**Actuarial Science**

**ACTS 6301** Theory of Actuarial Models: Life Contingencies I (3 semester credit hours) The purpose of this class is to develop the student's knowledge of the theoretical basis of life contingent actuarial models and the application of those models to insurance and other financial risks. Life contingencies, survival models, life insurances, annuities and premiums will be studied. This class covers parts of SOA Exam LTAM. Prerequisite: STAT 5351 or instructor consent required (3-0) T

**ACTS 6302** Theory of Actuarial Models: Financial Economics (3 semester credit hours) This course develops the student's knowledge of the theoretical basis of certain actuarial models and the application of those models to insurance and other financial risks. The topics discussed include mean-variance portfolio theory, asset pricing models, market efficiency and behavioral finance, investment risk and project analysis, capital structure, forwards and futures, and theory of options. This class covers parts of CAS exam 3F and SOA exam IFM. Prerequisite: STAT 5351 or instructor consent required. (3-0) T

**ACTS 6303** Theory of Actuarial Models: Life Contingencies II (3 semester credit hours) The purpose of this class is to develop the student's knowledge of the theoretical basis of life contingent actuarial models for multiple lives and the application of those models to insurance and other financial risks. Reserves, life contingencies for multiple lives, expenses and stochastic processes will be studied. This class covers parts of SOA Exam LTAM. Prerequisite: ACTS 6301 or instructor consent required. (3-0) T

**ACTS 6304** Construction and Evaluation of Actuarial Models I (3 semester credit hours) Introduction to useful frequency and severity models beyond those covered in Theory of Actuarial Models. Discussion of the steps involved in the modeling process and how to carry out these steps in solving business problems. At the end of the course the students should be able to: 1) analyze data from an application in a business context; 2) determine a suitable model including parameter values; and 3) provide measures of confidence for decisions based upon the model. This class also provides an introduction to a variety of tools for the calibration and evaluation of the models. This class covers parts of CAS Exam 4/SOA Exam C. Prerequisite: STAT 5351 or instructor consent required. (3-0) T

**ACTS 6305** Construction and Evaluation of Actuarial Models II (3 semester credit hours) Introduction to useful frequency and severity models beyond those covered in Principles of Actuarial Models. The topics discussed include parametric models, credibility and simulation. This class covers parts of CAS Exam 4/SOA Exam C. Prerequisite: ACTS 6304 or instructor consent required. (3-0) T

**ACTS 6306** Advanced Actuarial Applications (3 semester credit hours) This class covers parts of CAS Exam 5 (Basic Techniques for Ratemaking and Estimating Claim Liabilities)/SOA Exam FAP (Fundamentals of Actuarial Practice). Instructor consent required. (3-0) R

**ACTS 6308** Actuarial Financial Mathematics (3 semester credit hours) The purpose of this course is to provide an understanding of the fundamental concepts of financial mathematics, and how those concepts are applied in calculating present and accumulated values for various streams of cash flows as a basis for future use in: reserving, valuation, pricing, asset liability management, investment income, capital budgeting, and valuing contingent cash flows. The topics discussed include loans, bonds, and annuities, as well as determinants of interest rates and interest rates swaps. This class covers parts of the CAS Exam 2
and the SOA Exam FM. Instructor consent required. (3-0) Y

**Biology**

**BIOL 5303** Introduction to Microbiology for Graduate Students (3 semester credit hours) Microbes contribute to major biogeochemical processes, live in environments inhospitable to other organisms, and may comprise the majority of biomass on Earth. They form beneficial symbioses with multicellular organisms and play critical roles in the development of those organisms. In contrast to these beneficial roles, certain microbes are global public health concerns. This course surveys the form and function of the microbial world. Instructor consent required. (3-0) S

**BIOL 5312** Programming in the Biological Sciences for Graduate Students (3 semester credit hours) This course is an introduction to programming practices using C++ designed specifically for graduate students in the biological sciences with no prior programming experience. Special emphasis will be put in particular features of C++ like object oriented programming, data structures as well as applications to process, model, and analyze biological data. One goal of this course is to provide a strong background on programming skills on a basic level while leaving more advanced techniques of software development and algorithms for other advanced courses. Students work on programming assignments as well in a research project that can be addressed with the tools taught in this class. (3-0) S

**BIOL 5322 (SCI 5322)** Basis of Evolution (3 semester credit hours) From Assembling the Tree of Life to new drug developments, evolution theory is at the core of biology advancements. The concept of evolution is discussed for its relevance as a basic understanding for a scientifically literate society and processes and mechanisms of natural selection are examined. Topics include pertinent history, the fossil record, extinction, emergent species, the human experience, and applied evolution technologies. Students will explore the origins of evolution theory, public misconceptions, teaching, and evolution education research. An intensive scientific argumentation component (rather than debate) through discourse, advanced readings, presentations, panel discussions, and formal writing is required. Viewpoints examined include those of evolutionary biologists and research scientists. (3-0) T

**BIOL 5324 (SCI 5324)** Ecology (3 semester credit hours) This course will examine interrelationships between organisms and their environments in both theoretical and field-based contexts. Students will examine general ecological principles and their applications. Communities considered will be as small as the roadside and as vast as interconnected global systems. Topics analyzed by students in the context of ecological studies will include the flow of energy and matter through systems, predator/prey relationships, genetic diversity, evolution, population dynamics, interactions between microscopic and macroscopic organisms, and human impacts. Fieldwork examining North Texas ecosystems may be required. Critical thinking, metacognition, and reflections on the relevance of ecology in the teaching and learning of life and environmental sciences will be emphasized throughout the course. (3-0) T

**BIOL 5330 (SCI 5330)** Emerging Topics in Biology (3 semester credit hours) The media frequently announce biology advancements and research that affect human health, basic living needs, and biology education without critical analysis, often resulting in confusing the public and curtailing scientific literacy. Examination of resources and methods to critically evaluate biological information and scientific articles for sound theory development, research methods, and practical application. Topics include recent discoveries in the life sciences that meet the needs of society, health, and environmental issues. Although
the topics build on emerging issues, they may include content areas such as cell and molecular biology, agriculture, epidemiology, and global warming. Students will examine effective ways to bring in new curricula into established course settings. Advanced curriculum writing component focused on science literacy. Viewpoints include those of biological research scientists, health professionals, and science education researchers. (3-0) T

**BIOL 5375** Genes to Genomes (3 semester credit hours) is an expansive coverage of molecular genetics with emphasis on genomes rather than genes. Students will gain a new perspective on how genes function together and in concert in living cells, focusing at the genome level. Students also will learn how to study genomes, inspect genome anatomies, analyze how genomes function and determine how genomes replicate and evolve. The course is structured to involve students directly in individual topics by class discussions of research papers and reviews, the latest advances in genome science and new and innovative techniques. Instructor consent required. (3-0) Y

**BIOL 5376** (BMEN 6387) Applied Bioinformatics (3 semester credit hours) Genomic information content; data searches and multiple sequence alignment; mutations and distance-based phylogenetic analysis; genomics and gene recognition; polymorphisms and forensic applications; nucleic-acid and protein array analysis; structure prediction of biological macromolecules. Prerequisites: At least one semester of undergraduate statistics and probability, and two semesters of undergraduate calculus or instructor consent required. (3-0) T

**BIOL 5381** Genomics (3 semester credit hours) Genome sequence acquisition and analysis; genomic identification; biomedical genome research; DNA microarrays and their use in applied and healthcare research. (3-0) T

**BIOL 5385** Computational Molecular Evolution (3 semester credit hours) This course describes principles and models of evolutionary theory at the molecular level. It focuses primarily on the evolution of nucleotide sequences including genes, pseudogenes, and genomes as well as amino acid sequences used to study the evolution of proteins, protein complexes, and interactions. Phylogenetics and current leading quantitative models of sequence evolution are discussed in detail. Recent methods on amino acid evolution and its connections to molecular structure and function are also studied. Relevant examples of evolution at the molecular level presented in this course include protein interactions, signaling networks, and viral evolution. (3-0) S

**BIOL 5410** (MSEN 5410) Biochemistry (4 semester credit hours) Emphasis is on metabolic biochemistry, especially as it relates to human disease states. Prerequisite: at least one semester of undergraduate biochemistry and instructor consent required. (4-0) Y

**BIOL 5420** Molecular Biology (4 semester credit hours) Genetic analysis of gene structure (mutations and their analysis, complementation, and recombination), gene expression (transcription, RNA processing, translation), and the regulation of gene expression in selected model systems (viral, prokaryotic, organellar, eukaryotic); principles of genetic engineering (cloning and recombinant DNA technology). (4-0) Y

**BIOL 5440** (MSEN 5440) Cell Biology (4 semester credit hours) Molecular architecture and function of cells and subcellular organelles; structure and function of membranes; hormone and neurotransmitter action; growth regulation and oncogenes; immune response; eukaryotic gene expression. Prerequisite: **BIOL 5420** or equivalent or instructor consent required. (4-0) Y
**BIOL 5460** Quantitative Biology (4 semester credit hours) Fundamental mathematical and statistical concepts; hypothesis testing. Quantitative approaches to studying gene expression and protein-DNA interactions. Prerequisites: at least one semester of undergraduate calculus and one semester of general physics or instructor consent required. (4-0) Y

**BIOL 5V00** Topics in Biological Sciences (1-6 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) Y

**BIOL 5V01** Topics in Biological Sciences (1-6 semester credit hours) Includes a laboratory component. May be repeated for credit as topics vary (9 semester credit hours maximum). (1-[0-10]) Y

**BIOL 5V95** Advanced Topics in Molecular and Cell Biology: Individual Instruction (1-6 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) Y

**BIOL 6193** Colloquium in Molecular and Cell Biology (1 semester credit hour) Required for all degree students except non-thesis MS, to be taken before a Supervising Committee is appointed. Pass/Fail only. (1-0) Y

**BIOL 6252** Current Research in Molecular Biology (2 semester credit hours) Recent developments in biosynthesis, structure, function, and expression of nucleic acids in prokaryotes and eukaryotes. Students will participate in a critical analysis of current research publications. Pass/Fail only. May be repeated for credit as topics vary (8 semester credit hours maximum). (2-0) S

**BIOL 6315** Epigenetics (3 semester credit hours) Almost all cell types in our body share the same genetic information, but they perform very distinct functions. For example, our nerve cells are morphologically and functionally distinct from our muscle cells. How can the same genome give rise to hundreds of distinct cell types in our body? How can different diseases affect identical twins sharing the same genetic information? Why our parents and grandparents’ diet and health may have lasting influences on our own health? The field of epigenetics emerged over the past decades to tackle these fundamental questions that intersect our genome, development, environment, and disease. The course will provide a broad overview of epigenetic phenomena and epigenetic mechanisms with weekly lectures and small group discussions of primary literature. The course will introduce students to seminal works in epigenetics and recent developments with the goal of instilling critical knowledge of the field. (3-0) Y

**BIOL 6317** Pathobiology and Animal Models of Human Diseases (3 semester credit hours) This course is designed to provide graduate students with comprehensive and integrated advances of recent biomedical research within a clinically oriented framework. Topics including cancer, metabolic diseases, inflammation, and tissue injuries are presented with the aim that students will become aware of the contributions of various animal models to future developments of diagnosis and treatments. Students are also expected to acquire the necessary skills to interpret and present recent landmark research articles. Sessions include lectures, seminars from invited guest lecturers, and journal article presentation. (3-0) S

**BIOL 6327** RNA World (3 semester credit hours) The nature of modern RNA suggests a prebiotic RNA world. This course will begin with a presentation of the arguments that a RNA world existed before the evolution of protein synthesis. Additional topics will include RNA evolution, the origin and evolution of introns, RNA replication, the evolution and involvement of tRNAs and rRNAs in protein synthesis, the structure and mechanism of large catalytic RNAs such as Group I and Group II introns and the RNase P RNA, the structure and mechanism of small nuclear RNAs such as hammerheads and hairpins, RNA
editing, and the mechanism of telomerase. (3-0) T

**BIOL 6331** Molecular Genetics (3 semester credit hours) A graduate survey of the phenomena and mechanisms of heredity, its cytological and molecular basis, with a focus on bacterial and model eukaryotic systems. Topics will include fundamentals of Mendelian Genetics, genetic recombination and genetic linkage, as well as gene structure and replication, gene expression and the transfer of genetic information, mutation and mutagenesis, and applications of recombinant DNA techniques to genetic analysis. For students who have not had undergraduate genetics. Instructor consent required. (3-0) Y

**BIOL 6333** Macromolecules: Structure, Function, and Dynamics (3 semester credit hours) This course includes a discussion of DNA structures, protein structures, the folding and stability of domains, and the binding of proteins to DNA. Methods used to investigate the relation of structure to function are emphasized. Types of protein structures whose structure and function are considered include transcription factors, proteinases, membrane proteins, proteins in signal transduction, proteins on the immune system, and engineered proteins. Instructor consent required. (3-0) Y

**BIOL 6337** Regulation of Gene Expression (3 semester credit hours) An in depth look at how the cell makes use of its genetic information, with a primary focus on the mechanisms of transcription regulation. The course emphasizes a critical discussion of techniques and results from the recent scientific literature. Topics are taken from eukaryotic and/or prokaryotic systems and typically cover areas such as promoter organization, RNA polymerase and transcription factor structure and function, the organization and packaging of chromosomes, whole-genome analyses, and the pathways that control gene expression during growth and development. (3-0) Y

**BIOL 6341** Oncogenes (3 semester credit hours) Properties of cancer cells, in vivo and in vitro. Telomeres and cellular immortality. The role of DNA and RNA viruses in human cancers. Molecular biology of chronic leukemia retroviruses and the acutely transforming retroviruses. Retroviral oncogenes; the role of mutation, amplification, and chromosomal translocation of cellular oncogenes in human cancer. Regulation of the eukaryotic cell cycle, and the role of tumor suppressor genes. The role of oncogenes in growth hormone signal transduction. The role of apoptosis, and developmental signaling pathways in cancer. (3-0) Y

**BIOL 6343** Molecular Neuropathology (3 semester credit hours) This course is designed to give students a 360 degree view on pathology and the corresponding molecular basis of this pathology in different diseases linked to the brain and spinal cord. Here students acquire an in depth understanding of these diseased states and are able to analyze and critically review published journal articles. Instructor consent required. (3-0) S

**BIOL 6344** Molecular Neuropathology II (3 semester credit hours) This course is designed to give students a 360 degree view on pathology and the corresponding molecular basis of this pathology in different diseases linked to the brain and spinal cord. Here students acquire an in depth understanding of these diseased states and are able to analyze and critically review published journal articles. Instructor consent required. (3-0) Y

**BIOL 6345** Molecular Basis of Acquired Immune Deficiency Syndrome (3 semester credit hours) Topics include an analysis of the molecular basis of the infection of target cells by HIV, the intracellular replication of retroviruses, with special attention given to the HIV tat and rev genes, and an analysis of the roles of the
HIV accessory genes: vif, vpr, vpu and nef. The immunological response of the host to HIV is considered, as is the biological basis for the ultimate failure of the immune system to contain this virus, with attendant immune collapse. The molecular basis of a variety of existing and potential anti-retroviral therapies is considered. (3-0) Y

**BIOL 6351** Cellular and Molecular Biology of the Immune System (3 semester credit hours) Innate and adaptive immunity. Structure and function of immunoglobulins and MHC molecules, and their role in the adaptive immune response. Function of the primary and secondary lymphoid tissues, and the role of professional antigen presenting cells. The molecular basis for the generation of diversity during cellular development of B and T lymphocytes. The role of complement in innate immunity, and details of T cell and B cell mediated immunity. (3-0) Y

**BIOL 6352** Modern Biochemistry I (3 semester credit hours) Structure and function of proteins, including enzyme kinetics and catalytic mechanisms; structure and metabolism of carbohydrates, including oxidative phosphorylation and electron transport mechanisms. For students who have not had undergraduate biochemistry. (3-0) S

**BIOL 6353** Modern Biochemistry II (3 semester credit hours) Continuation of **BIOL 6352**. Structure and metabolism of lipids, including membrane structure and function. Nitrogen metabolism: amino acids and nucleotides. Polynucleotide replication, transcription, and translation. For students who have not had undergraduate biochemistry. (3-0) Y

**BIOL 6354** Microbial Physiology (3 semester credit hours) Microbial physiology considers the basic processes of microbes, especially those variations that are unique to microbes: energy generation, fermentations, and other pathways specific to bacteria, cellular structure and differentiation, and bacterial responses to the environment. (3-0) Y

**BIOL 6355** The Nucleus (3 semester credit hours) The nucleus is the defining feature of all eukaryotes. It contains our chromosomes and is the command center of all our cells. In the nucleus, our genetic information is interpreted, protected, duplicated and modified. Central control of gene expression occurs in the nucleus by transcription and post-transcription mechanisms. Moreover, the nucleus is organized into various functional compartments that specialized in transcription, splicing, rRNA processing and repression. The course will provide a broad overview of functional organization of the nucleus using recent primary literature from the field, focused particularly on genomic analyses of nuclear function. The course will introduce students to seminal works in the field and recent developments with the goal of instilling critical understanding of structure and function of the nucleus. Advanced knowledge of molecular biology is essential. Prior course work on genetics, genetic analysis and genomics is strongly recommended. Instructor consent required. (3-0) Y

**BIOL 6356** Eukaryotic Molecular and Cell Biology (3 semester credit hours) Regulation of cellular activities in eukaryotic cells; structural and molecular organization of eukaryotic cells; molecular basis of cell specialization; membranes and transport. For students who have not had undergraduate cell biology. (3-0) S

**BIOL 6358 (MSEN 6358)** Bionanotechnology (3 semester credit hours) Protein, nucleic acid and lipid structures. Macromolecules as structural and functional units of the intact cell. Parallels between biology and nanotechnology. Applications of nanotechnology to biological systems. (3-0) T
**BIOL 6359** Medical Cell Biology for MAT (3 semester credit hours) Organization of cells, structure and function of DNA and proteins, gene therapy, regenerative medicine, and the endocrine system. Designed for students who are pursuing a MAT degree. Instructor consent required. (3-0) S

**BIOL 6360** Medical Cell Biology for Biotechnology (3 semester credit hours) This course will explore cell structure, the structure of DNA, mutations in DNA, gene therapy, stem cells, cell signaling, and the immune system etc. Emphasis will be placed on understanding the cellular and molecular basis of health and disease. For students who have not had undergraduate cell biology and/or molecular genetics. Instructor consent required. (3-0) S

**BIOL 6373** (BMEN 6391) Proteomics (3 semester credit hours) Protein identification, sequencing, and analysis of post-translational modifications by liquid chromatography/tandem mass spectrometry; determination of protein three dimensional structure by x-ray crystallography; its use in drug design; understanding protein interactions and function using protein chip microarrays. Prerequisites: one semester of undergraduate biochemistry and one semester of graduate biochemistry or instructor consent required. (3-0) T

**BIOL 6384** Biotechnology Laboratory (3 semester credit hours) Laboratory instruction in LC/MS/MS mass spectral analysis of protein sequence, ICAT (isotope coded affinity tag) reagents, and MS analysis of cellular proteomes, PCR and DNA Sequencing, and DNA microarray analysis; fluorescence and confocal microscopy and fluorescence activated cell sorting. Instructor may require students to demonstrate adequate laboratory skills in order to enroll. (1-2) Y

**BIOL 6385** (BMEN 6389 and MATH 6343) Computational Biology (3 semester credit hours) Machine learning and probabilistic graphical models have become essential tools for analyzing and understanding complex systems biology data in biomedical research. This course introduces fundamental principles and methods behind the most important high throughput data analysis tools. Applications will cover molecular evolutionary models, DNA/protein motif discovery, gene prediction, high-throughput sequencing and microarray data analysis, computational modeling gene expression regulation, and biological pathway and network analysis. Prerequisite: Some background in elementary statistics/probability or introductory bioinformatics, or instructor consent required. (3-0) Y

**BIOL 6390** Metabolic Pathways for Translational Medicine (3 semester credit hours) This course will provide extensive discussion of major metabolic pathways in human and other experimental models of human diseases with emphasis on biochemical understanding, roles and effects of the pathways in the entire cellular network, and potential application to medicine. Prerequisite: BMEN 6389 or BIOL 6385 or instructor consent required. (3-0) T

**BIOL 6V00** Topics in Biological Sciences (1-6 semester credit hours) May be repeated for credit (9 semester credit hours maximum). Department consent required. ([1-6]-0) Y

**BIOL 6V01** Topics in Biological Sciences (1-6 semester credit hours) Includes a laboratory component. May be repeated for credit as topics vary (9 semester credit hours maximum). (1-[0-10]) Y

**BIOL 6V02** The Art of Scientific Presentation (1-2 semester credit hours) Students learn how to give an effective seminar by reading scientific articles on a central theme in biology and then delivering a presentation, first to their classmates, followed by another presentation to the Molecular and Cell Biology faculty and students. While learning the focused theme, students acquire skill sets in critical reading of
scientific literature and oral presentation. Required for all PhD students. Pass/Fail only. ([1-2]-0) Y

**BIOL 6V03** Research in Molecular and Cell Biology (1-9 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary. Instructor consent required. ([1-9]-0) S

**BIOL 6V19** Topics in Biochemistry (2-5 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([2-5]-0) Y

**BIOL 6V29** Topics in Molecular Biology (2-5 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([2-5]-0) Y

**BIOL 6V39** Topics in Biophysics (2-5 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. ([2-5]-0) T

**BIOL 6V49** Topics in Cell Biology (2-5 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. ([2-5]-0) Y

**BIOL 6V50** Internship in Biotechnology/Biomedicine (1-6 semester credit hours) Provides faculty supervision for a student's internship. Internships must be in an area relevant to the student's coursework for the MS in Biotechnology. Pass/Fail only. May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) R

**BIOL 6V95** Advanced Topics in Molecular and Cell Biology: Individual Instruction (1-6 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) Y

**BIOL 6V98** Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**BIOL 7V10** Research Seminar in Biochemistry (2-5 semester credit hours) Presentation and analysis of ongoing independent research projects, accompanied by evaluation of recent related literature. Pass/Fail only. May be repeated for credit as topics vary. ([2-5]-0) Y

**BIOL 7V20** Research Seminar in Molecular Biology (2-5 semester credit hours) Presentation and analysis of ongoing independent research projects, accompanied by evaluation of recent related literature. Pass/Fail only. May be repeated for credit as topics vary. ([2-5]-0) Y

**BIOL 7V30** Research Seminar in Biophysics (2-5 semester credit hours) Presentation and analysis of ongoing independent research projects, accompanied by evaluation of recent related literature. Pass/Fail only. May be repeated credit as topics vary. ([2-5]-0) R

**BIOL 7V40** Research Seminar in Cell Biology (2-5 semester credit hours) Presentation and analysis of ongoing independent research projects, accompanied by evaluation of recent related literature. Pass/Fail only. May be repeated for credit as topics vary. ([2-5]-0) Y

**BIOL 8V01** Research in Molecular and Cell Biology (1-9 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary. ([1-9]-0) S

**BIOL 8V99** Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Prerequisites: Open to PhD students only and instructor consent required. ([1-9]-0) S
Chemistry

**CHEM 5314** Advanced Physical Chemistry (3 semester credit hours) Modern concepts from the three pillars of physical chemistry: quantum mechanics, thermodynamics/statistical mechanics, and kinetics. Prerequisite: Undergraduate physical chemistry or instructor consent required. (3-0) Y

**CHEM 5331 (MSEN 5331)** Advanced Organic Chemistry I (3 semester credit hours) Modern concepts of bonding and structure in covalent compounds. Static and dynamic stereochemistry and methods for study. Relationships between structure and reactivity. Prerequisite: Undergraduate organic chemistry or instructor consent required. (3-0) Y

**CHEM 5333 (MSEN 5333)** Advanced Organic Chemistry II (3 semester credit hours) Application of the principles introduced in **CHEM 5331**, emphasizing their use in correlating the large body of synthetic/preparative organic chemistry. Prerequisite: **CHEM 5331** or **MSEN 5331**. (3-0) R

**CHEM 5340 (BMEN 6360 and MSEN 5340)** Advanced Polymer Science and Engineering (3 semester credit hours) Polymer structure-property relations, Glass transition temperature and mechanical properties of polymers, Thermoplastics, thermostets, and elastomers, morphology of polymers, rheology of polymers, biodegradable and biocompatible polymers for drug delivery and tissue engineering applications. (3-0) R

**CHEM 5341 (MSEN 5341)** Advanced Inorganic Chemistry I (3 semester credit hours) Physical inorganic chemistry addressing topics in structure and bonding, symmetry, acids and bases, coordination chemistry and spectroscopy. Prerequisite: Undergraduate inorganic chemistry or instructor consent required. (3-0) Y

**CHEM 5343** Advanced Inorganic Chemistry II (3 semester credit hours) Builds on **CHEM 5341** to explore the synthesis and reactivity of inorganic/organometallic molecules. Practical applications will be demonstrated by discussing industrial processes catalyzed by metal complexes. Prerequisite: **CHEM 5341**. (3-0) R

**CHEM 5355 (MSEN 5355)** Analytical Techniques I (3 semester credit hours) Study of fundamental analytical techniques, including optical spectroscopic techniques, mass spectrometry, and microscopic and surface analysis methods. (3-0) Y

**CHEM 5356 (MSEN 5356)** Analytical Techniques II (3 semester credit hours) Study of chromatography (GC, LC, CZE), statistical methods (standard tests and ANOVA), chemical problem solving, and modern bio/analytical techniques such as biochips, microfluidics, and MALDI-MS. Prerequisite: **CHEM 5355** or instructor consent required. (3-0) R

**CHEM 5361** Advanced Biochemistry (3 semester credit hours) Modern concepts in biochemistry addressing topics in bioenergetics as well as the structure, function, and interaction of macromolecules. Prerequisite: **CHEM 3361** or **BIOL 3361** or equivalent. (3-0) Y

**CHEM 5V84** Special Topics in Chemistry - Science and Mathematics Education (1-9 semester credit hours) Various special topics in chemistry of interest to teachers will be discussed. May not be used to fulfill degree requirements for the MS or PhD degrees except those in the Master of Arts in Teaching (MAT) program. May be repeated for credit. Instructor consent required. ([1-9]-0) R

**CHEM 5V87** Independent Study in Chemistry (1-9 semester credit hours) In conjunction with a member of
the Chemistry faculty, the student will develop a paper or project which emphasizes the ways in which chemical knowledge is confirmed and extended or which leads to improved instruction in chemistry. May not be counted as credit toward the MS or PhD degrees. May be repeated for credit (9 semester credit hours maximum). Instructor consent required. ([1-9]-0) R

**CHEM 6100** Chemistry Department Seminar (1 semester credit hour) A weekly seminar that features accounts of current research by outstanding investigators in chemistry and related scientific areas. Course not eligible for audit. Pass/Fail only. May be repeated for credit. Prerequisite: Graduate standing in chemistry. (1-0) S

**CHEM 6317** Industrial Chemistry (3 semester credit hours) Survey of chemical industry including commodities, chemical processes, scale-up and process development, environmental concerns, patents. Study of chemical engineering principles. (3-0) R

**CHEM 6361** Physical Biochemistry (3 semester credit hours) Protein structure, fundamental metabolism, structures and properties of macromolecules, interactions with electromagnetic radiation, thermodynamics of macromolecular solutions, transport processes, and other topics. Instructor consent required. (3-0) R

**CHEM 6372** Materials Science (3 semester credit hours) Relationship between the properties and behavior of materials and their internal structure. Treatment of the mechanical, thermal and electrical properties of crystalline and amorphous solids including metals, ceramics, synthetic polymers and composites. Instructor consent required. (3-0) R

**CHEM 6383** Computational Chemistry (3 semester credit hours) The application of computer techniques to the understanding of molecular structure and dynamics: force field, semi-empirical, ab initio, and molecular dynamics techniques. Information retrieval from large structural databases and use of this information. Instructor consent required. (3-0) R

**CHEM 6389** Scientific Literature and Communication Skills (3 semester credit hours) Acquaints students with techniques for searching the scientific literature using hard copy and electronic approaches. Introduces students to important steps in creating and improving technical communications in both written and oral formats. (3-0) Y

**CHEM 6V19** Special Topics in Physical Chemistry (1-9 semester credit hours) Examples of topics include spectroscopy, quantum mechanics, computational chemistry, and surface chemistry. May be repeated for credit as topics vary. Prerequisite: **CHEM 5314** or instructor consent required. ([1-9]-0) R

**CHEM 6V39** Special Topics in Organic Chemistry (1-9 semester credit hours) Examples of topics include organic photochemistry, organometallic chemistry, homogeneous and heterogeneous catalysis, solid state, polymer chemistry, and advanced NMR techniques. May be repeated for credit as topics vary. Prerequisites: **CHEM 5331** and instructor consent required. ([1-9]-0) R

**CHEM 6V49** Special Topics in Inorganic Chemistry (1-9 semester credit hours) Examples of topics include physical methods of inorganic chemistry, and bioinorganic chemistry. May be repeated for credit as topics vary. Prerequisites: **CHEM 5341** and instructor consent required. ([1-9]-0) R

**CHEM 6V59** Special Topics in Analytical Chemistry (1-9 semester credit hours) Examples of topics include
NMR, X-ray crystallography. May be repeated for credit as topics vary. Prerequisites: CHEM 5355 and instructor consent required. ([1-9]-0) R

**CHEM 6V69** Special Topics in Biochemistry (1-9 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. ([1-9]-0) R

**CHEM 6V79** Special Topics in Materials Chemistry (1-9 semester credit hours) Examples of topics include polymers, membrane technology, zeolites, nanoscience and technology. May be repeated as topics vary. Instructor consent required. ([1-9]-0) R

**CHEM 6V84** Special Topics in Applied Chemistry (1-9 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. ([1-9]-0) R

**CHEM 8V91** Research in Chemistry (2-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([2-9]-0) S

**CHEM 8V98** Thesis (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**CHEM 8V99** Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**Geosciences**

**GEOS 5101** Internship in Geosciences (1 semester credit hour) An internship in which a student gains experience through temporary employment at a geosciences based company or government organization. The activity must be monitored by one of the Geosciences faculty members and must be approved in advance of the employment. The student must provide regular progress updates and a final report to the faculty monitor. Pass/Fail only. May be repeated for credit (5 semester credit hours maximum). Instructor consent required. (1-0) S

**GEOS 5301** Geology of the Metroplex (3 semester credit hours) Lithologic constituents, stratigraphic history, and geologic environments of the greater Dallas-Fort Worth metropolitan area. Special emphasis is given to the Cretaceous sediments that underlie Tarrant and Dallas Counties, with a secondary focus on the broader geologic environment. Three to four 1-day (Saturday) field trips. (3-0) T

**GEOS 5306** Data Analysis for Geoscientists (3 semester credit hours) Advanced statistical techniques with important applications in Earth science. Topics include robust statistics, exploratory data analysis, surface modeling and contouring, Kriging, analysis of point patterns and directional data. Factor, cluster and time series analysis may also be considered. Emphasis will be on application and theoretical understanding. (3-0) R

**GEOS 5310** (GISC 5310) Hydrogeology (3 semester credit hours) Introduction to the principles and practice of ground- and surface- water hydrology. Study of the principles of occurrence and geologic controls of groundwater, physical flow and geochemistry of waters. Design and use of procedures for typical hydrologic investigations. (3-0) Y

**GEOS 5311** (GISC 5311) Applied Groundwater Modeling (3 semester credit hours) This course is designed
to provide students with hands-on experience using the most commonly-applied groundwater flow and transport models (e.g. modflow/modpath, MT3D/RT3D, GMS). Practical application of the models and design of modeling studies is emphasized; modeling theory and mathematics is de-emphasized. (3-0) Y

**GEOS 5313** Applied Surface Water Modeling (3 semester credit hours) The development and application of watershed models emphasizing runoff, stormflow and stormwater management design. This class combines aspects of GIS, remote sensing and surface water hydrology from an applied modeling perspective, using commonly applied computer models (e.g. Rational Method, TR-20, HEC-1) to address drainage problems related to urbanization and land-use changes. (3-0) T


**GEOS 5317** Natural Resources (3 semester credit hours) Overview of the exploration for and exploitation of petroleum, mineral and geothermal resources. Characteristics of natural resources and design of exploration programs through integration of geophysical and geochemical methods. Emphasis on student projects and presentations. (3-0) T

**GEOS 5319 (GISC 5319)** Principles of Environmental Health (3 semester credit hours) Introduction to epidemiology and biostatistics. U.S. regulatory agencies. Ethics, risk assessment and public policy. Diseases spread by food and water. Lung diseases associated with particles and fibers. Health significance of exposures to arsenic, cadmium, chromium, lead and mercury compounds and to chemical substances - solvents, PCBs, PBBs, dioxins, and dibenzofurans. Ionizing radiation. Health implications of global warming. (3-0) R

**GEOS 5322 (GISC 5322)** GPS (Global Positioning System) Satellite Surveying Techniques (3 semester credit hours) The theory and application of satellite positioning utilizing the Global Positioning System Code and phase methodology in field observations, data processing and analysis of Differential GPS, high accuracy static and other rapid measurements, in real time and with post-processing. (3-0) Y

**GEOS 5324 (GISC 5324)** 3D Data Capture and Ground Lidar (3 semester credit hours) The theory and applications of 3D data acquisition in the field for geosciences and non-geosciences studies. The basics and applications of field digital mapping with emphasis on RTK GPS, laser range finder, and terrestrial scanners (ground lidar). 3D digital photorealistic modeling with field photogrammetry and digital cameras. (3-0) T

**GEOS 5325 (GISC 6325)** Remote Sensing Fundamentals (3 semester credit hours) Introduction to remote sensing principles, sensor technologies, image processing techniques, and applications. Topics covered include electromagnetic radiation theories, various satellite and airborne remote sensing systems, processing of remote sensing data to solve real world problems. State-of-the-art commercial software is used for class exercises. (3-0) Y

**GEOS 5326 (GISC 7365)** Advanced Remote Sensing (3 semester credit hours) Examines advanced remote
sensing technologies, data processing techniques and applications. The latest remote sensors are introduced. The class will discuss how remote sensing data can be processed to extract information in support of important urban and environmental decision making. The current generation, industry standard software is used for labs and applications development. Prerequisite: **GEOS 5325** or **GISC 6325**. (3-0) Y

**GEOS 5329 (GISC 7366)** Applied Remote Sensing (3 semester credit hours) Focuses on the application of one or more specialized remote sensing techniques to solve specific real world urban and environmental problems. Prerequisite: **(GISC 6325 or GEOS 5325) or (GISC 7365 or GEOS 5326)**. (3-0) R

**GEOS 5335** Introductory Seismology (3 semester credit hours) This course covers the fundamentals of seismology and seismic wave propagation. An introduction to the theory of wave propagation in acoustic, elastic, anelastic and anisotropic medium, and observational methods in seismology applicable to the deep planetary structure of the Earth as well as petroleum deposits in the crust. The theory of earthquakes and methods for retrieving seismic source information will also be addressed. Class projects will emphasize the use of seismic data from public databases and processing using python packages. (3-0) Y

**GEOS 5336** Computational Geophysics (3 semester credit hours) An introduction to numerical methods, including finite-difference, finite-element, and spectral-element methods, used in computational geophysics. Basic surface and volume elements, representation of fields, quadrature, assembly, local versus global meshes, domain decomposition, time marching, and stability will be considered. Implementation of the numerical methods using parallel processing on computer clusters will be emphasized. Data assimilation techniques and related adjoint methods will be considered for parameter estimation and imaging. The course offers hands-on experience in multidimensional model building as well as numerical solution of partial differential equations relevant to geophysics. (3-0) T

**GEOS 5350** Geoinformatics of Igneous Rocks (3 semester credit hours) How geochemical and isotopic databases (EarthChem) can be used to understand the origin and evolution of igneous rocks from different tectonic environments. Project oriented. **GEOS 5352** and **GEOS 5356** recommended. Instructor consent required. (3-0) T

**GEOS 5352** Geochemistry of Igneous Rocks (3 semester credit hours) Chemical composition of igneous rocks and the major processes that control the distribution of the elements in silicate melts. Topics to be covered include the composition of the earth, the structure of silicate melts, trace element partitioning between crystals and melts, and the use of major and trace elements in deciphering the formation and evolution of silicate melts. (3-0) T

**GEOS 5356** Isotope Geochemistry (3 semester credit hours) Synthesis of the elements in stars and chronologies for the galaxy. Isotope systematics in meteorites, abundance anomalies, cosmogenic nuclides, and solar system chronologies. The development of the modern multi-collector mass spectrometer. Mass fractionation laws, double spiking techniques, and high precision isotope ratio measurements. Isotope geochemistry of noble gases and radiogenic nuclides as pertaining to the composition and history of the mantle and crust. Application of stable isotopes to studies of diagenesis and water-rock interaction, groundwater management, paleoceanography and secular variations in the isotopic composition of seawater. High-temperature and, where applicable, low-temperature water-rock interactions pertaining to the origin of igneous rocks. The evolution of radiogenic Sr in sea water. Radiometric age dating as applied to the solution of geologic problems. (3-0) R
GEOS 5369 Volcanic Successions (3 semester credit hours) Terrestrial volcanism is considered from the perspective of volcanic processes, and the properties, products and deposits of volcanic eruptions, all in the context of definable facies models. The effects of subsequent sedimentological processes are also considered. Volcanic settings are explored in detail as they are related to their plate tectonic settings. Recognition of volcanically derived deposits are emphasized using the facies model concepts, and are considered with respect to their geological and economic significance. Students will perform case studies on select volcanic environments to gain a thorough understanding of the specific processes, products and deposits associated with a diverse range of volcanic terranes. (3-0) T

GEOS 5370 Structural Analysis (3 semester credit hours) Application of structural geology concepts used to unravel the deformational history of rocks and regions. Topics include characterization and analysis of superposed brittle and ductile structures, assessment of displacement and strain fields, construction of inverse and forward structural sections and volumes, and integration of surface and subsurface data. Course requires familiarity with assigned reading assigned reading from the professional literature and oral and written presentations. Face-to-face discussion will be combined with online activities. Instructor consent required. (3-0) T

GEOS 5373 Physical Properties of Rocks (3 semester credit hours) This course provides an understanding of the physical phenomena and processes that determine properties of rocks and soils. Topics include porosity and permeability; surface energy, roughness, and absorption; percolation, fractures and heterogeneous media; problems of scale; mechanical behavior of dry and fluid saturated rocks; elasticity; viscoelasticity, and plasticity; acoustic, electric, dielectric, thermal, and magnetic properties. The approach is practical, with emphasis on understanding why rocks behave as they do, and how simple physical principles can be used to predict rock and soil properties under various conditions. Suitable for graduate students in any branch of geosciences who wish to obtain a broad introduction to physical properties as they pertain to lab and field measurements, and are applied to reservoir, engineering, and environmental problems. (3-0) R

GEOS 5375 Tectonics (3 semester credit hours) Study of the earth's present tectonic environments, including geochemistry, sedimentology, and structure; application of present tectonic environments towards the reconstruction of ancient crustal events; consideration of temporal aspects of crustal evolution. Oral and written presentations required. (3-0) Y

GEOS 5376 Tectonics and Evolution of the Gulf of Mexico Region (3 semester credit hours) Study of how the Gulf of Mexico formed and evolved from Precambrian times to the present, including plate tectonic environments, evolution of sedimentary basins, igneous activity and hydrocarbon resources. Oral and written presentations will be required. Prerequisite: GEOS 5375 and instructor consent required. (3-0) T

GEOS 5380 Seismic Interpretation (3 semester credit hours) Interpretation of seismic reflection profiles used together with surface maps and well data to characterize the subsurface geometry of sedimentary rocks and their relation to faults. The course focus is on the integration of data sets and development of conceptual models of stratal accumulation during displacement on faults. Work is performed in a digital environment (Computer Aided Design) with special emphasis on developing sound geologic interpretations and not the manipulation of standard seismic processing software packages. Face-to-face meetings, discussions, and presentations will be combined with directed assignments using online resources and interaction. (3-0) T
**GEOS 5381** Digital Geophysical Signal Processing (3 semester credit hours) Principles of the analysis of geophysical signals in both time and space. Includes integral transforms, spectral analysis, linear filter theory and deconvolution techniques. Computer applications are emphasized. (3-0) R

**GEOS 5384** Near-Surface Geophysical Imaging (3 semester credit hours) This course covers theoretical and practical aspects of Ground Penetrating Radar (GPR) data applications. It is a "hands-on" course that covers the physical basis, rock properties, equipment, planning and execution of small scale surveys, data processing and interpretation. Examples of applications include reservoir analogs, and engineering, groundwater and environmental site evaluations. Techniques include low and high frequency, single and multi-channel ground-penetrating radar. A one-day field trip for collection of GPR data from the Woodbine formation at Grapevine Lake is the basis of the laboratory report. A background in calculus and general physics is required. Instructor consent required. (2-3) T

**GEOS 5387** Applied Geophysics (3 semester credit hours) This is the Geosciences core graduate course in geophysics. Emphasis is on the application of geophysical methods to the solution of geological problems and the connection between geophysical measurements and the physical properties of Earth materials. Topics include seismology; gravity; magnetics; electromagnetics; resistivity; ground penetrating radar; and well logging. Case histories will be considered in addition to the technical aspects of data collection, processing and interpretation. (3-0) Y

**GEOS 5396** Miles Integrated Research I (3 semester credit hours) Assessment and background development for selected research projects employing integrated datasets. Students will access the professional literature and online data sources to establish background information and an understanding of project research objectives. Activities will focus on identification of geological and geophysical tools needed for the research, how the datasets will contribute to the overarching research objective, and provide training in the use of the required data acquisition and analysis tools. Oral presentations and discussions required. Instructor consent required. (3-0) Y

**GEOS 5397** Miles Field Project (3 semester credit hours) Field work and data acquisition. Preliminary data reduction and analysis following field work. Field work in remote regions for 4-6 weeks. Laboratory analysis for remainder of summer session following field work. Instructor consent required. (1-6) Y

**GEOS 5398** Miles Integration Research II (3 semester credit hours) Data reduction and analysis of results from preceding Miles Field Project (summer semester). Students will work individually and in teams to analyze data and to integrate results into a comprehensive model addressing research objectives. Oral presentations and discussions required. Instructor consent required. (3-0) Y

**GEOS 5399** Miles Integrated Research III (3 semester credit hours) Integration of geological and geophysical datasets to develop comprehensive solution to research project. Students to work individually and in teams. Oral and written presentations required. Joint report by team required. Instructor consent required. (3-0) Y

**GEOS 5441** Stratigraphy and Sedimentology (4 semester credit hours) Origin and classification of sedimentary rocks, reconstruction of ancient environments, and basic principles of modern stratigraphic nomenclature. Concepts of space and time in the rock record and methods of stratigraphic correlation. Integrated stratigraphic techniques. Study of sedimentary rocks in hand specimen and outcrop. Laboratory course. Field trips. Course is directed to graduate students not majoring in geology and is meant to provide
a practical overview of sedimentary geology. Instructor consent required. (3-3) Y

**GEOS 5470** Structural Geology (4 semester credit hours) Examination of stress and strain, failure criteria, fault analysis, rheologic properties of geologic materials, fold analysis, and a survey of major structural provinces in North America, with supplemental readings. Laboratory includes map interpretation, standard graphical techniques, and use of stereographic projections, oral presentations, and problem sets. Laboratory and field trip course. Instructor consent required. (3-3) Y

**GEOS 5V08** Special Topics in Geosciences (1-9 semester credit hours) Courses dealing with a variety of topics including new techniques and specific problems in rapidly developing areas of the science. Hours vary depending on course requirements. May be repeated for credit as topics vary. Instructor consent required. ([1-9]-[0-9]) R

**GEOS 6381 (GISC 6381)** Geographic Information Systems Fundamentals (3 semester credit hours) Examines the fundamentals of Geographic Information Systems and their applications. It emphasizes the concepts needed to use GIS effectively for manipulating, querying, analyzing, and visualizing spatial-based data. Lab exercises, which use industry-standard GIS software packages, provide GIS experience to investigate real world problems including social, economic, and environmental issues. (3-0) Y

**GEOS 6382** Geophysical Inversion Theory (3 semester credit hours) Theoretical and practical aspects of fitting mathematical models to data in geophysics. Topics covered include the inversion of both discrete systems and integral equations, for linear and non-linear relationships between data and parameters. Particular attention is paid to assessment of model accuracy and uniqueness. Instructor consent required. (3-0) R

**GEOS 6383 (GISC 6382)** Applied Geographic Information Systems (3 semester credit hours) Further develops hands-on skills with industry-standard GIS software for application in a wide variety of areas including urban infrastructure management, marketing and location analysis, environmental management, geologic and geophysical analysis and the Economic, Political and Policy Sciences. Prerequisite: (GISC 6381 or GEOS 6381) or equivalent with instructor consent required. (3-0) Y

**GEOS 6384 (GISC 6384)** Advanced Geographic Information Systems (3 semester credit hours) Treatment of more advanced GIS topics with real world applications. Topics covered include raster and vector data models, Geodatabase, map algebra, 3-D surface analysis, spatial interpolation and network analysis. Student will be acquainted with state-of-the-art software through hands-on laboratory experiences. Prerequisite: GEOS 6381 or GISC 6381. (3-0) Y

**GEOS 6385 (GISC 6385)** GIS Theories, Models and Issues (3 semester credit hours) Provides an understanding of the underlying theories, mathematical and geometric tools, and their computational implementations that establish GIS capabilities to handle and analyze geo-referenced information. Associated issues (such as uncertainty, spatial analysis and spatial data management) highlighted. Prerequisite: GEOS 6381 or GISC 6381 or equivalent with instructor consent required. (3-0) Y

**GEOS 6387 (GISC 6387)** Geospatial Sciences Workshop (3 semester credit hours) Fulfills the research project requirement for one of the Geospatial Science graduate certificate programs, e.g. GIS, remote sensing and geospatial intelligence. Each participant develops a project which should include aspects of geospatial database design, manipulation, and analysis, and cartographic production. Projects may be designed in coordination with a local government, utility, business, or other entity that uses GIS in its
GEOS 6392  Reflection Seismology (3 semester credit hours) Theoretical and practical aspects of seismic reflection data acquisition and processing. Includes the wave equation, the convolutional model, coded sources, the array response, velocity estimation, statics, filtering, pre- and post-stack migration, and direct and indirect detection of hydrocarbons, VSPs, AVO and 3-D processing. Instructor consent required. (3-0) R

GEOS 6393  Computational Seismology (3 semester credit hours) Principles of parallel computing with applications to seismology. Includes overviews of current computer cluster and switch architectures, writing and debugging parallel code, characterization of machine performance, fast Fourier transforms, Radon transforms, solution of matrix and wave equations. Prerequisites: GEOS 5381 and GEOS 6392 and any numerical analysis course. (3-0) R

GEOS 6395  Seismic Modeling (3 semester credit hours) Theory and application of the major techniques for computation of synthetic seismograms. Topics include asymptotic ray theory, spectral and slowness methods, finite differences, finite elements, Kirchhoff, and boundary integral methods. Readings will be drawn from the literature. Prerequisites: GEOS 6392 and instructor consent required. (3-0) R

GEOS 6396  Seismic Inversion (3 semester credit hours) Theory and application of the major techniques for inversion of seismic data. Topics include linear and nonlinear matrix methods, Wiechert-Herglotz integration, extremal inversion, migration, wavefield imaging of body and surface waves, and tomography, imaging of VSPs, Born inversion, and full wavefield inversion. Readings will be drawn from the literature. Prerequisite: GEOS 6392 and instructor consent required. (3-0) R

GEOS 6398  Thesis (3 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. (3-0) S

GEOS 7110  Workshop in Environmental Geosciences (1 semester credit hour) Discussion of current topics in environmental geoscience, including student and faculty research, scientific literature, and advanced techniques in environmental geosciences. May be repeated for credit. (1-0) R

GEOS 7170  Workshop in Structure/Tectonics (1 semester credit hour) Presentation and discussion of current research with emphasis on problems, techniques, and recent literature. May be repeated for credit. (1-0) Y

GEOS 7190  Workshop in Seismology (1 semester credit hour) Informal presentation and discussion of current research of graduate students and faculty, of new computing equipment and software, and of current research literature. Pass/Fail only. May be repeated for credit. (1-0) S

GEOS 7327 (GISC 7367) Remote Sensing Workshop (3 semester credit hours) An independent project is designed and conducted by the student, after instructor approval. The project develops and demonstrates student’s competence in using remote sensing techniques in a substantive application to his/her field of interest. Projects may be developed in coordination with a local government, utility, business, or other entity, which uses remote sensing in its operations and research. A formal presentation and a project report are required. Prerequisite: GISC 7365 or GEOS 5326. (3-0) Y
**GEOS 7V00** Research and Literature Seminar (1-2 semester credit hours) Presentations and critical analysis of independent work and of the recent literature. Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-2]-0) Y

**GEOS 8399** Dissertation (3 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. (3-0) S

**GEOS 8V10** Research in Hydrogeology-Environmental Geosciences (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**GEOS 8V21** Research in Remote Sensing, GIS and GPS (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**GEOS 8V50** Research in Geochemistry (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**GEOS 8V70** Research in Structural Geology-Tectonics (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**GEOS 8V80** Research in Geophysics (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**GEOS 8V90** Research in Seismology (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

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**Mathematical Science**

**MATH 5301** Elementary Analysis I (3 semester credit hours) Sets, real numbers, metric spaces, topology of Euclidean space, continuity and differentiability of functions of a single variable, uniform convergence, sequence and series of functions. Prerequisite: One year of calculus through multivariable calculus or instructor consent required. (3-0) Y

**MATH 5302** Elementary Analysis II (3 semester credit hours) Riemann and Darboux integrals, functions of bounded variation, Riemann-Stieltjes integration, Lebesgue measure, Introduction to Lebesgue integral. Prerequisite: **MATH 5301** or **MATH 4301**. (3-0) Y

**MATH 5303** Advanced Calculus and Linear Algebra (3 semester credit hours) Concise introduction to elementary functions; differentiation; simple integration techniques; improper integrals; series and sequences; convex functions. Systems of linear equations, eigenvectors, and spectral theorem for normal matrices. Partial derivatives and linear approximations; optimization in one or several variables; multiple integrals. Applications of calculus and matrix algebra to differential equations and geometry of curves and surfaces. Prerequisite: At least one semester of undergraduate calculus or instructor consent required. (3-0) Y

**MATH 5304** Applied Mathematical Analysis for Non-Majors (3 semester credit hours) Techniques of mathematical analysis applicable to the social, behavioral and management sciences. Differential and integral calculus of one and many variables. May not be used to fulfill degree requirements. Prerequisite: College algebra or instructor consent required. (3-1) S
**MATH 5305** Practical Applications in Higher Geometry (3 semester credit hours) Topics in modern Euclidean geometry including distinguished points of a triangle, circles including the nine-point circle, cross ratio, transformations; introduction to projective geometry. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Prerequisite: Junior-level mathematics course. (3-0) T

**MATH 5306** Practical Applications in Non-Euclidean Geometry (3 semester credit hours) The relations among elliptic, Euclidean and hyperbolic geometries, Euclidean models of elliptic and hyperbolic geometries. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Prerequisite: Junior-level mathematics course. (3-0) T

**MATH 5313** Modern Algebra for Teachers (3 semester credit hours) Study of modern algebra involving groups, rings, fields and Galois Theory. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Prerequisite: Junior-level mathematics course. (3-0) R

**MATH 5390** Topics in Mathematics - Level 5 (3 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. (3-0) R

**MATH 6301** Real Analysis (3 semester credit hours) Lebesgue measure in finite- dimensional spaces, Abstract measures, measurable functions, convergence a.e., Egorov's Theorem, convergence in measure, Lebesgue integral, Lebesgue's bounded convergence theorem, Levi's monotone convergence theorem, Fatou's Lemma, Fubini's theorem, Lp-spaces. Prerequisite: MATH 5302. (3-0) Y

**MATH 6302** Functional Analysis I (3 semester credit hours) Banach and Hilbert spaces, classical theorems of functional analysis, compact operators, Fredholm operators, elements of spectral theory, introduction to unbounded operators. Prerequisite: MATH 6301. (3-0) Y

**MATH 6303** Theory of Complex Functions I (3 semester credit hours) Complex integration, Cauchy's theorem, calculus of residues, power series, entire functions, Riemann mapping theorems. Riemann surfaces, conformal mapping with applications. Prerequisites: MATH 5301 and MATH 5302 or instructor consent required. (3-0) Y

**MATH 6304** Theory of Complex Functions II (3 semester credit hours) Riemann surfaces, meromorphic and holomorphic functions and differentials, the normalization theorem, the Riemann-Roch theorem, Abel theorem, applications to nonlinear equations. Prerequisite: MATH 6303. (3-0) T

**MATH 6305** Mathematics of Signal Processing (3 semester credit hours) The course is devoted to a mathematical foundation of some of the key topics in signal processing: discrete and continuous signal transforms, least squares methods and adaptive filtering, compressed sensing and related topics. Prerequisites: Linear algebra and calculus through multivariate calculus or instructor consent required. (3-0) T

**MATH 6307** Wavelets and Their Applications (3 semester credit hours) An introduction to windowed Fourier and continuous wavelet transforms, generalized frames, discrete wavelet frames, multiresolution analysis, Daubechies' orthogonal wavelet bases, and their applications in partial differential equations and signal processing. Prerequisites: Two semesters of calculus and differential equations or instructor consent required. (3-0) T
MATH 6308 Inverse Problems and Applications (3 semester credit hours) Exact and approximate methods of nondestructive inference, such as tomography and inverse scattering theory in one and several dimensions, with applications in physical and biomedical sciences and engineering. Prerequisites: Two semesters of calculus and differential equations or instructor consent required. (3-0) T

MATH 6309 Differential Geometry (3 semester credit hours) Smooth manifolds, tangent bundles, smooth partitions of unity, submanifolds, Sard's theorem, transversality, embeddings, Whitney theorem, differential forms, Frobenius Theorem, de Rham cohomology, degree theory on manifolds, Riemannian metric, Gauss-Bonnet theorem. Prerequisite: MATH 5301 or instructor consent required. (3-0) T

MATH 6310 Topology (3 semester credit hours) Metric spaces, introduction to topology, elements of homotopy theory, covering spaces, fundamental group, homotopy groups, fibrations, simplicial complexes and CW-complexes, degree theory. Prerequisite: MATH 5301 or instructor consent required. (3-0) Y

MATH 6311 Abstract Algebra I (3 semester credit hours) Basic properties of groups, rings, fields, and modules. Prerequisite: Two semesters of undergraduate abstract algebra or instructor consent required. (3-0) Y

MATH 6312 Combinatorics and Graph Theory (3 semester credit hours) This course covers theory and applications of combinatorics and graphs, topics from basic counting principles, principle of inclusion and exclusion, permutation statistics, ordinary and exponential generating functions, composition of integers, integer partitions, Stirling numbers of the first kind, q-analogs of binomial and multinomial coefficients, Euler's formula, Hamilton paths, planar graphs, chromatic and Tutte polynomials and algorithms on networks. Prerequisites: Theoretical Concepts of Calculus and Abstract Algebra I is required or instructor consent required. (3-0) T

MATH 6313 Numerical Analysis (3 semester credit hours) A study of numerical methods including the numerical solution of non-linear equations, interpolation, approximation by polynomials, numerical integration. Numerical solution of ordinary differential equations including initial value problems and two-point boundary value problems. Prerequisites: Knowledge of a high-level programming language and linear algebra and calculus through multivariable calculus and department consent required. (3-0) Y

MATH 6314 Algebraic Topology (3 semester credit hours) This course covers basics in algebraic topology. Topics will include simplicial and singular homology groups, cellular homology groups, exact sequences and excision, chain maps, Mayer-Vietoris sequences, homology with coefficients, Eilenberg-Steenrod axioms; cohomology theory, the universal coefficient theorem, cup products, Kunneth formulas, and Poincare duality. Prerequisites: Abstract Algebra I and Topology or equivalent is required or instructor consent required. (3-0) T

MATH 6315 Ordinary Differential Equations (3 semester credit hours) The study of ordinary differential equations with emphasis on existence, uniqueness, linear systems, boundary value problems, and stability. Prerequisites: Linear algebra and differential equations and MATH 5302 or instructor consent required. (3-0) Y

MATH 6316 Differential Equations (3 semester credit hours) Continuation of MATH 6315 and an introduction to partial differential equations. Prerequisite: MATH 6315. (3-0) T

MATH 6318 Numerical Analysis of Differential Equations (3 semester credit hours) Practical and theoretical
aspects of numerical methods for partial differential equations are discussed. Topics selected from: finite difference, finite element and boundary element approximations for partial differential equations. Application of methods will be illustrated using MATLAB. Prerequisite: MATH 6313 or equivalent. (3-0) T

**MATH 6319** Principles and Techniques in Applied Mathematics I (3 semester credit hours) Mathematical methods usually used in applied sciences and engineering. Topics chosen from advanced linear algebra; Hilbert spaces; positivity; quaternions; integral equations; Fourier analysis; distributions; convexity; asymptotic methods; special functions. Prerequisites: Linear algebra and differential equations or instructor consent required. (3-0) T

**MATH 6320** Principles and Techniques in Applied Mathematics II (3 semester credit hours) Continuation of Math 6319. Prerequisite: MATH 6319. (3-0) T

**MATH 6321** Optimization (3 semester credit hours) Introduction to theoretical and practical concepts of optimization in finite and infinite dimensional setting, least-squares estimation, optimization of functionals, local and global theory of constrained optimization, iterative methods. Prerequisites: Linear algebra or instructor consent required. (3-0) T

**MATH 6322** Mathematical Foundations of Data Science (3 semester credit hours) Graphs, topological polyhedra; homology of cubical sets; computations of homology groups, rational functions and interval arithmetic, maps on intervals, chain selectors; homology of maps; persistence diagram, applications to digital image processing, images and cubical sets, time-dependent patterns, and size function. Prerequisites: (MATH 6312 or equivalent) and instructor consent required. (3-0) Y

**MATH 6324** Applied Dynamical Systems I (3 semester credit hours) Topics from the theory of discrete time dynamical systems including symbolic dynamics, chaos, box counting dimension and fractals, bifurcations, period doubling route to chaos, Sharkovsky's theorem, Lyapunov exponents, maps of the circle and synchronization, area preserving maps, invariant curves, and strange attractors. Topics selected from the singularity theory and the theory of continuous time dynamical systems. Examples of models from ecology, epidemiology, economics, and engineering are presented. Prerequisite: MATH 6301. (3-0) T

**MATH 6325** Nonlinear Analysis I (3 semester credit hours) Topological degree in finite dimensions and applications to intermediate value theorem in dimension $n > 1$, Fundamental Theorem of Algebra, Argument Principle in Complex Analysis, Brouwer fixed point theorem, Poincare-Bendixson Theorem on periodic solutions to ODEs, Lyapunov stability of equilibrium, guiding function method, Leray-Schauder degree, solvability of boundary value problems, and bifurcation theory. Prerequisite: MATH 6301. (3-0) T

**MATH 6327** Stability and Bifurcations of Switched Systems (3 semester credit hours) This course will cover finite-time, asymptotic, and global stability of equilibria of switched systems, switched equilibria, stability of limit cycles of switched systems (including stick-slip oscillations and cycles with jumps), dimension reduction, and extension to larger classes of nonlinear switched systems via bifurcation theory. Prerequisites: Differential Equations and Multivariable Calculus and instructor consent required. (3-0) T

**MATH 6331** Mathematics of Signals, Systems, and Controls (3 semester credit hours) Basic principles of systems and control theory: state space representations, stability, observableness, controllability, realization theory, transfer functions, and feedback. Prerequisites: Linear algebra and differential equations or instructor consent required. (3-0) T
MATH 6332 Advanced Control (3 semester credit hours) Theoretical and practical aspects of modern control methodologies in state space and frequency domain, in particular LQG and H-infinity control: coprime factorizations, internal stability, Kalman filter, optimal regulator, robust control, sensitivity minimization, loop shaping, model reduction. Prerequisite: MATH 6331. (3-0) T

MATH 6336 Nonlinear Control Systems (3 semester credit hours) Differential geometric tools, input-output maps, feedback linearization, nonlinear observers, input-output linearization, output tracking, and regulation, passivity based control, control systems on Lie groups. Prerequisites: (MATH 6315 and MATH 6331) or instructor consent required. (3-0) T

MATH 6338 Delay Differential Equations (3 semester credit hours) Delay differential equations (DDEs) describe the phenomenon that the rate of change of the state variable is dependent on its historical memory. Course topics will be selected from: Existence and uniqueness of solutions, continuation and continuous dependence on parameters of solutions; Linear systems of delay differential equations; Basic notions of dynamical systems induced by DDEs; Periodic solutions and Hopf bifurcation; Analysis of DDE models; DDEs with state-dependent delays and their local and global Hopf bifurcation. Prerequisite: MATH 6315, or instructor's consent. (3-0) T

MATH 6339 Control of Distributed Parameter Systems (3 semester credit hours) Theoretical and technical issues for control of distributed parameter systems in the context of linear infinite dimensional dynamical systems. Evolution equations and control on Euclidean space, elements of functional analysis, semigroups of linear operators, abstract evolution equations, control of linear infinite dimensional dynamical systems, approximation techniques. Prerequisites: partial differential equations and MATH 5301 or instructor consent required. (3-0) T

MATH 6340 Numerical Linear Algebra (3 semester credit hours) Topics include direct and iterative methods for solving linear systems; vector and matrix norms; condition numbers; least squares problems; orthogonalization, singular value decomposition; computation of eigenvalues and eigenvectors; conjugate gradients; preconditioners for linear systems; computational cost of algorithms. Topics will be supplemented with programming assignments. Prerequisites: Knowledge of a high-level programming language and linear algebra and numerical analysis or instructor consent required. (3-0) Y

MATH 6341 Bioinformatics (3 semester credit hours) Fundamental mathematical and algorithmic theory behind current bioinformatics techniques are covered and implemented. They include hidden Markov models, dynamic programming, genetic algorithms, simulated annealing, neural networks, cluster analysis, and information theory. Prerequisites: Knowledge of Unix and a high level programming language. (3-0) T

MATH 6342 Scientific Computing (3 semester credit hours) Introduction to scientific computing through projects in computational science and engineering. Topics include mathematical modeling; theoretical analysis of such models; numerical and symbolic computation; verification and validation; computational simulation. Representative projects will include applications of dynamical systems, Monte Carlo simulations, numerical optimization, and linear and nonlinear partial differential equations. The course includes an introduction to symbolic computation and to programming in MATLAB, Python, and/or C. Some prior programming experience is recommended. Prerequisites: Prior courses in numerical analysis and partial differential equations and MATH 6315 or instructor consent required. (3-0) T

MATH 6343 (BMEN 6389 and BIOL 6385) Computational Biology (3 semester credit hours) Machine
learning and probabilistic graphical models have become essential tools for analyzing and understanding complex systems biology data in biomedical research. This course introduces fundamental principles and methods behind the most important high throughput data analysis tools. Applications will cover molecular evolutionary models, DNA/protein motif discovery, gene prediction, high-throughput sequencing and microarray data analysis, computational modeling gene expression regulation, and biological pathway and network analysis. Prerequisite: Some background in elementary statistics/probability or introductory bioinformatics, or instructor consent required. (3-0) Y

**MATH 6345** Mathematical Methods in Medicine and Biology (3 semester credit hours) Introduction to the use of mathematical techniques in solving biologically important problems. Some examples of topics that might be covered are biochemical reactions, ion channels, cellular signaling mechanisms, kidney function, and nerve impulse propagation. Prerequisite: One year of calculus is required with differential equations recommended or instructor consent required. (3-0) T

**MATH 6346** Medical Image Analysis (3 semester credit hours) Introduction to mathematical and computational methods in extracting clinically useful information from medical images. Topics include image enhancement, feature extraction and shape analysis, image segmentation algorithms used to localize and identify target structures in medical images, image registration algorithms used to determine the correspondence of multiple images of the same anatomical structure, and image classification. Prerequisites: Linear algebra and calculus through multivariable calculus, or consent of the instructor. (3-0) Y

**MATH 6350** Quantum Computation and Information (3 semester credit hours) Quantum states, channels, measurements; entropy, subadditivity; entanglement measures, discord; teleportation, dense coding, quantum key distribution; Shor’s algorithm, Grover’s search algorithm, hidden subgroup algorithms. Prerequisite: Linear algebra or instructor consent required. (3-0) T

**MATH 6364** Stochastic Calculus in Finance (3 semester credit hours) Brownian Motion, Ito Calculus, Feynman-Kac formula and an outline of Stochastic Control, Black Scholes Analysis, Transaction Costs, Optimal Portfolio Investment. Prerequisite: **STAT 5351** or instructor consent required. (3-0) T

**MATH 6390** Topics in Mathematics - Level 6 (3 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. (3-0) R

**MATH 6V81** Special Topics in Mathematics - Level 6 (1-9 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. ([1-9]-0) S

**MATH 6V98** Masters Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**MATH 7309** Knot Theory (3 semester credit hours) This course covers basics in combinatorial knot theory. Topics will include: ambient isotopy, basic invariants of knots and links in S3, polynomial invariants of knots and links, fundamental group of link complement, fundamental group of cyclic branched covers, Fox calculus, Alexander matrix, and categorification of polynomial invariants and their properties. Prerequisites: **MATH 6310** and **MATH 6311**, or instructor consent required. (3-0) T

**MATH 7313** Partial Differential Equations I (3 semester credit hours) Classical and modern solution techniques for initial and boundary value problems for parabolic, elliptic, and hyperbolic linear partial
differential equations. Existence, uniqueness, well-posedness, fundamental solutions, and Green's functions. First-order nonlinear equations, scalar conservation laws, and the method of characteristics. An introduction to weak solutions and the theory of Sobolev spaces. Prerequisite: MATH 6301 and Math 6315 or equivalent. (3-0) T

MATH 7314 Partial Differential Equations II (3 semester credit hours) Continuation of MATH 7313. Prerequisite: MATH 7313, (3-0) T

MATH 7316 Wave Propagation with Applications (3 semester credit hours) Study of the wave equation in one, two and three dimensions, the Helmholtz equation, associated Green's functions, asymptotic techniques for solving the propagation problems with applications in physical and biomedical sciences and engineering. Prerequisites: MATH 6303 and MATH 6318 or equivalent. (3-0) T

MATH 7318 (OPRE 7318) Stochastic Dynamic Programming (3 semester credit hours) Stochastic Dynamic Programming (SDP) is a general methodology which plays an essential role in many areas of economics and management science. The course provides students with a solid background on SDP, the core theory and its evolution and applications. The course discusses many models, particularly in finance and operations management, as well as additional concepts such as principal-agent concepts for dynamic systems. Instructor consent required. (3-0) Y

MATH 7319 Functional Analysis II (3 semester credit hours) Topological vector spaces, locally convex spaces, Frechet spaces, test function spaces and tempered distributions, Fourier transforms and applications to differential equations. Recommended Prerequisite: MATH 6303. Prerequisites: MATH 6301 and MATH 6302. (3-0) T

MATH 7325 Nonlinear Analysis II (3 semester credit hours) This course covers elements of the equivariant topology, Burnside ring and the related algebraic structures, Euler ring, equivariant degrees. This subject has applications to differential equations, symmetric Hopf bifurcation theory and critical point theory. Prerequisite: MATH 6325. (3-0) T

MATH 7329 Topological and Algebraic Methods in Nonlinear Differential Equations (3 semester credit hours) This course covers Polynomial homogeneous systems of ODEs, Poincare index, elliptic, hyperbolic and parabolic sectors, Bendixson formula, classification of plane quadratic systems, Riccati equation in non-associative commutative algebras, nilpotents and equilibria, idempotents and ray solutions, complex structures in algebras and bounded/periodic regimes, applications to Kasner equation, Euler equation and second order chemical reactions. Prerequisite: MATH 6315. (3-0) T

MATH 7361 Algebraic Geometry and Non-linear Equations (3 semester credit hours) This course covers Theta-functions of one variable, Analytic construction of the Jacobian of a compact Riemann surface, Related theta-functions, Algebraic construction of the hyperelliptic Jacobians, C. Neumann dynamical system, Characterization of the hyperelliptic period matrices, Soliton equations, The Riemann-Schottky problem and the Novikov conjecture. This subject has applications to Mechanics, Geometry, and Cryptography. Prerequisite: MATH 5301 or MATH 6301. (3-0) T

MATH 7390 Topics in Mathematics - Level 7 (3 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. (3-0) R

MATH 8V02 Individual Instruction in Mathematics (1-6 semester credit hours) Pass/Fail only. May be
repeated for credit as topics vary. Instructor consent required. ([1-6]-0) S

**MATH 8V04** Topics in Mathematics - Level 8 (1-6 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) R

**MATH 8V07** Research (1-9 semester credit hours) Open to students with advanced standing subject to approval of the Graduate Advisor. Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

**MATH 8V99** Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. Prerequisite: Open to PhD students only. ([1-9]-0) S

Math Education

**MTHE 5300** Foundations in Algebra (3 semester credit hours) The course is designed to enhance conceptual understanding of mathematics content. Topics include variables, functions, patterns, equations, and polynomials. Emphasis on problem solving, precise reasoning, and communicating mathematics both orally and in writing. Does not count toward Master's degree in Mathematics. Must register in department office. Instructor consent required. Admission to Master of Arts (MAT) program. (3-0) R

**MTHE 5301** Foundations in Geometry (3 semester credit hours) The course is designed to enhance conceptual understanding of mathematics content related to Euclidean and analytic geometry, including triangles, circles, areas and volumes, trigonometric functions, and their connections with algebra. Emphasis on problem solving, precise reasoning, and communicating mathematics both orally and in writing. Does not count toward Master's degree in Mathematics. Must register in department office. Instructor consent required. Admission to Master of Arts (MAT) program. (3-0) R

**MTHE 5302** Foundations in Probability and Statistics (3 semester credit hours) The course is designed to provide tools to collect, display, analyze, and interpret data. Topics include basic statistics and probability, data analysis, and their applications. Emphasis on problem solving, precise reasoning, and communicating mathematics both orally and in writing. Does not count toward Master's degree in Mathematics. Must register in department office. Instructor consent required. Admission to Master of Arts (MAT) program. (3-0) R

**MTHE 5321** Problems Using Algebra (3 semester credit hours) Analysis of the relationship of "school algebra" to "abstract algebra," solving non-routine problems involving these concepts and adapting them for classroom use. The role of functions, the relationships between the verbal, visual, and symbolic representations of algebraic concepts, and the role of technology in learning algebra will be emphasized. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Recommended Prerequisite: A junior-level mathematics course. (3-0) T

**MTHE 5322** Problems Using Geometry (3 semester credit hours) Analysis of the relationship of "school geometry" to "college geometry," solving non-routine problems involving these concepts, and adapting them for classroom use. Topics include the van Hiele levels of reasoning, geometric transformations, the role of conjecture and proof, applications of geometry, and the role of technology in learning geometry.
May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Recommended Prerequisite: A junior-level mathematics course. (3-0) T

**MTHE 5323** Problems Using Pre-calculus (3 semester credit hours) Analysis of the relationship of pre-calculus to real analysis, solving non-routine problems involving these concepts and adapting them for classroom use. The role of functions will be emphasized. Topics include functions [polynomial, rational, trigonometric, exponential, logarithmic], measurement trigonometry, vector functions [parametric equations], conic sections, real-world applications, and the role of technology in learning pre-calculus. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Recommended Prerequisite: A junior-level mathematics course. (3-0) T

**MTHE 5324** Problems Using Discrete Mathematics (3 semester credit hours) Selected concepts in discrete mathematics. Solving non-routine problems and adapting them for classroom use and incorporating topics from discrete mathematics into existing high school courses. Topics include number theory, combinatorics, probability, and applications of matrices. Appropriate technology will be used. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Recommended Prerequisite: A junior-level mathematics course. (3-0) T

**MTHE 5325** Problems Using Mathematical Modeling (3 semester credit hours) Selected concepts in mathematical modeling. Solving non-routine problems and adapting them for classroom use and incorporating topics from mathematical modeling into existing high school courses. Topics include the construction, use, and analysis of empirical and analytical mathematical models, using modeling tools such as functions, curve fitting, simulation, matrices, difference and differential equations, finite graph theory. Appropriate technology will be used. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Recommended Prerequisite: A junior-level mathematics course. (3-0) T

**MTHE 5326** Problems Using Statistics and Probability (3 semester credit hours) Selected concepts in statistics and probability. Solving non-routine problems and adapting them for classroom use and incorporating topics from statistics, probability, and data analysis into existing high school courses. Topics include describing patterns in data and their variability, sampling and experimental design, exploring random phenomena using probability and simulation, and statistical inference. Appropriate technology will be used. May not be used to fulfill degree requirements for mathematical sciences majors except those in the Master of Arts in Teaching (MAT) program. Recommended Prerequisite: A junior-level mathematics course. (3-0) T

**MTHE 5327** Functions and Modeling (3 semester credit hours) Explorations and lab activities designed to strengthen and expand knowledge of topics taught in middle school mathematics using functions as a basis for real world application models in science, engineering and technology. Emphasis on models involving proportional reasoning. Analysis of relationships between analogous topics in middle school and high school/college mathematics. Approaches may include lecture, explorations, laboratory activities, technology use, and problem based learning. May not be used to fulfill degree requirements for mathematical sciences majors except those in MAT program. Department consent required. (3-0) R

**MTHE 5V06** Special Topics in Mathematics Education (1-3 semester credit hours) This course will cover selected topics in Mathematics Education. May be repeated for credit as topics vary (6 semester credit
hours maximum). May not be used to fulfill degree requirements within the MS or PhD degrees in Mathematical Sciences. Instructor consent required. ([1-3]-0) R

**MTHE 5V09** Math Ed Independent Study (1-6 semester credit hours) Faculty-supervised independent study in Mathematics Education and Mathematics Education research. This course will cover selected topics in Mathematics Education. May be repeated for credit as topics vary (6 semester credit hours maximum). Instructor consent required. ([1-6]-0) Y

**Physics**

**PHYS 5301** Mathematical Methods of Physics I (3 semester credit hours) Vector analysis (and index notation); Cylindrical and Spherical coordinates; Sturm-Liouville theory; Legendre Functions; Differential Equations (including Green Functions). (3-0) Y

**PHYS 5302** Mathematical Methods of Physics II (3 semester credit hours) Functions of Complex Variable (including contour integration and the residue theorem); Tensor Analysis; Gamma and Beta functions; and Bessel functions. (3-0) Y

**PHYS 5303** Mathematical Methods of Physics III (3 semester credit hours) Continuation and extension of topics from **PHYS 5301** and **PHYS 5302** with applications related to problems and techniques encountered in physical sciences. (3-0) R

**PHYS 5305** Monte Carlo Simulation Method and its Application (3 semester credit hours) An introductory course on the method of Monte Carlo simulation of physical events. This course covers the generation of 0-1 random number, simulation of arbitrary distributions, modeling, simulation and statistical analysis of experimental activities in physics research and engineering studies. As a comparison the concepts and applications of the Neural Networks will be discussed. Prerequisites: Background knowledge in probability and statistics and in a programming language or instructor consent required. (3-0) T

**PHYS 5311** Classical Mechanics (3 semester credit hours) A course that aims to provide intensive training in problem solving. Rigorous survey of Newtonian mechanics of systems, including its relativity principle; the ellipsoid of inertia and its eigenstructure, with applications, Poinset's theorem; Euler's equations, spinning tops; Lagrangian and Hamiltonian formalism with applications; chaos, small oscillations, velocity dependent potentials, Lagrange multipliers and corresponding constraint forces, canonical transformations, Lagrange and Poisson brackets, Hamilton-Jacobi theory. (3-0) Y

**PHYS 5313** Statistical Physics (3 semester credit hours) Phase space, distribution functions and density matrices; microcanonical, canonical and grand canonical ensembles; partition functions; principle of maximum entropy; thermodynamic potentials and laws of thermodynamics; classical and quantum ideal gases; non-interacting magnetic moments; phonons and specific heat of solids; degenerate electron gas, its specific heat and magnetism; statistics of carriers in semiconductors; Bose-Einstein condensation; Black-body radiation; Boltzmann transport equation and H-theorem; relaxation time and conductivity; Brownian motion, random walks and Langevin equation; Einstein's relation; fluctuations in ideal gases; linear response and fluctuation-dissipation theorem; virial and cluster expansions, van der Waals equation of state; Poisson-Boltzmann and Thomas-Fermi equations; phases, phase diagrams and phase transitions of the first and second order; lattice spin models; ordering, order parameters and broken symmetries;
Mean-field theory of ferromagnetism; Landau and Ginzburg-Landau theories; elements of modern theory of critical phenomena. (3-0) Y

**PHYS 5314** Applied Numerical Methods (3 semester credit hours) Core course for Applied Physics Concentration. A hands-on approach to the development and use of computational tools in solving problems routinely encountered in upper level applied physics and engineering. Main topics include curve fitting and regression analysis, significance tests, principles of numerical modeling, verification and validation of numerical algorithms, and nonlinear model building. Examples from real world applications will be presented and discussed to illustrate the appropriate use of numerical techniques. Prerequisites: PHYS 5301 or equivalent, and proficiency in a programming language. (3-0) Y

**PHYS 5315** Scientific Computing (3 semester credit hours) An introduction to computational methods for solving systems of ordinary and partial differential equations using numerical techniques. Prerequisite or Corequisite: PHYS 5301. (3-0) Y

**PHYS 5319** (SCI 5326) Astronomy: Our Place in Space (3 semester credit hours) Focus is on developing student understanding of how our planet fits within a larger astronomical context. Topics include common misconceptions in astronomy, scale in the Solar System and beyond, phases of the Moon, seasons, navigating the night sky, our Sun as a star, space weather, properties and lifecycles of stars, galaxies, and cosmology. (3-0) T

**PHYS 5320** Electromagnetism I (3 semester credit hours) Electrostatic boundary value problems, uniqueness theorems, method of images, Green's functions, multipole potentials, Legendre polynomials and spherical harmonics, dielectric and magnetic materials, magnetostatics, time-varying field and Maxwell's equations, energy and momentum of the field, Lienard-Wiechert potentials, electromagnetic radiation, polarization, refraction and reflection at plane interfaces. (3-0) Y

**PHYS 5321** Experimental Operation and Data Collection Using Personal Computers (3 semester credit hours) Computer interfacing to physical experiments using high level interface languages and environments. The student will have the opportunity to learn how to develop data acquisition software using LabView and LabWindows/CVI as well as how to write drivers to interface these languages to devices over the general purpose interface buss (GPIB). A laboratory is provided for hands-on training in these devices. (3-0) R

**PHYS 5322** Electromagnetism II (3 semester credit hours) Fields and potentials, Gauge transformations and the wave equation. Electromagnetic waves in unbounded media - non-dispersive and dispersive media. Boundary conditions at interfaces. Solutions to the wave equation in rectangular cylindrical and spherical coordinates. Electromagnetic waves in bonded media - waveguides and resonant cavities. Radiating systems - electric and magnetic dipole radiation, electric quadruple radiation. Fundamentals of scattering and scalar diffraction. Lorentz transformation and covariant forms for Maxwell's equations. Radiation from moving charges - Synchrotron, Cherenkov and Bremstrahlung Radiation. Prerequisite: PHYS 5320 or equivalent. (3-0) Y

**PHYS 5323** Virtual Instrumentation with Biomedical Clinical and Healthcare Applications (3 semester credit hours) The application of the graphical programming environment of LabView will be demonstrated with examples related to the health care industry. Examples will be provided to highlight the use of the personal computer as a virtual instrument in the clinical and laboratory environment. A laboratory is
provided for hands-on training to augment the lecture. (3-0) R

**PHYS 5327 (SCI 5327)** Comparative Planetology (3 semester credit hours) Every world in the solar system is unique, but none more so than our own planet Earth. The course is an exploration of the astrophysical, chemical, and geological processes that have shaped each planet, moons and the myriad of rocky and icy bodies in our solar system with a special emphasis on what each tells us about Earth, and what discoveries of worlds orbiting other stars may tell us about our planetary system and home world. (3-0) T

**PHYS 5331 (SCI 5331)** Conceptual Physics I: Force and Motion (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics, emphasizing its applicability to the pre-college and undergraduate classroom. Uses inquiry-based approaches including examples of physics in the everyday world and connections to other fields of science. Topics include foundational concepts of forces, Newton's laws, energy, and momentum. Instructor consent required. (3-0) T

**PHYS 5332 (SCI 5332)** Conceptual Physics II: Particles and Systems (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics emphasizing its applicability to the pre-college and undergraduate classroom. Uses an inquiry-based approach including examples of physics in the everyday world and connections to other fields of science. This second class in the Conceptual Physics series builds on concepts from SCI 5331 to explore transfers of energy and forces within and between systems of particles. Topics include states of matter, fluids, waves and sound, and thermodynamics. Instructor consent required. (3-0) T

**PHYS 5333 (SCI 5333)** Conceptual Physics III: Atoms, Charges, and Interactions (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics, emphasizing critical thinking and applications to the pre-college and undergraduate classroom. Uses inquiry-based approaches including examples of physics in the everyday world and connections to other fields of science. This third class in the Conceptual Physics series builds on concepts from SCI 5331 and SCI 5332 to explore interactions between particles of matter. Topics include inter- and intra-molecular forces, light, electricity and magnetism, and the nature of the atom. (3-0) T

**PHYS 5335** Remote Sensing of the Earth (3 semester credit hours) This course covers the basic physical principles and applications of remote sensing of the earth system (air, land and sea), covering the types of platforms (satellites and aerial vehicles) and sensors used (UV/Visible, IR, Microwave, Radio). (3-0) R

**PHYS 5336** Big Data and Machine Learning for Scientific Discovery (3 semester credit hours) This class introduces a wide range of machine learning techniques suitable for Big Data analysis. The techniques covered include multivariate non-linear non-parametric regression and classification, both supervised and unsupervised. These approaches are directly applicable to many issues of major scientific and societal importance. The practical tools introduced (Neural Networks, Support Vector Regression, Decision Trees, Random Forests, etc) can be readily used in a wide range of applications from research to real time decision support. The data used can come from a wide variety of sources including scientific instrumentation, social media, remote sensing, aerial vehicles, and the internet of things. (3-0) R

**PHYS 5341 (SCI 5341)** Astrobiology (3 semester credit hours) The ultimate integrated science, astrobiology brings together cutting-edge research from the fields of astrophysics, planetary science, terrestrial geosciences, and biology, to build understanding of how the history and diversity of life on our own planet relates to the possibilities for life on other worlds. This graduate-level survey course is designed to
challenge participants of all backgrounds in a thoughtful and scientifically-based exploration of the young and dynamic multidisciplinary field of astrobiology. Instructor consent required. (3-0) T

**PHYS 5367** Photonic Devices (3 semester credit hours) Basic principles of Photophysics of Condensed Matter with application to devices. Topics covered include photonic crystals, PBG systems, low threshold lasers, photonic switches, super-prisms and super-lenses. Photodetectors and photocells. (3-0) R

**PHYS 5371 (MSEN 5371)** Solid State Physics (3 semester credit hours) Symmetry description of crystals, bonding, properties of metals, electronic band theory, thermal properties, lattice vibration, elementary properties of semiconductors. Prerequisites: **PHYS 5301** and **PHYS 5320** or equivalent. (3-0) Y

**PHYS 5372** Solid State Devices (3 semester credit hours) Basic concepts of solid state physics with application to devices. Topics covered include semiconductor homojunctions and heterojunctions, low dimensional physics, one and two dimensional electron gases, hot electron systems, semiconductor lasers, field effect and heterojunction transistors, microwave diodes and infrared and solar devices. Prerequisite: **PHYS 5371**. (3-0) R

**PHYS 5376 (MECH 5300 and MSEN 5300)** Introduction to Materials Science (3 semester credit hours) This course provides an extensive overview of materials science and engineering and includes the foundations required for further graduate study in the field. Topics include chemical bonding, crystalline structures, imperfections and diffusion in solids, mechanical properties, strengthening and failure mechanisms, phase diagrams and transformations, corrosion and degradation of materials, metal alloys, ceramics, polymers, composites, as well as their electrical, thermal, magnetic, and optical properties. Quantitative analyses will be emphasized. (3-0) R

**PHYS 5377 (MSEN 5377)** Computational Physics of Nanomaterials (3 semester credit hours) This course introduces atomistic and quantum simulation methods and their applications to modeling study nanomaterials (nanoparticles, nanowires, and thin films). The course has three main parts: basic theory of materials (thermodynamics, statistical mechanics, and solid state physics), computational methods to model materials systems, and applications to practical problems. There are three main themes of the course: structure-property relationship of nanomaterials; atomistic modeling for atomic structure optimization; and quantum simulations for electronic structure study and functional property analysis. Prerequisite: **MSEN 6319** or equivalent. (3-0) R

**PHYS 5381** Space Science (3 semester credit hours) Introduction to the dynamics of the middle and upper atmospheres, ionospheres and magnetospheres of the earth and planets and the interplanetary medium. Topics include: turbulence and diffusion, photochemistry, aurorae and airglow, space weather and the global electric circuit. (3-0) R

**PHYS 5382** Space Science Instrumentation (3 semester credit hours) Design, testing and operational criteria for space flight instrumentation including retarding potential analyzers, drift meters, neutral and ion mass spectrometers, auroral particle spectrometers, fast ion mass spectrometers, Langmuir probes, and optical spectrometers; ground support equipment; microprocessor design and operations. (3-0) R

**PHYS 5383 (EEMF 5383 and MSEN 5383)** Plasma Technology (3 semester credit hours) Hardware oriented study of useful laboratory plasmas. Topics will include vacuum technology, gas kinetic theory, basic plasma theory and an introduction to the uses of plasmas in various industries. (3-0) T
PHYS 5385  Natural And Anthropogenic Effects on The Atmosphere (3 semester credit hours) An examination of the physical, chemical and electrical effects on the atmosphere and clouds due to varying solar photon and solar wind inputs; and of the physical and chemical effects on ozone and atmospheric temperature following anthropogenic release of CFC's and greenhouse gases into the atmosphere. Suitable for Science Education and other non-physics majors. (3-0) R

PHYS 5391  Relativity I (3 semester credit hours) Mach's principle and the abolition of absolute space; the principle of relativity; the principle of equivalence; basic cosmology; four-vector calculus; special relativistic kinematics, optics, mechanics, and electromagnetism; basic ideas of general relativity. (3-0) T

PHYS 5392  Relativity II (3 semester credit hours) Tensor calculus and Riemannian geometry; mathematical foundation of general relativity; the crucial tests; fundamentals of theoretical relativistic cosmology; the Friedmann model universes; comparison with observation. Normally follows PHYS 5391. (3-0) T

PHYS 5395  Cosmology (3 semester credit hours) The course is an overview of contemporary cosmology including: cosmological models of the universe and their parameters; large scale structure of the universe; dark matter; cosmological probes and techniques such as gravitational lensing, cosmic microwave background radiation, and supernova searches; very early stages of the universe; dark energy and recent cosmic acceleration. (3-0) T

PHYS 5V48  Topics in Physics (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Instructor consent required. ([1-6]-0) R

PHYS 5V49  Special Topics in Physics (1-6 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

PHYS 6300  Quantum Mechanics I (3 semester credit hours) Dirac formalism, kets, bras, operators and position, momentum, and matrix representations, change of basis, Stern-Gerlach experiment, observables and uncertainty principle, translations, wave functions, time evolution, the Schrodinger and Heisenberg pictures, simple harmonic oscillator, wave equation, WKB approximation, rotations, angular momentum, spin, Clebsch-Gordan coefficients, perturbation theory, variational methods. Prerequisite: PHYS 5311 or consent of instructor. (3-0) Y

PHYS 6301  Quantum Mechanics II (3 semester credit hours) Non-relativistic many-particle systems and their second quantization description with creation and annihilation operators; Interactions and Hartree-Fock approximation, quasi-particles; attraction of fermions and superconductivity; repulsion of e bosons and super fluidity; lattice systems, classical fields and canonical quantization of wave equations; free electromagnetic field, gauges and quantization: photons; coherent states; Interaction of light with atoms and condensed systems: emission, absorption and scattering; vacuum fluctuations and Casimir force; elements of relativistic quantum mechanics: Klein-Gordon and Dirac equations; particles and antiparticles; spin-orbit coupling; fine structure of the hydrogen atom; micro-causality and spin-statistics theorem; non-relativistic scattering theory: scattering amplitudes, phase shifts, cross-section and optical theorem; Born series; inelastic and resonance scattering; perturbative analysis of the interacting fields: Time evolution and interaction representation, S-matrix and Feynman diagrams; simple scattering processes; Dyson's equation, self-energy and renormalization. Prerequisite: PHYS 6300. (3-0) Y

PHYS 6302  Quantum Mechanics III (3 semester credit hours) Advanced topics in quantum mechanics. Prerequisite: PHYS 6300 and PHYS 6301. (3-0) R
**PHYS 6303** Applications of Group Theory In Physics (3 semester credit hours) Group representation theory and selected applications in atomic, molecular and elementary-particle physics. Survey of abstract group theory and matrix representations of SU(2) and the rotation group, group theory and special functions, the role of group theory in the calculation of energy levels, matrix elements and selection rules, Abelian and non-Abelian gauge field theories, the Dirac equation, representations of SU(3), and the standard model of elementary-particle physics. Prerequisite: PHYS 5301. (3-0) R

**PHYS 6313** Elementary Particles (3 semester credit hours) Elementary particles and their interaction; classification of elementary particles; fermions and bosons; particles and antiparticles; leptons and hadrons; mesons and baryons; stable particles and resonances; hadrons as composites of quarks and antiquarks; fundamental interactions and fields; electromagnetic, gravitational, weak and strong interactions; conservation laws in fundamental interactions; parity, isospin, strangeness, G-parity; helicity and chirality; charge conjugation and time reversal; strong reflection and CPT theorem; gauge invariance; quarks and gluons; discovery of c, b and t quarks and the W+ and Z0 particles; recent discoveries. (Normally follows PHYS 6300 or 6301.) (3-0) T

**PHYS 6314** High Energy Physics (3 semester credit hours) Electromagnetic and nuclear interactions of particles with matter; particle detectors; accelerators and colliding beam machines; invariance principles and conservation laws; hadron-hadron interactions; static quark model of hadrons; weak interactions; lepton-quark interactions; the parton model of hadrons; fundamental interactions and their unification; generalized gauge invariance; the Weinberg-Salam Model and its experimental tests: quantum chromodynamics; quark-quark interactions; grand unification theories; proton decay, magnetic monopoles, neutrino oscillations and cosmological aspects; supersymmetries. (3-0) R

**PHYS 6339** Special Topics In Quantum Electronics (3 semester credit hours) Topics vary from semester to semester. May be repeated for credit (9 semester credit hours maximum). (3-0) R

**PHYS 6341** Nuclear Physics I: The Principles of Nuclear Physics (3 semester credit hours) Atomic physics; atomic spectra, x-rays and atomic structure. The constitution of the nucleus; isotopes, natural radioactivity, artificial nuclear disintegration and artificial radioactivity; alpha-, beta-, and gamma-decay; nuclear reactions, nuclear forces and nuclear structure. Nuclear models, neutron physics and nuclear fission. (3-0) R

**PHYS 6342** Nuclear Physics II: Physics and Measurement Of Nuclear Radiations (3 semester credit hours) Interaction of nuclear radiation with matter; electromagnetic interaction of electrons and photons; nuclear interactions. Operation and construction of counters and particle track detectors; electronic data acquisition and analysis systems. Statistical evaluation of experimental data. (3-0) R

**PHYS 6349** Special Topics in High Energy Physics (3 semester credit hours) Topics vary from semester to semester. May be repeated for credit as topics vary (9 semester credit hours maximum). (3-0) R

**PHYS 6353** Atomic and Molecular Processes (3 semester credit hours) Study of theory and experimental methods applied to elastic scattering, excitation and ionization of atoms and molecules by electron and ion impact, electron attachment and detachment, and charge transfer processes. (3-0) R

**PHYS 6369** Special Topics in Optics (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) R
**PHYS 6371 (MSEN 6371)** Advanced Solid State Physics (3 semester credit hours) Continuation of MSEN 5371 or PHYS 5371, transport properties of semiconductors, ferroelectricity and structural phase transitions, magnetism, superconductivity, quantum devices, surfaces. Prerequisite: MSEN 5371 or PHYS 5371 or equivalent. (3-0) R

**PHYS 6372** Physical Materials Science (3 semester credit hours) Advanced concepts of Materials Science. New directions in fabrication routes and materials design, such as biologically-inspired routes to electronic materials. Advanced materials and device characterization. Prerequisite: PHYS 5376 or equivalent. (3-0) R

**PHYS 6374 (MSEN 6374)** Optical Properties of Solids (3 semester credit hours) Optical response in solids and its applications. Lorentz, Drude and quantum mechanical models for dielectric response function. Kramers-Kronig transformation and sum rules considered. Basic properties related to band structure effects, excitons and other excitations. Experimental techniques including reflectance, absorption, modulated reflectance, Raman scattering. Prerequisite: MSEN 5371 or PHYS 5371 or equivalent. (3-0) R

**PHYS 6376** Electronics and Photonics of Molecular and Organic Solids (3 semester credit hours) Electronic energy bands in molecular solids and conjugated polymers. Elementary excitations: Frenkel, Wannier and charge transfer excitons. Polaron, bipolaron and solitons. Mobility of excitons and charge carriers, photoconductivity. Charge generation and recombination, electroluminescence, photovoltaic phenomena. Spin selective magnetic effects on excitons and carriers. Superconductivity: granular SC, and field induced SC in organic FETs. (3-0) R


**PHYS 6379** Special Topics in Solid State Physics (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) R

**PHYS 6383 (EEMF 6383 and MECH 6383)** Plasma Science (3 semester credit hours) Theoretically oriented study of plasmas. Topics to include: fundamental properties of plasmas, fundamental equations (kinetic and fluid theory, electromagnetic waves, plasma waves, plasma sheaths), plasma chemistry and plasma diagnostics. Prerequisite: EEGR 6316 or equivalent. (3-0) T

**PHYS 6388** Ionospheric Electrodynamics (3 semester credit hours) Generation of electric fields in the earth's ionosphere. The role of internal dynamos and external generators from the interaction of the earth with the solar wind. Satellite and ground-based observations of ionospheric phenomena such as ExB drift, the polar wind and plasma instabilities. Prerequisites: PHYS 5320 and PHYS 6383. (3-0) R

**PHYS 6389** Special Topics in Space Physics (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) S

**PHYS 6398** Thesis (3 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent
PHYS 6399 Special Topics in Relativity (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) R

PHYS 7V10 Internal Research (3-6 semester credit hours) On campus research for Masters in Applied Physics. May be repeated for credit. Instructor consent required. ([3-6]-0) S

PHYS 7V20 Industrial Research (3-6 semester credit hours) Industrial research for Masters in Applied Physics. May be repeated for credit. Instructor consent required. ([3-6]-0) S

PHYS 8V10 Research in High Energy Physics and Elementary Particles (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V20 Research in Cosmology and Astrophysics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V30 Research in Quantum Electronics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V40 Research in Applied Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V50 Research in Atomic and Molecular Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V60 Research in Optics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V70 Research in Materials Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V80 Research in Atmospheric and Space Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V90 Research in Mathematical Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

PHYS 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

Science Education

SCE 5334 Instructional Strategies in Science (3 semester credit hours) Designed for the master teacher/department leader, strategies for fostering an integrated science program based on national and Texas curriculum and assessment standards are presented through hands-on activities. (3-0) T

SCE 5V06 Special Topics in Science Education (1-3 semester credit hours) This course will cover selected topics in science education. May be repeated as topics vary (6 semester credit hours maximum). ([1-3]-0) S
**SCE 5V07** Independent Study in Science Education (1-6 semester credit hours) Individual independent study in science education under the supervision of a faculty member. May be repeated for credit as topics vary (6 semester credit hours maximum). Instructor consent required. ([1-6]-0) R

**Science**

**SCI 5310** Perspectives in Science and Math (3 semester credit hours) Journey through science and mathematics as a human endeavor through historical context. Science and mathematics have advanced by the struggles of diverse people, on the basis of often-conflicting criteria and interests. In this graduate-level survey course, future science and mathematics teachers will explore their disciplines through the broader perspective of discovery, individual and community struggles, social influences, and societal impacts. The course is designed for science, technology, engineering, and mathematics (STEM) content degree holders seeking UTeach Dallas secondary science and/or mathematics teacher certification preparation. UTeach Dallas/MAT advisor approval required. (3-0) Y

**SCI 5322 (BIOL 5322)** Basis of Evolution (3 semester credit hours) From Assembling the Tree of Life to new drug developments, evolution theory is at the core of biology advancements. The concept of evolution is discussed for its relevance as a basic understanding for a scientifically literate society and processes and mechanisms of natural selection are examined. Topics include pertinent history, the fossil record, extinction, emergent species, the human experience, and applied evolution technologies. Students will explore the origins of evolution theory, public misconceptions, teaching, and evolution education research. An intensive scientific argumentation component (rather than debate) through discourse, advanced readings, presentations, panel discussions, and formal writing is required. Viewpoints examined include those of evolutionary biologists and research scientists. (3-0) T

**SCI 5324 (BIOL 5324)** Ecology (3 semester credit hours) This course will examine interrelationships between organisms and their environments in both theoretical and field-based contexts. Students will examine general ecological principles and their applications. Communities considered will be as small as the roadside and as vast as interconnected global systems. Topics analyzed by students in the context of ecological studies will include the flow of energy and matter through systems, predator/prey relationships, genetic diversity, evolution, population dynamics, interactions between microscopic and macroscopic organisms, and human impacts. Fieldwork examining North Texas ecosystems may be required. Critical thinking, metacognition, and reflections on the relevance of ecology in the teaching and learning of life and environmental sciences will be emphasized throughout the course. (3-0) T

**SCI 5326 (PHYS 5319)** Astronomy: Our Place in Space (3 semester credit hours) Focus is on developing student understanding of how our planet fits within a larger astronomical context. Topics include common misconceptions in astronomy, scale in the Solar System and beyond, phases of the Moon, seasons, navigating the night sky, our Sun as a star, space weather, properties and lifecycles of stars, galaxies, and cosmology. (3-0) T

**SCI 5327 (PHYS 5327)** Comparative Planetology (3 semester credit hours) Every world in the solar system is unique, but none more so than our own planet Earth. The course is an exploration of the astrophysical, chemical, and geological processes that have shaped each planet, moons and the myriad of rocky and icy bodies in our solar system with a special emphasis on what each tells us about Earth, and what discoveries of worlds orbiting other stars may tell us about our planetary system and home world. (3-0) T
SCI 5328  Marine Science (3 semester credit hours) Acquaint STEM teachers with basic principles of marine science and with issues surrounding our use of the oceans and their resources. Students will also gain experience in conducting research, presenting results, and developing lessons for their students. (3-0) R

SCI 5329  Bioethics (3 semester credit hours) Bioethics incorporates philosophy and values that are at the heart of emerging technology, research, public understanding, and government policy. Focus on issues related to biotechnology in health care, ecology, agriculture and environmental disciplines including genetic transference, applied evolution technologies, assisted suicide, and new reproductive technologies. Students explore hypothetical and actual cases of bioethical dilemmas. Intensive writing component and discussion of teaching and policy development. Viewpoints examined include those of scientists, health professionals, theologians, policymakers and laypeople. (3-0) T

SCI 5330  Emerging Topics in Biology (3 semester credit hours) The media frequently announce biology advancements and research that affect human health, basic living needs, and biology education without critical analysis, often resulting in confusing the public and curtailing scientific literacy. Examination of resources and methods to critically evaluate biological information and scientific articles for sound theory development, research methods, and practical application. Topics include recent discoveries in the life sciences that meet the needs of society, health, and environmental issues. Although the topics build on emerging issues, they may include content areas such as cell and molecular biology, agriculture, epidemiology, and global warming. Students will examine effective ways to bring in new curricula into established course settings. Advanced curriculum writing component focused on science literacy. Viewpoints include those of biological research scientists, health professionals, and science education researchers. (3-0) T

SCI 5331  Conceptual Physics I: Force and Motion (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics, emphasizing its applicability to the pre-college and undergraduate classroom. Uses inquiry-based approaches including examples of physics in the everyday world and connections to other fields of science. Topics include foundational concepts of forces, Newton's laws, energy, and momentum. Instructor consent required. (3-0) T

SCI 5332  Conceptual Physics II: Particles and Systems (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics emphasizing its applicability to the pre-college and undergraduate classroom. Uses an inquiry-based approach including examples of physics in the everyday world and connections to other fields of science. This second class in the Conceptual Physics series builds on concepts from SCI 5331 to explore transfers of energy and forces within and between systems of particles. Topics include states of matter, fluids, waves and sound, and thermodynamics. Instructor consent required. (3-0) T

SCI 5333  Conceptual Physics III: Atoms, Charges, and Interactions (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics, emphasizing critical thinking and applications to the pre-college and undergraduate classroom. Uses inquiry-based approaches including examples of physics in the everyday world and connections to other fields of science. This third class in the Conceptual Physics series builds on concepts from SCI 5331 and SCI 5332 to explore interactions between particles of matter. Topics include inter- and intra-molecular forces, light, electricity and magnetism, and the nature of the atom. (3-0) T

SCI 5337  Rockin' Around Texas (3 semester credit hours) Provides greater familiarity with earth science and
a bank of resources and instructional materials needed to lead geology field trips anywhere in Texas. Teachers will participate in extensive field, laboratory, and class work mostly conducted in a problem-based learning format. (3-0) T

**SCI 5338** Conceptual Chemistry: The Atom and the Bridge from Physics to Biology (3 semester credit hours) This class will focus on deepening participants' conceptual understanding of chemistry through laboratory demonstrations and activities as well as inquiry-based approaches. Students will prepare their own demonstrations and lab activities, with an emphasis on both presentation skills and conceptual content with applications to pre-college and undergraduate students. The class will use real world examples to explore topics such as element properties, behaviors of gases, and solutions. (3-0) T

**SCI 5339** Practical Approaches in Genetics (3 semester credit hours) This graduate course is designed to cover key concepts and laboratory techniques in the field of Genetics. Students will analyze genetic model systems, such as Planaria, Drosophila, Caenorhabditis elegans, and Zebrafish, and their applications in the context of constructing understanding of essential biological processes that are not only interesting, but also often relevant to human health and welfare issues. The experiments conducted in the course will examine basic principles of genetic model systems, transmission genetics, cytological genetics, and molecular genetics. This exploratory experience will focus on both concepts in genetics and the basic culturing, genetic manipulation, and phenotypic analysis techniques necessary to utilize genetic model organisms in investigations of stem cells, cell division, modes of inheritance, genetic mutations, and much more. Throughout this inquiry-based course participants will be given "Discussion Questions" to ponder in which there may not be right or wrong answers for the purpose of examining the creative and discovery aspect of science. Critical thinking, metacognition, and reflections on the relevance of practical experience with model organisms in the teaching and learning of genetics will be emphasized throughout the course. Department consent required. (3-0) T

**SCI 5340** Statistics for Science/Mathematics Education (3 semester credit hours) Understanding and application of statistical techniques needed in design and interpretation of research in Science/Mathematics Education. Includes descriptive and inferential statistics, computer-based tools, and other appropriate topics. (3-0) T

**SCI 5341 (PHYS 5341)** Astrobiology (3 semester credit hours) The ultimate integrated science, astrobiology brings together cutting-edge research from the fields of astrophysics, planetary science, terrestrial geosciences, and biology, to build understanding of how the history and diversity of life on our own planet relates to the possibilities for life on other worlds. This graduate-level survey course is designed to challenge participants of all backgrounds in a thoughtful and scientifically-based exploration of the young and dynamic multidisciplinary field of astrobiology. Instructor consent required. (3-0) T

**SCI 5342** Research Methods in STEM (3 semester credit hours) An introduction research process used by faculty in STEM disciplines. Through examples and/or projects, students will see the STEM research process, including conception, design, experimentation, analysis of results, and writing/publication. Instructor consent required. (3-0) T

**SCI 5V06** Special Topics in Science (1-3 semester credit hours) This course will cover selected topics in Science. May be repeated for credit as topic vary (6 semester credit hours maximum). Department consent required. ([1-3]-0) S
SCI 5V08  Independent Study in Science (1-3 semester credit hours) Faculty-supervised independent study in science content areas. May be repeated for credit as topics vary (6 semester credit hours maximum). Instructor consent required. ([1-3]-0) S

Science Math Education

SMED 5301  Science, Mathematics, and Society (3 semester credit hours) Exploration of the state of the world as informed by STEM issues in society. Students make connections to global STEM topics as they explore the importance of universal citizen involvement in the learning, teaching, and application of science and mathematics. International topics include current research into sustainability, development, climate change, security, resources, and innovation. (3-0) Y

SMED 5302  Teaching and Learning of Science and Mathematics (3 semester credit hours) Includes the history of science and mathematics education with emphasis on the continuing struggle to improve classroom practice. Learning theories are explored with a focus on cognitive studies and application in the classroom. The importance of learning environments, problem solving and assessment strategies are also emphasized. Teaching strategies and the research behind those strategies will be evaluated. (3-0) Y

SMED 5303  Introduction to Research and Evaluation in Science and Mathematics Education (3 semester credit hours) Expansion of students’ knowledge and application of STEM education research including research approaches to evaluation of curricula and student achievement. Focus on designing research questions concerning current understanding in science and mathematics education and questions for future investigations. For the major project, students explore the appropriateness of action research in answering practical questions. Prerequisite: SMED 5302. (3-0) Y

SMED 5304  Research Methods in Science and Mathematics (3 semester credit hours) Open-ended, inquiry projects grounded in critical and logical thinking that involve observations, research, investigation planning, data collection with instruments or surveys, analysis and interpretation of data, proposing explanations, considering alternatives, generating predictions, and conveying results in student peer-reviewed papers and presentations appropriate for a professional forum. Students conduct open-ended research into subjects of their choosing. Students develop and pursue inquiries based on original ideas, literature research, discussions with experts, and via trial and error. Recommended Prerequisite: SMED 5303. (3-0) Y

SMED 6V98  Thesis Research (3-6 semester credit hours) Thesis development. May be repeated for credit (9 semester credit hours maximum). Only 6 semester credit hours may apply for credit toward the Master of Arts in Teaching (MAT). Instructor consent required. ([3-6]-0) R

Statistics

STAT 5191  Statistical Computing Packages (1 semester credit hour) Introduction to use of major statistical packages such as SAS, BMD, and Minitab. Based primarily on self-study materials. May not be used to fulfill degree requirements. Prerequisites: One semester of statistics and instructor consent required. (1-0) S

STAT 5351  Probability and Statistics I (3 semester credit hours) A mathematical treatment of probability
theory. Random variables, distributions, conditioning, expectations, special distributions and the central limit theorem. The theory is illustrated by numerous examples. This is a basic course in probability and uses calculus extensively. Prerequisite: Calculus through multivariate calculus or instructor consent required. (3-0) T

**STAT 5352** Probability and Statistics II (3 semester credit hours) Theory and methods of statistical inference. Sampling, estimation, confidence intervals, hypothesis testing, analysis of variance, and regression with applications. Prerequisite: **STAT 5351**. (3-0) T

**STAT 5353** Probability and Statistics for Data Science and Bioinformatics (3 semester credit hours) Probability; Kolmogorov’s axioms; independence; random variables; discrete and continuous distributions; expected values; joint, marginal and conditional distributions; Monte Carlo simulation; sampling distributions; law of large numbers; central limit theorem; maximum likelihood estimation; confidence intervals and hypothesis testing involving one- and two-sample problems; linear regression; proofs of key results; practical examples illustrating the theory; and introduction to a statistical software package. Prerequisite: Calculus through multivariate calculus and department consent required. (3-0) Y

**STAT 5390** Topics in Statistics - Level 5 (3 semester credit hours) May be repeated for credit as topics vary. Instructor consent required. (3-0) R

**STAT 6313 (CS 6313)** Statistical Methods for Data Science (3 semester credit hours) Statistical methods for data science. Statistical Methods are developed at an intermediate level. Sampling distributions. Point and interval estimation. Parametric and nonparametric hypothesis testing. Analysis of variance. Regression, model building and model diagnostics. Monte Carlo simulation and bootstrap. Introduction to a statistical software package. Prerequisite: **CS 3341** or **SE 3341** or **STAT 3341** or equivalent. (3-0) S

**STAT 6326** Sampling Theory (3 semester credit hours) Introduction to sampling theory and methods. Statistical inference for the popular sampling designs. Simple random sampling; stratified, systematic, cluster, unequal probability, multistage, and spatial sampling designs. Statistical methods for a finite population. Use of auxiliary data. Optimal allocation. Capture-recapture methods. Detectability. Multiplicity. Prerequisite: **STAT 5351** or a course in basic statistics or instructor consent required. (3-0) T

**STAT 6329** Applied Probability and Stochastic Processes (3 semester credit hours) Basic random processes used in stochastic modeling, including Poisson, Gaussian, and Markov processes with an introduction to renewal processes and queuing theory. Measure theory not required. Prerequisite: **STAT 5351**. (3-0) T

**STAT 6331** Statistical Inference I (3 semester credit hours) Introduction to fundamental concepts and methods of statistical modeling and decision making. Basic distribution theory. Decision theory. Exponential families of models. Sufficiency. Estimation and hypothesis testing. Likelihood methods and optimality. Large sample approximations. Prerequisites: **STAT 5352** or equivalent and **MATH 5302** or equivalent. (3-0) Y

**STAT 6332** Statistical Inference II (3 semester credit hours) Elementary and advanced asymptotic methods, treating sample quantiles, U-statistics, differentiable statistical functions, and influence curves, the MLE, L-statistics, M-statistics, and the bootstrap. Advanced aspects of statistical inference, likelihood-based inference, robust statistics. General forms of Neyman-Pearson Lemma. Metrics on spaces of probability distributions. Prerequisite: **STAT 6331**. Prerequisite or Corequisite: **STAT 6344**. (3-0) T

**STAT 6338** Advanced Statistical Methods II (3 semester credit hours)  This course continues STAT 6337. Topics include one-way and multi-way analysis of variance, general and generalized linear models with fixed, random, and mixed effects, diagnostics, and implementation of statistical methods using statistical software. Prerequisite: STAT 6337. (3-0) T

**STAT 6339** Linear Statistical Models (3 semester credit hours)  Theoretical treatment of general and generalized linear models. Topics include random vectors; multivariate normal distribution; distributions of quadratic forms; general linear models for normal data; extension to generalized linear models for non-normal data such as binary, polytomous and count data; point and interval estimation; and hypothesis testing. Prerequisite: STAT 6331 or equivalent. (3-0) T

**STAT 6340** Statistical and Machine Learning (3 semester credit hours)  Statistical models, including linear models, generalized linear models, spline models and additive models; model selection, validation and regularization; smoothing techniques; classification; support vector machines; clustering; principal components analysis; and principal components regression. Prerequisites: (STAT 5353 or equivalent) and instructor consent required. (3-0) Y

**STAT 6341** Numerical Linear Algebra and Statistical Computing (3 semester credit hours)  A study of computational methods used in statistics. Topics to be covered include the simulation of stochastic processes, numerical linear algebra, QR decomposition and least squares regression, SV decomposition and multivariate data, statistical programming languages, and graphical methods. Prerequisite: STAT 5352 or STAT 6337. (3-0) T

**STAT 6343** Experimental Design (3 semester credit hours)  Basic design principles; sample size computation; crossed and nested treatment factors; confounding; inference on contrasts; analysis of variance; analysis of covariance; designs such as completely randomized designs, factorial designs, complete block designs, incomplete block designs, Latin square designs, crossover designs, repeated measures designs and split plot designs; fractional replication in factorial experiments; variance components models; and implementation of statistical methods using a statistical software package. Prerequisite: STAT 6337 or equivalent. (3-0) T

**STAT 6344** Probability Theory I (3 semester credit hours)  Measure theoretic coverage of probability theory. Topics include: Axioms of probability, Integration; Distributions and moments; Probability Inequalities; Convergence of probability measures; Laws of large numbers; Central limit theorem; Three-series theorem; Zero-one laws; Glivenko-Cantelli theorem; Law of iterated logarithm; Conditional probability and expectation; Introduction to martingales. Prerequisite: MATH 5302 or equivalent. (3-0) T

**STAT 6347** Applied Time Series Analysis (3 semester credit hours)  Introduction to time series data; autocorrelation function; stationarity; classical decomposition of a time series; linear processes; forecasting stationary time series; basic time series models such as autoregressive models, moving
average models, ARMA models, ARIMA models and seasonal ARIMA models; model fitting; model checking; model-based forecasting; regression with ARMA errors; spectral analysis; multivariate time series; and implementation of statistical methods using a statistical software package. Prerequisite: STAT 6337 or equivalent. (3-0) T

**STAT 6348** Applied Multivariate Analysis (3 semester credit hours) Statistical methods used in analysis of multivariate data. Topics include Hotelling's T test, the multivariate ANOVA, principal components analysis, factor analysis, cluster analysis, discriminant analysis, classification problems, graphics and visualization tools. Emphasis on computations with R or other software. Additional topics may be covered as time allows. Prerequisite: STAT 5352 or STAT 6331. Corequisite: STAT 6337. (3-0) T

**STAT 6365** Statistical Quality and Process Control (3 semester credit hours) Statistical methodology of monitoring, testing, and improving the quality of goods and services is developed at the intermediate level. Topics include control charts for variables and attributes, assessment of process stability and capability, construction and interpretation of CUSUM, moving average charts and V-masks, optimal sampling techniques, and evaluation of operating-characteristic curves and average time to detection. Prerequisite: STAT 5351 or equivalent. (3-0) T

**STAT 6390** Topics in Statistics - Level 6 (3 semester credit hours) Topics selected from but not limited to choices such as spatial statistics, nonparametric curve estimation, functional data analysis, statistical learning and data mining, actuarial science, sampling theory, statistical quality and process control, sequential analysis, survival analysis, longitudinal data analysis, categorical data analysis, and clinical trials, for example. May be repeated for credit as topics vary. (3-0) R

**STAT 6V98** Masters Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**STAT 6V99** Statistical Consulting (1-3 semester credit hours) Practical experience in collaboration with individuals who are working on problems which are amenable to statistical analysis. Problem formulation, statistical abstraction of the problem, and analysis of the data. May be repeated for credit. Only a maximum of three semester credit hours may be used to fulfill the master's degree. Instructor consent required. ([1-3]-0) T

**STAT 7330** Decision Theory and Bayesian Inference (3 semester credit hours) Statistical decision theory and Bayesian inference are developed at an intermediate mathematical level. Topics include utility theory; Bayesian estimation, hypothesis testing, and prediction; empirical and hierarchical Bayes rules; Bayesian robustness; admissibility; minimax decisions and introduction to game theory. Prerequisite: STAT 6331. (3-0) T


**STAT 7334** Nonparametric and Robust Statistical Methods (3 semester credit hours) Order statistics, ranks,

STAT 7338 Time Series Modeling and Filtering (3 semester credit hours) Theory of correlated observations observed sequentially in time. Stationary processes, Autocovariance function. ARMA models. Optimal forecasting in time domain and in frequency domain. Spectral representation. Estimation and model selection. Nonstationary time series models. Prerequisite: STAT 6331. (3-0) T

STAT 7345 Advanced Probability and Stochastic Processes (3 semester credit hours) Taught as a continuation of STAT 6344. Exponential probability inequalities. Large deviation theory. Martingales, sub- and supermartingales, random walk, Markov chains, Yule and Poisson processes, the general birth and death process, shot noise, branching processes, renewal processes, Brownian motion and diffusion, stationary processes, and the empirical process. Selected other topics. Prerequisite: STAT 6344. (3-0) T

STAT 7390 Topics in Statistics - Level 7 (3 semester credit hours) Topics selected from but not limited to choices such as spatial statistics, nonparametric curve estimation, functional data analysis, statistical learning and data mining, actuarial science, sampling theory, statistical quality and process control, sequential analysis, survival analysis, longitudinal data analysis, categorical data analysis, and clinical trials, for example. May be repeated for credit as topics vary. Instructor consent required. (3-0) T

STAT 8V02 Individual Instruction in Statistics (1-6 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) S

STAT 8V03 Advanced Topics in Statistics (1-6 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary. Instructor consent required. ([1-6]-0) R

STAT 8V07 Research in Statistics (1-9 semester credit hours) Open to students with advanced standing, subject to approval of the graduate advisor. Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S

STAT 8V99 Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S