers used in biomedical engineering. Topics include: processing-structure-properties relationships for polymers, polymer fibers and composites, degradation of polymers, and medical applications for composite biomaterials.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2009-2010 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5330 - Biomimetic Materials**

This course introduces students to biologically inspired approaches to design functional biomaterials. Topics include the discovery and incorporation of biological designs into novel materials and their application in the biomedical field.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5335 - Smart Polymers**

This course introduces students to smart polymers that change their physical properties in response to various environmental stimuli. Topics include the molecular origin of the stimuli responsiveness of these materials and their application in the biomedical field.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2015-2016 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5350 - Cell Biomechanics and Mechanical Transduction**

This course is designed to introduce the mechanical analysis and characterization of mammalian cells. Mechanotransduction, whereby cells detect loading and respond to the morphology and mechanical properties of the surrounding extracellular matrix, will be emphasized.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5390 - Scientific Computing**

Set in a Linux environment, course offers exposure to Foss tools for developing computational and visualization workflows. Students will learn to translate problems into programs, understand sources of errors, and debug, improve the performance of and parallelize the code.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BE 5410 - Medical Imaging**

This course covers the physical nature of the interactions between the waves and matter, especially the biological tissues, principle imaging modalities used in modern medicine and the common techniques used for processing of the resulting images.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5510 - Cardiovascular Engineering**

Fundamental cardiovascular pathology and the biomedical engineering approaches being developed and used toward problems resulting in significant cardiovascular deficiency such as myocardial infarction, chronic kidney disease, atherosclerosis, and heart valve disease.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5550 - Biostatistics for Health Science Research**

An overview course of biostatistical methods used in the health sciences. Topics include a review of undergraduate statistical concepts, NIH, CDC, and FDA guidelines for clinical trial research, proper use of biostatistical methods including anova models, logistic regression, risk analysis, survivorship analysis and any other statistical methods that are common in the enrolled students' discipline.

Credits: variable to 4.0

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 2720 or MA 3710

**BE 5670 - Micro & Nano Technologies**

This course will introduce students to micro- and nano- technologies and the processes involved in their manufacturing. Particular emphasis will be on their use in biomedical applications. Goal is to provide information beneficial in research and development, and the industry.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5700 - Biosensors**

This course introduces the student to the fundamentals of biosensor development and applications. It provides an understanding of biological components, immobilization methods, transducers, and fabrication techniques.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2009-2010 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5755 - Medical Devices**

An introduction to medical devices used for diagnosis, monitoring, and treatment in clinical medicine. Topics covered include product planning, reliability, clinical trial design, regulatory aspects as well as technical aspects of common medical devices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5770 - Biomedical Microcontrollers**

The focus of this course is to provide biomedical engineering students the necessary skills to develop microcontroller-based devices. Provides basic knowledge on computer programming languages, microcontrollers, digital circuits, and microcontroller development kits. Students will design and fabricate a microcontroller-based device using a microcontroller development kit for a specific biomedical application.

Credits: 3.0

Lec-Rec-Lab: (1-0-2)

Semesters Offered: Fall - Offered alternate years beginning with the 2016-2017 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5800 - Advanced Biomaterials Interfaces**

This course introduces the students to the effects of topography and texture on the performance of biomaterials. Special emphasis is placed on tissue engineering scaffolds and microfabrication and nanofabrication techniques.

Some of the topics include: self-organization of biomembranes and supramolecular systems, bioactive materials, and the molecular basis for surface recognition and masking.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5850 - Tissue Mechanics**

This course integrates continuum mechanics, experiments, and computational methods to understand soft tissue mechanics. The first half of the course is dedicated to building continuum mechanics foundation, which will be used to formulate constitutive equations for arteries and the heart in the second half.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5900 - Biomedical Engineering Masters Topics**

Biomedical engineering courses will be offered as professional electives dependent upon the interest of the faculty.

Credits: variable to 6.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 5930 - Biomedical Engineering Topics**

Biomedical engineering courses will be offered on new or emerging technical subjects depending on student demand and faculty interest and expertise.

Credits: variable to 6.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 6000 - Doctoral Research**

Includes the study of an acceptable biomedical engineering problem and the preparation of a report or thesis.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BE 6900 - Biomedical Engineering Doctoral Topics**

Biomedical engineering courses will be offered as professional electives dependent upon the interest of the faculty.

Credits: variable to 6.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

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**Biological Sciences****BL 5012 - Graduate Seminar in Biology**

Graduate students will listen to seminars given by visiting scientists that pertain to various research topics in biology. Through assignments students will gain experience in summarizing seminars and learning what makes a "good" seminar.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BL 5021 - Biochemistry II**

Dynamic aspects of living systems. Broad exposure to cellular metabolic pathways, intermediary metabolism and its regulation and bioenergetics.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): BL 4010

**BL 5025 - The Scientific Profession**

The practice of sciences for graduate students, including how to plan a research project, grantsmanship, publication, navigating the job market, and timely issues (e.g. ethical conduct, diversity and bias, etc.).

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**BL 5030 - Molecular Biology**

Molecular biology of gene structure, expression and regulation. Molecular techniques and their application to biotechnology and genomes are covered.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BL 5034 - Community Ecology and Evolutionary Dynamics**

This is an advanced course that looks at the study of ecology and evolutionary biology at the community level: how populations interact with the abiotic environment and each other to determine patterns of diversity, distribution, and abundance of plants and animals.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 3400 and BL 3190

**BL 5035 - Bioimaging**

Current concepts in light and electron microscopy and scanning probe techniques. Theory and practice of fluorescence (including confocal and multi-photon), atomic force, scanning and transmission electron, and video microscopy as applied to biological specimens with an emphasis on sample preparation. Emphasis will be placed on application of advanced techniques. Half semester course.

Credits: 2.0

Lec-Rec-Lab: (0-4-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**BL 5036 - Ecology and Evolution of Interactions Between Plants, Herbivores, and Pollinators**

Plants, herbivores, and pollinators have played major roles in influencing each others evolutionary diversification. We will examine the ecology and evolution of plant-herbivore- pollinator interactions in basic and applied contexts. A solid foundation of tools in ecology and evolution will be established and class will include lectures and interactive discussions from readings of primary literature. Students will design, conduct, and analyze independent research projects in the lab.

Credits: 3.0

Lec-Rec-Lab: (2-0-2)

Semesters Offered: Summer - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 3400 and BL 3190

**BL 5038 - Epigenetics**

An introduction to the fundamentals of epigenetic control that is not encoded by genomic DNA sequences of an organism. Topics include major regulatory mechanisms including DNA methylation, histone modification, and non-coding RNA (ncRNA) mediated gene regulation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 3300 or BL 4030

**BL 5042 - Scanning Electron Microscopy of Biological Specimens**

Hands-on training in operation of the scanning electron microscope (SEM). Students prepare biological specimens of their choice for observation. Emphasis will be placed on application of advanced techniques. Successful completion of course is prerequisite to becoming a certified SEM operator in the ACMAL. Half semester course.

Credits: 2.0

Lec-Rec-Lab: (0-2-6)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Co-Requisite(s): BL 5035

**BL 5044 - Human Pathophysiology**

Course will cover abnormal function (physiology) and investigate the signs and symptoms of major diseases in humans. Extension of Anatomy & Physiology by working through the systems of the human body. Course will include a clinical focus and case-study approach.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2020-2021 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 2010 and BL 2020

**BL 5051 - Scientific Writing and Publishing**

This course is designed to give graduate students the skills necessary to write and publish scientific journal articles. Topics covered include: general principles of scientific writing, plagiarism and ethics in publishing, critical evaluation of scientific articles, and using reviewers' comments to improve the quality of articles.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**BL 5052 - Fluorescence and Video Microscopy of Biological Sciences**

Hands-on training in fluorescence microscopy and video microscopy. Students prepare biological specimens of their choice for observation. Emphasis will be placed on application of advanced techniques. Half semester course.

Credits: 2.0

Lec-Rec-Lab: (0-2-6)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): BL 5035

**BL 5062 - Transmission Electron Microscopy of Biological Specimens**

Hands-on training in operation of the transmission electron microscope (TEM). Students prepare biological specimens of their choice for observation. Emphasis will be placed on application of advanced techniques. Successful completion of course is prerequisite to becoming a certified TEM operator in the ACMAL. Half semester course.

Credits: 2.0

Lec-Rec-Lab: (0-2-6)

Semesters Offered: Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): BL 5035

**BL 5070 - Environmental Toxicology**

Introduction to the range anthropogenic pollutants released into the environment. Concepts of bioaccumulation, biomagnification and environmental persistence, modes of toxicity and detoxification, transport and fate in aquatic and terrestrial ecosystems. Toxic equivalent factors and quotients, regulatory guidelines and practices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Medical Laboratory Science, Biochem & Molec Biology-Bio Sc, Bioinformatics, Pharmaceutical Chemistry

Pre-Requisite(s): (BL 1020 or BL 1040) and CH 1160

**BL 5120 - Environmental Remediation**

Toxicology of major environmental pollutants, their dose-response relationships and fundamentals of environmental remediation. Topics include physical, chemical, and biological remediation methods and effect of environmental toxins on biological systems. Laboratory will involve the application of chemical and biological remediation techniques.

Credits: 3.0

Lec-Rec-Lab: (2-0-2)

Semesters Offered: Fall - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): BL 1020 or BL 1040

**BL 5145 - Plant-Microbe Interactions**

Interactions between plants and microorganisms in the environment. Topics include microbial virulence, signaling, gene expression, beneficial interactions and disease resistance in plants. Laboratory will focus on plant biochemical and microbiological methods as they relate to environmental problems.

Credits: 3.0

Lec-Rec-Lab: (2-0-2)

Semesters Offered: Fall - Offered alternate years beginning with the 2012-2013 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**BL 5200 - Microbial Physiology**

Structure and function of microorganisms, with emphasis on mechanisms for responding to changing environmental and nutritional conditions.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 3210 or BL 3310

**BL 5300 - Applied Genomics**

This course is an overview of techniques involved in genomics including hands-on experience in next-generation sequencing (NGS) platforms, and NGS sequence analysis including de novo assembly, gene annotation, and analysis including comparative genomics, pathway mapping, and core and pan genome analysis.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

**BL 5340 - Special Topics in Biology**

A discussion of recent developments in the biological sciences. Recent offerings have included population genetics, taxonomy of aquatic insects, herpetology, bryology, fungi, and lichens.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5350 - Special Topics in Physiology**

A discussion of recent developments in physiology. Recent offerings have included respiratory physiology, renal physiology, clinical cardiology, and neurophysiology.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5360 - Special Topics in Biochemistry**

A discussion of recent developments in the field of biochemistry. Topics taught recently include steroid biochemistry, immunology, and metabolic control theory.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5370 - Special Topics in Microbiology**

A discussion of recent developments in the field of microbiology. Topics taught recently include bacterial genetics, industrial microbiology, and advanced microbial ecology.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5371 - Advanced Cell Biology**

This course is to develop an understanding of the structure and function of the cell. Course topics include details of basic genetic mechanisms, cell structure and function, and examination of cells in their social context.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): (BL 2200 or BL 3012) and (CH 2420 or BL 4010)

**BL 5380 - Special Topics in Ecology**

A discussion of recent developments in the field of ecology. Topics taught recently include systems ecology, ecology of Great Lakes fisheries, ecology of algae, aquatic macrophytes, and world ecosystems.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5390 - Special Topics in Clinical Laboratory Science**

A discussion of recent developments in clinical laboratory science.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5400 - Special Topics in Plant Sciences**

A discussion of recent developments in plant science. Topics may include biotechnology, physiology, systematics, phylogenetics, biochemistry, and molecular genetics.

Credits: variable to 10.0; Repeatable to a Max of 10

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**BL 5421 - Lake Superior Exploration**

Field intensive course with significant time spent on a research vessel (R/V Agassiz or some other) where students will learn the use of a variety of state-of-the-art techniques to characterize biological communities and measure important physical and biological processes.

Credits: 3.0

Lec-Rec-Lab: (4-0-6)

Semesters Offered: Summer - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BL 5447 - Stream Ecology**

Field course combining river and stream ecosystem and foodweb study with fishes in lake systems. Students will be exposed to research methods used in lakes for comprehensive abiotic and biotic understanding.

Credits: 4.0

Lec-Rec-Lab: (3-0-3)

Semesters Offered: Summer - Offered alternate years beginning with the 2019-2020 academic year

**BL 5451 - Advanced Ecology**

This course will provide advanced coverage of ecological pattern, science, and theory of aquatic and terrestrial systems and their interface. Topics will range from individuals and populations to communities and landscapes. Lectures and discussions will be guided by published literature.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Permission of instructor required

**BL 5461 - Ecosystem Ecology**

History, key concepts, and practice of ecosystem ecology in aquatic and terrestrial environments. Emphasizes inter-connectedness of energy and nutrient flows globally and in regional case studies.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 3400 and CH 1122 or (CH 1160 and CH 1161)

**BL 5500 - Graduate Seminar in Biological Sciences**

Analysis, evaluation, and synthesis of primary scientific literature on a specific topic in recitation/discussion format.

Credits: 1.0; Repeatable to a Max of 4

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BL 5501 - Graduate Research Seminar Ecology/Environmental**

Seminar is designed to facilitate critical discussions of student research projects at various stages of their development. The presenter will provide an overview or seminar on their project and research goals, which will establish the foundation for the discussion thereafter.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**BL 5503 - Graduate Research Seminar Biomolecular**

Seminar is designed to facilitate critical discussions of student research projects at various stages of their development. The presenter will provide an overview or seminar on their project and research goals, which will establish the foundation for the discussion thereafter.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**BL 5678 - Biological Sciences Field Service**

This course provides a supervised field experience in biological sciences, natural resources, and community development.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Biological Sciences

**BL 5752 - Cancer Biology**

Emphasis on characteristic genetic, molecular, and cellular changes leading to cancer. Topics will include the role of tumor viruses, oncogenes, tumor suppressors, immortalization, apoptosis, and angiogenesis in cancer initiation, and/or progression. Consideration of current therapies and future directions for treatment.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 3012 or BL 4370 or BE 2400

**BL 5800 - Molecular Diagnostics**

This course provides the scientific background behind modern molecular techniques applied in the diagnosis of human diseases. Topics to be covered include nucleic acid structure and function as well as introduction to nucleic acid characterization techniques used in disease diagnosis and genetic disorders.

Credits: 5.0

Lec-Rec-Lab: (3-0-2)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BL 5990 - Masters Research in Biological Sciences**

An original investigation in biology that culminates in a thesis.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**BL 5994 - International Biological Sciences Practicum**

Thesis or project work conducted by graduate students enrolled in the Peace Corps Master's International Program in Biological Sciences.

Credits: 1.0; Repeatable to a Max of 18

Lec-Rec-Lab: (0-0-1)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Biological Sciences

**BL 6990 - Doctoral Research in Biological Sciences**

An original investigation in theoretical or experimental biology, or both, and submission of a dissertation in partial fulfillment of the requirements for the PhD degree.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

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## Biochemistry & Molecular Biology

### BMB 6010 - Advanced Biochemistry

Course will focus on the relationships between structure and function of proteins, nucleic acids, lipids, and carbohydrates. Specific topics include enzyme catalysis; binding and allostery; protein-protein, protein-carbohydrate, and protein-nucleic acid interactions; membrane function, and, signal transduction.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### BMB 6020 - Advanced Molecular Biology

Course will focus on gene structure, gene duplication, gene expression, gene regulation, DNA recombination, DNA repair and transposition. Comparison between prokaryotes and eukaryotes will be drawn. Genomics and modern biotechnology methods will be discussed. Classic and current papers may accompany the lecture material. Foundations in basic biochemistry and molecular biology are required for this course.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### BMB 6030 - Modern BMB Laboratory

This is an intensive laboratory course that focuses on protein chemistry, nucleic acid chemistry, genomics and biotechnology. Students will rotate between research labs of four faculty where they will gain in-depth laboratory experience in modern biochemistry and molecular biology.

Credits: 3.0

Lec-Rec-Lab: (0-0-9)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### BMB 6990 - Doctoral Research in Biochemistry and Molecular Biology

Original research that culminates in a PhD dissertation.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

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## Civil & Environmental Engineering

### CEE 5101 - Bituminous Materials

Applications and properties of asphalt binder, aggregates for bituminous mixtures, and analysis and design of asphalt concrete mixtures. Includes asphalt cement production, rheology, chemistry, and grading, aggregate grading and blending, and mixture design and characterization. Also discusses asphalt mixture production, construction, and recycling.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CE 3101 or CEE 3101

### CEE 5102 - Advanced Concrete Materials

Properties and applications of portland cement and portland cement concrete. Includes cement production, chemistry and hydration, concrete admixtures, and the properties of fresh and hardened concrete. Presents concrete microstructure and durability. Other topics include high-strength and high early-strength concrete, fiber-reinforced concrete, and advanced cement-based materials.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### CEE 5109 - Sustainable Pavement Engineering and Civil Engineering Materials

This class will develop fundamental knowledge of sustainable pavements, recycled materials, asphalt and concrete materials, basic concept of characterization of pavement materials, data analysis, and basic modeling procedures. The course will cover a wide range of advanced knowledge of sustainable pavements and materials.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Permission of instructor required

Pre-Requisite(s): CE 3101 or CEE 3101

### CEE 5190 - Special Topics in Civil Engineering Materials

Advanced study of materials related topics, including discussions of recent research developments at an advanced level.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

### CEE 5201 - Advanced Structural Analysis

The study of nonlinear structural analysis techniques, especially energy methods, applied to elastic buckling analysis, large deflections of beams, second-order effects in frames, plastic analysis of steel structures, and yield analysis of concrete beams and slabs.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2016-2017 academic year

Pre-Requisite(s): CE 4201 or CEE 4201

### CEE 5202 - Finite Element Analysis

Introduction to the use of finite element methods in structural analysis. Covers the finite element formulation, 1- and 2-D elements, including isoparametric elements, axisymmetric analysis, plate and shell elements, dynamics, buckling, and nonlinear analysis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CE 4201 or CEE 4201

### CEE 5212 - Prestressed Concrete Design

Theory of prestressed and post-tensioned members. Covers analysis and design of prestressed concrete beams, slabs, box girders, and bridge girders by elastic and ultimate strength methods. Precast and cast-in-place system construction techniques will be included.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): CE 4213 or CEE 4213

### CEE 5213 - Concrete and Masonry Building Systems

Design of reinforced concrete two-way slabs and reinforced masonry systems for buildings. Includes design of bearing walls, shear walls, lintels, pilasters, slender columns, torsional beams and connections. A design project may be included during the semester.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): CE 4213 or CEE 4213

### CEE 5223 - Steel Design II

Additional topics in steel design including beam-columns, floor vibrations, diaphragms, buckling behavior of thin elements, torsional buckling, and beam and column bracing. Includes an introduction to cold-formed steel design.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CE 4223 or CEE 4223

### CEE 5233 - Advanced Structural Timber Design

Advanced design of timber structures, including arches and traditional timber frames, advanced shear wall design, advanced connection design, including timber connectors, and advanced analysis and behavior of wood, including cumulative damage modeling.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2011-2012 academic year

Pre-Requisite(s): CE 4233 or CEE 4233

### CEE 5241 - Structural Dynamics

Free and forced vibration of undamped and damped single degree of freedom systems. Multiple degree-of-freedom systems, including shear buildings and frames. Basic seismic design.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): CE 4201 or CEE 4201(C)

### CEE 5242 - Advanced Structural Dynamics

Earthquake engineering and advanced dynamic analysis. Includes time history response of multiple degree-of-freedom systems, seismicity, equivalent static force method, modal analysis, base isolation, soil-structure interaction, and an introduction to random vibrations.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CE 5241 or CEE 5241

### CEE 5250 - Special Topics in Structural Engineering

Advanced study of structural engineering topics, including discussions of recent research developments at an advanced level. Topics might include loading analysis, advanced topics in steel design, composite materials for structures, and behavior of a variety of reinforcements for concrete applications.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5261 - Bridge Design and Construction**

Introduction to design and behavior of short and medium span bridges. Topics include aesthetics, preliminary design and layout, design of prestresses and plate girders bridges, deck design, foundation design. Project may alternate between structural steel and prestressed concrete member design.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): (CE 4213 or CEE 4213) and (CE 4223 or CEE 4223)

**CEE 5350 - Infrastructure Life Cycle Engineering**

The course examines how life cycle assessment (LCA), life cycle costing analysis (LCCA), green rating systems, value engineering and alternative project delivery systems influence design decisions and project outcomes. Topics will be discussed within the context of the underlying scientific principles and relevant standards.

Credits: 3.0

Lec-Rec-Lab: (2-0-1)

Semesters Offered: Spring - Offered alternate years beginning with the 2020-2021 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CEE 5390 - Special Topics in Construction Engineering**

Advanced study of construction engineering topics including discussion of recent research developments.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

**CEE 5400 - Pavement Design**

Analysis, behavior, performance, and structural design of highway pavements. Introduces pavement types and performance concepts, highway traffic and subgrade characterization, materials employed in highway construction, and highway drainage. Presents common methods used for designing pavement structures as well as mechanistic- empirical approaches.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): (CE 3401 or CEE 3401) and (CE 3101 or CEE 3101)

**CEE 5401 - Advanced Pavement Design**

Advanced analysis, behavior, performance, and structural design of highway and airport pavements. Focuses on mechanistic characterization of pavement structures and approaches used to characterize existing structures for the purpose of rehabilitation. Subjects include advanced materials characterization, mechanistic modeling, nondestructive testing, and pavement rehabilitation. Includes airport pavement design and rehabilitation.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): (CE 3401 or CEE 3401) and (CE 3101 or CEE 3101)

**CEE 5402 - Traffic Flow Theory**

This course is an introduction to traffic flow theory. Course is concerned with the behavior of vehicular traffic as a complex system through the development of mathematical models of these processes. Topics will include macroscopic and microscopic traffic flow theory, as well as connected and automated vehicles.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CEE 4402

**CEE 5404 - Transportation Planning**

An introduction to urban transportation planning, planning data collection, transportation planning models, and development and evaluation of transportation plans. Includes extensive use of transportation planning software to evaluate transportation plans in multimodal networks.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

**CEE 5408 - Public Transit**

An introduction to public transit, user characteristics, management, transit modes, data collection and surveys, planning, operations, scheduling, transit finances, and future trends.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CEE 5414 - Railroad Engineering**

Rail transportation systems require infrastructure, vehicles, motive power and energy, and control systems to move goods and people. This multi-disciplinary course provides students with understanding of these system components and related engineering and technology enabling efficient operation of today's system.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CEE 3490 or CE 4490

**CEE 5417 - Transportation Design**

Introduction to computer aided geometric design of highways and railways. Covers design principles and use of standards for horizontal and vertical alignments and cross sections, including road intersections, railway turnouts and grade crossings. Students develop engineering drawings and related cost estimates for road/rail project.

Credits: 4.0

Lec-Rec-Lab: (3-0-2)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): (CE 3401 or CEE 3401) and SU 2000

**CEE 5490 - Special Topics in Transportation Engineering**

Topics of special interest in transportation engineering.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**CEE 5501 - Environmental Process Engineering**

Review of mass transfer, kinetics, reactor design, and mathematical modeling principles. Includes illustration by application to several important natural systems and environmental engineering unit processes. Mathematical models of selected environmental engineering systems are developed and solved using PCs.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5502 - Biological Treatment Processes**

Application of kinetics, reactor theory, and microbiology to modeling and design of aerobic and anaerobic wastewater treatment systems. Topics include activated sludge process models and application of these models to process design and operation.

Credits: 3.0

Lec-Rec-Lab: (0-2-3)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ENVE 4502 or CEE 4502 or ENVE 4508

**CEE 5503 - Physical-Chemical Treatment Processes**

Advanced theory, fundamentals, and application of physical and chemical processes employed in design and operation of drinking water treatment systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ENVE 5501 or CEE 5501

**CEE 5504 - Modeling and Management of Lakes and Rivers**

Principles of surface water quality management are introduced and examined in the context of the mathematical models used to design and test lake and river management strategies. Case histories and guest lectures will be provided to broaden students' exposure.

Credits: 3.0

Lec-Rec-Lab: (0-2-3)

Semesters Offered: Spring

Pre-Requisite(s): ENVE 4505 or CEE 4505 or BL 4450

**CEE 5508 - Global Biogeochemistry**

This course gives an overview of important biogeochemical processes occurring in land, air, and water. An emphasis is put on modeling as an integrating tool.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2015-2016 academic year

Pre-Requisite(s): ENVE 4501 or CEE 4501

**CEE 5509 - Transport and Transformation of Organic Pollutants**

Assessment of factors controlling environmental fate, distribution, and transformation of organic pollutants. Thermodynamics, equilibrium, and kinetic relationships are used to quantify organic pollutant partitioning and transformations in air, water, and sediments. Use of mass balance equations to quantify pollutant transport.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Pre-Requisite(s): ENVE 4501 or CEE 4501 or CH 3510

**CEE 5510 - Practical Applications and Analytical Techniques for Environmental Measurements**

Develop methods and skills for laboratory work required for experimental research in environmental engineering. Topics include laboratory safety, quality control/quality assurance, purchasing, and use of analytical equipment. Students select one or more of the following topics for specialized study: GC, AA, carbon analysis, HPLC, UV/Vis spectroscopy, liquid scintillation counting.

Credits: variable to 3.0

Semesters Offered: Fall, Summer

Restrictions: Permission of instructor required

**CEE 5512 - Applied Boundary Layer Meteorology**

Study of how forcing phenomena affect transport of water and chemicals in the atmospheric boundary layer and how this transport is measured in the field, including relevant aspects of fluid dynamics, boundary layer structure, surface energy balance, and flux measurement.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5515 - Atmospheric Chemistry**

Study of the photochemical processes governing the composition of the troposphere and stratosphere, with application to air pollution and climate change. Covers radical chain reaction cycles, heterogeneous chemistry, atmospheric radiative transfer, and measurement techniques for atmospheric gases.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ENVE 4501 or CEE 4501 or ENVE 4504 or CEE 4504 or CH 3510

**CEE 5517 - Soil Biogeochemistry**

Study of the relationship between soil composition and the circulation of major elements through the earth system. Responses of biogeochemical cycles of the elements in agricultural, forest, grassland, and wetland soils to changes in landuse, biodiversity, nutrient supply, plant stressors, and climate change will be discussed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): CH 1150

**CEE 5518 - Aquatic Biogeochemistry**

Covers interactions among chemical, biological, and physical processes within aquatic ecosystems as well as role of aquatic ecosystems in global biogeochemistry. Modeling as an integrative tool is stressed.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CEE 5519 - Atmospheric Biogeochemistry**

Study of the relationship between atmospheric composition, global change, and the circulation of major elements through the Earth system. Responses of ecosystem emissions to changes in landuse, biodiversity, nutrient supply, plant stressors, and climate change are discussed.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

**CEE 5520 - Introduction to Hydrodynamic Modeling**

Introduce fundamental concept and numerical methods used in hydrodynamic modeling, physical process in the hydrodynamic system and their numerical representation using governing equations. Students construct simplified numerical models with application to problems of coastal oceans and large lakes, as well as engineering systems of interest to environmental and other engineers.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): MA 3520 or MA 3521 or MA 3530 or MA 3560

**CEE 5521 - Bioremediation Engineering**

Introduction to the microbiological and engineering fundamentals of bioremediation. Topics include relevant microbial biochemistry, physiology, and ecology; necessary site data; design and operation of current and emerging bioremediation systems; monitoring methods for bioremediations projects; and technical evaluation of selected case studies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CEE 5560 - Advanced Topics in Air Quality Engineering**

Advanced study of topics related to atmospheric chemistry and/or modeling the transformation and transport of atmospheric pollutants.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**CEE 5561 - Advanced Topics in Biological Processes**

Advanced study of biological processes associated with natural and engineering systems.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**CEE 5562 - Advanced Topics in Physical-Chemical Processes**

Advanced study of physical and chemical processes that occur in natural and engineered systems.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**CEE 5563 - Advanced Topics in Surface Water Quality Engineering**

Advanced topics related to understanding the biogeochemistry of surface waters (lakes, rivers, wetlands) and the mathematical modeling of those systems.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**CEE 5590 - Special Topics in Environmental Engineering**

Advanced study of environmental engineering topics including discussion of recent research developments.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

**CEE 5620 - Stochastic Hydrology**

Application of statistics to problems in surface hydrology. Topics include the flood flow and streamflow frequency analysis, goodness-of-fit tests, model selection, treatment of historical and censored data, regionalization and regression, time series analysis, Bayesian inference, sensitivity and uncertainty analysis methods.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): CEE 3620 and (CEE 3710 or CEE 3502 or MA 3710)

**CEE 5630 - Advanced Hydrology**

Students will understand hydrologic processes such as transpiration, evaporation, infiltration, base flow, and surface runoff. Students will learn principles of hydrometeorology, principles of sustainability applied to surface water resources, how to collect/analyze hydrologic data, and how to predict/estimate hydrologic responses.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CE 3620 or CEE 3620

**CEE 5640 - Stormwater Management and LID**

Design techniques for stormwater collection, conveyance, infiltration, and detention storage systems are discussed, both traditional stormwater management systems and newer approaches based on the philosophy of low impact development (LID) that seek not to alter the natural ecology of a site.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Summer

Pre-Requisite(s): CE 3620 or CEE 3620

**CEE 5665 - Stream Restoration**

Basin mechanics of the transport of sediments in natural systems, including tractive forces and geomorphic functions.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CE 3620 or CEE 3620

**CEE 5666 - Water Resources Planning and Management**

Economic and environmental aspects of water use. Topics include flood damage reduction, water demand and hydrologic forecasting, water supply planning, and water resource systems operation.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Pre-Requisite(s): (CE 3620 or CEE 3620) and EC 3400

**CEE 5680 - Geophysical Fluid Dynamics**

Fundamental forces and conservation laws that govern fluid flow; applications to the atmosphere and ocean, including balanced flow (pressure gradient and Coriolis Force), vorticity dynamics, turbulence, waves and boundary layers.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): PH 2300 and (MA 3520 or MA 3521 or MA 3530 or MA 3560)

**CEE 5690 - Special Topics in Water Resources**

Advanced study of water resources topics including discussion of recent research developments.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

**CEE 5710 - Modeling and Simulation Applications for Decision-Making in Complex Dynamic Systems**

Introduces students to the theory and application of modeling techniques and simulations in the analysis of decision alternatives in complex engineering problems. Topics include queuing theory, system dynamics modeling, agent-based modeling, discrete event simulations, etc. Students will be required to conceptualize and implement an appropriate research/engineering problem of choice (this could be a dissertation/thesis problem).

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5730 - Probabilistic Analysis and Reliability**

Examines probabilistic analysis of engineering systems including first-order methods, Monte Carlo simulation, and time-to-failure analysis. Reliability analysis will include capacity/demand reliability and system reliability. Emphasis will be on civil and environmental engineering systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): CE 3710 or CEE 3710 or MA 3710

**CEE 5740 - Frequency-Domain Modeling and Identification of Continuous Civil Engineering Systems**

Introductory course in modeling of continuous systems with an emphasis on frequency and complex-domain analysis for civil engineering systems. Potential applications include system identification and control. Preliminary topics include data acquisition and signal conditioning, Fourier, Laplace, and Z-transforms.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 3520 or MA 3521 or MA 3530

**CEE 5760 - Optimization Methods in Civil and Environmental Engineering**

Decision analysis and optimization techniques, including linear programming, nonlinear programming, and dynamic programming. Computer-based solutions of design problems in various civil and environmental engineering specialty areas are considered.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): MA 2160 and (MA 2320 or MA 2321 or MA 2330)

**CEE 5800 - Mathematical Modeling of Earth Systems**

Introduction to numerical techniques for mathematical modeling of various earth-system phenomena, including groundwater flow, heat transfer, and atmospheric transport. Numerical techniques covered include finite-difference, finite-element, collocation, and characteristic methods. Students write their own mathematical models. Prerequisite: experience in programming computer languages such as FORTRAN.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5810 - Advanced Soil Mechanics**

Provides advanced studies in the topics of soil compressibility and soil strength.

Develop advanced procedures for determining stress distribution and stress changes from a fundamental basis. Students are strongly advised to take CE5820 concurrently.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Pre-Requisite(s): CE 3810 or CEE 3810

**CEE 5811 - Fundamentals of Soil Behavior and Engineering Laboratory**

The course will focus on the fundamentals of soil behavior through coursework and laboratory investigation. Coursework will include soil formation, composition, engineering properties, conduction phenomena, strength, and volume change. Laboratory testing will include 1D consolidation, permeability, and monotonic and cyclic triaxial testing.

Credits: 4.0

Lec-Rec-Lab: (3-0-3)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CE 5810 or CEE 5810

**CEE 5870 - Multiphysics of Porous Materials**

Overview of multiphysics, typical multiphysical phenomena in porous materials, and the simulation of these phenomena using numerical techniques.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): MA 2160

**CEE 5890 - Special Topics in Geotechnical Engineering**

Advanced study of geotechnical engineering topics including discussion of recent research developments.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5920 - Civil Engineering Independent Study**

Approved research or design project in civil engineering, originating with an individual student or assigned by the instructor.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CEE 5930 - Environmental Engineering Independent Study**

Approved research or design project in environmental engineering, originating with an individual student or assigned by the instructor.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5990 - Civil Engineering Graduate Seminar**

Detailed study and group discussions of current literature and graduate research projects related to the broad field of civil engineering. Topics will be combined to address the student's area of interest, including construction, environmental, geotechnical, structures, transportation, and water resources. External speakers discuss current related issues.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 5991 - Environmental Engineering Graduate Seminar I**

Presentations and discussion of current literature and research related to the broad field of environmental engineering.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Environmental Engineering, Civil Engineering

**CEE 5992 - Environmental Engineering Graduate Seminar II**

Presentations and discussion of current literature and research related to the broad field of environmental engineering.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Environmental Engineering, Civil Engineering

**CEE 5993 - Engineering with Developing Communities**

Study of applying appropriate, community-based, and sustainable engineering in developing communities. Concepts of human-centered design and sustainable development are covered. Topics are drawn from several areas of engineering, including water and wastewater treatment, construction materials, solid waste, energy, and information systems.

Credits: 2.0

Lec-Rec-Lab: (0-1-2)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): (ENG 2120 or MEEM 2150) and (CE 3620 or CEE 3620)

**CEE 5994 - International Civil & Environmental Engineering Field Experience**

Field work and reporting from students in the Peace Corps Master's International Program in Civil & Environmental Engineering.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-2)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CEE 5997 - Natural Resources Engineering Field Service**

This course provides a supervised field experience in natural resources engineering and community development.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CEE 5998 - Engineering Design Practicum**

Advanced independent study for students in the Master of Engineering program.

In consultation with student's advisor, develop and execute a project demonstrating capabilities in problem solving, communications, and decision making. The practicum can be done on campus or at the site of a Michigan Tech corporate partner.

Credits: variable to 4.0; Repeatable to a Max of 4

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CEE 5999 - Master's Research**

Study of an acceptable civil or environmental engineering problem and preparation of a report or thesis.

Credits: variable to 10.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CEE 6999 - Doctoral Research**

Original research leading to the preparation of a dissertation in partial fulfillment of the requirements for the PhD degree.

Credits: variable to 10.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Environmental Engineering, Engineering - Environmental, Civil Engineering

**CH 5130 - Professional Development: Chemical Safety**

The course will examine Michigan Tech's Chemical Hygiene Plan, understand responsibilities as lab workers, learn how to write Standard Operating Procedures, how to conduct safety inspections, how to be safer in a chemical lab environment and review OSHA rules and regulations regarding conducting research in a chemical laboratory.

Credits: 1.0

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): CH 3510 or CH 3540

**CH 5140 - Introduction to Pharmaceutical Analysis**

This course will present a systematic introduction to chemical analysis of pharmaceutical raw materials, finished pharmaceutical products, and of drugs in biological fluids, which are carried out in pharmaceutical laboratories worldwide.

Credits: 3.0

Lec-Rec-Lab: (2-0-2)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 5210 - Analytical Separations**

Covers theory and applications of modern gas chromatography, high performance liquid chromatography, and ion chromatography as well as instrumentation for these techniques. Studies trace organic analysis and environmental problems.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CH 5240 - Advanced Mass Spectrometry**

Advanced instrumentation and methods are the focus of this course. Design of various mass analyzers and their advantages and limitations will be reviewed. Advanced identification methods such as tandem mass spectrometric analysis and exact mass analysis will be discussed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CH 4212 or CH 4222

**CH 5241 - Advanced Mass Spectrometry Laboratory**

Students will learn how to perform mass spectrometry (MS) experiments to identify and quantify molecules. The experiments will include the following method approaches: electrospray ionization (ESI), matrix associated laser desorption ionization (MALDI) and tandem MS analysis (MS/MS).

Credits: 1.0

Lec-Rec-Lab: (0-0-1)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Co-Requisite(s): CH 5240

Pre-Requisite(s): CH 4212 or CH 4222

**CH 5310 - Advanced Inorganic Chemistry**

Covers the organometallic chemistry of the transition elements, beginning with a historical overview of the subject, as well as basic ideas in complex and transition metal chemistry.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Pre-Requisite(s): CH 4320

**CH 5410 - Advanced Organic Chemistry: Reaction Mechanisms**

Advanced study of mechanistic organic and physical organic chemistry intended to bring the student to the level of current research activity. Topics may include methods for determining organic reaction mechanisms, chemical bonding as it applies to organic compounds, structure-reactivity relationships, molecular rearrangements, and molecular orbital theory.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 5412 - Spectroscopy of Organic Chemistry**

Emphasizes spectral data interpretation to determine structures of organic compounds. Discuss proton and carbon nuclear magnetic resonance (including two-dimensional techniques), training to perform structural analysis (UV, NMR, MS); will be given unknown organic molecules for analysis and structural elucidation.

Credits: 3.0

Lec-Rec-Lab: (2-0-2)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

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## Chemistry

**CH 5110 - Pharmaceutical Chemistry: Drug Action**

Focuses on structural and mechanistic approaches to pharmaceuticals and drug action. General principles of absorption, distribution, action, metabolism, and toxicity of drugs will be presented followed by action of drug classes such as antibiotics, cardiovascular, and anti-inflammatory drugs.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 5120 - Pharmaceutical Chemistry: Drug Design**

Focuses on the important concepts in the design and synthesis of drugs. Rational basis for drug design including synthetic, computational, and biochemical concepts will be discussed. Topics include structure-activity relationships, synthesis and reaction mechanism, and case studies of drugs.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 5420 - Advanced Organic Chemistry: Synthesis**

Advanced study of organic reactions and synthetic organic chemistry intended to bring the student to the level of current research activity. Topics may include retrosynthetic analysis and synthesis design, synthons, protecting groups, and analysis of syntheses from recent literature.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 5509 - Transport and Transformation of Organic Pollutants**

Assessment of factors controlling environmental fate, distribution, and transformation of organic pollutants. Thermodynamics, equilibrium, and kinetic relationships are used to quantify organic pollutant partitioning and transformations in air, water, and sediments. Use of mass balance equations to quantify pollutant transport.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2005-2006 academic year

Pre-Requisite(s): ENVE 4501 or CEE 4501 or CH 3510

**CH 5515 - Atmospheric Chemistry**

Study of the photochemical processes governing the composition of the troposphere and stratosphere, with application to air pollution and climate change. Covers radical chain reaction cycles, heterogeneous chemistry, atmospheric radiative transfer, and measurement techniques for atmospheric gases.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CH 3510 or ENVE 4501 or ENVE 4504 or CEE 4501 or CEE 4504

**CH 5516 - Aerosol and Cloud Chemistry**

This course is focused on the chemistry of atmospheric aerosols and cloud processes. Students will learn about methods for chemical characterization, the chemical composition of aerosol and the chemical reactions pertinent to secondary aerosol and cloud composition.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CH 5517 - Soil Biogeochemistry**

Study of the relationship between soil composition and the circulation of major elements through the earth system. Responses of biogeochemical cycles of the elements in agricultural, forest, grassland, and wetland soils to changes in landuse, biodiversity, nutrient supply, plant stressors, and climate change will be discussed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CH 5519 - Atmospheric Biogeochemistry**

Study of the relationship between atmospheric composition, global change, and the circulation of major elements through the earth system. Responses of ecosystem emissions to changes in landuse, biodiversity, nutrient supply, plant stressors, and climate change are discussed.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CH 5520 - Chemical Kinetics**

An advanced study of chemical reaction rates, collision theory, enzyme kinetics, reaction dynamics, transition state theory, photochemistry, atmospheric chemistry, including methods of analysis and theory of rate processes.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): CH 3510

**CH 5535 - Physical Chemistry III - Molecular Driving Forces from Fundamentals to Applications**

Advance course design to bridge concepts in thermodynamics, kinetics, and quantum chemistry through the application of statistical mechanics to understand the molecular driving forces acting in chemical/physical/material/biological systems at both microscopic, and macroscopic level.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CH 3510 and CH 3520

**CH 5550 - Solid State Chemistry**

Introduces principles of solid state chemistry and the application to produce compounds with the desired physical and chemical properties. Discusses reactivity, preparation techniques, structure, impurity or dopant effects, phase transformations, electric and magnetic properties, and point defect chemistry.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): CH 3520

**CH 5560 - Computational Chemistry**

Focuses on the theory and method of modern computational techniques applied to the study of molecular properties and reactivity through lecture and computer projects. Covers classical mechanical as well as quantum mechanical approaches.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Pre-Requisite(s): CH 3520

**CH 5570 - Advanced Biophysical Chemistry**

A discussion of experimental techniques and applications of physical chemistry principles to the study of the structure, dynamics, and chemical reactions of proteins, nucleic acids, and other biopolymers.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): CH 3520

**CH 5665 - Surface and Interface Science for Chemical and Materials Analysis**

Coursework and hands-on laboratory experiences explore physical and chemical properties governing surface processes and the appropriate analysis techniques used to study interfaces and surface chemical reactions. Topics include principles of physical chemistry and materials science for understanding and applying modern surface analysis.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

**CH 5730 - Confocal Laser Scanning Microscopy: Foundations, Applications, and Advances**

Principles of fluorescence microscopy, confocal microscope design, practical aspects of confocal microscopy, live cell imaging, high speed imaging, fluorescent stains, quantitative fluorescence, immunofluorescence, fluorescent proteins, biosensors. Confocal applications in biology and health related sciences will be covered.

Credits: 1.0

Lec-Rec-Lab: (0-0-2)

Semesters Offered: Fall, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CH 5800 - Special Topics in Graduate Chemistry**

Discussion of special topics in chemistry at the graduate level.

Credits: variable to 3.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CH 5820 - Independent Study in Chemistry**

Individualized project-based course designed to integrate academic and professional interests to foster student's career goals. Project can be on or off-campus, internship, or combination of these, to enhance the student's expertise and develop career-relevant skills.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Chemistry

**CH 5900 - Chemistry Graduate Seminar**

Graduate seminar in chemistry.

Credits: 1.0; Repeatable to a Max of 2

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Chemistry

**CH 5990 - Chemistry Master Research**

An original investigation in chemistry for students seeking an MS degree.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6290 - Special Topics in Analytical Chemistry**

Discussion of current research developments at an advanced level. Topics may include chromatography, magnetic resonance, surface analysis, mass spectrometry, or environmental analysis.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6390 - Special Topics in Inorganic Chemistry**

Discussion of recent developments in inorganic chemistry.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Pre-Requisite(s): CH 4320

**CH 6490 - Special Topics in Organic Chemistry**

Advanced study in special areas of organic chemistry. Topics could include organic synthetic methods, production and reactions of enolate ions, heterocyclic, carbohydrate, bioorganic, or free-radical chemistry.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6590 - Special Topics in Physical Chemistry**

A discussion of recent research developments at an advanced level. Topics could include atomic and molecular structure, kinetic theory of gases, solid-state chemistry, thermodynamics, electrochemistry, and molecular spectroscopy.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6640 - Synthesis of Nanoparticles**

This hands-on course teaches methods of preparing different types of nanoparticles, and controlling nanoparticle size, structure, and functionalization. Students will analyze selected papers from professional literature to see emerging trends in nanoparticle design and use.

Credits: 3.0

Lec-Rec-Lab: (0-1-4)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6690 - Special Topics in Polymer Science**

Advanced study in special areas of polymer science. Topics could include thermal analysis, polymer surface science, advanced polymerization processes, scaling laws, etc. Some topics may include a laboratory component.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6790 - Special Topics in Biochemistry**

Advanced study in special areas of biochemistry and molecular biology. Topics could include bioorganic chemistry, signal transduction or transcriptional control.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**CH 6800 - Current Topics in Graduate Chemistry**

Discussion of recent topics in chemistry at a graduate level.

Credits: variable to 3.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CH 6990 - Chemistry Doctoral Research**

Laboratory research in preparation of the PhD thesis. Requires permission of the student's advisory committee and the graduate faculty.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5300 - Advanced Transport Phenomena**

Single- and multi-component mass, energy, and momentum transport. Derivation and use of the general transport equations for Newtonian and non-Newtonian flows, convective flows, and mass transport in flowing systems. Applications to complex systems.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CM 5100

**CM 5310 - Laboratory Safety**

Provides the technical and cultural background necessary to operate and manage a safe Laboratory.

Credits: 1.0

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Fall, Spring

**CM 5400 - Adv Reactive Systems Analysis**

An analytical study of various aspects of chemical reactor behavior, such as multiple steady-states, dynamics, stability, and control. Also covers transport phenomena in packed beds of solids and mathematical modeling of packed-bed reactors.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5500 - Theory and Methods of Research**

Discusses modern methods of research. Topics could include statistical analysis, presentation of data, modern experimental methods, or oral presentation skills.

Credits: 2.0

Lec-Rec-Lab: (1-0-2)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5510 - Advanced Interfacial Engineering**

Examines the physics and chemistry of interfaces, and the relevance of these principles in engineering applications. It may include liquid surfaces, electric double layer, surface forces, contact angle phenomena, surfactants, adsorption, surface energy, emulsions.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5715 - Advanced Biochemical Processes**

Introduction to fundamental and applied industrial biochemical processing.

Topics may include basic cell and genetic design, enzymes, metabolism, bioreactor analysis and design, bioseparations and industrial applications. Graduate expectations will exceed those of the undergraduate course. Not open to students with credit in CM4710.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5720 - Advanced Mineral Processing**

Topics in mineral processing of current interest. Will cover grinding, flotation, agglomeration, pollution prevention, surface chemistry, and other areas where rapid advancement is occurring.

Credits: variable to 3.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CM 5721 - Literature Reviews in Chemical Engineering**

Literature review course promotes learning and critical scrutiny of chemical engineering literature, on a topic pertinent to the student's research. Discussion of articles will increase knowledge breadth and depth for research. Enhances research communication skills via reviews and discussions.

Credits: 1.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of instructor required

**CM 5770 - Advanced Analytical Microdevice Technologies**

Course will provide background in micro/nano-scale technologies for biomedical diagnostic applications. Includes theoretical and experimental advances in chemical, mechanical, optical, and biological analysis. Reading of news and technical articles will develop skills/knowledge to envision microdevice applications for a semester-long project which students taking this course will be leading.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2012-2013 academic year

Restrictions: Permission of instructor required

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## Chemical Engineering

**CM 5100 - Appl Mathematics for CM**

The solution to basic equations for momentum, mass, and heat transfer by use of separation of variables, numerical methods, and other mathematical techniques.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5200 - Advanced CM Thermodynamics**

Emphasis in phase equilibria and related concepts, such as molecular or statistical thermodynamics, nonideal fluids and solids.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5780 - Advanced Biomanufacturing and Biosafety**

Students to perform as an engineer in a biomanufacturing facility. Focus is on mammalian cell culture derived products and federal laws in biosafety. Process design software explored. Regular literature review required. Not open to students with credit in CM4780.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CM 5900 - Special Topics in CM**

A discussion of chemical engineering topics of current interest not included in regular graduate courses.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CM 5950 - Advanced Special Projects**

This is a course for graduate students who wish to do extensive work on projects or topics not directly related to their thesis topic and not covered in one of the graduate courses.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CM 5990 - MS Research**

An original investigation of a chemical engineering problem.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

**CM 6990 - Doctoral Research**

An original investigation in theoretical or applied chemical engineering or both, and submission of a dissertation in partial fulfillment of the requirements for the PhD degree.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

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**Computer Science****CS 5000 - National Cybersecurity Policy and Law**

This course introduces the role of government in securing cyberspace. Students learn the basic national cybersecurity policy and law. Topics include federal, state, and local entities involved in cybersecurity, relevant laws and regulations, concepts of civil liberties, intellectual property, and privacy, development and diffusion of standards, and national security.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

**CS 5090 - Special Topics in Computer Science**

Special topics in computer science offered on occasion based on student and faculty demand and interest.

Credits: variable to 4.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required

**CS 5091 - Graduate Seminar in Computer Science**

From time to time, depending on student demand, a seminar will be offered on advanced topics in current computer science research.

Credits: variable to 3.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**CS 5130 - Compiler Design, Theory, and Optimization**

Design and theory of programming language translators and the theory and implementation of optimizers. Topics include: intermediate representations, advanced code generation, control- and data-flow analysis, advanced compiler optimization, dynamic compilation, global register allocation and instruction scheduling.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 4121

**CS 5311 - Theory of Computation**

Topics covered include Turing machines and their variants, the halting problem and decidability, computability, reducibility, NP-completeness, time and space complexity, and topics from recursive function theory. The course starts with a brief review of the computation models from CS3311.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Pre-Requisite(s): CS 3311

**CS 5321 - Advanced Algorithms**

Design and analysis of advanced algorithms. Topics include algorithms for complex data structures, probabilistic analysis, amortized analysis, approximation algorithms, and NP-completeness. Design and analysis of algorithms for string-matching and computational geometry are also covered.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CS 4321

**CS 5331 - Parallel Algorithms**

Advanced topics in the design, analysis, and performance evaluation of parallel algorithms. Topics include advanced techniques for algorithm analysis, memory models, run time systems, parallel architectures, and program design, particularly emphasizing the interactions of these factors.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CS 4431 and CS 4331

**CS 5411 - Advanced Operating Systems**

Advanced concepts in operating systems. Topics include real-time and multiprocessor scheduling, I/O, modern file systems, and performance analysis. Also requires a substantial implementation project.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CS 4411

**CS 5431 - Advanced Computer Architecture**

An in-depth study of various aspects of parallel processing, with an emphasis on parallel architectures. The course has an analytical focus and investigates models of various aspects of the design and analysis of parallel systems. Topics include simple uniprocessor/multiprocessor performance models, pipelining, instruction-level parallelism, and multiprocessor design issues.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CS 4431

**CS 5441 - Distributed Systems**

Covers time and order in distributed systems; mutual exclusion, agreement, elections, and atomic transactions; Distributed File Systems, Distributed Shared Memory, Distributed System Security; and issues in programming distributed systems. Uses selected case studies.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CS 4411 and CS 4461

**CS 5461 - Mobile Networks**

This course will explore the Mobile network issues including routing and mobility management strategies in ad hoc networks, sensor networks, and personal area networks such as Bluetooth.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: May not be enrolled in one of the following Class(es): Freshman,

Sophomore, Junior

Pre-Requisite(s): CS 4461 or EE 4272

**CS 5471 - Computer Security**

This covers fundamentals of computer security. Topics include practical cryptography, access control, security design principles, physical protections, malicious logic, program security, intrusion detection, administration, legal and ethical issues.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 3411 or CS 4411

**CS 5472 - Advanced Topics in Computer Security**

This course covers various aspects of producing trusted computer information systems. Topics include network perimeter protection, host-level protection, authentication technologies, formal analysis techniques, and intrusion detection. Current systems will be examined and critiqued.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): (CS 4471 or CS 5471)

**CS 5481 - Systems Performance Analysis**

Analysis of the performance of computer systems. Topics include: measurement techniques and tools, probability theory and statistics, experiment design and analysis, simulation, queuing models. Course includes a significant experimental component.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CS 4411 and MA 2720

**CS 5491 - Cloud Computing**

Overview of the principles, methods, and leading technologies of cloud computing. Topics include cloud computing concepts: Hadoop, MapReduce; Software as a Service (SaaS); Platform as a Service (PaaS); Infrastructure as a Service (IaaS); workload patterns and resource management; migrating to the cloud; and case studies. Students will build their own cloud application using Amazon or IBM cloud services.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Pre-Requisite(s): CS 3425

**CS 5495 - Software/Hardware Design of Multimedia Systems**

A comprehensive overview of the design and implementation of the hardware and software of a platform for multimedia applications. Topics include system level design methodology, single-instruction-multiple data processor (SIMD), virtual platform implementation, development of an SIMD parallel compiler, and real-time operating systems (RTOS).

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 3411 and CS 3421

**CS 5496 - GPU and Multicore Programming**

Introduction to Graphics Processing units (GPU) and multi-core systems, their architectural features and programming models, stream programming and compute unified driver architecture (CUDA), caching architectures, linear and non-linear programming, scientific computing on GPUs, sorting and search, stream mining, cryptography, and fixed and floating point operations.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 3411 and CS 3421

**CS 5497 - Multimedia Data Security in Hardware Firmware and Software**

Software and hardware aspects of digital media security, data protection; Analysis of digital media for purposes of authentication and protection against tampering and forgery; Electronic tamper detection; Secure exchange of digital content over the Internet or electronic media; Cryptographic processors.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Pre-Requisite(s): CS 4321

**CS 5611 - Computer Graphics: Advanced Rendering and Modeling**

Topics include polygonal objects, lighting models, shadows and textures, ray-tracing, radiosity, photon mapping, parametric curves and surfaces, meshes, and mesh modeling.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CS 4611

**CS 5631 - Data Visualization**

Introduction to scientific and information visualization. Topics include methods for visualizing three-dimensional scalar and vector fields, visual data representations, tree and graph visualization, large-scale data analysis and visualization, and interface design and interaction techniques.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Pre-Requisite(s): CS 4611 or CS 5611

**CS 5641 - Immersive Virtual Environments**

An introduction to immersive virtual environment technologies and their applications. Topics include: wall-sized displays, head-mounted displays, 3D displays, orientation and position tracking, human perception, and recent research utilizing virtual reality systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CS 4611(C)

**CS 5740 - Development of Trusted Software**

This course exposes students to the concepts of secure software development. Students will learn how to develop high-quality software that is resistant against cyber-attacks, by minimizing the number of vulnerabilities that can be exploited by an attacker. Topics include: access control, race conditions, buffer overflows, code injection, fuzzing techniques, cryptographic software, web application and Java security.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Pre-Requisite(s): CS 4471

**CS 5760 - Human-Computer Interactions and Usability Testing**

Current issues in human-computer interaction (HCI), evaluation of user interface (UI) design, and usability testing of UI. Course requires documenting UI design evaluation, UI testing, and writing and presenting a HCI survey, concept or topic paper.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): CS 4760

**CS 5761 - Human-Robot Interaction**

This course covers topics, such as anthropomorphism and embodied, dialogue, emotion, human-robot team interaction, assistive robots, ethical issues, and measurement and evaluation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

**CS 5770 - Affective Design and Computing**

An examination of emotions and affect in Human Factors and HCI. Topics may include brain and cognitive mechanisms and methods/techniques, affective computing, Kansei engineering, hedonomics, emotional design, and application domains.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

**CS 5811 - Advanced Artificial Intelligence**

Course topics include current topics in artificial intelligence including agent-based systems, learning, planning, use of uncertainty in problem solving, reasoning, and belief systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): CS 4811

**CS 5821 - Computational Intelligence - Theory and Application**

This course covers the four main paradigms of Computational Intelligence, viz., fuzzy systems, artificial neural networks, evolutionary computing, and swarm intelligence, and their integration to develop hybrid systems. Applications of Computational Intelligence include classification, regression, clustering, controls, robotics, etc.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CS 5831 - Advanced Data Mining**

Data mining focuses on extracting knowledge from large data sources. The course covers data mining concepts, methodology (measurement, evaluation, visualization), algorithms (classification/regression, clustering, association rules) and applications (web mining, recommender systems, bioinformatics).

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): (CS 3425 or MIS 3100) and (MA 2330 or MA 2320 or MA 2321 and (MA 2710 or MA 2720 or MA 3710)

**CS 5841 - Machine Learning**

This course will explore the foundational techniques of machine learning. Topics are pulled from the areas of unsupervised and supervised learning. Specific methods covered include naive Bayes, decision trees, support vector machine (SVMs), ensemble, and clustering methods.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CS 4821

**CS 5990 - Master's Research in Computer Science**

The study of an acceptable computer science problem and the preparation of a thesis

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CS 5994 - International Computer Science Field Experience**

Field work and reporting from students in the Peace Corps Master's International Program in Computer Science.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-2)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science

**CS 5999 - Master's Reading and Research in Computer Science**

Individual reading and research on current topics in computer science.

Credits: variable to 9.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CS 6090 - Special Topics in Computer Science**

Special topics in Computer Science offered on occasion based on student and faculty demand and interest.

Credits: variable to 4.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required

**CS 6091 - Doctoral Seminar in Computer Science**

Seminar covers advanced topics in current Computer Science research for doctoral degree candidates. Offered according to student demand.

Credits: variable to 3.0; May be repeated

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**CS 6990 - Doctoral Research in Computer Science**

The study of an acceptable computer science problem and the preparation of a dissertation.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CS 6999 - Doctoral Reading and Research in Computer Science**

Individual reading and research on current topics in Computer Science for doctoral degree candidates.

Credits: variable to 9.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Computational Science & Engineering****CSE 5091 - Computational Science and Engineering Seminar**

From time to time, depending on student demand, a seminar will be offered on current topics in computational science and engineering.

Credits: variable to 3.0; May be repeated

Semesters Offered: Fall, Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CSE 5311 - Theory of Computation**

Topics covered include Turing machines and their variants, the halting problem and decidability, computability, reducibility, NP-completeness, time and space complexity, and topics from recursive function theory. The course starts with a brief review of the computation models from CS3311.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 3311

**CSE 5321 - Advanced Algorithms**

Topics include algorithms for complex data structures, amortized analysis, and NP-completeness. Application areas include approximation algorithms, network flow, combinatorics, string matching, and parallel algorithms. Additional topics as time permits.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 4321

**CSE 5331 - Parallel Algorithms**

Emphasizes the principles used in the development of algorithms for parallel computers, including programming paradigms, implementation, analysis, and performance evaluation. Considers algorithms in the areas of scientific computation and nonnumeric processing as well as software tools for performance visualization and debugging.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 4321 and CS 4431

**CSE 5710 - Modeling and Simulation Applications for Decision-Making in Complex Dynamic Domains**

Introduces students to the theory and application of modeling techniques and simulations in the analysis of decision alternatives. Topics include queuing theory, system dynamics modeling, agent based modeling, and discrete event simulation. Students conceptualize and implement an appropriate research/engineering problem of choice (this could be a dissertation/thesis problem).

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CSE 5720 - Descriptive Modeling of Data using Statistical and Graphical Methods**

Focuses on the fundamentals of probability theory and graph theory and how relevant concepts apply to describe, model, and analyze data sets. Topics include probability distributions, Bayes theorem, conditional independence, discrete and continuous models, regression models, hypothesis testing, and Markov chain methods.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**CSE 5811 - Advanced Artificial Intelligence**

Current topics in artificial intelligence including agent-based systems, learning, planning, use of uncertainty in problem solving, reasoning, and belief systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): CS 4811

**CSE 6090 - Special Topics in Computational Science and Engineering**

Special topics in Computational Science and Engineering offered on occasion based on student and faculty demand and interest.

Credits: variable to 4.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required

**CSE 6091 - Computational Science and Engineering Seminar**

From time to time, depending on student demand, a seminar will be offered on current topics in computational science and engineering.

Credits: variable to 3.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**CSE 6990 - Doctoral Research**

By arrangement with the instructor directing the PhD dissertation.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**CSE 6999 - Doctoral Reading and Research**

Individual reading and research on current topics in computational science and engineering.

Credits: variable to 9.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Economics****EC 5000 - Microeconomic Theory**

The study of consumer and producer choices, market demand and supply, and market structures. Not open to students with credit for EC3002.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**EC 5010 - Macroeconomics**

The study of the determinants of the level of income, employment, the rate of inflation, economic growth, and cyclical variations in the economy, including considerations of the rationale for monetary and fiscal policy and their impact on the business community.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EC 3003

### **EC 5300 - Managerial Economics**

Economic analysis of the operation of a business. Topics include optimization, demand theory and forecasting, production/cost analysis, market structure and strategic behavior, risk analysis, antitrust policy and regulation of safety and the environment, and international management.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Business Administration, Applied Natural Resource Econ., Accounting

### **EC 5400 - Advanced Engineering Economics**

Presents and demonstrates procedures and quantitative techniques used in capital budgeting and project evaluation and selection for industry. Topics include cash flow analysis, decision methods, risk and uncertainty, cost of capital, taxes and depreciation, and forecasting market variables. Topics presented with study problems, applying spreadsheet programs.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand - Offered alternate years beginning with the 2002-2003 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): EC 3400

### **EC 5620 - Energy Economics**

Introduction to the institutional, technical, and economic issues of the production and use of energy resources, including petroleum, natural gas, coal, nuclear, electric utilities, and alternative energy. Research project applies economic analysis to supply, distribution, and use of energy resources, including environmental and social consequences.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### **EC 5630 - Mineral Industry Economics**

Analyzes the economic aspects of the production/use of minerals in society. Uses economic analysis to explain behavior and policy implications for issues of supply, demand, markets, and foreign trade for important minerals. Analyzes the impact of government policies on the minerals industries.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **EC 5640 - Natural Resource Economics**

Analyzes the economic aspects of producing/using natural resources. Nonrenewable resources and renewable resources are discussed. The economics of land use, macroeconomic topics such as economic growth, sustainability and green accounting are considered.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): EC 2001 or EC 3002

### **EC 5650 - Environmental Economics**

Considers the efficient and equitable use of environmental resources. Measures the benefits and costs of decreasing pollution and protecting scarce ecological resources; addresses market failures and the economic valuation of environmental amenities. Requires students to learn quantitative and technical techniques to determine the efficient use of resources.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): EC 2001 or EC 3002

### **EC 5900 - Special Topics**

Economic topics of interest to students or independent study in economics under the guidance of a faculty member.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### **EC 5994 - Field Work in Applied Natural Resource Economics**

Field work and reporting from students in the Peace Corps Master's International Program in applied natural resource economics.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### **EC 5999 - Graduate Research**

Under the guidance of a faculty member, students will read, conduct research, and prepare a report, paper, or thesis.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

## **Education**

### **ED 0510 - Graduate Teaching Assistant Training**

Half semester course for training graduate teaching assistants (GTAs). Covers course preparation, educational testing and evaluation, instructional strategies (discussions, lecturing, collaborative learning, cases/simulations, etc.), using instructional technologies, motivating students, and institutional resources.

Credits: 1.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### **ED 5100 - College Teaching**

Focuses on instructional planning, delivery, and assessment in a higher education context. Students learn to write objectives, apply backward design, create objective-linked high-engagement classroom activities, and assess student learning. Additional topics include course syllabi, teaching portfolios, and teaching philosophy statements.

Credits: 1.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Co-Requisite(s): ED 0510

### **ED 5101 - Foundations of Online Teaching**

This course provides an introduction to the planning, design development, and delivery of an online course. Students learn to create measurable learning objectives, engaging online activities, and authentic assessments for use in a future online course. Students will create and deliver an online lesson as their course capstone.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### **ED 5110 - Psychological Foundations of Education**

The course examines how human beings grow and learn across the lifespan. Psychological basis of educational procedures and practices are established with special reference to formal schooling, higher and tertiary education, and workplace settings.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

### **ED 5300 - Instructional Technology**

Provides the development of knowledge and skills required to make use of information and communication technologies as instructional tools. Use of instructional technology will be considered within a context of relevant research and theory pertaining to human learning. Students will engage in analysis of technology-integrating teaching methods.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate  
Co-Requisite(s): ED 4700

### **ED 5540 - Special Topics in Education**

Group studies of specially selected issues or problems in education.

Credits: variable to 6.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required

### **ED 5560 - Ecology of Isle Royale for Educators**

K-12 teachers participate in a field-based camping experience on Isle Royale National Park, exploring basic ecological concepts regarding the interrelatedness of plants, animals, geology, climate, and human influences on Isle Royale.

Prepares teachers to help students understand interrelationships, energy distribution in ecosystems and change over time.

Credits: variable to 3.0

Semesters Offered: On Demand

Restrictions: Permission of department required

### **ED 5562 - Isle Royale Special Studies for Educators**

Field course for K-12 teachers to explore specific aspects of the Isle Royale environment with emphasis on integration of the experience into the science classroom.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Permission of department required

**ED 5570 - Lesson Study**

Teachers will engage in an intensive method of improving instruction that includes designing a lesson with a group of colleagues, implementing the lesson in one of their classrooms, and collectively examining the lesson's effectiveness in engaging students in meaningful learning.

Credits: variable to 3.0; Repeatable to a Max of 3

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5581 - Teaching and Communicating Scientific Research**

Discussion of practical aspects of implementing inquiry-based instruction, communicating science and scientific research to the public, and educational resources for science teaching.

Credits: 1.0; Repeatable to a Max of 6

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5590 - Developing Science, Technology, Engineering and Mathematics (STEM) Instruction**

Exploration of foundational theories of STEM education. Students will participate in engineering-integrated learning activities, engage in inquiry-based learning tasks in mathematics and science, and utilize technology to enhance student learning. Students will practice backwards design to develop their own STEM learning activity.

Credits: 2.0; Repeatable to a Max of 4

Lec-Rec-Lab: (2-0-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5600 - Independent Study in Education**

Through an independent study, gain additional insights to relevant topics in education and research. Students must work directly with select faculty to develop a structured line of study on select educational topics.

Credits: variable to 6.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required

**ED 5601 - Special Content Studies in Education**

Intensive institutes designed to help elementary, middle and high school educators integrate important concepts in math and science into classroom teaching units.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of department required

**ED 5602 - Special Applications in Education**

Practical application following special content studies during which elementary, middle and high school teachers implement and evaluate a teaching unit that they designed for their own classroom inspired by the previous content course. A mandatory teachers' forum provides opportunity to share ideas with other participating teachers.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of department required

**ED 5620 - Professional Development for Educators: Teaching Earth Science**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of earth science.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5630 - Professional Development for Educators: Teaching Life Sciences**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of life science.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5640 - Professional Development for Educators: Teaching Environmental Science**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of environmental science.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5641 - Global Change Institute for Teachers**

This course will provide teachers with the skills necessary to engage middle/high school students in real-world study of global climate change and its effects on ecosystems. National Content Standards for mathematics, and life, earth, and physical sciences will be addressed.

Credits: variable to 4.0; Repeatable to a Max of 4

Semesters Offered: On Demand

Restrictions: Permission of department required

**ED 5650 - Professional Development for Educators: Teaching Physical Science**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of physical science.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5660 - Professional Development for Educators: Teaching Mathematics**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of mathematics.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5665 - Professional Development for Educators: Teaching Computer Science**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of computer science.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5670 - Teaching Technologies for Educators**

This course guides educators in using technologies to design, implement, and assess learning experiences. Outcomes include the development of strategies to engage students, improve learning, and enrich professional practice through the thoughtful integration of technology.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5680 - Professional Development for Educators: Teaching Social Studies**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of social studies.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5690 - Professional Development for Educators: Teaching Language Arts**

A course for the professional development of professional K-12 educators.

Topics address ideas, trends, and applications in the teaching and learning of language arts.

Credits: variable to 4.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of department required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**ED 5700 - Introduction to Education Research**

Overview of education research methods to develop an understanding of designing education research, including the relationship between research question, theoretical framework(s), and methods. Focus is placed on developing a literature review to help lay theoretical groundwork for pursuing education research.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5703 - Action Research in Depth**

A web-based study of education research methods linking classroom practice, curriculum standards, and program evaluation with research about learning. Teachers will learn about data presentation, action learning, and developing students into communities of science learners.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5705 - Action Research Project**

Teachers will engage in the systematic study of their own practice by designing an action research study and then collecting and analyzing data to answer a question about their own teaching and/or student learning. Course enrollment is restricted to practicing teachers.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5720 - Inquiry-Based practices for Science and Mathematics Teaching**

Examination of science and mathematics inquiry-based teaching practices and learning materials that support student understanding and engagement, and align to state and national standards.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5730 - Assessment and Evaluation**

Methodological perspectives and techniques for assessing and evaluating student learning to inform instructional decision making.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5740 - Designing Education Research**

Course focuses on designing a research project for the MSASE program. Emphasis on motivating a study, developing research questions, conducting a literature review, and selecting appropriate research methodology. Should be taken within one year of beginning research project.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ED 5700

**ED 5750 - Diagnosis and Remediation of Reading Problems**

Identification of problems related to reading and language processing; identification and application of diagnostic, remediation and assessment strategies and instruments. Classroom specific experience in diagnosis and remediation of the total communication process.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**ED 5780 - Intro to Qualitative Research**

An introduction to the use of qualitative research methods in social science contexts. Emphasis is placed on understanding the underpinnings of qualitative research, research traditions, and theoretical orientations. Students will be introduced to specific qualitative analysis techniques, ways to interpret data, and writing strategies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**ED 5800 - Applied Internship for Educators**

Students will work in an industry or on a research project. At the conclusion of the internship, students will write a paper regarding how they will apply what they have learned in their pre-college classroom or in their own research.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Co-Requisite(s): ENG 5100

**ED 5820 - Advanced Methods of Teaching Science**

Application of learning and instructional theories to the teaching of science. Emphasizes methods of materials used to teach early adolescents. Taught from the perspective of science teachers. Lab offers opportunities to refine instructional techniques. K-12 science classroom teaching experience required.

Credits: 2.0; Repeatable to a Max of 4

Lec-Rec-Lab: (1-0-2)

Semesters Offered: On Demand

Restrictions: Permission of department required

**ED 5860 - STEM Education Practicum**

Practical experience in teaching, education research, and/or assessment in a STEM discipline. Students either teach/mentor undergraduate STEM students, work with a faculty member on a STEM education research project or work with STEM assessment activities. A seminar is required.

Credits: variable to 5.0; Repeatable to a Max of 5

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ED 5100 and ED 5110 and ED 5700

**ED 5900 - Graduate Research in Education**

Students will conduct a research project/report as a capstone to an approved plan of study. The student should present a project plan to their education advisor for approval, conduct whatever work is necessary for the project, prepare a final report at the conclusion of the project, and defend the project/report in an oral presentation.

Credits: variable to 6.0; Repeatable to a Max of 6; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor and department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ED 5700

**ED 5910 - Teaching Internship**

Knowledge of human growth and learning theories, methods and materials, and individual differences applied to classroom settings, conducted under the supervision of an experienced middle or secondary school teacher. Completion of MTTC Basic Skills Test. See department for application deadlines.

Credits: 12.0

Lec-Rec-Lab: (0-0-36)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ED 5110 and ED 5210 and ED 5410

**ED 5920 - Teaching Internship - Preparation for International Teaching**

Application of learning theory, including individual differences and content specific pedagogy, in a classroom setting, conducted under supervision of an experienced secondary teacher. Preparation for placement in teaching position with the Peace Corps. Requires completion of MTTC Basic Skills Test.

Credits: variable to 6.0

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ED 4720 or ED 5820

**ED 5921 - International Teaching Internship**

Application of learning theory, including individual differences and content specific pedagogy, in an international classroom through Peace Corps service. Internship is conducted under the supervision of an experienced secondary teacher. Requires completion of MTTC Basic Skills Test.

Credits: 1.0; Repeatable to a Max of 18

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ED 4720 or ED 5820

**ED 5994 - Field Work in International Science Education**

Field work and reporting from students in the Peace Corps Master's International Program in Science Education.

Credits: 1.0; Repeatable to a Max of 18

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Electrical & Computer Engineering****EE 5200 - Advanced Methods in Power Systems**

Advanced analysis and simulation methods for load flow, symmetrical components, short circuit studies, optimal system operation, stability, and transient analysis. Application of commonly used software reinforces concepts and provides practical insights.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): EE 4222

**EE 5220 - Transient Analysis Methods**

A study of transient behaviors and their analysis and prediction. Addresses analytical methods and their numerical implementation, switching and lightning surges, short circuits, and non-linear effects. Includes computer simulations.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2007-2008 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): EE 4222

**EE 5221 - Advanced Electric Machinery and Drives**

Advanced electromechanics of rotating and linear machines. Topics include dynamic analysis of machines, reference frame transformations, reduced order models, models of mechanical loads, power electric drives for motors, and digital simulation of machines and electric drive systems. Applications discussed will include renewable energy and electric propulsion systems.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2013-2014 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**EE 5223 - Power System Protection**

Real-time monitoring and protection of modern power systems. Secure and reliable operation of radial and grid systems. Protection of transmission lines, buses, generators, motors, transformers, and other equipment against disturbances.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2008-2009 academic year

**EE 5224 - Power System Protection Lab**

Theory-based application of software and hardware used for power system protection. Fault simulations, protective relay settings and coordination, and test operation of relays under static, dynamic, and transient conditions.

Credits: 1.0

Lec-Rec-Lab: (0-0-2)

Semesters Offered: Spring - Offered alternate years beginning with the 2008-2009 academic year

Pre-Requisite(s): EE 5223(C)

**EE 5227 - Advanced Power Electronics**

Advanced topics of circuits for electrical energy processing. Covers switching converter principles for dc-dc, ac-dc, and dc-ac power conversion. Other topics include harmonics, pulse-width modulation, classical feedback control, nonlinear control, magnetic components, power semiconductors, and digital simulation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2012-2013 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 4227

**EE 5230 - Power System Operations**

Study of advanced engineering and economic algorithms and analysis techniques for the planning, operation, and control of the electric power system from generation through transmission to distribution.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering

**EE 5231 - Energy Control Center Applications**

Monitoring and control technologies for control centers that govern electrical power transmission systems. Topics include study of historical power blackouts, state estimation, alarm processing, fault diagnosis, telecommunication assessment, defense strategies, system-wide restoration, and visualization.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required

Pre-Requisite(s): EE 3120

**EE 5232 - Power System Optimization**

Linear, non-linear, and integer programming, simplex method, branch and bound, steepest descent method, convex, stochastic, and distributed optimization, interior-point method, evolutionary algorithm, optimal power flow, unit commitment, vot/var optimization, state estimation, feeder reconfiguration.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EE 5240 - Computer Modeling of Power Systems**

Topics include modeling and computer methods applied to electrical power systems, matrix formulations, network topology and sparse matrix data structures, loadflow, short-circuit and stability formulations, constrained optimization methods for loadflow and state estimation, and time-domain simulation methods for transient analysis.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2008-2009 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering

Pre-Requisite(s): EE 5200

**EE 5250 - Distribution Engineering**

Modeling and analysis of electrical distribution systems; load characteristics, load modeling, unbalanced three-phase overhead and underground line models, and distribution transformers. Analysis of primary system design, applications for capacitors, voltage drop, power loss, distribution system protection, and introduction to advanced distribution automation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2007-2008 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 4221

**EE 5251 - Distribution Engineering II**

Course covers fundamentals of feeded reconfiguration for distribution systems. The unbalanced three-phase power flow will be used throughout the course for fault location, fault isolation and service restoration, outage management for crew coordination, trouble tickets, and switching procedure management.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

**EE 5260 - Wind Power**

Wind turbines are the fastest growing segment of the generator mix being added to power systems today. There is a growing need to understand the many issues caused by these additions. This course covers the theoretical background, regulations, integration experience, and modeling.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EE 5275 - Energy Storage Systems**

Designing energy storage solutions for grid, vehicle and portable/autonomous systems. Quantitative and qualitative analysis of energy storage aging, cost, and performance improvement.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

EE 5290 - Selected Topics in Power Systems 1

Selected topics of current interest.

Credits: variable to 4.0; May be repeated

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering

**EE 5295 - Advanced Propulsion Systems for Hybrid Electric Drive Vehicles**

Hybrid electric vehicles (HEV) will be studied and simulated using advanced powertrain component analysis and modeling. An in-depth analysis and study of power flows, losses, and energy usage are examined for isolated powertrain components and HEV configurations. Simulation tools will be developed and applied to specify powertrain and vehicle components and to develop control and calibration for a constrained optimization to vehicle technical specifications.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Pre-Requisite(s): MEEM 4295 or EE 4295

**EE 5296 - Powertrain Integration in HEV**

This hands-on course examines challenges with powertrain integration in Hybrid Vehicles. Topics include Vehicle Development Process, Thermal Management, Vehicle Controls, Safety, Calibration, and Vehicle Simulation Models. The course project includes optimizing performance of a configurable HEV using modeling and experimentation.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Pre-Requisite(s): MEEM 4296(C) or EE 4296(C)

**EE 5300 - Mathematical and Computational Methods in Engineering**

Overview of problem-solving tools and techniques in engineering, considered from both the analytical and computational point of view. Systems of linear equations, eigenvalue and eigenvector computations, boundary value and initial value problems, Fourier analysis, large-scale systems, optimization. Mathematical modeling and computer programming.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Fall, Spring  
 Restrictions: Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EE 5315 - Cyber Security of Automotive Systems I**

Modern automotive control and communications systems from a cyber security perspective. Topics include: V2X communications, vehicle attack surfaces and vulnerabilities, in-vehicle networks, threat analysis and vulnerabilities, security mechanisms and architectures, security requirements analysis, hardware security modules, and standards.

Credits: 3.0  
 Lec-Rec-Lab: (0-3-0)  
 Semesters Offered: Spring  
 Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science, Mechanical Engineering, Mechanical Eng-Eng Mechanics, Computer Engineering, Electrical Engineering  
 Pre-Requisite(s): MEEM 5300 or EE 5455

**EE 5365 - In-Vehicle Communication Networks**

Course focuses on in-vehicle system domains and their requirements, and in-vehicle communication bus Controller Area Network (CAN) and its related physical layers standards. It also covers other buses such as LIN, FlexRay, MOST, Ethernet, as well as introduction to V2V and V2I.

Credits: 3.0  
 Lec-Rec-Lab: (2-0-3)  
 Semesters Offered: Fall, Summer  
 Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science, Engineering Mechanics, Mechanical Engineering, Computer Engineering, Electrical Engineering  
 Pre-Requisite(s): EE 3250

**EE 5367 - Vehicular Networking**

Theories/principles, technologies, standards and applications of vehicular ad-hoc networks (VANET), as well as design considerations and main challenges to implement inter-vehicular communication networks. Topics include vehicle mobility modeling, physical layer considerations, routing protocols, and data security. Requires Linux OS, Python or C++.

Credits: 3.0  
 Lec-Rec-Lab: (2-0-3)  
 Semesters Offered: Spring  
 Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science, Engineering Mechanics, Mechanical Engineering, Computer Engineering, Electrical Engineering  
 Pre-Requisite(s): EE 5365 and EE 4272

**EE 5373 - Advanced Programmable Controllers**

Using Allen Bradley Contr Logix and SLC500 programmable controllers, course covers structured programming, Sequential Function Charts, networking, proportional integral differential control, data acquisition and interfacing. The course requires proposing, executing, and defending at the graduate level related to the course material project.

Credits: 4.0  
 Lec-Rec-Lab: (0-2-3)  
 Semesters Offered: Spring  
 Pre-Requisite(s): EE 3373

**EE 5390 - Scientific Computing**

Set in a Linux environment, course offers exposure to Foss tools for developing computational and visualization workflows. Students will learn to translate problems into programs, understand sources of errors, and debug, improve the performance of and parallelize the code.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Fall, Spring  
 Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering

**EE 5410 - Engineering Electromagnetics**

A mathematically rigorous study of dynamic electromagnetic fields, beginning with Maxwell's equations. Topics include scalar and vector potentials, waves, and radiation.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Fall  
 Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering  
 Pre-Requisite(s): EE 3140

**EE 5415 - Applied Optics and Photonics**

Rigorous study of nonlinear optics, anisotropic, optical materials, dielectric waveguides, directional couplers, semiconductor optics, light sources, lasers, and photodetectors.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Spring  
 Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
 Pre-Requisite(s): EE 3090 or PH 3210 or EE 4411

**EE 5430 - Electronic Materials**

A study of the physical principles, operational characteristics, models, and basic applications of selected solid-state devices.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Fall  
 Restrictions: Must be enrolled in one of the following Level(s): Graduate

**EE 5451 - Risk Assessment for Critical Infrastructure Protection**

Risk assessment and vulnerabilities for industrial control environments including electrical power grids. Cyber-physical attack tools and techniques. Interaction of cybersecurity issues with physical systems and physical security. Limitations of current cybersecurity technologies. Design and cost considerations for various defensive methods.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Spring  
 Restrictions: Permission of instructor required  
 Pre-Requisite(s): EE 3120

**EE 5455 - Cybersecurity of Industrial Control Systems**

General introduction to cybersecurity of industrial control systems and critical infrastructures. Topics include NIST and DHS publications, threat analysis, vulnerability analysis, red teaming, intrusion detection systems, industrial networks, industrial malware, and selected case studies.

Credits: 3.0  
 Lec-Rec-Lab: (0-3-0)  
 Semesters Offered: On Demand  
 Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Science, Computer Engineering

**EE 5460 - Solid State Devices**

A study of the physical principles, operational characteristics and models and basic applications of solid state devices such as p-n junctions, metal-semiconductor junctions and transistors.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Spring  
 Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EE 5461 - Mobile Networks**

This course will explore the Mobile network issues including routing and mobility management strategies in ad hoc networks, sensor networks, and personal area networks such as Bluetooth.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Spring, Summer  
 Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
 Pre-Requisite(s): EE 4272 or CS 4461

**EE 5470 - Semiconductor Fabrication**

Graduate level introduction to the science and engineering of semiconductor device fabrication.

Credits: 3.0  
 Lec-Rec-Lab: (3-0-0)  
 Semesters Offered: Fall  
 Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EE 5471 - Microfabrication Laboratory**

A hands-on laboratory experience in which the students fabricate devices with micro-and nano- scale dimensions. Lecture component covers safety training, background on microfabrication processes and systems, and facility tours to observe additional systems.

Credits: 2.0  
 Lec-Rec-Lab: (1-0-3)  
 Semesters Offered: Fall, Spring  
 Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**EE 5480 - Advanced MEMS**

This course will cover advanced topics dealing with MEIXIS technologies, transduction mechanisms, and microfabricated sensors and actuators and is a continuation of EE4240/MY4240

Credits: 4.0

Lec-Rec-Lab: (3-1-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): EE 4240 or MY 4240

**EE 5490 - Solar Photovoltaic Science and Engineering**

Solar photovoltaic materials, the device physics of photovoltaic cells and practical applications of solar electric systems engineering.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**EE 5496 - GPU and Multicore Programming**

Introduction to Graphics Processing Units (GPU) and multi-cores, their architectural features and programming models, stream programming, and compute unified driver architecture (CUDA), caching architectures, linear and non-linear programming, scientific computing on GPUs, sorting and search, stream mining, cryptography, and fixed and floating point operations.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 3411 and EE 4173

**EE 5497 - Multimedia Data Security in Hardware Firmware and Software**

Software and hardware aspects of digital media security, data protection; Analysis of digital media for purposes of authentication and protection against tampering and forgery; Electronic tamper detection; Secure exchange of digital content over the Internet or electronic media; Cryptographic processors.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 4321

**EE 5500 - Probability and Stochastic Processes**

Theory of probability, random variables, and stochastic processes, with applications in electrical and computer engineering. Probability measure and probability spaces. Random variables, distributions, expectations. Random vectors and sequences. Stochastic processes, including Gaussian and Poisson processes. Stochastic processes in linear systems. Markov chains and related topics.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EE 5511 - Information Theory**

Mathematical models for channels and sources; entropy, information, data compression, channel capacity, Shannon's theorems, and rate-distortion theory.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2007-2008 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 5500

**EE 5520 - Fourier Optics**

Analysis and modeling of diffraction effects on optical systems, emphasizing frequency-domain analytic and computational approaches. Presents wave propagation, imaging, and optical information processing applications.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering

Pre-Requisite(s): EE 3190

**EE 5521 - Detection & Estimation Theory**

Detecting and estimating signals in the presence of noise. Optimal receiver design. Applications in communications, signal processing, and radar.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering

Pre-Requisite(s): EE 5500

**EE 5522 - Digital Image Processing**

Fundamentals of image processing are covered including image representation, geometric transformations, binary image processing, compression, space and frequency domain processing. Computer programming in MATLAB and Python required.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering

**EE 5525 - Wireless Communications**

Principles of wireless communications systems. Projects may include cell phones, computer networks, paging systems, satellite communications, radio, television and telemetry.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 5527

**EE 5526 - Microwave Engineering**

Basics of microwave engineering. Topics include: microwave sources; wave equations and their solutions; wave propagation; reflection, and guiding; transmission line theory and practice; microwave network analysis and impedance matching; microwave resonators, filters, and dividers; left-handed materials and devices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 3140 or EE 5140

**EE 5527 - Digital Communications**

This course focuses on the basic principles that underlie the analysis and design of digital communication systems. Topics covered include: characterization of communication signals and systems, modulation schemes, optimum receiver design and performance analysis in AWGN and band-limited channels, concepts of information theory and channel coding, carrier and symbol synchronization, and ISI channel equalization.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 3250

**EE 5528 - Antenna Engineering**

Topics include: basics of radiation theory, Hertzian dipole and loop antennas, near and far fields, bandwidth, gain and other antenna parameters, Yagi-Uda, bow-tie, cavity-backed and traveling wave antennas, microstrip solutions, miniaturization, substrates and superstrates.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2013-2014 academic year

Pre-Requisite(s): EE 5526

**EE 5531 - Introduction to Robotics**

Introduction to autonomous systems and robotics with focus on automated ground vehicles. Project based course using distributed computing to solve problems related to motion planning, perception, and localization. Requires experience with Linux operating systems variants, version control systems, and C++ or Python.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Spring

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**EE 5532 - Sensing and Processing for Robotics**

Sensing modes, signal and image processing for industrial robotic automation processes. Emphasis placed on widely used sensors, including cameras and 3-D sensors for process control and computer vision for autonomous navigation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): EE 5522

**EE 5650 - Biomedical Optics**

Light plays a significant role in modern clinical diagnostics and in the clinical treatment of disease. Examples include non-invasive surgery, optical biopsy, and cancer therapy. This course will focus on the study of how light propagates through biological tissue.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2016-2017 academic year

**EE 5715 - Linear Systems Theory and Design**

Overview of linear algebra, Modern Control: state-space based design of linear systems, observability, controllability, pole placement, observer design, stability theory of linear time-varying systems, Lyapunov stability, optimal control, Linear Quadratic regulator, Kalman filter, Introduction to robust control.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering

Pre-Requisite(s): EE 3261 or MEEM 3750

**EE 5726 - Wireless Sensor Networks**

Introduces the concepts of wireless sensor networks. Topics include sensor network coverage and sensor deployment, time synchronization and sensor node localization, network protocols, data storage and very, collaborative signal processing. Introduce sensor network programming network reliability and tolerance.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): (CS 4461 or EE 4272 or EE 5722) and (EE 3170 or EE 3173) and (CS 1129 or CS 2141)

**EE 5750 - Model-Based Embedded Control System Design**

This course introduces embedded control system design using a model-based approach. Course topics include model-based embedded control system design, discrete-event control, sensors, actuators, electronic control unit, digital controller design, and communication protocols. Prior knowledge of hybrid electric vehicles is highly recommended.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering; Must be enrolled in one of the following Major(s): Electrical Engineering

Pre-Requisite(s): (MEEM 4700 or MEEM 4775 or EE 3261 or EE 4261) and EE 4295

**EE 5755 - Fault-Tolerant Systems**

Covers both the theory and the practice of how to design, model, evaluate, and implement reliable systems out of unreliable components. Includes: Fault Models, Redundancy Management, Agreement, Consensus, Voting, Clock synchronization and reliable broadcast. Material is reinforced with real-world case studies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): (MA 3710 or EE 3180) and (EE 4173 or CS 4431)

**EE 5777 - Advanced Open-Source 3-D Printing**

An introduction to distributed additive manufacturing using open-source 3-D printing. Design, use, and maintenance of open-source electronics and self-replicating rapid prototypers (RepRap). Graduate students will be expected to complete coursework and an in-depth project.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**EE 5780 - Advanced VLSI Computer-Aided Design**

Nanoscale chip design presents issues for IC designs and new market areas for design automation. This course provides a comprehensive introduction on layout design. Advanced algorithms and optimization techniques are presented to give students the skills needed for nanometer VLSI design.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 4321 and EE 4271

**EE 5805 - Directed Study in Electrical & Computer Engineering**

Directed study on a topic mutually agreed upon by the student and the instructor. Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Electrical Engineering

**EE 5811 - Automotive Systems**

Automotive systems for light duty vehicles are examined from the perspectives of requirements, design, technical, and economic analysis for advanced mobility needs. This course links the content for the automotive systems graduate certificate in controls, powertrain, vehicle dynamics, connected and autonomous vehicles.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Automotive Systems & Controls, Computer Engineering

**EE 5812 - Automotive Control Systems**

Introduction to automotive control systems. Modeling and control methods are presented for: air-fuel ratio, transient fuel, spark timing, idle speed, transmission, cruise speed, anti-lock brakes, traction, active suspension systems, and hybrid electric vehicles. Advanced control methodologies are introduced for appropriate applications.

Credits: 3.0

Lec-ec-Lab: (0-3-0)

Semsters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering

Pre-Requisite(s): EE 3261 or MEEM 4700 or MEEM 4775

**EE 5821 - Computational Intelligence - Theory and application**

This course covers the four main paradigms of Computational Intelligence, viz., fuzzy systems, artificial neural networks, evolutionary computing, and swarm intelligence, and their integration to develop hybrid systems. Applications of Computational Intelligence include classification, regression, clustering, controls, robotics, etc.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**EE 5841 - Machine Learning**

This course will explore the foundational techniques of machine learning. Topics are pulled from the areas of unsupervised and supervised learning. Specific methods covered include naive Bayes, decision trees, support vector machine (SVMs), ensemble, and clustering methods.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): CS 4090

**EE 5900 - Special Topics in Electrical Engineering**

Special topics in electrical engineering selected by the student and approved by his/her advisor and the faculty member who will approve the study.

Credits: variable to 5.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering

**EE 5990 - Thesis Research in Electrical Engineering**

Study of some acceptable electrical engineering problem and preparation of a thesis.

Credits: variable to 10.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**EE 5991 - Project Research in Electrical Engineering**

Study of some acceptable electrical engineering problem and preparation of a report.

Credits: variable to 6.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required

**EE 5992 - Practical Experience in Electrical Engineering**

A collaboration with industry on some acceptable electrical engineering task and preparation of a report.

Credits: variable to 4.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required

**EE 5994 - International Electrical and Computer Engineering Field Experience**

Field work and reporting from students in the Peace Corps Master's International Program in Electrical and Computer Engineering.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-2)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Electrical Engineering, Computer Engineering

**EE 6210 - Power System Dynamics and Stability**

A study of the dynamic behavior of power systems. A review of synchronous machine modeling, system dynamic equations, and method of analysis.

Examines overall system behavior via small signal and transient stability and energy functions. Also studies voltage stability and non-linear effects.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): EE 5200

**EE 6320 - Cyber Security of Automotive Systems II**

This course covers advanced topics in cyber security of automotive systems. Topics include modeling and simulation of cyber attacks on vehicle subsystems, communications security for V2X systems, vulnerabilities in cooperative vehicle infrastructures, threat analysis, and cyber security of SAE level 2, 3, and 4 autonomous driving systems.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science, Mechanical Engineering, Mechanical Eng-Eng Mechanics, Computer Engineering, Electrical Engineering; Must be enrolled in one of the following Campus(s): Co-op and Online Course(s), Co-op Program, Off Campus, Off Campus MTU On-Line  
Pre-Requisite(s): MEEM 5310 or EE 5310

**EE 6702 - Nonlinear System Analysis and Control**

Studies nonlinear systems from perspective of analysis/control system design. Explores fundamental properties for nonlinear differential equations in addition to describing functions, phase plane analysis, stability/instability theorems. Develops and applies control system design approaches for nonlinear systems, including feedback linearization and sliding mode control.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Spring  
Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): EE 5715 or MEEM 5715

**EE 6990 - Doctoral Research**

Original research leading to the preparation of a dissertation in partial fulfillment of the requirements for the PhD degree.  
Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Permission of instructor required

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**Electrical Engineering Technology****EET 5000 - Independent Study in Electrical Engineering Technology**

Independent study in an approved topic under the guidance of an Electrical Engineering Technology staff member. Course of study may either be research or academic to be determined by student and faculty.  
Credits: variable to 3.0; Repeatable to a Max of 6  
Semesters Offered: On Demand  
Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**EET 5100 - Test Engineering Fundamentals**

Fundamental concepts of testing electrical or mechatronic devices are presented. Topics include design for testability, test economics and product quality, fault models, functional and statistical techniques, IC parametric tests, boundary scans, built-in self tests, and board level design for testability.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: On Demand  
Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EET 5120 - Electronic Manufacturing**

Emphasizes fundamentals of signal transmission theory, digital circuit design, the role of packaging in circuit performance, and PCB manufacturing.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: On Demand  
Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
Pre-Requisite(s): EET 3281

**EET 5142 - Digital Signal and Image Processing**

Provides students with digital signal and image processing techniques with emphasis on applications. Covers concepts of sampling, digital filters and discrete Fourier transforms, image processing, enhancement, and restoration. The course requires proposing, executing, and defending at the graduate level, related to the course material project.  
Credits: 4.0  
Lec-Rec-Lab: (0-3-3)  
Semesters Offered: Spring  
Pre-Requisite(s): EET 3367 and (EET 4141 or EET 4311)

**EET 5144 - Real-Time Robotics Systems**

Covers the components of a robot system, safety, concepts of a work-cell system, geometry, path control, automation sensors, programming techniques, hardware, and software.  
Credits: 4.0  
Lec-Rec-Lab: (0-3-3)  
Semesters Offered: On Demand  
Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): EET 1411 or EET 2220 or PH 2230 or EE 2110 or EE 3010

**EET 5147 - Industrial Robotic Vision System and Advanced Teach Pendant Programming**

Procedures for setting up, teaching, testing, and modifying robot vision systems widely used in industrial automation. Introduces advanced Teach Pendant Programming to develop complex scenarios for integrating robots into industrial cells. Final project must demonstrate proficiency in setting up and programming an advanced robotic vision scenario.  
Credits: 4.0  
Lec-Rec-Lab: (0-3-3)  
Semesters Offered: Fall, Summer  
Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): EET 4144 or EET 5144

**EET 5171 - Quality Control**

Fundamentals of statistical quality control are studied. Areas of study include process improvement, reduction of variation, root cause analysis, measures and costs of quality, systems thinking, and analysis and use of non-numeric test results such as modeling using ordinal variables.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: On Demand  
Restrictions: Permission of instructor required; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EET 5221 - EMC Test Engineering Fundamentals**

Introduction to concepts and methodologies used in Electromagnetic Compatibility conformance testing. Course will explore common design flaws that result in EMC issues as well as industry standard test methods used to uncover those flaws. Intended as preparation for NARTE EMC Technician and Engineer exam.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: On Demand  
Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
Pre-Requisite(s): EET 5100

**EET 5241 - Digital Hardware Testing**

The course emphasizes fundamentals of digital hardware design for testability, faults in digital circuits, fault simulation and test generation, memory testing, testing of sequential circuits, microprocessor testing, digital circuit design, the role of packaging in circuit performance and PCB manufacturing.  
Credits: 3.0  
Lec-Rec-Lab: (0-2-2)  
Semesters Offered: On Demand  
Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior  
Pre-Requisite(s): EET 5100

**EET 5261 - Optical System Design and Testing**

The fundamental concepts of optical system design and testing are presented at the moderate level. Simulation tools for modeling a broad range of optical components are designed to enhance the learning process. Laboratory experiments are intended to provide hands-on experience.  
Credits: 3.0  
Lec-Rec-Lab: (0-2-2)  
Semesters Offered: On Demand  
Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**EET 5311 - Advanced Circuits and Controls**

Topics include: Fourier and Laplace transforms, signal comparison techniques and transfer functions. Control techniques addressed will include feedback, cascade, feedforward, multivariable and model based methods. Graduate students are expected to demonstrate ability in modeling/simulation techniques of linear systems.  
Credits: 4.0  
Lec-Rec-Lab: (0-3-3)  
Semesters Offered: Fall  
Pre-Requisite(s): EET 3131 or EET 4253

**EET 5373 - Advanced Programmable Controllers**

Using Allen Bradley Contr Logix and SLC500 programmable controllers, course covers structured programming, Sequential Function Charts, networking, proportional integral differential control, data acquisition and interfacing. The course requires proposing, executing, and defending at the graduate level related to the course material project.  
Credits: 4.0  
Lec-Rec-Lab: (0-2-3)  
Semesters Offered: Spring  
Pre-Requisite(s): EET 3373

**EET 5990 - Special Topics in Electrical Engineering Technology**

Electrical Engineering Technology topic of interest to faculty and student.  
Credits: variable to 3.0; Repeatable to a Max of 12  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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## Engineering Fundamentals

### ENG 5100 - The Engineering Process

This course introduces the engineering problem solving and design processes. Students will learn about the engineering profession and will complete a design/build/test project.

Credits: 4.0

Lec-Rec-Lab: (0-3-2)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### ENG 5200 - Engineering Applications in the Physical Sciences

This class will show how engineers use principles from the physical sciences to solve problems and design systems. Key concepts will be linked to the Michigan Curriculum Frameworks for precollege education.

Credits: 4.0

Lec-Rec-Lab: (0-3-2)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ENG 5100 or (ENG 5101 and ENG 5102)

### ENG 5300 - Engineering Applications in the Earth Sciences

This course will show how engineers use principles from the earth sciences to solve problems and design systems. Key concepts will be linked to the Michigan Curriculum Frameworks for precollege education.

Credits: 4.0

Lec-Rec-Lab: (0-3-2)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ENG 5100

### ENG 5400 - Engineering Applications in the Life Sciences

Students will gain hands-on experience linking engineering technologies to the biological sciences. Participants will visit labs and field sites at Michigan Tech to observe and participate in current research. Topics covered include biofuels, environmental restoration, environmental toxins, and ecosystem measurement.

Credits: 4.0

Lec-Rec-Lab: (0-3-2)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): ENG 5100

### ENG 5510 - Sustainable Futures I

Covers introductory and intermediate concepts of Sustainable Development. Explores methods/tools for assessing sustainability (economic, environmental, societal impacts) of current and emerging industrial technologies. Explores relationships between government policies and markets for introducing sustainable technologies into national economies and corporations.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

### ENG 5520 - Sustainable Futures II

Covers sustainability in developed and developing countries. Topics include policy analysis, regulatory impact & cost benefit analyses, trade & markets, laws & regulations, international disasters, GIS applications, green manufacturing, and evolution of environmental policy in U.S. and other countries.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

### ENG 5540 - Sustainable Forest-Based Biofuel Pathways

This course provides an integrated multidisciplinary education in forest-based biofuel; forest biomass production, conversion by pyrolysis, catalytic upgrading, and vehicular combustion. Sustainability topics will include government biofuel policy, community impacts, techno-economics, and life cycle environmental impacts, with use of software.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2013-2014 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### ENG 5990 - Special Topics in Engineering

Engineering topics of interest to students and faculty that are not normally covered in the existing courses.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### ENG 5998 - Engineering Design Practicum

An advanced independent study for students in the Master of Engineering program. In consultation with his/her advisor, the student develops and executes a project demonstrating capabilities in problem solving, communications, and decision making. The practicum can be completed on or off campus.

Credits: variable to 4.0; Repeatable to a Max of 4

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

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## Enterprise

### ENT 5950 - Graduate Enterprise Project Work

Interdisciplinary teams work as part of an enterprise to address real-world design projects or problems. Graduate students will actively participate in project work as defined by the team advisor, and provide technical expertise and mentorship to undergraduate team members.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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## Forest Resources & Environmental Science

### FW 5000 - Distinguished Ecologist Lecture Series

An opportunity to meet with some of the world's leading ecologists and to discuss their research. Pre- and post-lecture meetings enable students to review some of the research and discuss how it has impacted the field of ecology.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### FW 5020 - Woody Plants of North America

Identification and ecology of forest plants with an emphasis on tree and shrubs. Includes systematic study of the major forest vegetation types of North America.

Credits: 2.0

Lec-Rec-Lab: (1-0-3)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### FW 5021 - Forest Certification

Reviews the history and application of the four major certification programs applicable to forests in the United States: Forest Stewardship Council (FSC); Sustainable Forestry Initiative (SFI); American Tree Farm System (ATFS); and Programme for the Endorsement of Forest Certification (PEFC). Prior knowledge of forest ecology is helpful.

Credits: 1.0

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Summer

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

### FW 5079 - Forest Management

Focus on forest resource management planning and decision making, emphasizing structured problem solving frameworks and decision support tools/models at forest and landscape scales.

Credits: 2.0

Lec-Rec-Lab: (1-0-1)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### FW 5081 - Professionalism in Forestry

This class engages professional students in practicing soft skills for a forestry and/or natural resources management career. Emphasis will be on networking, communicating clearly to their intended audience, handling meetings, leadership, and public presentations. The professional society's code of ethics will be explored.

Credits: 1.0

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Forestry

**FW 5082 - Gene Expression Data Analysis**

This course is designed for students majoring in molecular biology, computer science, data science and related majors to develop fundamental but essential skills for manipulating, preprocessing, and analyzing high throughput gene expression data for pattern extraction and knowledge discovery.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): FW 4099 or CS 1121 or CS 1122 or CS 1131 or CS 1141 or CS 2321

**FW 5083 - Programming Skills for Bioinformatics**

Students will learn computer programming skills in Perl for processing genomic sequences and gene expression data and become familiar with various bioinformatics resources.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5084 - Data Presentation and Visualization with R**

This course is designed for graduate students majoring in forestry, wildlife, ecology, and natural resource management and data science to develop fundamental but essential skills for data presentation and visualization through generating informative graphs with R.

Credits: 2.0

Lec-Rec-Lab: (1-0-2)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5088 - Economic Analysis of Forestry**

Financial analysis and economic theory applied to forestry project analysis and selection, focusing on prices. Covers risk, capital markets, taxation, auctions, land valuation, harvesting decisions, and non-market valuation.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5092 - Experimental Design for Forestry and Natural Sciences**

This lab is designed for graduate students majoring in forestry, wildlife, ecology, and natural resource management to develop fundamental but essential skills for designing experiments and analyzing data.

Credits: 3.0

Lec-Rec-Lab: (2-0-1)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5100 - Advanced Terrestrial Ecology**

Structure and function of terrestrial ecosystems, focusing primarily on upland forests. Roles of climate, population structure, competition for above and belowground resources, natural disturbance, management, and global change on ecosystem community composition, succession, carbon exchange, productivity, and nutrient cycling.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5115 - Restoration Ecology**

Study the tools, challenges, and philosophical underpinnings associated with ecological restoration. Restoration of forest, grassland, and wetland communities (plant and animal) will be discussed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5130 - Forest Vegetation Dynamics**

Investigation of how trees grow and interact in a variety of stand structures from a functional standpoint at both the tree- and stand-level. These principles will be used to test the use of silvicultural management tools for meeting a variety of objectives. Linkages will be made between stand development patterns and management options, with an emphasis on disturbance ecology.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore  
Pre-Requisite(s): BL 3400 or FW 3010 or FW 3012 or FW 3020

**FW 5133 - Intensive Silviculture**

Applied forest ecology practices involving interventions to produce high levels of ecosystem services. Covers a full range of ecosystem goods and services, including carbon sequestration and biomaterials. Emphasizes quantitative metrics and methods for assessing and evaluating outcomes, including growth and yield.

Credits: 3.0

Lec-Rec-Lab: (1-2-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5135 - Plant Community Ecology**

Investigation of the theoretical underpinnings and quantitative tools associated with the study of plant communities.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5180 - Ethics of Conservation and Sustainability**

Discusses relationship between ecological science and environmental ethics as it relates to natural resource management, conservation and sustainability.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5201 - Forest Biometrics and Modeling**

Overview and application of statistical techniques and sampling designs used in the forest environment for attribute monitoring and inventory. Use and evaluation of models that simulated forest development and their application in management and planning.

Credits: 2.0

Lec-Rec-Lab: (1-0-3)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Forestry

**FW 5221 - Advanced Wetlands and Global Peatlands**

This class concentrates on theoretical and technological advances understanding peatlands globally. Readings will pertain to major topics in wetland ecology, hydrology, soils, vegetation, biogeochemistry of arctic, boreal, temperate, mountain and tropical peatlands.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5330 - Applied Soil Science**

A review of the chemical, physical, and biological properties of soil with emphasis on forest soils and emerging issues in forest management.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5340 - Population Genetics and Applied Forest Genetics**

The course highlights populations genetic topics and deals with the effects of evolutionary factors on genetic diversity. The relevance of genetic variation patterns for the future management and conservation of forests is stressed. Quantitative methods in population genetics are presented.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

**FW 5368 - Forest Ecophysiology**

Exploration of both classic and cutting-edge literature on the mechanistic aspects of tree and forest ecosystem function. Emphasis on the interactions between canopy structure, carbon flux, nutrient cycling, and water uptake in the context of global change.

Credits: 2.0

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2016-2017 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5369 - Hydrology and Watershed Management**

This survey course introduces the applications of hydrological concepts to evaluate the impacts of forest management and other land use activities/events on water yield, infiltration, evapotranspiration, stormflow, erosion, sedimentation, and water quality.

Credits: 1.0

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5370 - Measuring Plants and the Environment**

Hands-on exploration of instrumentation and data analysis techniques used in the study of forest ecophysiology and hydrology. Methods include: measurement of photosynthesis, respiration, sap flux, water potential, and micro-meteorological and hydrological variables.

Credits: 3.0

Lec-Rec-Lab: (0-2-3)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5371 - Snow Hydrology**

This course will cover snow formation in the atmosphere, snow accumulation and distribution, snow metamorphism, avalanche dynamics, snowmelt and runoff, remote sensing of snow properties, and the impact of forests and under-snow biogeochemical processes.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5376 - Advanced Forest and Environmental Resource Management I**

Application of forest and environmental management practices and topical investigations by teams of students with the assistance of faculty, staff and representatives of state, federal and corporate land management groups as well as non-governmental organizations.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5377 - Advanced Forest & Environmental Resource Management II**

Application of forest and environmental management practices and topical investigations by teams of students with the assistance of faculty, staff and representatives of state, federal and corporate land management groups as well as non-governmental organizations.

Credits: 2.0; May be repeated

Lec-Rec-Lab: (0-2-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5378 - Field Methods**

To gain real world experience in measuring, monitoring, and assessing various projects involving active management and conservation of our university forest resources.

Credits: 1.0

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Forestry

**FW 5400 - Advanced Conservation Biology**

Introduction to biological, social, political, and economic facets of conservation biology. Emphasizes evaluation of how best to maintain and restore biodiversity through management of populations and ecosystems. Topics include mass extinctions, global change, loss and degradation of habitat, and over exploitation of biological resources.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5411 - Applied Regression Analysis**

Regression as a tool for the analysis of forest and environmental science data. Topics include multiple linear, curvilinear and non-linear regression, hierarchical and grouped data and mixed-effects models. Emphasis is placed on application of tools to real-world data.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5412 - Regression in R**

Use of R for basic data manipulation, statistical summary and regression. Topics include installing R, data import and export, basic statistics, graphics and fitting of linear, non-linear and mixed-effects models.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Co-Requisite(s): FW 5411

**FW 5421 - Climate Change and Management in Great Lakes Forested Systems**

Provides an overview of climate change science, effects and adaptation for natural resource management in the Great Lakes region. Students develop climate change adaptation plans for real world forested ecosystem examples and learn how to communicate these climate change projects and plans with stakeholders.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5510 - Special Topics in Natural Resources**

Independent study of a specific area of natural resources.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5517 - Soil Biogeochemistry**

Study of the relationship between soil composition and the circulation of major elements through the earth system. Responses of biogeochemical cycles of the elements in agricultural, forest, grassland, and wetland soils to changes in land use, biodiversity, nutrient supply, plant stressors, and climate change will be discussed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): CH 1150

**FW 5519 - Atmospheric Biogeochemistry**

Study of the relationship between atmospheric composition, global change, and the circulation of major elements through the Earth system. Responses of ecosystem emissions to changes in landuse, biodiversity, nutrient supply, plant stressors, and climate change are discussed.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2016-2017 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): CH 1150

**FW 5540 - Remote Sensing of the Environment**

Remote sensing principles and concepts. Topics include camera and digital sensor arrays, types of imagery, digital data structures, spectral reflectance curves, applications, and introductory digital image processing.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Co-Requisite(s): FW 5541

**FW 5541 - Remote Sensing of the Environment Lab**

Applied introductory remote sensing analysis using industry standard software for digital image processing.

Credits: 1.0

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall

Co-Requisite(s): FW 5540

**FW 5550 - Geographic Information Science and Spatial Analysis**

Use of geographic information systems (GIS) in resource management. Studies various components of GIS in detail, as well as costs and benefits. Laboratory exercises use ArcGIS software package to solve resource management problems.

Credits: 4.0

Lec-Rec-Lab: (3-0-3)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): MA 2710 or MA 2720 or MA 3710

**FW 5553 - Python Programming for ArcMap GIS**

An introduction to Python scripting and basic Python coding within ArcMap. Labs cover tasks found in typical GIS workflows. Students learn how to write and debug Python scripts, models and mapping programs.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Fall

Pre-Requisite(s): FW 5550 or FW 3540

**FW 5554 - GPS Field Techniques**

This course will provide hands-on experience with various types of GPS units and different applications of the technology. These applications include planning, data collection, data processing, and data management. Emphasis will be on practical applications of Global Positioning System technology.

Credits: 2.0

Lec-Rec-Lab: (1-0-3)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5555 - Advanced GIS Concepts and Analysis**

This course moves beyond the fundamentals of GIS to explore the application of GIS technology to environmental monitoring and resource management issues. Students learn graphic modeling techniques, network analysis, 3D visualization, geodatabase construction and management, and multivariate spatial analysis.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): FW 5550

**FW 5556 - GIS Project Management**

Course provides exposure to data collection techniques, web mapping applications, and advanced database structures. Students will investigate GIS system design, GIS project planning and data management, learn map atlas creation and cartographic techniques, and discuss geospatial ethics.

Credits: 3.0

Lec-Rec-Lab: (1-0-4)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): FW 5550

**FW 5557 - Applied Spatial Statistics**

Focus on spatial statistical methods such as spatial regression, geographically weighted regression and cluster analysis. ArcMap is utilized for analysis.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): FW 5550

**FW 5560 - Digital Image Processing: A Remote Sensing Perspective**

Presents the theory and quantitative procedures of digital image processing using remotely sensed data. Emphasizes image acquisition, preprocessing, enhancement, transformation classification techniques, accuracy assessment, and out-products. Discusses linkages to GIS. Also covers evaluating applications of the technology to current resource management problems via peer-reviewed literature.

Credits: 4.0

Lec-Rec-Lab: (3-0-1)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): FW 5540

**FW 5580 - UAS(Drone)Remote Sensing and Photogrammetry**

Applied fundamentals of aerial image interpretation, analysis and accurate measurements. Flight fundamentals, film and digital imagery, LIDAR, sensors, cameras, and lenses. Remotely Piloted Aircraft flight mission planning, image acquisition, aerotriangulation, point cloud and DEM/DSM generation. Preparation for FAA Remote Pilot Exam.

Credits: 4.0

Lec-Rec-Lab: (3-0-1)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): MA 1032 and (FW 5540 or FW 4540)

**FW 5620 - Herpetology**

The biology of amphibians and reptiles, including evolution, zoogeography, ecology, behavior and physiology.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5678 - Natural Resources Field Service**

This course provides a supervised field experience in natural resources and community development.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s):

Sch of Forest Res & Envir Sci

**FW 5700 - Graduate Field Forestry**

For graduate students without an undergraduate degree in forestry or a closely related field. Covers field skills in mapping/GPS work, forest diseases and insects, wildlife, timber harvesting, natural resource inventory, and silviculture.

Credits: 8.0

Lec-Rec-Lab: (3-0-15)

Semesters Offered: Fall, Summer

**FW 5701 - Graduate Field Applied Ecology**

Field skills in mapping/GPS work, forest diseases and insects, wildlife, vegetation geomorphology, natural resource inventory and silviculture for graduate students without an undergraduate degree in environmental science or a closely related degree.

Credits: 8.0

Lec-Rec-Lab: (3-0-15)

Semesters Offered: Fall, Summer

**FW 5730 - Field Work in International Forestry**

Field work and reporting from students in the Peace Corps Loret Miller Ruppe Masters International Program in Forestry.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**FW 5780 - Agroforestry**

Fundamental ecological processes and traditional use of woodlands, and socioecological issues including tenure, access, management, and policy. Farm systems analysis and the role of trees in farming systems. Also covers specific material on tropical soil conservation and crops.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5800 - Master's Graduate Seminar**

Presentation by students of current natural resource- related problems and research. Some instruction on presentation skills.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5801 - Masters Seminar in GIS**

Students will review, present, and discuss current research and applications of geospatial technology. This course is designed for students in the professional MS in GIS degree program, but will be open to students in other programs.

Credits: 1.0; Repeatable to a Max of 4

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Fall, Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5810 - Research Methods in Natural Resources**

Overview of science and scientific research. The process of graduate education including choosing an advisor, selecting a research problem, writing a thesis proposal, scientific hypothesis testing, analyzing data, and communicating results through various media.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5811 - Advanced Responsible Conduct of Research in Natural Resources**

Three four-hour workshops on advanced responsible conduct of research drawing on examples in natural resources. It covers the topics necessary for this training including ethical standards, publication practices, peer review process, conflict of interest and societal expectations.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Summer

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**FW 5812 - Public Relations for Natural Resource Professionals**

Explores current methods to effectively communicate natural resource concepts to the public. Students will develop a public relations plan for their organization and will gain skills in crafting a message, writing promotional materials, sourcing compelling imagery, managing digital media, organizing outreach events, and engaging stakeholders.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 5999 - Forest Resources and Environmental Science Master's Research**

An original investigation in forest science, ecology, and forest molecular genetics that culminates in a Master's degree.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 6800 - Doctoral Graduate Seminar**

A seminar course in which current forest resource related problems and research are presented by students in the class. Some instruction on presentation skills.

Credits: 1.0; Repeatable to a Max of 2

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 6980 - Graduate Teaching**

Development of teaching skills through assisting in instruction. Students gain experience in course organization, lecture and laboratory instruction, and laboratory preparation.

Credits: variable to 4.0; Repeatable to a Max of 4

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**FW 6999 - Forest Resources and Environmental Science Doctoral Research**

An original investigation in theoretical or experimental natural resources and submission of a dissertation in partial fulfillment of the requirements of the PhD degree.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**Geological & Mining Engineering & Sciences****GE 5150 - Advanced Natural Hazards**

Exploration of how to develop comprehensive plans to mitigate the impact of natural hazards on humans. Requires a project and report.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5180 - Volcanology**

Volcanoes and how they work. Volcanic products, their recognition, and significance. Applies chemistry, physics, and fluid mechanics in a volcanological context.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5187 - Volcanological Field Seminar**

Field Seminars of 1-3 weeks to volcanological sites of interest. These are offered in association and following GE5185. The field seminars are complemented by the preceding semester's classes, which examine the broad context of the field events. The two classes may be taken together as 4 credits or separately.

Credits: 2.0; May be repeated

Lec-Rec-Lab: (0-0-6)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Major(s): Geology, Geophysics, Geological Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore

**GE 5195 - Volcano Seismology**

Will prepare students, including those with no seismology background, to interpret seismic and acoustic signals from volcanoes. Topics: basic seismology, monitoring techniques, tectonic and volcanic earthquakes, infrasound, deformation over a range of time scales.

Credits: 3.0

Lec-Rec-Lab: (2-0-1)

Semesters Offered: Spring

Pre-Requisite(s): (MA 1160 or MA 1161 or MA 1135) and GE 2000 and PH 2100

**GE 5200 - Advanced Geochemistry**

Introduction to advanced elements of modern geochemistry including aqueous solutions, isotopes, age dating, etc. Emphasizes concepts of quantitative methods. Teaches principles of thermodynamics and phase equilibria from an introductory perspective as they pertain to geologic systems Project and report required.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5250 - Advanced Computational Geosciences**

Introduction to quantitative analysis and display of geologic data using R/Matlab, covering basic R/Matlab syntax and programming, and analysis of one-dimensional (e.g. time series) and two-dimensional datasets (e.g. spatial data).

Techniques are applied to geological datasets. Requires an in-depth project, report, and presentation.

Credits: 3.0

Lec-Rec-Lab: (2-0-1)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5260 - Scientific Communication**

Provide practice and advanced strategies in preparing, critiquing, and evaluating written communication. Will cover knowing your audience, scientific manuscript and proposal writing, reviewing, critiquing, and interpreting feedback. Students will prepare and critique written communication.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5400 - Plate Tectonics and Global Geophysics**

Plate tectonics and the internal structure of the earth using information from seismology, geomagnetism gravity, and heat flow.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 3160 and PH 2200 and GE 2000

**GE 5430 - Advanced Planetary Geology and Geophysics**

Geological, geophysical, and geochemical processes in the Solar System. Topics include the formation and evolution of the Solar System, planetary geological processes, impact structures, composition, structure, and dynamics of planetary interiors, geophysical exploration of planets. A term project/report is required.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

Pre-Requisite(s): GE 2000 and PH 2200 and MA 2160

**GE 5560 - Advanced Earthquake Seismology**

Course covers fundamentals of the physics of earthquakes and seismic energy propagation, and seismic methods to determine Earth structure. Emphasis is placed on natural source techniques, with extension to exploration applications. Weekly labs apply techniques.

Credits: 3.0

Lec-Rec-Lab: (2-0-2)

Semesters Offered: Fall - Offered alternate years beginning with the 2015-2016 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): GE 3050 and PH 2100 and MA 3160

**GE 5600 - Advanced Reflection Seismology**

Principles and application of reflection seismic techniques. Includes acquisition, data processing, and 2D/3D data interpretation. Project and report required.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5735 - Advanced Igneous Petrology**

A quantitative examination of the thermodynamic and physical conditions of igneous rock formation using geochemistry, mineralogy, and rock textures.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5785 - Seismic Petrophysics**

Seismic petrophysics describes the use of rock physics information and logging data in the interpretation of reflection seismic data. The theories and empirical models relating seismic properties to other properties of rocks will be reviewed, and the logging techniques responsible for identifying those properties discussed. Various approaches to the quantitative interpretation of seismic data are covered. For varying course credit, projects with real data will be conducted by students.

Credits: variable to 3.0

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5800 - Mathematical Modeling of Earth Systems**

Introduction to numerical techniques for mathematical modeling of various earth-system phenomena, including groundwater flow, heat transfer, and atmospheric transport. Numerical techniques covered include finite-difference, finite-element, collocation, and characteristic methods. Students write their own mathematical models. Prerequisite: experience in programming computer languages such as FORTRAN.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 5850 - Advanced Groundwater Engineering and Remediation**

Computer modeling and other advanced topics in the analysis hydrological systems, contaminant transport and fate, and subsurface remediation systems.  
Credits: 3.0

Lec-Rec-Lab: (0-2-3)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Class(es): Graduate

**GE 5860 - Advanced Data Analysis and Inversion**

The course covers a variety of topics in signal analysis and inversion. The signal analysis encompasses different methodologies and concepts to improve data quality and remove noise. Whereas data inversion is used to extract model parameters from the data. The course is useful for any discipline dealint with data analysis and inversion.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Fall

**GE 5870 - Geostatistics & Data Analysis**

This course covers the handling of spatial and temporal data for knowledge discovery. Major topics include spatial interpolation, clustering, association analysis, and supervised and unsupervised classification. Students will learn how to use geostatistical and pattern recognition tools for geoscience applications.

Credits: 3.0

Lec-Rec-Lab: (2-0-1)

Semesters Offered: Fall, Spring

Pre-Requisite(s): GE 3250

**GE 5930 - Special Topics in Geological Engineering**

Study and discussion of geological engineering topics.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**GE 5940 - Special Topics in Geology**

Study and discussion of geology topics.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**GE 5950 - Special Topics in Geophysics**

Study and discussion of geophysics topics.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**GE 5960 - Special Topics in Mining Engineering**

Study and discussion of mining engineering topics.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**GE 5970 - Special Topics in Global Environment Change**

Course will focus on emerging topics on global environment change including changes in atmospheric composition and air quality, air pollution meteorology, extreme meteorological events, and ocean chemistry. Anthropogenic contributions to these changes will be presented and analyzed. Students will work on course projects based on historical records from multiple datasets to evaluate and appreciate the long-term changes in the global environment and better understand the perturbations due to human activities.

Credits: 3.0; Repeatable to a Max of 6

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Fall, Spring

**GE 5994 - International Geological Practicum**

Geological field work outside of the U.S. used by Peace Corps Master International students during their field assignments. May be used repeatedly up to 12 credits.

Credits: 1.0; Repeatable to a Max of 12

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Major(s): Geology, Geophysics, Geological Engineering

**GE 5995 - Domestic Geological Practicum**

Project course for students serving in a U.S. based service activity for one or more semesters. The service activities pertain to community development in the context of geological resource development, restoration, or protection or geological hazard mitigation.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**GE 5998 - International Geology Master's Research**

An original investigation in theoretical or experimental natural geological hazard mitigation and submission of a thesis or report in partial fulfillment of the MS degree conducted while in the Peace Corps Program.

Credits: variable to 9.0; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**GE 5999 - Master's Graduate Research**

Research of an acceptable geological engineering, mining engineering, geology, or geophysics problem and preparation of a thesis.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**GE 6999 - Doctoral Graduate Research**

Original research of an acceptable geological engineering, mining engineering, geology, or geophysics problem and preparation of a PhD dissertation.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

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**Humanities****HU 5000 - Introduction to Graduate Studies in Rhetoric, Theory, and Culture**

Prepares students for graduate level work in the RTC program and introduces them to the fields of scholarly inquiry covered by graduate faculty.

Credits: 1.0; Graded Pass/Fail Only

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture

**HU 5002 - Rhetoric and Composition**

This course considers key theoretical, pedagogical, and historical issues and events that have linked the fields of rhetoric, composition, and literacy studies.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5003 - Technical and Scientific Communication**

This course considers key historical, pedagogical, and theoretical issues in technical and scientific communication, and technology studies. Considerable attention is paid to the practice and critique of technical communication and technology in academic and non-academic settings.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5004 - Cultural Theory**

Study of major cultural theories such as structuralism, poststructuralism, Marxism, feminist theory, postmodernism, cultural studies, postcolonial studies, and discourse theory.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5006 - Continental Philosophy**

Study of major figures and themes in continental philosophy. Topics might include: human being, temporality, historicity, tradition, language, perception, embodiment, intersubjectivity, politics, and technology. Approaches to these issues may include phenomenology, hermeneutics, deconstruction, feminist theory, and critical theory.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5007 - Critical Perspectives on Globalization**

Advanced study of genres, stages, and manifestations of globalization, with an emphasis on critical discourses that seek to understand this phenomenon from humanistic and cultural perspectives.

Credits: 3.0; Repeatable to a Max of 6

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5008 - Critical Approaches to Literature and Culture**

Advanced study of genres, periods and movements in literature and culture. May include transnational movements, comparative studies, oral literature, electronic literature, literary and critical theory and other disciplines and/or arts.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5010 - Organizational Communication**

Theoretical review of the role of communication in organizations. Emphasizes critical interpretive approaches.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5011 - Technology, Culture and Communication**

Examines philosophical and theoretical concepts for understanding the cultural role of technology such as causality, determinism, progress, identity, agency, articulation, assemblage, social space, control, and change.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5012 - Communication Theory**

Traces the development of communication theories. Emphasizes interactions among theoretical, political, historical, and socio-cultural factors.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5020 - Composition Theory**

An introduction to such issues in composition theory as the relationships of thought to language, of spoken to written language, of reading to writing, of writing to learning, and of process to product.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5021 - Literacy Theory and Research**

A study of the social, cultural, and ideological implications of literacy practices using a variety of historical, theoretical, and ethnographic accounts.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5030 - Linguistic Analysis**

The study of linguistic theories and methods for analyzing oral, written, and/or electronic texts. Topics may include how societies construct and are constructed through language; gender, ethnicity, power, class, and region in sociolinguistic variation; theories of discourse; pragmatics; semantics; and methods, ethics, and coding in data collection and analysis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5050 - Theories of Interculturality**

A comparative, critical examination of cross-language and cross-cultural equivalencies and differences through the study of acculturation, values, traditions, role expectations, perceptions, stereotypes, and gender issues.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5070 - History and Theory of Rhetoric**

History and theory of rhetoric, focusing on ancient rhetoric, alternative rhetorics, and/or modern rhetorical theory.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5090 - Writing Creative Nonfiction**

Writing and revising creative nonfiction in a workshop format. Course may include introduction to contemporary and historical works in the field, as well as study of its theories, techniques, and sub-genres.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5091 - Writing for Publication**

Practice in writing to the requirements of professional publications and in identifying the rhetorical considerations of writing for different publications.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5100 - Qualitative Humanistic Research**

Examination of qualitative methodology and compatible methods, with attention to modes of data collection and analysis, and ethical research practices, such as confidentiality and informed consent. Approaches may include ethnographic; phenomenological; narratological; rhetorical; historical; grounded theory; or standpoint theory.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5110 - Backgrounds of Critical Theory**

Study of major critical theories that have influenced contemporary theories such as feminist theory, postmodern theory, cultural studies, critical pedagogy, and discourse theory. Focuses on primary texts in Marxist theory, structuralism, poststructuralism, and phenomenology, and introduces students to the challenges of reading theoretical texts and texts in translation.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5112 - Theoretical Perspectives on Technology**

Philosophical, rhetorical, literary, and/or cultural studies perspectives on technology.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5113 - Cultural Studies**

Introduction to the theoretical history, methods, and practice of cultural studies. Includes the influence of literary humanism, Marxism, structuralism, subcultural studies, feminism, postmodernism, articulation theory, Deleuze and Guattari.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5114 - Visual Theory and Analysis**

A critical survey of selected theoretical, analytic and methodological issues that inform various disciplinary perspectives on visibility, visual culture, images, and image-based media, and visual representation.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5116 - Approaches to Alterity and Difference**

A critical examination of discourses, theories, and representations of otherness or difference according to race, gender, sexuality, class, age, nationality, ethnic background, and other socio-cultural categories. May include discussion of issues of self-representation within and among groups, the rhetorics of exile or diaspora, colonial and postcolonial constructions of identity.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5117 - Theories of Language**

Study of major theories of language that have influenced contemporary work on discourse, language, and literacy. Focuses on language theorists from one or more of a variety of disciplines, such as philosophy, linguistics, literary studies, psychology, anthropology, and rhetoric.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5119 - Fieldwork in International English Education**

Fieldwork and reporting from students in the Peace Corps Master's International Program in Rhetoric and Technical Communication.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**HU 5711 - Biomedical Research Ethics**

Examination of bioethical issues in biomedical research. Topics include research on human subjects, on vulnerable populations, and animals, principles of ethical research, and societal expectations for researchers. This course qualifies for credit in Advanced RCR Training.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**HU 5870 - New Media Theory**

Examines development of theories explaining the cultural significance of new media technology in communication. Emphasizes strengths and weaknesses of these theories, the concept of "new", and emergent theories challenging the centrality of media in the digital and biotechnological age.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5900 - Independent Study**

Guided research under the direction of a member of the graduate faculty. Open to advanced master's students in RTC only. Students must meet with their supervising instructor and receive approval of their study plan from the Director of RTC before registering.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5901 - Directed Reading**

Directed reading in a focused area under the direction of a member of the graduate faculty, open to advanced MS students in RTC. Students must file a plan of study and receive approval from the supervising faculty and the Director of RTC before registering.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5902 - Internship**

Work experience under the direction of a member of the graduate faculty, for advanced MS students. May be conducted on or off campus. Work off campus requires additional direction by an off-campus supervisor. Students must receive approval from their supervising instructor and the Director of RTC before registering.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5931 - Composition Pedagogy**

A study of pedagogical techniques, technologies, evaluation, and assessment. Topics may include practical strategies and theories of rhetorical analysis, reflective speaking practices, critical visual design, and composition. GTAs in the RTC program in their first year of teaching are required to enroll in two consecutive semesters of this course.

Credits: variable to 3.0

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5932 - Practicum in Teaching Technical Communication**

Principles of technical and scientific communication pedagogies and practices. Offers guidance in assignment design, institutional assessment, and policy development through discussion, classroom observation, and reading. One semester required for GTIs new to teaching HU3120.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): HU 5931

**HU 5933 - Practicum in Modern Language Pedagogy**

Discussion and development of effective pedagogical practices and reading of research, scholarship, and theory of modern language pedagogy. GTAs will observe modern language classes regularly and reflect on their own and others' practices. Required of all GTAs in the RTC program in their first year of language teaching at MTU.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 5934 - Practicum in Communication Pedagogy**

Principles of the practice and pedagogy of teaching communications. Offers guidance in class and assignment design, class policy, options for readings, and strategies for teaching. One semester required for graduate students new to teaching communications.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): HU 5931

**HU 5935 - Practicum in Writing Center Administration**

Study of theory and practice of writing center administration. Topics may include pedagogical and tutoring techniques, writing center assessment, and research methods.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s):

Rhetoric, Theory and Culture

Pre-Requisite(s): HU 5931

**HU 5936 - Practicum in Media Pedagogy**

Principles of media studies pedagogies and practices. Offers guidance in class and assignment design, class policy, options for readings and strategies for teaching. Required for students new to teaching media.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s):

Rhetoric, Theory and Culture

Pre-Requisite(s): HU 5931

**HU 5990 - Thesis**

Individual research or scholarship under the direction of a graduate faculty advisor. Open to students in the master's program in rhetoric and technical communication. Students must meet with their advisors before registering.

Credits: variable to 10.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s):

Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5991 - Special Projects**

Individual projects under the direction of a graduate advisor. Open to master's students in RTC only. Students must meet with their advisors before registering.

Credits: variable to 6.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s):

Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 5992 - Independent Study: Coursework Paper**

Students prepare a coursework paper in preparation for the oral coursework defense.

Credits: variable to 3.0; Repeatable to a Max of 3

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s):

Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 6000 - Special Topics in Literacy Studies**

Advanced study of special topics in literacy studies including theories of pedagogy and relationships among literacy, technology, society, and education.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6010 - Special Topics in Communication**

In-depth examination of topics in communication.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6020 - Special Topics in Composition**

In-depth examination of theoretical perspectives on composing. May include discussion of current-traditional, expressivist, social constructionist, and postmodern perspectives.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6050 - Special Topics in Language and Literature**

Advanced study of topics in languages and literature including U.S., British, and world. May include intercultural and comparative studies and the reading of literature, literary and critical theory, translation, and film.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6060 - Special Topics in Philosophy**

Advanced study of selected topics in philosophy. Possible topics include philosophy of literature, philosophy of mind, continental philosophy, analytic philosophy, theories of truth, philosophical issues in cognitive science, contemporary feminist philosophy, and issues in social, political, and legal philosophy.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6070 - Special Topics in Rhetoric and Composition**

Advanced study of special topics in rhetorical or composition theory, history, or practice.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6090 - Special Topics in Pedagogy**

Special topics in pedagogy. Offers guidance in course design and teaching strategies for a specific undergraduated course in Humanities.

Credits: 1.0; Repeatable to a Max of 3

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): HU 5931

**HU 6110 - Special Topics in Critical Inquiry**

Advanced study of contemporary theoretical perspectives in rhetoric and technical communication. Topics might include cultural studies, theories of representation, feminist theory, Marxist theory, postmodern theory, critical perspectives on the environment.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6111 - Special Topics in Gender Studies**

An inquiry into the ways in which gender is constituted within and affects rhetorical, representational, and communicative processes, situations, and structures.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6112 - Special Topics in New Media**

A study of the design and evaluation of interactive texts on the computer, with emphasis on critical and theoretical issues raised by the visually, shifting word-image ratio, and interactivity possible on computer screens.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6114 - Special Topics in Visual Representation**

A critical examination of selected topics in visual representation, with an emphasis on the theoretical, industrial, cultural, international and national, and aesthetic contexts that inform an understanding of particular visual media. May include such topics as genre studies, reception theory and theories of spectatorship, gender and visual representation, etc.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6115 - Special Topics in Technical Communication**

Advanced study of special topics in Technical Communication (TC). May include theories of TC; feminist studies of TC; study of TC in international contexts; theories and practices of usability; TC research methods and methodologies.

Credits: 3.0; Repeatable to a Max of 9

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**HU 6900 - Independent Study**

Guided research under the direction of a member of the graduate faculty. Open to advanced doctoral students in RTC only. Students must meet with their supervising instructor and receive approval of their study plan from the Director of RTC before registering.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 6901 - Directed Reading**

Directed reading in a focused area under the direction of a member of the graduate faculty, for advanced PhD students in RTC. Credit varies according to the nature of the reading. Students must file a plan of study and receive approval from the supervising faculty and the Director of RTC before registering.

Credits: variable to 6.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 6902 - Internship**

Work experience under the direction of a member of the graduate faculty, for advanced PhD students. May be conducted on or off campus. Work off campus requires additional direction by an off-campus supervisor. Students must receive approval from their supervising instructor and the Director of RTC before registering.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 6903 - Doctoral Qualifying Exam**

Students prepare for comprehensive examination.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

**HU 6990 - Doctoral Research**

By arrangement with the instructor directing the PhD dissertation

Credits: variable to 10.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Rhetoric, Theory and Culture, Rhetoric & Tech Communication

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**Kinesiology & Integrative Physiology****KIP 5000 - Advanced Exercise Physiology**

This course focuses on exercise physiology in both humans and rodents. Topics include detailed muscle physiology, fatigue mechanisms, the autonomic nervous system, advanced cardiovascular adaptations with exercise, exercise metabolism, and environmental exercise physiology. The importance of translational research will be highlighted.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Fall

Pre-Requisite(s): (EH 4210 or KIP 4100) and (EH 4211 or KIP 4110)

**KIP 5100 - Advanced Biomechanics**

This course includes the quantitative analysis of human motion through bioinstrumentation during dynamic performance. A detailed analysis of different movements and movement techniques, as well as investigations into the mechanics of tissues and their function, are included in this course.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring

Pre-Requisite(s): (EH 4500 or KIP 4200) and (EH 4511 or KIP 4210)

**KIP 5200 - Advanced Strength and Conditioning**

Advanced theory and practice in development and administration of comprehensive strength and conditioning programs for both the athlete and individual of any level. Includes knowledge, safety concerns and skill techniques necessary for teaching and administering any strength and conditioning facility.

Credits: 3.0

Lec-Rec-Lab: (2-1-0)

Semesters Offered: Spring

Pre-Requisite(s): EH 5310 or KIP 5000 or EH 5320 or KIP 5100 or EH 5330 or KIP 5300

**KIP 5300 - Advanced Motor Learning and Control**

This course will provide the current theories and concepts involved in the processes of motor skill acquisition and performance from a behavioral perspective. Additional peer-reviewed literature will be utilized toward an oral presentation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of department required

**KIP 5450 - Aging, Cognition, and Motor Behavior**

Seminar on current research on age-related changes in cognitive function, motor behavior, and the interaction between cognitive decline and motor performance.

Topics include the impact of aging on memory, attention, cognitive control, gait, balance, and motor learning.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**KIP 5500 - Systems Physiology**

A comprehensive systemic study of the physiological functions of the adult human, including an introduction to the underlying etiologies and clinical indicators of molecular, cellular, and tissue bases for common organ system diseases in humans.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**KIP 5510 - Molecular Physiology**

Introduction on how different biochemical and molecular pathways of the cell work together to produce various physiological functions. Emphasis will be placed on the molecular and cellular mechanisms underlying physiological processes. Structure and function relationship will be addressed throughout the course.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**KIP 5700 - Graduate Seminar**

Graduate seminars are designed to facilitate critical discussions of student research projects and peer-reviewed research in related fields. The presenter will provide an overview or seminar of the research of interest, which will establish the foundation for the discussion thereafter.

Credits: 1.0; Repeatable to a Max of 2

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of department required

Pre-Requisite(s): EH 5310 or KIP 5000 or EH 5320 or KIP 5100 or EH 5330 or KIP 5300

**KIP 5711 - Biomedical Research Ethics**

Examination of bioethical issues in biomedical research. Topics include research on human subjects, on vulnerable populations, and animals, principles of ethical research, and societal expectations for researchers. This course qualifies for credit in Advanced RCR training.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**KIP 5800 - Special Topics in Kinesiology**

Selected additional topics in kinesiology for advanced students based on interests of faculty and students. Interested students should contact the Exercise Science, Health and Physical Education department.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**KIP 5900 - Graduate Internship in Kinesiology**

Practical experience in the field of kinesiology at an approved internship site. Internships must be approved by department chair or graduate director, and work a minimum of 42 hours for each credit earned.

Credits: variable to 6.0

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required

**KIP 5999 - Master's Thesis in Research**

An original research investigation in kinesiology that culminates in a thesis.

Credits: variable to 9.0; Repeatable to a Max of 20; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**KIP 6100 - Doctoral Graduate Seminar in Integrative Physiology**

The graduate seminar is designed to facilitate critical discussions of peer-reviewed research and student research projects in the field of integrative physiology. The presenter will provide an overview or seminar of the research of interest, which will establish the foundation for the discussion thereafter.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Integrative Physiology

**KIP 6800 - Special Topics in Integrative Physiology**

Examination of current topics in the field of integrative physiology. Literature and research topics are addressed.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Integrative Physiology, Kinesiology

**KIP 6999 - Doctoral Research**

An original investigation in theoretical or experimental physiology, or both, and submission of a dissertation.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Integrative Physiology

**Mathematical Sciences****MA 5201 - Combinatorial Algorithms**

Basic algorithmic and computational methods used in the solution of fundamental combinatorial problems. Topics may include but are not limited to backtracking, hill-climbing, combinatorial optimization, linear and integer programming, and network analysis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MA 5221 - Graph Theory**

Review of basic graph theory followed by one or more advanced topics which may include topological graph theory, algebraic graph theory, graph decomposition or graph coloring.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2003-2004 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 5301 or MA 4209

**MA 5222 - Design Theory**

Methods for the construction of different combinatorial structures such as difference sets, symmetric designs, projective geometries, orthogonal latin squares, transversal designs, steiner systems and tournaments.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): MA 4209 and MA 5301

**MA 5231 - Error-Correcting Codes**

Basic concepts, motivation from information transmission, finite fields, bounds, optimal codes, projective spaces, duality and orthogonal arrays, important families of codes, MacWilliams' identities, applications.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

**MA 5280 - Topics in Applied Combinatorics**

Topics will vary with instructor but will emphasize real world applications of combinatorial methods. Topics include: cryptography, network reliability, operations research or scheduling, among many other possible choices.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Permission of department required

**MA 5301 - Algebra I**

Theory of finite groups, their actions and applications. Review of basic group theory (Sylow theorems). Simple groups and group actions (transitivity). Symmetric and alternating groups, linear groups and more general classical groups. Applications: finite fields, designs, finite geometries.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 4310

**MA 5302 - Algebra II**

Introduction to polynomial rings, finite fields and field extensions. Review of basic notions concerning rings, polynomials and power series. General theory of finite and algebraic field extensions. The basics of Galois theory (field extensions and their Galois groups).

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): MA 5301

**MA 5320 - Commutative Algebra**

Introduction to commutative algebra and combinatorial algebra. A first description of research issues is also given. Topics include: commutative rings (quotients, morphisms; prime, maximal ideals); modules, Noetherian, artinian rings; combinatorial algebra (gradings, monomials, Hilbert functions, resolutions, level, Gorenstein algebras).

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Permission of instructor required

Pre-Requisite(s): MA 4310

**MA 5360 - Number Theory**

Topics may include, but not limited to, unique factorization, elementary estimates on the distribution of prime numbers, congruences, Chinese remainder theorem, primitive roots,  $n$ -th powers modulo an integer, quadratic residues, quadratic reciprocity, quadratic characters, Gauss sums, and finite fields.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: Permission of instructor required

Pre-Requisite(s): MA 4310

**MA 5390 - Scientific Computing**

Set in a Linux environment, course offers exposure to Foss tools for developing computational and visualization workflows. Students will learn to translate problems into programs, understand sources of errors, and debug, improve the performance of and parallelize the code.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**MA 5401 - Real Analysis**

A graduate-level study of the Lebesgue integral including its comparison with the Riemann integral; the Lebesgue measure, measurable functions and measurable sets. Integrable functions, the monotone convergence theorem, the dominated convergence theorem, and Fatou's lemma.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MA 5501 - Theoretical Numerical Analysis**

Functional analytic basis of modern numerical analysis. Linear spaces, including Sobolev space theory, linear operators, approximation theory, and applications to Fourier analysis, fixed point theorems, iterative methods, finite difference methods, etc.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 4330 and MA 4450

**MA 5510 - Ordinary Differential Equations I**

Qualitative theory of solutions of ordinary differential equations, including existence, uniqueness, and continuous dependence; theory of linear equations; solution of constant coefficient systems; phase plane analysis; design and analysis of numerical methods.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 4450 and MA 4330

**MA 5565 - Partial Differential Equations**

Theory of partial differential equations. Covers classification, appropriate boundary conditions and initial conditions, PDEs of mathematical physics, characteristics, Green's functions, and variational principles.

Credits: 3.0

Lec-ec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MA 5501

**MA 5580 - Topics in Applied Mathematics**

Topics will vary with instructor, but will cover areas in applied mathematics.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

**MA 5627 - Numerical Linear Algebra**

Design and analysis of algorithms for the numerical solution of systems of linear algebraic equations, least-square problems, and eigenvalue problems. Direct and iterative methods will be covered.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): MA 4330 or MA 4630

**MA 5629 - Numerical Partial Differential Equations**

Analysis and design of algorithms for the numerical solution of partial differential equations.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 4610 or MA 5627 and MA 5501

**MA 5630 - Numerical Optimization**

Numerical solution of unconstrained and constrained optimization problems and nonlinear equations. Topics include optimality conditions, local convergence of Newton and Quasi-Newton methods, line search and trust region globalization techniques, quadratic penalty and augmented Lagrangian methods for equality-constrained problems, logarithmic barrier method for inequality-constrained problems, and Sequential Quadratic Programming.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2002-2003 academic year

Pre-Requisite(s): MA 4330 or MA 4610 or MA 4630 or MA 5627

**MA 5701 - Statistical Methods**

Introduction to design, conduct, and analysis of statistical studies, with an introduction to statistical computing and preparation of statistical reports. Topics include design, descriptive, and graphical methods, probability models, parameter estimation and hypothesis testing.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MA 5711 - Mathematical Statistics I**

Review of distribution theory and transformation theory of random variables.

Topics include sufficiency; exponential and Bayesian models; estimation methods, including optimality theory; basics of confidence procedures and hypothesis testing, including the Neyman-Pearson framework.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 4450 and MA 4760 and MA 4770

**MA 5712 - Mathematical Statistics II**

Optimal tests and decision theory. Other topics may include regression and analysis of variance, discrete data analysis, nonparametric models.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): MA 5711

**MA 5730 - Nonparametric Statistics**

Introduces nonparametric techniques that require less restrictive assumptions on the data. Topics include statistical inference concerning location and dispersion parameters as well as the general distributions. Goodness-of-fit tests for count and ordinal data are also discussed.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Pre-Requisite(s): MA 2710 or MA 2720 or MA 3710 or MA 3715

**MA 5731 - Linear Models**

A unified development of linear statistical models that includes the following topics: matrices and quadratic forms, normal and chi-square distribution theory, ordinary and generalized least squares modeling, estimability, estimation and tests of hypothesis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 4710 and MA 4720 and MA 4760 and MA 4330

**MA 5732 - Generalized Linear Models**

The focus of this course is on generalized linear models (GLM), including the structure of GLM, statistical theory for GLM (maximum-likelihood estimation of GLM and hypothesis tests), and their applications. Also covers generalized linear mixed and random effects models.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Pre-Requisite(s): (MA 4710 or MA 5731) and (MA 4770 or MA 5712)

**MA 5741 - Multivariate Statistical Methods**

Random vectors and matrix algebra. Multivariate Normal distribution. Theory and application of multivariate techniques including discrimination and classification, clustering, principal components, canonical correlation, and factor analysis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): (MA 4710 or MA 4720) and MA 2320

**MA 5750 - Statistical Genetics**

Application of statistical methods to solve problems in genetics such as locating genes. Topics include basic concepts of genetics, linkage analysis and association studies of family data, association tests based on population samples (for both qualitative and quantitative traits), gene mapping methods based on family data and population samples.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2015-2016 academic year

**MA 5761 - Computational Statistics**

Introduction to computationally intensive statistical methods. Topics include resampling methods, Monte Carlo simulation methods, smoothing technique to estimate functions, and methods to explore data structure. This course will use the statistical software S-plus.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 4770(C)

**MA 5770 - Bayesian Statistics**

The theory of Bayesian inference. Topics include prior specifications, basics of decision theory, Markov chain, Monte Carlo, Bayes factor, linear regression, linear random effects model, hierarchical models, Bayesian hypothesis testing, Bayesian model selection.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2016-2017 academic year

Pre-Requisite(s): MA 4330 and MA 4710 and MA 4760

**MA 5781 - Time Series Analysis and Forecasting**

Statistical modeling and inference for analyzing experimental data that have been observed at different points in time. Topics include models for stationary and non stationary time series, model specification, parametric estimation, model diagnostics and forecasting, seasonal models and time series regression models.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): (MA 2710 or MA 2720 or MA 3710 or MA 3715) and (MA 3720 or EE 3180)

**MA 5790 - Predictive Modeling**

Application, construction, and evaluation of statistical models used for prediction and classification. Topics include data pre-processing, over-fitting and model tuning, linear and nonlinear regression models and linear and nonlinear classification models.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Pre-Requisite(s): MA 3740 or MA 4710 or MA 4720 or MA 4780

**MA 5791 - Categorical Data Analysis**

Structure of 2-way contingency tables. Goodness-of-fit tests and Fisher's exact test for categorical data. Fitting models, including logistic regression, logit models, probit and extreme value models for binary response variables. Building and applying log linear models for contingency tables.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2005-2006 academic year

**MA 5901 - Teaching College Mathematics I**

Survey key issues in undergraduate mathematics education, including course preparation, assessment, student learning, developing assignments, instructional strategies, technology, motivating students and institutional resources. The lab involves practical training in the computer algebra system used in the mathematics lab.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Major(s): Mathematical Sciences, Statistics, Mathematics; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MA 5904 - Teaching Online Courses**

An introduction to college-level online teaching principles. Based on nationally recognized standards for online course evaluation, the course will focus on course preparation, assessment, instructional strategies to increase student learning and motivation, and the use of instructional technology to optimize an online course.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Summer

**MA 5980 - Special Topics in Mathematics**

Special topics in mathematics.

Credits: variable to 12.0; Repeatable to a Max of 48

Semesters Offered: Fall, Spring, Summer

**MA 5999 - Graduate Research in Mathematics**

Original investigation in theoretical, or applied mathematics, and submission of a thesis in partial fulfillment of the requirements for the master's degree in mathematics.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**MA 6222 - Advanced Topics in Design Theory**

Advanced topics in design theory.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: Permission of department required

Pre-Requisite(s): MA 5222

**MA 6231 - Advanced Topics in Coding Theory**

Advanced topics in coding theory.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Permission of department required

Pre-Requisite(s): MA 5231

**MA 6280 - Advanced Topics in Combinatorics, Algebra, or Number Theory**

Advanced topics in combinatorics, algebra, or number theory.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Permission of department required

**MA 6300 - Advanced Topics in Algebra**

Advanced topics in algebra.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: Permission of department required

Pre-Requisite(s): MA 5302

**MA 6500 - Advanced Topics in Applied Mathematics**

Advanced topics in applied mathematics.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2011-2012 academic year

Restrictions: Permission of department required

**MA 6600 - Advanced Topics in Computational Mathematics**

Advanced topics in computational mathematics.

Credits: 3.0; Repeatable to a Max of 48

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Permission of department required

**MA 6700 - Advanced Topics in Statistics**

Topics may include but are not limited to experimental designs, methods of quality improvement, discrete data analysis, regression analysis, sampling theory, multivariate methods, resampling methods, statistical computing, integral and measure theory, stochastic processes, asymptotic methods, optimization, modeling, nonparametric and parametric statistics.  
Credits: variable to 12.0; Repeatable to a Max of 48  
Semesters Offered: Spring - Offered alternate years beginning with the 2010-2011 academic year  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MA 6701 - Probability**

Review of discrete probability, probability measures, random variables, distribution functions, expectation as a Lebesgue-Stieltjes integral, independence, modes of convergence, laws of large numbers and iterated logarithms, characteristic functions, central limit theorems, conditional expectation, martingales, introduction to stochastic processes.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall - Offered alternate years beginning with the 2011-2012 academic year  
Pre-Requisite(s): MA 3720 and MA 5401

**MA 6980 - Special Topics in Mathematics**

Special topics in mathematics.  
Credits: variable to 12.0; Repeatable to a Max of 48  
Semesters Offered: Fall, Spring, Summer

**MA 6999 - Mathematical Sciences Doctoral Research**

Taken in partial fulfillment of the doctoral thesis requirement.  
Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Mechanical Engineering – Engineering Mechanics****MEEM 5010 - Professional Engineering Communication**

Course introduces graduate students to conventions of professional engineering communication such as composing technical documents and working effectively in teams. Students will practice creating effective visuals for reports and slides and develop and deliver presentations.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall, Spring  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5110 - Continuum Mechanics/Elasticity**

Covers development of Cartesian tensors and indicial notation applied to vector analysis; analysis of stress, principal stresses, invariants, strain tensors, material derivatives, and continuity equations; basic conservation laws and constitutive relationships; the theory of elasticity, including 2-D problems in plane stress/strain, stress functions, and 3-D problems with polar symmetry.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5130 - Nanoscale Science and Technology**

The course covers fundamentals of nanoscience (synthesis, properties, characterization) and recent technological advances in renewable energy, biotechnology, and nanodevices. This course is appropriate for students with backgrounds in mechanical engineering, materials science, chemistry, chemical engineering, civil engineering, and physics.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall, Spring

**MEEM 5150 - Advanced Mechanics of Mats**

A study of incorporating complexities into the classical theories of axial rods, torsion of circular and non-circular shafts, bending of beams and plates. Use of variational principles to obtain boundary value problems of aforementioned structural members.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5160 - Experimental Stress Analysis**

Review of elastic stress-strain relationships. Covers theory and use of resistive strain gages, strain gage circuits, rosette analysis, static and dynamic strain measurement; discusses other current strain measuring techniques; introduces photoelasticity, Moire, and other optical techniques.  
Credits: 3.0  
Lec-Rec-Lab: (0-2-2)  
Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following College(s): College of Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MEEM 5170 - Finite Element and Variational Methods in Engineering**

Presents fundamental concepts of variational methods including Rayleigh-Ritz technique. Introduces foundations of finite element modeling through direct method, variational method, and weighted residual method. Reviews elements commonly used in static structural analysis and heat transfer problems. Advanced topics such as nonlinearity and time-dependent problems may also be discussed.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5180 - Mechanics of Composite Mats**

Introduces engineering properties and advantages of fibrous composites, the governing equations of mechanics of anisotropic, laminated materials. Develops micromechanics methods for predicting the elastic properties of the composite and classical lamination theory, including hygrothermal effects, and applies them to stress and failure analysis of composite structures.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Spring - Offered alternate years beginning with the 2009-2010 academic year  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5201 - Fundamentals of SI Engines**

A combination of lab lecture and hands-on activities. Operation fundamentals, performance metrics, thermochemistry, combustion, Miller & Atkinson cycle, fuel & air system, supercharging & turbocharging, exhaust systems, energy balance, variable valve actuation, simulation, and advanced concepts & trends.  
Credits: 1.0  
Lec-Rec-Lab: (0-0-2)  
Semesters Offered: Summer - Offered alternate years beginning with the 2017-2018 academic year  
Restrictions: Must be enrolled in one of the following College(s): College of Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MEEM 5202 - Fundamentals of Diesel Engines**

A combination of lab lecture and hands-on activities. Fundamentals of operation, performance metrics, thermochemistry, combustion, fuel injection and spray, air systems and turbocharging, EGR, energy balance, heat transfer, diesel engine simulation, and advanced concepts and trends in diesel engines.  
Credits: 1.0  
Lec-Rec-Lab: (0-0-2)  
Semesters Offered: Summer - Offered alternate years beginning with the 2018-2019 academic year  
Restrictions: Must be enrolled in one of the following College(s): College of Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MEEM 5203 - SI Engine Control Systems**

A combination lab lecture and hands-on activities. Review engine operation, regulations, intro to engine control, sensors & actuators, causality effects, combustion phasing, lambda, valve timing, load, control of, throttle, knock, turbo, fuel, emissions control, algorithm & calibration, OBD, controller communications.  
Credits: 1.0  
Lec-Rec-Lab: (0-0-2)  
Semesters Offered: Summer - Offered alternate years beginning with the 2017-2018 academic year  
Restrictions: Must be enrolled in one of the following College(s): College of Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MEEM 5204 - Diesel Engine Control Systems**

A combination of lab lecture and hands-on activities. Review diesel operation, regulations, intro to engine control, diesel engine actuators, load control, Start of Injection, Rail Pressure, Turbo Control, EGR & Engine Out Emissions, after treatment, algorithm & calibration, OBD, controller communications.  
Credits: 1.0  
Lec-Rec-Lab: (0-0-2)  
Semesters Offered: Summer - Offered alternate years beginning with the 2018-2019 academic year  
Restrictions: Must be enrolled in one of the following College(s): College of Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MEEM 5210 - Advanced Fluid Mechanics**

Develops control volume forms of balance laws governing fluid motion and applies to problems involving rockets, pumps, sprinklers, etc. Derives and studies differential forms of governing equations for incompressible viscous flows. Some analytical solutions are obtained and students are exposed to rationale behind computational solution in conjunction with CFD software demonstration. Also covers qualitative aspects of lift and drag, loss of stability of laminar flows, turbulence, and vortex shedding.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5212 - Intermediate Thermodynamics**

A graduate-level thermodynamics course with emphasis on chemically reacting mixtures, thermodynamic property relations, entropy production/exergy destruction, and chemical and phase equilibrium.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5215 - Computational Fluids Engineering**

This course introduces students into the theoretical and practical aspects of computational methods in fluid mechanics and thermal transport problems. Computer based tools are used to reinforce principles on advanced topics in thermo-fluids science.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5220 - Fuel Cell Technology**

Fuel cell basics, operation principles and advanced performance analysis. Emphasis on component materials and two-phase transport phenomena on proton exchange membrane fuel cells. Hydrogen production, transportation, and storage. Balance of plant and systems analysis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5225 - Advanced Power System and Pollution Control**

Course will cover stationary systems for industrial and power applications; will include coal power plants, open-and combined-cycle gas turbines, co-generation, post combustion pollution control, biomass based fuels for power generation, and economic considerations.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5230 - Advanced Heat Transfer**

Advanced topics on conduction, convection, radiation, and heat exchangers are covered. Emphasis is on problem formulation, exact solutions, empirical correlations/results, and on computational techniques.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5235 - Wind Energy**

This course introduces students to the underlying principles of wind energy conversion, with an emphasis on the theoretical aspects of wind turbine design, aerodynamics, construction, control, and operation.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5240 - Comp Fluid Dynamics for Engg**

Introduces finite-difference and finite-volume methods used in solving fluid dynamics and heat transfer problems. Covers numerical grid generation, turbulence modeling, and application to some selected problems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2001-2002 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): MEEM 5210

**MEEM 5250 - Internal Combustion Engines II**

Advanced topics in internal combustion engines with emphasis on CI operation, modeling of engines, modeling of combustion processes, tribology, second law applications, and other topics of current interest.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2001-2002 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics  
Pre-Requisite(s): MEEM 4220 and (MEEM 4201(C) or MEEM 5212(C))

**MEEM 5255 - Advanced Powertrain Instrumentation and Experimental Methods**

Course is for those interested in experimentation, engines, and powertrain.

Objective is prepare to acquire quality data, and efficient experiments.

Investigate transducers, calibration, data acquisition, signal conditioning, noise, and specific applications; engine combustion and emissions. Hands-on homework and structured lab activities.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): MEEM 4220(C)

**MEEM 5265 - Physical Gasdynamics**

Equilibrium gaskinetic theory, chemical thermodynamics, introduction to quantum and statistical mechanics, flow with finite rate (e.g. vibrational energy relaxations, and chemical reactions), nonequilibrium kinetic theory, selected gaskinetic related computational methods.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5270 - Advanced Combustion**

The objective is to understand basic combustion processes through detailed chemical reaction step analysis. Introduces both analytical and modern experimental methods. Emphasizes gas liquid fuel combustion, flame propagation, and critical phenomena of ignition and extinction.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Pre-Requisite(s): MEEM 4240 or MEEM 4201 or MEEM 5212

**MEEM 5275 - Energy Storage Systems**

Designing energy storage solutions for grid, vehicle, and portable/autonomous systems. Quantitative and qualitative analysis of energy storage aging, cost, and performance improvement.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5280 - Phase-Change & Two-Phase Flows**

Air-water, condensing, and boiling flows are discussed in the context of interface conditions and instabilities. Wettability conditions and nucleation mechanisms are considered. Two-phase flow predictions are discussed in the context of correlations for: flow-regime maps, heat transfer coefficients, pressure-drop, void-fraction, etc.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5290 - Principles of Energy Conversion**

Introduces fundamentals of energy conversion and storage. Topics includes fossil and nuclear fuels, thermodynamic power cycles, solar energy, photovoltaics, and energy storage. Students will apply energy economics and complete semester-long project.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Pre-Requisite(s): MEEM 5212(C)

**MEEM 5295 - Advanced Propulsion Systems for Hybrid Electric Vehicles**

Hybrid electric vehicles (HEV) will be studied and simulated using advanced powertrain component analysis and modeling. An in-depth analysis and study of power flows, losses and energy usage are examined for isolated powertrain components and HEV configurations. Simulation tools will be developed and applied to specify powertrain and vehicle components and to develop control and calibration for a constrained optimization to vehicle technical specifications.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

Pre-Requisite(s): MEEM 4295

**MEEM 5296 - Powertrain Integration in HEV**

This hands-on course examines challenges with powertrain integration in Hybrid Vehicles. Topics include Vehicle Development Process, Thermal Management, Vehicle Controls, Safety, Calibration, and Vehicle Simulation Models. The course project includes optimizing performance of a configurable HEV using modeling and experimentation.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Pre-Requisite(s): MEEM 4296(C) or EE 4296(C)

**MEEM 5300 - Cybersecurity of Industrial Control Systems**

General introduction to cybersecurity of industrial control systems and critical infrastructures. Topics include NIST and DHS publications, threat analysis, vulnerability analysis, red teaming, intrusion detection systems, industrial networks, industrial malware, and selected case studies.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

Pre-Requisite(s): MEEM 5300 or EE 5455

**MEEM 5315 - Cyber Security of Automotive Systems I**

Modern automotive control and communications systems from a cyber security perspective. Topics include: V2X communications, vehicle attack surfaces and vulnerabilities, in-vehicle networks, threat analysis and vulnerabilities, security mechanisms and architectures, security requirements analysis, hardware security modules, and standards.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science, Mechanical Engineering, Mechanical Eng-Eng Mechanics, Computer Engineering, Electrical Engineering

Pre-Requisite(s): MEEM 5300 or EE 5455

**MEEM 5401 - Design for Reliability**

Emphasizes the importance of reliability in design, covering basic concepts of series, parallel, standby and mixed systems. Uses conditional probability and multimodefuctions as methods for problem solution. Considers derating and reliability testing.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5430 - Human Factors - Transportation**

This course aims to provide an understanding of drivers as a system component in the operation of vehicles and other transportation systems. Topics covered include human factors, driver-vehicle interaction, intelligent transportation systems, connected vehicle technology, and user interface.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MEEM 5440 - Advanced Vehicle Dynamics**

This course will develop advanced nonlinear models to predict vehicle dynamic response of road vehicles by means of Matlab Simulink environment. Topics covered by this course include advanced tire modeling, powertrain modeling, lateral dynamics and vertical dynamics.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Eng-Eng Mechanics, Engineering Mechanics, Mechanical Engineering, Computer Engineering, Electrical Engineering

**MEEM 5610 - Advanced Machining Processes**

Covers mechanics of 2-D and 3-D cutting and their extension to commonly used processes such as turning, boring, milling, and drilling. Topics include force modeling, surface generation, heat transfer, tool life and dynamics.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5615 - Advanced Metal Forming**

Introduces fundamentals of plasticity theory and applies to the analysis of deformation processes. Processes considered are forging, extrusion, wire drawing, bending, deep drawing, and stretch forming. Emphasizes sheet metal formability.

Credits: 4.0

Lec-Rec-Lab: (0-3-2)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5625 - Precision Manuf and Metrology**

Presents theory and practice involved in the manufacturing and measuring of precision components. Topics include precision machining processes, precision machine/mechanism design, and dimensional metrology. Addresses current manufacturing challenges in the bearings, optics, and microelectronics industries.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5640 - Micromanufacturing Processes**

Introduction, analysis and reporting of the processes and equipment for fabricating microsystems and the methods for measuring component size and system performance. Fabrication processes include microscale milling, drilling, diamond machining, and lithography. Measurement methods include interferometry and scanning electron microscopy.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5645 - Numerical Analy Manuf Proc**

Nonlinear FEM and BEM analyses, modeling of bulk forming processes, sheet forming processes, machining processes, casting processes, grinding of ceramics.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5650 - Advanced Quality Engineering**

Stresses the concepts and methods for quality and productivity improvement. Topics include principles of Shewhart, Deming, Taguchi; meaning of quality: control charts for variables, individuals, and attributes; process capability analysis; variation of assemblies; Monte Carlo simulation, multi-variate situations; and computer-based workshops. No credit for both MEEM4650 and MEEM5650.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5655 - Introduction to Lean Manufacturing**

Lean manufacturing is emerging globally as a paradigm by which business units must function to be globally competitive. Quality, cost, and delivery have become critical measures that impact profits and, in turn, the success of an organization. Significant improvements in all these three measures come from the continuous elimination of waste, or non-value added activities, in manufacturing. Numerous tools are available for the elimination of waste and making businesses lean. This course is intended to familiarize students with this new philosophy of lean manufacturing and arm them with a basic toolset that enables the identification, measurement, and elimination of non-value added activities.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring, Summer - Offered alternate years beginning with the 2007-2008 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering, School of Business & Economics

**MEEM 5670 - Experimental Design in Engg**

Review of basic statistical concepts. Models for testing significance of one or many factors. Reducing experimental effort by incomplete blocks, and Latin squares. Factorial and fractional factorial designs. Response surface analysis for optimal response.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5680 - Optimization I**

Provides introductory concepts to optimization methods and theory. Covers the fundamentals of optimization, which is central to any problem involving engineering decision making. Provides the tools to select the best alternative for specific objectives.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5685 - Environmentally Responsible Design and Manufacturing**

Examines impact of engineering and, in particular, design/manufacturing decisions on the environment. Topics include sustainability; energy/material flows; risk assessment, life cycles, manufacturing process waste streams, product design issues, including disassembly/post-use product handling; techniques for pollution prevention. Requires course project. Credit may not be received for both MEEM4685 and MEEM5685.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2001-2002 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5695 - Additive Manufacturing**

Background, principles, process chain, software aspects, post-processing, open-source tools, applications, and future directions of AM technologies are discussed. Advanced topics include process modeling and selection, DFAM, and opportunities and challenges of AM processes.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 5700 - Dynamic Measurement/Signal Analysis**

Assessment of measurement system requirements: transducers, conditioners, and displays of dynamic measurands. Time-, frequency-, probabilistic-, and correlative-domain approaches to dynamic signal analysis: sampled data, discrete Fourier transforms, digital filtering, estimation errors, system identification, calibration, recording. Introduction to wavelet analysis. All concepts reinforced in laboratory and simulation exercises.

Credits: 4.0

Lec-Rec-Lab: (0-3-3)

Semesters Offered: Fall, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5701 - Intermediate Dynamics**

Intermediate study of several topics in engineering dynamics, including three-dimensional kinematics and kinetics, generalized coordinates, Lagrange's equation, and Hamilton's principle. Uses computer-aided dynamic simulation tools for analyzing dynamic systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5702 - Analytical Vibroacoustics**

First in a series of two courses on vibro-acoustics to provide a unified approach to study noise and vibration. Emphasizes interaction between sound waves and structures. Presents advanced vibration concepts with computational tools. Discusses wave-modal duality.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5703 - Exp Methods Vibro-Acoustics**

Covers operating data measurement and analysis, including multisource ODS. Includes signature analysis and order tracking; modal theory, modal scaling. FRF estimators; multiple input excitation techniques; parameter estimation methods; sound measurements and acoustic intensity; sound quality; field data acquisition, DAT; binaural recording and playback with equalization.

Credits: 4.0

Lec-Rec-Lab: (0-3-3)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): MEEM 5700 and MEEM 5702

**MEEM 5705 - Introduction to Robotics and Mechatronics**

Cross-discipline system integration of sensors, actuators, and microprocessors to achieve high-level design requirements, including robotic systems. A variety of sensor and actuation types are introduced, from both a practical and a mathematical perspective. Embedded microprocessor applications are developed using the C programming language. A final project is required including analysis, design, and experimental demonstration. Cannot receive credit for both MEEM4705 and MEEM5705.

Credits: 4.0

Lec-Rec-Lab: (0-3-3)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics  
Pre-Requisite(s): MEEM 3750

**MEEM 5715 - Linear Systems Theory and Design**

Overview of linear algebra, modern control; state-based design of linear systems, observability, controllability, pole placement, observer design, stability theory of linear time-varying systems, Lyapunov stability, optimal control, linear quadratic regulator, Kalman filter,

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics  
Pre-Requisite(s): MEEM 3750 or EE 3261

**MEEM 5720 - Advanced Space Mechanics**

This course presents the vector-based solution of the two-body problem and the solution for Kepler's equations. The course will also cover basic orbit determination techniques, impulsive orbit transfer maneuvers, interplanetary trajectories, ground tracks, and rendezvous problems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 5750 - Model-Based Embedded Control System Design**

This course introduces embedded control system design using model-based approach. Course topics include model-based embedded control system design, discrete-event control, sensors, actuators, electronic control unit, digital controller design, and communications protocols. Prior knowledge of hybrid electric vehicles are highly recommended.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics  
Pre-Requisite(s): (MEEM 4700 or MEEM 4775 or EE 4261 or EE 3261) and MEEM 4295

**MEEM 5800 - Advanced Engineering Mathematics with Applications**

This course is for engineering graduate students to learn about in-depth ordinary differential equations (ODEs) and partial differential equations (PDEs) widely employed in the field of Mechanical Engineering. 'Vector Calculus' will also be covered. The students will be asked to demonstrate their knowledge of the material covered in this Advanced Engineering Mathematics course.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5811 - Automotive Systems**

Automotive systems for light duty vehicles are examined from the perspectives of requirements, design, technical, and economic analysis for advanced mobility needs. This course links the content for the automotive systems graduate certificate in controls, powertrain, vehicle dynamics, connected and autonomous vehicles.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Eng-Eng Mechanics, Automotive Systems & Controls, Engineering Mechanics, Mechanical Engineering

**MEEM 5812 - Automotive Control Systems**

Introduction to automotive control systems. Modeling and control methods are presented for: air-fuel ratio, transient fuel, spark timing, idle speed, transmission, cruise speed, anti-lock brakes, traction, active suspension systems, and hybrid electric vehicles. Advanced control methodologies are introduced for appropriate applications.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

Pre-Requisite(s): MEEM 4700 or MEEM 4775

**MEEM 5990 - Special Topics**

Study of selected subjects related to mechanical engineering or engineering mechanics.

Credits: variable to 3.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**MEEM 5994 - International Mechanical Engineering Field Experience**

Field work and reporting from students in the Peace Corps Master's International Program in Mechanical Engineering.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-2)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering

**MEEM 5995 - Graduate Research (Online/Off Campus)**

Research/investigation on a topic related to mechanical engineering or engineering mechanics leading to the submission of a thesis or report in a partial fulfillment of the requirements for the master's degree.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 5999 - Graduate Research**

Research/investigation on a topic related to mechanical engineering or engineering mechanics leading to the submission of a thesis or report in partial fulfillment of the requirements for the master's degree.

Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 6000 - Graduate Seminar**

Presentations/seminars on issues related to mechanical engineering and engineering mechanics. May include invited speakers from industry, government labs, and academe.

Credits: 1.0; Repeatable to a Max of 2

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MEEM 6010 - Engineering Research Communications**

Guides students through the process of preparing proposals, publishing research, and presenting at conferences and other venues, with a focus on practical application of rhetorical concepts. Students will prepare proposals, papers, and presentations related to their own research.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 6110 - Advanced Continuum Mechanics**

Presents fundamental concepts in hyperelasticity, damage mechanics, linear viscoelasticity, quasi-linear viscoelasticity, poroelasticity, continuum jump conditions, plasticity, and viscoplasticity. These theories are applied to describe the mechanical behavior of a wide range of engineering materials and biomaterials such as polymers, metals, soil, collagen, muscle tissue, bone tissue, and cartilage.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2008-2009 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

Pre-Requisite(s): MEEM 5110

**MEEM 6120 - Dynamic Behavior of Materials**

Covers the dynamic stress-strain aspects of material behavior, discusses elastic waves in bounded media, describes the Hopkinson bar, an experimental tool for the determination of the dynamic strength of materials, and includes impacts of bars and response of high strain rate.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand - Offered alternate years beginning with the 2001-2002 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

**MEEM 6130 - Engineering Fracture Mechanics**

Development of the stress and deformation fields present near the tips of cracks. Uses elasticity solutions, plasticity corrections, and numerical methods in modeling these fields. Introduces fracture criteria and explains the various parameters used to develop these criteria.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring, Summer - Offered alternate years beginning with the 2008-2009 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 6212 - Advanced Thermodynamics**

This course includes classical (equilibrium) thermodynamics and statistical mechanics. Topics include thermodynamic potentials, state relations, statistical mechanics, stability, chemical equilibrium and reaction kinetics, phase equilibrium, and non-equilibrium phase change. Objectives are to develop a deeper understanding of thermodynamic methods.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Pre-Requisite(s): MEEM 5212

**MEEM 6230 - Conduction**

Fundamental aspects of conductive heat transfer applied to steady-state and transient conditions. Studies multidimensional conduction problems with exact and approximate solutions techniques.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MEEM 5230

**MEEM 6240 - Convective Heat Transfer**

An introduction to flow and boundary layer theory for forced and natural convection heat and mass transfer. Includes derivation and application of the equations for conservation of mass, energy, and momentum; dimensional analysis and correlation of experimental results.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MEEM 5230

**MEEM 6250 - Radiative Heat Transfer**

Fundamentals of thermal radiation for black, gray, nongray, diffuse, and specular surfaces. Includes radiation combined with conduction and convection at boundaries; properties for radiation in absorbing, emitting, and scattering media; and the engineering treatment of gas radiation in enclosures.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MEEM 5230

**MEEM 6320 - Cyber Security of Automotive Systems II**

This course covers advanced topics in cyber security of automotive systems. Topics covered include modeling and simulation of cyber attacks on vehicle subsystems, communications, security for V2X systems, vulnerabilities in cooperative vehicle infrastructures, threat analysis, and cyber security of SAE level 2, 3, and 4 autonomous driving systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Computer Science, Mechanical Engineering, Mechanical Eng-Eng Mechanics, Computer Engineering, Electrical Engineering

Pre-Requisite(s): MEEM 5310 or EE 5310

**MEEM 6701 - Advanced Acoustics**

Advanced concepts in acoustics with emphasis on modeling of sound sources, sound interaction with solid structures, transmission and radiation of sound. Discusses numerical acoustics, statistical energy analysis, and sound quality concepts. Provides beneficial background in basic vibrations and noise control.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): MEEM 4704

**MEEM 6702 - Nonlinear Sys Analy & Control**

Studies nonlinear systems from perspective of analysis/control system design. Explores fundamental properties for nonlinear differential equations in addition to describing functions, phase plane analysis, stability/instability theorems. Develops and applies control system design approaches for nonlinear systems, including feedback linearization and sliding mode control.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Spring  
Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): MEEM 5715

**MEEM 6703 - Advanced Vibrations**

Free and forced vibration of continuous systems with applications to strings, shafts, beams, plates and membranes. Problems formulated using Hamilton's principle and Lagrange's equations. Approximate methods of solution include the Rayleigh-Ritz method and Galerkin's method.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: On Demand  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Engineering, Mechanical Eng-Eng Mechanics, Engineering Mechanics

**MEEM 6990 - Special Topics**

Study of selected subjects related to mechanical engineering or engineering mechanics.  
Credits: variable to 6.0; May be repeated  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**MEEM 6995 - Graduate Research (Online/Off Campus)**

Research/investigation on a topic related to mechanical engineering or engineering mechanics leading to the submission of a dissertation in partial fulfillment of the requirements for the PhD degree.  
Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Mechanical Eng-Eng Mechanics

**MEEM 6999 - Doctoral Research**

Research/investigation on a topic related to mechanical engineering or engineering mechanics leading to the submission of a dissertation in partial fulfillment of the requirements for the PhD degree.  
Credits: variable to 15.0; May be repeated; Graded Pass/Fail Only  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

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**Mechanical Engineering Technology****MET 5000 - Independent Study in Mechanical Engineering Technology**

Independent study in an approved topic under the guidance of a Mechanical Engineering Technology faculty member. Course of study may either be research or academic determined by student and faculty.  
Credits: variable to 3.0; Repeatable to a Max of 6  
Semesters Offered: On Demand  
Restrictions: Permission of instructor required; Must be enrolled in one of the following Class(es): Senior

**MET 5378 - Advanced Hydraulics: Electro-hydraulic Components & Systems**

This course covers electro-hydraulic components including solenoid operated valves, proportional valves, and servo valves. Also covered are hydraulic systems including open-loop and closed-loop.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall  
Pre-Requisite(s): MET 4377

**MET 5800 - Dynamics and Kinetics of Robotics Platforms**

This course covers the dynamics and kinematics of rigid bodies as the foundation for analyzing the motion of robots. Robotic kinematics is reviewed by analyzing the motion of the robot. The dynamics is reviewed by analyzing the relation between the joint actuator torques and resulting motion.  
Credits: 3.0  
Lec-Rec-Lab: (0-2-2)  
Semesters Offered: Spring  
Pre-Requisite(s): MET 2130 or MET 3130

**MET 5801 - Controls of Dynamics Systems**

This course covers the modeling, analysis, and control of dynamic systems. It used the controlling equations for the control of mechanical and electrical systems. Theory is verified with simulation and lab testing. Included is a major project with a report and presentation on the subject.  
Credits: 3.0  
Lec-ec-Lab: (0-2-2)  
Semesters Offered: Fall  
Pre-Requisite(s): MET 4800 or MET 5800

**MET 5802 - Vibrations of Mechanical Systems**

This course deals with the modeling and analysis of mixed physical systems. Introduction to modeling and oscillatory response analysis for discrete and continuous mechanical and structural systems. Time and frequency domain analysis of linear system vibrations. Vibration of multi-degree-of-freedom systems. Free vibration eigenvalue problems.  
Credits: 3.0  
Lec-Rec-Lab: (0-3-0)  
Semesters Offered: Fall  
Pre-Requisite(s): MET 2130

**MET 5990 - Special Topics in Mechanical Engineering Technology**

Mechanical Engineering Technology topics of interest to faculty and student.  
Credits: variable to 3.0; Repeatable to a Max of 12  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Materials Science & Engineering****MSE 5100 - Introduction to Materials Science and Engineering with Advanced Topics**

A survey of the processing structure property relationships including metals, ceramics, and polymers. The course will cover the same material as in MY2100 plus advanced topics on materials structure, characterization, processing, and properties.  
Credits: 4.0  
Lec-Rec-Lab: (4-0-0)  
Semesters Offered: Summer  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Materials Science and Engrg

**MSE 5102 - Advanced Concrete Materials**

Properties and applications of portland cement and portland cement concrete. Includes cement production, chemistry and hydration, concrete admixtures, and the properties of fresh and hardened concrete. Presents concrete microstructure and durability. Other topics include high-strength and high early-strength concrete, fiber-reinforced concrete, and advanced cement-based materials.  
Credits: 3.0  
Lec-Rec-Lab: (0-2-2)  
Semesters Offered: Spring  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5110 - Thermodynamics and Kinetics I**

Solution thermodynamics and application to phase equilibria. Driving force for phase transformations. Chemical thermodynamics applied to materials processing. Corrosion and oxidation of metals. Applications to engineering situations.  
Credits: 3.0  
Lec-Rec-Lab: (3-0-0)  
Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5120 - Thermodynamics and Kinetics II**

The kinetics of liquid-to-solid and solid-to-solid phase transformations. Diffusion-controlled phase transformations, including nucleation, growth, coarsening, spinodal decomposition, eutectic and eutectoid transformations, cellular transformations, and massive transformations. Martensitic transformations.  
Credits: 3.0  
Lec-Rec-Lab: (3-0-0)  
Semesters Offered: Spring  
Restrictions: Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): MY 5100 or MSE 5110

**MSE 5130 - Crystallography & Diffraction**

Crystallographic concepts and diffraction analyses in materials science.  
Credits: 3.0  
Lec-Rec-Lab: (2-0-3)  
Semesters Offered: On Demand  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5140 - Mechanical Behavior of Materials**

Deformation-related physical behaviors of materials in the mathematical framework of tensor analysis. Material symmetry and tensor property. Stress, strain, and elastic constitutive relation. Non-elastic strain, thermomechanical, electromechanical, and magnetomechanical behaviors.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5190 - Advanced Materials Processing for Mechanical, Energy, and Biomedical Applications**

Advanced materials processing technologies will be instructed with examples of various applications in mechanical, energy, and biomedical areas. Powder production, surface chemistry, separation, agglomeration, composites, forming, shaping, conventional and microwave heating, and nano materials and structures will be introduced.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2014-2015 academic year

Restrictions: Must be enrolled in one of the following College(s): College of Engineering; May not be enrolled in one of the following Class(es): Freshman, Sophomore

**MSE 5410 - Materials for Energy Applications**

Advanced solid materials for hydrogen energy will be introduced, including hydrogen storage materials, hydrogen production catalysts, and proton exchange membranes with emphasis on structures and properties. Silicon semiconductors, compound semiconductors, and nanostructured semiconductors will be discussed for solar energy applications.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MSE 5430 - Electronic Materials**

A study of the physical principles, operational characteristics, models, and basic applications of selected solid-state devices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5440 - Materials Recycling: Processing and Utilization**

Methods for materials recycling is the emphasis. Topics include the recycling of materials for steel, aluminum, automobile, foundry, glass, plastics, energy, construction, and other industries. Background of the industry, characteristics of materials, materials flow, and the processing and utilization methods to recycle the materials are presented.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MSE 5460 - Solid State Devices**

A study of the physical principles, operational characteristics and models and basic applications of solid state devices such as p-n junctions, metal-semiconductor junctions and transistors.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

**MSE 5470 - Semiconductor Fabrication**

Graduate level introduction to the science and engineering of semiconductor device fabrication.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**MSE 5480 - Advanced MEMS**

This course will cover advanced topics dealing with MEIXIS technologies, transduction mechanisms, and microfabricated sensors and actuators and is continuation of EE4240/MY4240.

Credits: 4.0

Lec-Rec-Lab: (3-1-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): EE 4240 or MY 4240 or MSE 4240

**MSE 5490 - Solar Photovoltaic Science and Engineering**

Solar photovoltaic materials, the device physics of photovoltaic cells and practical applications of solar electric systems engineering.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**MSE 5510 - Advanced Contact Mechanics and Nanoindentation**

The application of elastic and plastic contact mechanics in relation to nanoindentation with emphasis on the application of instrumentation, models and experimental techniques used to examine the small-scale mechanical behavior of metals, ceramics, polymers, composites, biomaterials, hydrogels, and structured devices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5540 - Advanced Computational Materials Science: Theory, Modeling, Simulation, and Practice**

Theories of materials science from first principles to constitutive laws. Materials modeling and computer simulation at multiple length and time scales. Laboratory practice of various computational methods.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5550 - Transmission Electron Microscopy**

Practical aspects of materials characterization by transmission electron microscopy.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5580 - Introduction to Scanning Probe Microscopy**

Students will learn basics of design and fundamental physics behind the scanning probe microscopy techniques. The lectures will also discuss analysis of the solid surfaces regarding roughness, topography, composition, heterogeneity, and adhesion properties using atomic force microscopy (AFM). Artifacts associated with inappropriate conditions in atomic AFM imaging will be discussed as well. Training in the operation of the AFM instrument and exploration of its capability during the laboratory sessions will complement the lectures.

Credits: 2.0

Lec-Rec-Lab: (1-0-3)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**MSE 5610 - Powder Processing**

Processing of metal and ceramic powders into bulk products. Powder manufacture and characterization, compaction, sintering, pressure-assisted consolidation to full density. Emphasis on principles underlying consolidation practices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand - Offered alternate years beginning with the 2005-2006 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): MY 2100 or MSE 2100

**MSE 5621 - Open Source Scientific Hardware**

This course provides an introduction to the use of distributed digital manufacturing of open source hardware for scientific and engineering applications. The course outcome will be a design of an open hardware tool.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

**MSE 5665 - Surface and Interface Science for Chemical and Materials Analysis**

Coursework and hands-on laboratory experiences explore physical and chemical properties governing surface processes and the appropriate analysis techniques used to study interfaces and surface chemical reactions. Topics include principles of physical chemistry and materials science for understanding and applying modern surface analysis.

Credits: 3.0

Lec-Rec-Lab: (2-0-3)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

### **MSE 5760 - Vehicle Battery Cells and Systems**

The behavior and application of batteries will be examined by introducing concepts from thermodynamics, materials science, transport processes and equivalent circuits. The non-ideal power source behavior of rechargeable batteries in applications will be treated using electrolyte: electrode transport and electrode materials chemistry. Prior exposure to freshman chemistry, elementary electrical circuits, and elementary transport theory is assumed.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2010-2011 academic year

Restrictions: Must be enrolled in one of the following College(s): College of Engineering; Must be enrolled in one of the following Major(s): Biomedical Engineering, Engineering, Civil Engineering, Chemical Engineering, Computer Engineering, Electrical Engineering, Engineering Mechanics, Environmental Engineering, Geological Engineering, Geology, Mechanical Engineering, Materials Science and Engrg, Applied Physics, Chemistry, Physics, Applied Geophysics; May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

### **MSE 5777 - Advanced Open-Source 3-D Printing**

An introduction to distributed additive manufacturing using open-source 3-D printing. Design, use, and maintenance of open-source electronics and self-replicating rapid prototypers (RepRap). Graduate students will be expected to complete coursework and an in-depth project.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following College(s): College of Engineering

### **MSE 5900 - Graduate Professional Preparation**

Graduate student presentations at departmental seminars.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **MSE 5970 - Special Topics - Graduate Materials Science and Engineering**

Special Topics in Materials Science and Engineering at the Graduate level.

Credits: variable to 4.0; Repeatable to a Max of 8

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

### **MSE 5990 - MS Thesis Research**

Fundamental and applied research in metallurgical and materials engineering. Taken by graduate students in partial fulfillment of the MS thesis requirements.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **MSE 6110 - Advanced Topics in Materials Processing**

Advanced treatment of various unit operations of materials processing.

Operations may include deformation processing, powder and particulate technology, solidification processing, thermomechanical processing, optimum process selection, etc.

Credits: variable to 4.0; May be repeated

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **MSE 6200 - Advanced Topics in Materials Characterization**

Advanced concepts in materials characterization. Specific course content is tailored to meet the interests of the students and faculty.

Credits: variable to 4.0; May be repeated

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **MSE 6400 - Advanced Topics in Mechanical Behavior of Materials**

Advanced concepts in mechanical behavior of materials. Specific course content is tailored to meet the interests of the students and faculty.

Credits: variable to 4.0; May be repeated

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **MSE 6990 - PhD Thesis Research**

Fundamental and applied research in metallurgical and materials engineering. Taken by graduate students in partial fulfillment of the PhD thesis requirements.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

## **Physics**

### **PH 5010 - Graduate Journal Club**

Presentation and discussion of current issues in physics and recent research by departmental faculty and others. One credit in journal club is required for all graduate degrees in physics. Attendance is required in the physics department colloquium series.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **PH 5090 - Special Topics in Physics**

The subject matter may vary from term to term and year to year depending on the needs of advanced students.

Credits: variable to 3.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **PH 5110 - Classical Mechanics**

Lagrangian methods, symmetries and conservation laws, variational formulation, small oscillations, Hamilton's equations, contact transformations, Poisson brackets, Hamilton-Jacobi theory, Lorentz-invariant formulation.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2002-2003 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **PH 5151 - Quantum Field Theory for Photonics and Materials**

This course will review the basics of quantum mechanics and second quantization, and cover quantum field theoretical methods, including Wick's theorem and Feynman diagram techniques, for absolute zero and non-zero temperatures (Matsubara frequencies) and their application in photonics, properties of materials and condensed matter physics.

Credits: 2.0; Graded Pass/Fail Only

Lec-Rec-Lab: (2-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2020-2021 academic year

Pre-Requisite(s): PH 3410 and PH 3411(C)

### **PH 5210 - Electrodynamics I**

Electrostatics and magnetostatics, boundary value problems, multipoles, Maxwell's equations, time-dependent fields, propagating wave solutions, radiation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PH 5320

### **PH 5211 - Electrodynamics II**

Scattering and diffraction, special relativity, relativistic particle dynamics, Lorenz transformation, 4-vectors, transformation of fields, charges and currents, Thomas precession, retarded potentials, radiation from moving charges.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: On Demand - Offered alternate years beginning with the 2008-2009 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PH 5210

### **PH 5310 - Statistical Mechanics**

Ensembles, partition functions and distributions, thermodynamic potentials, quantum statistics, ideal and nonideal gases, interacting systems. Applications may include classical and quantum liquids, phase transitions and critical phenomena, correlation functions, linear response and transport theory, or other topics.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2007-2008 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

### **PH 5320 - Mathematical Physics**

Partial differential equations of physics, separation of variables, boundary value problems, Sturm-Liouville theory, Legendre and Bessel functions, inhomogeneous partial differential equations, Green's functions. Fourier series, Fourier and Laplace transforms, complex variables, evaluation of integrals by contour integration, linear algebra, matrix methods with emphasis on numerical applications.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PH 5390 - Scientific Computing**

Set in a Linux environment, course offers exposure to Foss tools for developing computational and visualization workflows. Students will learn to translate problems into programs, understand sources of errors, and debug, improve the performance of and parallelize the code.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Physics, Applied Physics

**PH 5410 - Quantum Mechanics I**

Study of the postulates of quantum mechanics framed in Dirac notation, the Heisenberg uncertainty relations, simple problems in one dimension, the harmonic oscillator, the principles of quantum dynamics, rotational invariance and angular momentum, spherically symmetric potentials including the hydrogen atom, and spin.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PH 5411 - Quantum Mechanics II**

Continuation of PH5410. Includes the study of symmetries and their consequences, the variational method, identical particles, the Hartree-Fock approximation time-independent perturbation theory, time-dependent perturbation theory, diatomic molecules with applications to H<sub>2</sub><sup>+</sup>, many-body perturbation theory, and the Dirac equation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PH 5410

**PH 5510 - Theory of Solids**

Free electron theory, Bloch's theorem, electronic band structure theory, Fermi surfaces, electron transport in metals and semiconductors. Lattice vibrations and phonons, other topics as time permits.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2000-2001 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PH 5320 and PH 5410

**PH 5520 - Materials Physics**

Materials classification and structures; phase diagrams; lattice imperfections; quasiparticles; boundaries and interfaces; mechanical, electronic, optical, magnetic and superconducting properties of materials.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2001-2002 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PH 5530 - Selected Topics in Nanoscale Science and Technology**

Presentation and discussion of selected topics in nanoscale science and engineering. Topics include growth, properties, applications, and societal implication of nanoscale materials. Evaluation: attendance and assignment.

Credits: 2.0

Lec-Rec-Lab: (2-0-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**PH 5640 - Atmospheric Physics**

Essential elements of atmospheric physics, including thermodynamics (e.g. adiabatic processes, phase transformations, stratification), aerosol and cloud physics (e.g. nucleation, Kohler theory, growth by condensation and collection), and radiative transfer (e.g. Beer's law, transfer equations with and without scattering).

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2008-2009 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PH 2300 and (MA 3520 or MA 3521 or MA 3530 or MA 3560)

**PH 5680 - Geophysical Fluid Dynamics**

Fundamental forces and conservation laws that govern fluid flow; applications to the atmosphere and ocean, including balanced flow (pressure gradient and Coriolis force), vorticity dynamics, turbulence, waves, and boundary layers.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

Pre-Requisite(s): PH 2300 and (MA 3520 or MA 3521 or MA 3530 or MA 3560)

**PH 5999 - Master's Research**

Master's-level research conducted under the direction of a graduate faculty advisor. Attendance is required in the physics department colloquium series.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Physics, Applied Physics

**PH 6999 - Doctoral Research**

Independent research conducted in partial fulfillment of the requirements for the PhD degree. Scheduled by arrangement. Attendance is required in the physics department colloquium series.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor and department required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Physics, Applied Physics

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**Psychology****PSY 5001 - Tools of the Profession**

Review of professional practices and tools including APA formatting, commonly used experimental programming software, review of statistical programs, equipment training, responsible conduct of research, and IRB applications, journals and conferences, and other professional expectations/resources.

Review of departmental and university expectations, resources, and services.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5010 - Cognitive Psychology**

A systematic survey of classical and contemporary research topics in human cognition, including perception, attention, mental representation and processing, memory, knowledge, visual imagery, problem solving, reasoning, and decision making. Students will read original research papers and develop a research proposal.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5015 - Cognitive Task Analysis Methods**

Cognitive task analysis is a group of methods to model how experts do their work to design new human-machine systems, knowledge management systems, and use cases for new tools. Students will learn several CTA methods including knowledge audit, cognitive walk, and critical decision method.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5020 - Research Methods**

This course provides a foundation in research methods in cognitive science and human factors, with an emphasis on experimental design, research ethics, and scientific communication. Course meets Michigan Tech's Advanced Responsible Conduct of Research (RCR) requirements.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5095 - Practicum**

Independent activity where students apply their existing knowledge, skills, and methods already acquired in the program and demonstrate acquisition of new design-based knowledge, skills, and methods from the operational setting in which the practicum takes place.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**PSY 5100 - Applied Cognitive Science**

Survey of applied human information processing literature, detailed review of recent developments in applied cognitive science, and examination of the purposes, role and scope of cognitive systems engineering.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2017-2018 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5160 - Sensation and Perception**

This course will investigate sensory mechanisms and perceptual interpretations of the sensory stimuli. In addition to the basic five senses, proprioception, pain perception, and time perception will also be covered. Students will also write a research proposal.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5170 - Human Attention**

This course will examine theories and empirical findings from the study of human attention and consider their implications for human performance in real-world contexts.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5210 - Advanced Statistical Analysis and Design I**

An overview of data analysis methods including visualization, data programming, and univariate statistics such as t-test and ANOVA.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5220 - Advanced Statistical Analysis and Design II**

Course covers multivariate statistics such as ANCOVA, Multiple Regression, factor analysis, clustering, machine learning, and mixture modeling.

Credits: 3.0; Repeatable to a Max of 12

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PSY 5110

**PSY 5390 - Testing and Measurement Advanced Psychometrics**

Provides an advanced foundation in concepts, theories, and methods of psychological testing and measurement. Topics include: validity and reliability, cognitive process-tracing, test construction, survey construction, and evaluation, data analysis and interpretation, applications in human factors, workplace, neuropsychological, and educational contexts, test administration, ethics, laws, and standards. Satisfies some requirements for professional administration of psychological and educational assessments.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): PSY 5210

**PSY 5410 - Computational and Mathematical Models of Human Cognition and Behavior**

This course focuses on analysis and use of computational and mathematical models of human cognition and behavior. Topics include models of memory, learning, information theory, decision making, vision, semantics, production systems, game theory, and network analysis.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

**PSY 5450 - Aging, Cognition, and Motor Behavior**

Seminar on current research on age-related changes in cognitive function, motor behavior, and the interaction between cognitive decline and motor performance.

Topics include the impact of aging on memory, attention, cognitive control, gait, balance, and motor learning.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5500 - Supervised Teaching Practicum**

An experiential course in which student gain practical experience with course design and instruction.

Credits: variable to 3.0; Repeatable to a Max of 9; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**PSY 5510 - Memory and Learning: Review, Synthesis, and Applications**

Review of literature on human memory and learning from behavioral, neural, and applied perspectives. Readings and discussion will focus on foundational research studies that have formed the basis for our knowledge about human memory and learning, with a focus on the implications for applied work in learning, training, and human factors.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

**PSY 5610 - Automation**

An overview of the changing role of human users in automated systems. Topics include levels of automation, automation trust issues, automation uses and misuses, and the role of automation in human performance.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5620 - Displays and Alarms**

An overview of display and alarm design principles for human-machine systems. Topics include visual, auditory, and tactile display design, masking and alarm detection, and the cry wolf effect and alarms.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PSY 5160

**PSY 5750 - Judgment and Decision Making**

Decision making is a skill. To improve that skill and design better decision support systems, we examine how people make decisions, sources of power, common biases, and errors. This interdisciplinary approach includes three levels of analysis: descriptive, normative, and prescriptive.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5761 - Human-Robot Interaction**

This course covers topics, such as anthropomorphism and embodied, dialogue, emotion, human-robot team interaction, assistive robots, ethical issues, and measurement and evaluation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5770 - Affective Design and Computing**

An examination of emotions and affect in Human Factors and HCI. Topics may include brain and cognitive mechanisms and methods/techniques, affective computing, Kansei engineering, hedonomics, emotional design, and application domains.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5780 - Introduction to Qualitative Research Methods and Analysis**

An introduction to the use of qualitative research methods in social science contexts. Emphasis is placed on understanding the underpinnings of qualitative research, research traditions, and theoretical orientations. Students will be introduced to specific qualitative analysis techniques, ways to interpret data, and writing strategies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**PSY 5850 - Human Factors Psychology**

Advanced concepts critical to the design of human-technological systems, such as capitalizing upon human capabilities and compensating for human limitations. Topics may include perceptual and motor abilities, human error and cognitive engineering.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 5860 - Human Factors Tools and Techniques**

An overview of the tools and techniques used by human factors researchers and practitioners. Topics include task analysis, eye tracking, human error in systems, simulation, workload analysis, and physiological assessment techniques.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): PSY 5850

**PSY 5870 - Human-Centered Design**

This course will focus on the human-system (computers, appliances, mobile devices, etc.) interaction regarding the design and development of products. Students will experience a complete cycle of the interaction design project, including analysis, design, and evaluation.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman

**PSY 5910 - Independent Research**

Research experience, preparation, and data collection for projects that will not result in a thesis or dissertation.

Credits: variable to 12.0; Repeatable to a Max of 21; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**PSY 5999 - Graduate Research**

Fundamental and applied research in cognitive science and/or human factors leading to the submission of a thesis or report in partial fulfillment of the requirements for the master's degree.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**PSY 6990 - Special Topics in Cognitive Science**

Study of special topics in cognitive science as designed by section title.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 6991 - Special Topics in Human Factors**

Study of special topics in human factors as designed by section title.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**PSY 6999 - Doctoral Research**

Fundamental and applied research in cognitive science and/or human factors.

Leading to the submission of a dissertation in partial fulfillment of the requirements for the PHD degree.

Credits: variable to 12.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: On Demand

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**Systems Administration Technology****SAT 5001 - Introduction to Medical Informatics**

Course covers fundamental subjects such as medical decision support systems, telemedicine, medical ethics and biostatistics. Topics include consumer health informatics, international health care systems, global health informatics, translational research informatics and homecare. Students will see medical informatics from diverse perspectives. Scientific writing and communication will be encouraged.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5002 - Application Programming Introduction**

Students will develop problem solving skills through the application of a commonly used high-level programming language. Topics include: nature of the programming environment; fundamentals of programming languages; structured programming concepts; object-oriented programming concepts; desirable programming practices and design; and debugging and testing techniques.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5111 - Security and Privacy**

Examines key health information security, policy, and procedures. Investigates how to distinguish elements of a security audit and key security policies.

Analyzes the roles of people maintaining health information security and explains elements of these roles within the organization.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5114 - Introduction to Artificial Intelligence in Health**

Explores AI methods for clinical and healthcare applications with a focus on machine learning (ML). Covers concepts of algorithmic fairness, interpretability, and causality. Considers how AI techniques will shape healthcare policy and precision medicine.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

**SAT 5121 - Introduction to Medical Sciences, Human Pathophysiology, Healthcare**

Course provides basic concepts in medicine and human pathophysiology to introduce a molecular understanding of human metabolism and disease. Topics also include physical examination of patient, taking medical history, laboratory medicine, disease management and treatment, medical diagnostics, clinical workflow, and medical special/subspecialties.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5131 - System Analysis and Design**

Provides knowledge of tools available to perform systems analysis, examines key factors in systems design, emphasizes importance of communication, and an understanding of the primary factors in systems implementation. Course will examine strategies, risks, and key factors in purchasing systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5141 - Clinical Support Modeling**

Course addresses complex medical decisions, evidence-based medicine, disease management and comprehensive laboratory informatics. Topics include improving physical order entry and healthcare, using medical literature, clinical case discussions, meaningful use of medical data, enhancing patient and caregiver education, disease prevention, and public health and environmental health informatics.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall, Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Co-Requisite(s): SAT 5114

**SAT 5151 - Application Integration and Interoperability**

Defines and explains the role of interoperability in the development of a functioning EHR. Analyzes predominant standardization in the healthcare field such as ASTM and HL7. Examines the challenges to the development of interoperability in healthcare.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5161 - Data Warehousing and Business Intelligence**

Identifies database solutions and key elements of an enterprise data warehouse. Explains how to apply best practices for development of data warehouses, the role of business intelligence and data mining in supporting the strategic business decision process, and OLAP (Online Analytical Processing) and its use in reporting and analyzing database and data warehouse information. Defines security practices for a data warehouse environment.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Fall, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 3210

**SAT 5171 - Human-Computer Interaction in Healthcare**

Addresses human-computer interaction (HCI) evaluation methods and their applications in the healthcare domain. Topics include: user-centered design; measurements in HCI; usability testing; experimental research; data collection methods; statistical analysis; and qualitative data analysis. Software programming language R will be used.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 1111 or SAT 5002

**SAT 5231 - Statistical Methods for Intrusion Detection**

An introduction to the data and methodologies of computer intrusion detection. Focuses on statistical and machine learning approaches to detection of attacks on computers. Topics include network monitoring and analysis, network-based attacks such as probes and denial of service, host-based attacks such as buffer overflows and race conditions, and malicious code such as viruses and worms. Statistical pattern recognition methods will be described for the detection and classification of attacks.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5241 - Designing Security Systems**

Provides an overview of techniques used in the design of secure systems with a primary focus on real-world case studies. Students will examine attacks on deployed systems and investigate how these vulnerabilities have been addressed. Practical advantages and shortcomings of several notions of provable security will also be examined. Students will be expected to read, understand, and present recent research papers.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 5111

**SAT 5251 - Advanced Topics in Network Security**

Focuses on advanced research topics in communications security. The course is structured as a research seminar where students present research papers.

Topics include protocol analysis, security in inter-domain routing, broadcast authentication protocols, covert channels and anonymous communication, key management, advanced trace-back schemes, and attack propagation modeling. A course project is required.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 5231 or SAT 5241

**SAT 5255 - Medical Imaging I**

Introduction to the underlying physics, image formation theories and application of imaging methods used in medicine. This course is not a comprehensive presentation of imaging science but is an overview of the characteristics of each modality and their use.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): BL 2010 or BL 3080 or EH 1500 or KIP 1500

**SAT 5256 - Medical Imaging II**

Continuation of Medical Imaging I presenting more advanced imaging methods and their use in medicine. Topics such as MRI and Ultrasound will be covered in depth.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 5255

**SAT 5261 - Medical Image Analysis**

Overview of medical image analysis techniques. Topics will include: fundamentals of medical imaging; image enhancement; image compression; image segmentation; noise reduction; image registration; content-based medical image retrieval, feature extraction and image recognition; and computer-aided diagnosis and detection systems.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): CS 1111 or SAT 1200

**SAT 5283 - Information Governance and Risk Management**

Course will consist of the legal and regulatory requirements and security privacy concept principles regarding healthcare information. Best practices of how organizations manage information risk through risk assessment practices and procedures will be conducted.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following College(s): School of Technology

**SAT 5422 - Clinical Applications**

Introduces the concepts and processes of clinical applications. Critical insight into the medical field will be provided by blending both the clinical and medical informatics perspectives. Students will gain hands-on clinical application experiences within predefined clinical settings.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SAT 5424 - Population Health Management and Monitoring**

Introduces organization context of health data for the use of managing populations. Types of health data sources, interventions, data analytics, and policy factors affecting population health are covered. Also explores how information is used for managing population health surveillance.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 5001 and SAT 5114

**SAT 5600 - Web Application Development**

An introduction to the building and administration of web applications. Topics covered include: Apache web server development; Tomcat application server; HTML; cascading style sheets; JavaScript; JQuery; server side includes; server side application development; web services; SSL/TLS; and authentication/authorization.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 5002

**SAT 5761 - Introduction to Hadoop and Applications**

This course will introduce the basic concepts of the Hadoop system. Topics include: programming languages for Hadoop, Hadoop Architecture, MapReduce, administration of Hadoop clusters, Hadoop input and output; basic concepts of Yarn, Spark, Pig, HBase, and Hive, and the applications of Hadoop for data analysis.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Summer

**SAT 5816 - Digital Forensics**

Introduction of the basic principles and technology of digital forensics, including acquisition, preservation, and recovery and investigation of the evidence stored in digital devices.

Credits: 3.0

Lec-Rec-Lab: (0-2-2)

Semesters Offered: Fall

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SAT 2511 and (SAT 2711 or SAT 5111)

**SAT 5817 - Security Penetration Testing and Audit**

To provide knowledge and demonstrated methods to help prevent security breaches and develop safeguards to protect sensitive information and confidential data. Primary focus will be on the healthcare sector. Students learn offensive and defensive security concepts, audit best-practices.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following College(s): School of Technology

**SAT 5990 - Special Topics in Medical Informatics**

Medical informatics topic of interest to the faculty and student.

Credits: variable to 3.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**SAT 5998 - Practical Experience in Medical Informatics**

The study of an acceptable medical informatics research problem and the preparation of a report.

Credits: variable to 9.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**SAT 5999 - Thesis Research in Medical Informatics**

The study of an acceptable medical informatics research problem and the preparation of a thesis.

Credits: variable to 10.0; Repeatable to a Max of 10; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Social Sciences****SS 5001 - Advanced Social Science Methods**

Introduction to quantitative and mixed methods research in the social sciences. Topics include: survey design, sampling frames, data collection and analysis, error estimation, and the application of statistical methods. Literature will highlight the use and misuse of advanced methods.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

**SS 5003 - Survey Methods**

A general introduction to survey methods. Students will learn the basics of survey design from questionnaire construction to the measurement of complex social science concepts. Students will also demonstrate their ability to conduct an original survey through a class project.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

**SS 5004 - Statistics for the Social Sciences**

A general introduction to quantitative analysis for the social sciences. The course uses common statistical software tools, such as SPSS, to aid in the analysis of data. Students apply their data analysis techniques to social science problems of their choosing in a semester-long project.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

**SS 5005 - Introduction to Computational Social Science**

An introduction to computational methods for the social sciences. The course provides an introduction to complexity theory and Agent-Based Modeling. Students will apply what they have learned in this course to develop a pilot simulation to understand any social phenomena of their choosing.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

**SS 5010 - Directed Study**

Directed readings or research conducted under the direction of a member of the graduate faculty. Students must meet with their supervising instructor and receive approval of their study plan before registering.

Credits: variable to 4.0; Repeatable to a Max of 9

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**SS 5015 - Cultural/Environmental Office of Surface Mining VISTA Field Service Internship**

Students enroll in this course during a supervised field experience dealing with natural and cultural heritage, natural or cultural resources, and/or community development. This course allows progress toward MS degrees in Industrial Archaeology and Environmental and Energy Policy while serving as an intern through OSM VISTA.

Credits: 1.0; May be repeated

Lec-Rec-Lab: (0-0-3)

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Industrial Archaeology, Environmental Policy

**SS 5049 - GIS Applications for the Graduate Researcher**

Applications of Geographic Information Science and Technologies for research problem identification, analysis, and dissemination. Students learn how to use GIS as a tool to collect and analyze qualitative and quantitative data for graduate research. Hands-on experience in data collection, analysis, and problem solving.

Credits: 3.0

Lec-Rec-Lab: (1-0-2)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**SS 5050 - Advanced GIS Methods and Projects**

Advanced application of Geographic Information Systems in social sciences as a tool to collect and analyze qualitative and quantitative data. Students gain hands-on experience in data collection, advanced spatial analysis, and scripting.

Credits: 3.0

Lec-Rec-Lab: (1-0-2)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SS 5049

**SS 5201 - Cultural Dimensions of International Immersion and Research**

Students reflect on their culture and assumptions about the world; discuss conducting research responsibly; consider structural, material, and historical dimensions of social problems and social change; and explore how to live and work effectively with people from other cultural groups.

Credits: 1.0

Lec-Rec-Lab: (0-0-2)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5230 - Archaeological Analysis and Interpretation**

Course focuses on how archaeologists mobilize material data to understand everyday life in the past. Discussion, exercises, and lab time are used to cover the goals of archaeology, nature of archaeological data, research design, sampling, typology, classification, database management, and quantitative and qualitative analytical methods.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand - Offered alternate years beginning with the 2017-2018 academic year

**SS 5300 - Environmental and Natural Resources Policy**

An overview of environmental and natural resource policies in the U.S. and internationally. Emphasizes policies regarding forests, wildlife, public lands, pollution, and climate change. Discussion of policy administration by the USDA Forest Service and National Park Service.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5301 - The Policy Process**

This course introduces key concepts in the policy making process (agenda, setting, formulation, decision-making, implementation, and evaluation). Theories of policy change are also introduced.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring - Offered alternate years beginning with the 2016-2017 academic year

**SS 5302 - Environmental Governance and Decision Making - Nature, Culture, and Power**

Reviews the dominant social scientific narratives related to understanding interactions between society and the environment. Involves learning to think critically about environmental problems and the social, political, and cultural contexts in which these problems arise.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5310 - Ecological Economics**

Ecological economics starts with a preanalytical vision that the economy is a sub-system of the Earth's ecological systems. Foundational topics include examination of the optimal scale of the economy, efficient allocation of resources, and the equitable distribution of resource flows.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5313 - Sustainability Policy**

Foundational scientific concepts (dynamic systems and catastrophe theory) as applied to socioecological systems. Use of indicators and indices to track progress towards sustainability goals. Review of local, national, and global sustainability policies to avoid catastrophes and guide sustainable development.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5315 - Population and Environment**

This course investigates relationships between the world's population, population change, population distribution, resource consumption, and environmental and social consequences. Addresses local and global relationships and the population processes (mortality, fertility, and migration) involved.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Pre-Requisite(s): SS 5400(C) or SS 3760 or FW 3760

**SS 5320 - Special Topics in Environmental Policy**

An intensive, student-led seminar focused on environmental and sustainability policy issues at local, regional, or global scales. Topics may include climate change, pollution, sustainable agriculture or development, environmental justice, globalization, or other current topics. May be repeated if topic differs.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5325 - Water Policy, History, and Governance**

This seminar will explore the global history, politics, and governance of freshwater resources. Topics will include the effects of forestry, mining, watershed management, sanitation systems, privatization, climate change, fisheries, emerging contaminants, and agriculture on water systems and policies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2016-2017 academic year

**SS 5330 - Advanced Topics in Energy Policy**

An intensive student-led seminar focused on energy policy issues at local, regional, or global scales. Topics may include climate change, renewable energy, energy efficiency, nuclear wastes, and government mandates. May be repeated if topic differs.

Credits: variable to 3.0; Repeatable to a Max of 9

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5350 - Environmental Policy Analysis**

An overview of the policy process, including a detailed review of the major instruments that are used by federal, state, regional, and local governments.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SS 5300 and EC 2001

**SS 5400 - Sociology of the Environment**

Provides students with an introduction to basic sociological concepts as they apply human relationships to the environment. Topics include social values, organizations, norms, ideologies, and political systems. Themes will include the relationship of expertise to lay knowledge, public participation, and urban-rural relationships.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2015-2016 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5500 - History of Technology**

Provides a basic introduction to work in the history of technology.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2013-2014 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5501 - Industrial Communities**

A graduate seminar covering studies of industrial communities. Introduces the methods and approaches of this field through reading and discussion of selected articles and case studies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2013-2014 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5502 - Historical Archaeology**

Graduate seminar covering the essential elements of historical archaeology through reading and discussion of selected articles and case studies.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5503 - Material Culture Studies**

Graduate seminar covering the basic elements of material culture studies through readings, discussion, and projects.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5530 - Deindustrialization and the Urban Environment**

This course examines economic, environmental, and social problems associated with deindustrialization in postwar North American cities and the strategies adopted to ameliorate them. Major topics include segregation and housing, environmental regulation, environmental justice, industrial heritage, and economic and urban development policy.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2016-2017 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**SS 5550 - Global Environmental History**

Examines changes in human interactions with earth systems over time, starting with the development of agriculture and continuing to the present—with flows of material through economies and ecologies now intertwined in complex ways. Places the notion of sustainability in historical perspective.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2015-2016 academic year

**SS 5551 - Global Industrial History**

Graduate seminar examining the interlinked processes of industrialization and globalization ca. 1700-present. The course covers key theoretical debates and explores different methodological approaches through case studies of selected topics and themes.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**SS 5600 - Industrial Archaeology**

Directed readings and lectures in industrial archaeology using wide range of material from the historical engineering and archaeology literature. Central focus is on regional case studies. Students complete a substantial directed research project.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring - Offered alternate years beginning with the 2018-2019 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5635 - International Environmental Policy**

This course delves into the international law associated with environmental issues. Students begin with the treaty language and associated jurisprudence (if any) and then study how the treaty was negotiated, adapted by national governments, and used in political discourse.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5700 - Archaeological Field Methods**

Practical experience in methods and techniques of field archaeology. Background readings followed by participation in site survey, testing, excavation, and record keeping. Students involved in ongoing research projects in upper Great Lakes Region. Offered with SS 3210. Graduate students complete independent project in addition to regular work. Recommended SS2020.

Credits: variable to 8.0; Repeatable to a Max of 16

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5720 - Social Thought and Contemporary Issues**

This course reviews the ways social scientists understand the nature of social organization, how these ideas have changed over time in concert with particular socio-historic transformations, and how, specifically, these ideas relate to understanding interactions between industrial society and the environment.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall

**SS 5800 - Documentation of Historic Structures**

Principles and practice of survey and documentation of historic structures. Techniques include reconnaissance survey, in-depth survey, measured drawings, architectural photography, primary research, and written descriptions. Students use survey and documentation to analyze historic structures.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2012-2013 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5820 - Advanced, Ethical, Legal and Societal Implications (ELSI) of Nanotechnology**

Advanced exploration of the implications of molecularism as brought about by emergent nanotechnology and nanoscience. Involves comparative investigations, extended reading and writing assignments in seminar setting.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5900 - Heritage Management**

Introduces the current field of heritage management; the legislation that underwrites its practice; the articulation of federal, state, and local governmental activity; the evolving philosophies of archaeologists and historic preservationists operating in the public interest; parallels on the international scene; and the impacts of heritage tourism.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 5950 - Professional Development**

This course will prepare graduate students in the social sciences department for the expectations for success in graduate school and future careers. The course will provide a foundation in understanding academic and professional development, including research, presentations and conference attendance, and professional preparation.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**SS 5990 - Graduate Research**

Individual research work leading towards master's thesis or project. Open by arrangement to students in master's programs in the Department of Social Sciences.

Credits: variable to 10.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 6002 - Research Design**

This objective of this course is to explore the fundamentals of research design and analysis, particularly as these are applied to identifying, initiating, carrying out, and completing a thesis or dissertation research in environmental and energy policy.

Credits: 3.0

Lec-Rec-Lab: (3-0-0)

Semesters Offered: Spring

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 6010 - Special Topics in Industrial Heritage**

Examines themes or topics related to studies of industrial heritage. May include such topics as advanced cultural resource & heritage management and tourism; industrial heritage field methods; international dimension of industrial heritage; government policy. May be repeated.

Credits: variable to 6.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 6020 - Special Topics in Industrial History**

Examines themes or topics related to the study of industrial history of technology. Topics may include global history of industrialization; theoretical models of industrial evolution; and social history of technology and work. May be repeated.

Credits: variable to 6.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 6100 - Advanced Seminar in Energy and Climate Policy**

This course will review the complex process of energy policy making in the U.S. focusing on political, economic, social, organizational, and technological dimensions. Students will examine the prospects for policy change in the light of global climate change.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2012-2013 academic year

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 6500 - Directed Reading/Independent Study**

Directed reading or independent study with appropriate faculty at the graduate level.

Credits: variable to 9.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SS 6600 - PhD. Dissertation Research**

Fundamental and applied research in industrial heritage, industrial archeology, history of technology, and in environmental and energy policy. Taken by graduate students in partial fulfillment of the PhD thesis requirements.

Credits: variable to 9.0; May be repeated; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

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**Surveying****SU 5002 - Infrared Technology, Sensors, and Applications**

Infrared remote sensing fundamentals, current and future technologies, and applications are considered. Remote sensing for both civilian applications such as environmental resource mapping and military applications will be included.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5004 - Introduction to Geospatial Image Processing**

Introduction to the basic concepts of Image Processing and Understanding. Applications focus on preprocessing of satellite and aerial images, remote sensing, and image/video enhancement. This course will provide mathematical foundations and explore modern practical algorithms and methods.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5010 - Geospatial Concepts, Technologies, and Data**

High-level review of geospatial data acquisition systems, sensors and associated processing technologies. Course considers geospatial metadata generation principles, interoperability, and major tools for manipulation with geospatial data. Course may help in transition of non-geospatial majors to geospatial field.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5011 - Cadastre and Land Information Systems**

Topics include: an introduction to land rights, land ownership, lease, and traditional rights, mortgaging and land as capital, description of land rights, boundary description, land information systems, examples of cadastre types over the globe, and modern technical aspects.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year

**SU 5012 - Geospatial Data Mining and Crowdsourcing**

This course comprises theory and applications of geospatial data mining. Typical application scenarios are covered. Attention is given to open-source data and systems crowdsourcing, as well as social media. Special focus on imaging and visual analytics.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Spring - Offered alternate years beginning with the 2020-2021 academic year

**SU 5013 - Hydrographic Mapping and Surveying**

This course comprises theory and applications of hydrographic mapping technologies. Typical application scenarios are covered. An intensive lab component provides hands-on experience in hydrographic data processing and visualization.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: Spring

**SU 5020 - Data Analysis and Adjustments**

Course explores fundamentals of mathematical error propagation theory including various observation equations, least squares adjustment, and Kalman filter methods. Blunder detection, decorrelation, and inversion of patterned large matrices processes are considered. Involves analysis of position estimation deploying geospatial measurements.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5021 - Geodetic Models**

Course provides solid geospatial background in geodetic reference frames: datums; geoids; and reference ellipsoids. 2D and 3D geodetic network adjustments are considered based on 3D spherical models.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SU 5020(C)

**SU 5022 - Positioning with GNSS**

In-depth study of GPS, GLONASS, Galileo, COMPASS satellite systems, theory, and processing of global positioning measurements. Strongly recommended for geospatial practitioners.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SU 5020

**SU 5023 - Geospatial Positioning**

High-level summary of GPS-GAP courses. This course is intended for interdisciplinary graduate students who seek just ONE combination course in adjustments, geodesy and GPS (with emphasis on GPS/GNSS). Not available to students who have taken SU5020, SU5021, SU5022.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5142 - 3D Surveying and Modeling with Laser Scanner Data**

Theory and application of terrestrial LIDAR scanning. Typical application scenarios are also included. Intensive lab component provides hands-on experience in LIDAR point cloud processing and visualization.

Credits: 3.0

Lec-Rec-Lab: (0-2-1)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5540 - Advanced Photogrammetry - Satellite Photogrammetry**

Fundamentals of spaceborne imaging systems relevant to topographic mapping. Imagery products: preprocessing levels and metadata. Specific methods of space photogrammetry. Review of contemporary spaceborne imaging systems and imagery products available. Airborne non-frame sensors and photogrammetric processing of the imagery.

Credits: 3.0

Lec-Rec-Lab: (0-2-3)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SU 4140

**SU 5541 - Close-range Photogrammetry**

The main topics that will be covered are: math fundamentals; imaging technology; the photogrammetric process; image acquisition planning; interior orientation; bundle block adjustment; 3D plotting; orthorectification; image-matching techniques; and close range photogrammetry applications.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): SU 4140

**SU 5800 - Geospatial Master's Graduate Seminar**

Student presentations of geospatial related research. Graduate committee organization assistance, presentation skills training and guidance for final Master's research presentation.

Credits: 1.0

Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5930 - Synthetic Aperture Radar (SAR) Fundamentals and Applications**

Review of radar concepts, applications of SAR (InSAR) data, types of available satellite/airborne systems, and data processing methods. Applications for creating topographic data, recognizing targets, classifying ice and vegetation, and oceans/large lakes will be presented based on real-world examples.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**SU 5990 - Special Topics in Integrated Geospatial Technology**

Integrated Geospatial Technology topic of interest to the faculty and student.

Credits: variable to 3.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**SU 5998 - Practical Experience in Integrated Geospatial Technology**

The study of an acceptable geospatial related research problem and the preparation of a report.

Credits: variable to 6.0; Repeatable to a Max of 6

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**SU 5999 - Thesis Research in Integrated Geospatial Technology**

The study of an acceptable geospatial related research problem and the preparation of a thesis.

Credits: variable to 10.0; Repeatable to a Max of 10; Graded Pass/Fail Only

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**Technology****TE 5000 - Independent Study in Technology**

Students undertake an independent study in an approved technology topic under the guidance of a School of Technology faculty member. The course of study may either be research or academic and is decided upon between the student and faculty member.

Credits: variable to 3.0; Repeatable to a Max of 6

Semesters Offered: On Demand

Restrictions: Permission of instructor required; May not be enrolled in one of the following Class(es): Senior

**TE 5001 - Special Topics in Technology**

Topics of special interest in technology will be offered depending on student demand and faculty interest or expertise.

Credits: variable to 3.0; Repeatable to a Max of 12

Semesters Offered: On Demand

Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**TE 5100 - Systems Design and Integration**

System specification and design with an overview of technical performance measurements, activity management, risk management, decision analysis, cost analysis, and concurrent engineering. A broad view of customer and vendor integration, design reviews, quality systems, producibility, and sustainability are also presented.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**TE 5200 - Systems Quality and Reliability**

Technology and methodology for setting standards and measuring component performance. Testing and methods for evaluating internal and external subcontractor components and data are also presented. Contemporary issues of continuous improvement in quality and manufacturing, 6-sigma, and service industries are examined. Documentation related to offshore manufacturing is also introduced.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**TE 5300 - Systems Project Management**

Management techniques for large scale projects with multiple components and subsystems. Includes establishing and tracking responsibilities and costs of both internal and external value streams. Methods of investigating delivery, payment, and mechanical performance are also presented.

Credits: 3.0

Lec-Rec-Lab: (0-3-0)

Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore, Junior

**University Wide****UN 0500 – Effective Scholarship**

Course meets federal requirements for responsible conduct of research training for graduate students. Students who pass the course will be awarded a certificate of completion.

Credits: 1.0; Graded Pass/Fail Only

Lec-Rec-Lab: (0-2-0)

Semesters Offered: On Demand

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**UN 5000 - Graduate Cooperative Education I**

Credits may count as free or technical electives based on academic department. Requires advisor approval, good standing, registration with Career Services, and an official letter.

Credits: variable to 6.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**UN 5001 - Advanced Responsible Conduct of Research**

Three, 4 hour workshops on advanced responsible conduct of research. Covers topics necessary for this training, including ethical standards, publication practices, peer review process, conflict of interest and societal expectations.

Credits: 1.0

Lec-Rec-Lab: (1-0-0)

Semesters Offered: Summer

Restrictions: Must be enrolled in one of the following Level(s): Graduate

**UN 5002 - Graduate Cooperative Education II**

Credits may count as free or technical electives based on academic department. Requires advisor approval, good standing, registration with Career Services, and an official offer letter.

Credits: variable to 6.0; May be repeated

Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

Pre-Requisite(s): UN 5000

**UN 5003 - Graduate Cooperative Education III**

Credits may count as free or technical electives based on academic department. Requires advisor approval, good standing, registration with Career Services, and an official offer letter.

Credits: variable to 6.0; May be repeated  
Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): UN 5000 and UN 5002

**UN 5004 - Graduate Cooperative Education IV**

Credits may count as free or technical electives based on academic department. Requires advisor approval, good standing, registration with Career Services, and an official offer letter.

Credits: variable to 6.0; May be repeated  
Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate  
Pre-Requisite(s): UN 5000 and UN 5002 and UN 5003

**UN 5100 - Water and Society Colloquium**

Seminar based class covers current topics in water resources. Objectives: build towards a common literacy on water resources issues; identify areas of common interest among students and faculty in water resources topics.

Credits: 1.0; Repeatable to a Max of 2  
Lec-Rec-Lab: (0-1-0)

Semesters Offered: Spring  
Restrictions: Permission of instructor required

**UN 5200 - Interdisciplinary Colloquium**

An interdisciplinary discussion-focused course covering special topics as specified by section title.

Credits: variable to 3.0; May be repeated  
Semesters Offered: On Demand

Restrictions: May not be enrolled in one of the following Class(es): Freshman, Sophomore

**UN 5390 - Scientific Computing**

Set in a Linux environment, course offers exposure to Foss tools for developing computational and visualization workflows. Students will learn to translate problems into programs, understand sources of errors, and debug, improve the performance of and parallelize the code.

Credits: 3.0  
Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall, Spring  
Restrictions: Permission of instructor required; Must be enrolled in one of the following Level(s): Graduate

**UN 5400 - Climate Science and Policy**

An interdisciplinary discussion-format course covering the basic science of climate change and the development of international climate policy. Includes an analysis of policy targets in their scientific context and links to global sustainable development goals. Additional topics will be guided by the interests of the class and current events.

Credits: 3.0; Repeatable to a Max of 6  
Lec-Rec-Lab: (3-0-0)

Semesters Offered: Fall - Offered alternate years beginning with the 2019-2020 academic year  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**UN 5500 - Advanced Research Integrity**

Three 4-hour workshops introduce students to the principles, practices, and regulations of responsible conduct research. Topics might include: societal expectations; professional and ethical standards; conflicts of interest; peer review; collaboration; publication and authorship; research misconduct; violations and sanctions.

Credits: 1.0  
Lec-Rec-Lab: (0-1-0)

Semesters Offered: On Demand  
Restrictions: Must be enrolled in one of the following Level(s): Graduate

**UN 5550 - Introduction to Data Science**

Course provides an introduction to Big Data concepts, with focus on data management, data modeling, visualization, security, cloud computing, and data science from different perspectives: computer science, business, social science, bioinformatics, engineering, etc. Course introduces tools for data analytics such as SPSS Modeler, R, SAS, Python, and MATLAB. Two case study projects which are integrated with communication and business skills.

Credits: 3.0  
Lec-Rec-Lab: (2-0-3)

Semesters Offered: Fall  
Restrictions: Must be enrolled in one of the following Level(s): Graduate; Must be enrolled in one of the following Major(s): Data Science

**UN 5951 - Graduate Status - Maintenance of Continuous Enrollment**

Meets continuous enrollment requirement for graduate students needing "time out" for special circumstances (such as active military duty) and for online programs with inactive terms.

Credits: 0.0; May be repeated; Graded Pass/Fail Only  
Semesters Offered: Fall, Spring, Summer

Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**UN 5953 - Graduate Status - Maintenance of Continuous Enrollment**

Course can be used to meet the minimum one credit enrollment requirement for graduate students. Students enrolled in research-oriented degree programs must instead register in one credit of research with the appropriate faculty member.

Not available to students who need to be enrolled fulltime with 9 credits.  
Credits: 1.0; Graded Pass/Fail Only

Lec-Rec-Lab: (0-1-0)  
Semesters Offered: Fall, Spring, Summer  
Restrictions: Permission of department required; Must be enrolled in one of the following Level(s): Graduate

**UN 5990 - Special Topics - Interdisciplinary**

Study of interdisciplinary special topics as specified by section title.

Credits: variable to 6.0; May be repeated  
Semesters Offered: On Demand  
Restrictions: Permission of instructor required