Physics and Astronomy

General Information

The Department’s faculty members have a diversity of interests and are active in various experimental and theoretical research areas. Students successfully completing this program will obtain an understanding of basic physics concepts, mathematical and problem-solving skills needed to solve basic physics problems, experimental skills in physics, astrophysics, or biophysics, and the ability to analyze and interpret scientific data and write scientific papers or reports.

Degrees and Areas of Concentration

The Department of Physics and Astronomy offers superb course work leading to the following baccalaureate degrees:

- **B.A. in Physics**
- **B.S. in Physics with emphasis areas of**
  - Astrophysics
  - Engineering Physics
  - General Physics
  - Biophysics
- **B.A. or B.S. in Physics with Master’s Level Coursework for Secondary Teacher Certification**
- **B.S. in Secondary Education with Emphasis in Physics.**

The Department of Physics and Astronomy also offers the following graduate degree programs:

- **Master of Science in Physics**: The M.S. program combines a sound basis in the fundamental areas of classical and modern physics from both a theoretical and an applied perspective. The program is designed to enable students with undergraduate backgrounds in physics or other technical areas to further their professional development and maintain and improve their technical development. Students receiving a M.S. in physics will obtain an understanding of advanced physics concepts and mathematical and problem-solving skills needed to solve advanced physics problems. Students are strongly encouraged to be involved with faculty research programs that will develop experimental skills in physics, astrophysics, or biophysics as well as experience in analyzing and interpreting scientific data and the writing of scientific papers, reports, or theses. The writing of a thesis is optional.
- **Ph.D. in Physics**: The Ph.D. degree is offered in cooperation with the Missouri University of Science and Technology Physics Department. Students must satisfy the Missouri S&T admission standards, and the Missouri S&T Qualifying Exam in Physics is required of University of Missouri-St. Louis Ph.D. students. However, all course work and dissertation research may be completed while the student is in residence at UMSL. In addition to obtaining an understanding of advanced physics concepts and mathematical and problem-solving skills needed to solve advanced physics problems, Ph.D. students are expected to conduct independent scientific research in physics, astrophysics, or biophysics while learning to analyze and interpret scientific data and write scientific papers, reports, and a dissertation.

Fellowships and Scholarships

The Department of Physics and Astronomy offers a number of scholarships and awards.

- **Physics & Astronomy Alumni Scholarship** is available to new physics majors with outstanding ACT or SAT scores or continuing physics majors with outstanding academic records.
- **The Richard D. Schwartz Scholarship** is available to full-time junior/senior physics majors in good standing.
- **The Don C. and Susan P. Winter Endowed Scholarship** in Physics & Astronomy is available to physics majors with a minimum ACT score of 24 or who have a minimum GPA of 3.0.
- **The Pierre Laclede/Physics & Astronomy Alumni Scholarship** for undergraduate physics majors is available to physics majors who are also accepted into the Pierre Laclede Honors College.
- **The Junior Alumni Award** is awarded to physics majors who attain a 3.5 average or better in Physics 2111 and 2112. The award is given to the student in the semester they enroll in Physics 3200. Transfer students must take Physics 2112 on this campus to be eligible for this scholarship.
- **The Senior Alumni Award** is given to the outstanding physics major at the senior level with the highest GPA among the senior class.
- **The Jeffrey Earl Award** is given to an outstanding graduating senior every May.

Undergraduate Research Awards are available for undergraduate physics majors who conduct a research project with a faculty mentor. Students receiving this award are required to enroll for at least one credit hour of Physics 3390 and present their research results at the campus Undergraduate Research Symposium in April.

- **Teaching Assistantships** with stipends may also be available to qualifying students to prepare them for the independent effort required in industry or graduate school.
- **NASA Research Internships** for the summer and academic year are available for students interested in astrophysics through the NASA/Missouri Space Grant Consortium.

Departmental Honors

The Department of Physics & Astronomy will award departmental honors to those B.A. and B.S. degree candidates in Physics with an overall grade point average of 3.2 or better. They must also successfully complete at least 3 credits of PHYS 3390 (Research).

Career Outlook

Many of our students have been successful in subsequent graduate studies in astrophysics and meteorology, as well as physics. Our alumni have pursued graduate studies and earned doctorate degrees at institutions such as Cornell University, MIT, University of Wisconsin, University of Chicago and Washington University. Students who have elected for careers in industry are now working in a variety of settings for such firms as Emerson Electric, Hewlett Packard, IBM, Boeing and MEMC Electronic Materials (now SunEdison). Several former students are currently teaching physics in high schools around the St. Louis area.

Degrees

**Physics, Bachelor of Arts** ([http://bulletin.umsl.edu/programs/physics-ba/](http://bulletin.umsl.edu/programs/physics-ba/))

**Physics, Bachelor of Science**

Emphasis Areas:

- [Astrophysics](http://bulletin.umsl.edu/programs/physics-bs-astrophysics-emphasis/)
- [Engineering Physics](http://bulletin.umsl.edu/programs/physics-bs-engineering-physics-emphasis/)
• General Physics (http://bulletin.umsl.edu/programs/physics-bs/)
• Biophysics (http://bulletin.umsl.edu/programs/physics-bs-biophysics-emphasis/)

Physics, Master of Science (http://bulletin.umsl.edu/programs/physics-ms/)
Physics, Doctor of Philosophy (http://bulletin.umsl.edu/programs/physics-phd/)

Minor
Physics (http://bulletin.umsl.edu/programs/physics-minor/)

Other Affiliated Programs

Astronomy Courses

ASTRON 1001 Cosmic Evolution Introductory Astronomy (MOTR ASTR 100): 3 semester hours
This course presents an overview of astronomy from the planets to the Big Bang. Topics include the celestial motions, planets and the formation of the solar system, stars and stellar evolution, galaxies, and cosmology. Students will be introduced to the latest discoveries and how they affect our understanding of the universe.

ASTRON 1001A Cosmic Evolution/Introduction Astronomy (MOTR ASTR 100): 3 semester hours
Overview of astronomy, from the planets to the Big Bang. Topics include the celestial motions, planets and the formation of the solar system, stars and stellar evolution, galaxies, and cosmology. Students will be introduced to the latest discoveries and how they affect our understanding of the universe. Three classroom hours per week. Same as ASTRON 1001 without the laboratory.

ASTRON 1001L Introductory Astronomy Laboratory: 1 semester hour
Prerequisite: ASTRON 1001 (may be taken concurrently). An introductory Astronomy laboratory to accompany ASTRON 1001. The format is a 2-hour laboratory session per week to enhance lecture material.

ASTRON 1011 Planets and Life in the Universe: 3 semester hours
Man's concept of the solar system from Stonehenge to Einstein; geology and meteorology of the planets of our solar system, with particular attention to results from the space program; exobiology--study of the possibilities of life on other worlds and the best method of communicating with it. Three lecture hours per week.

ASTRON 1012 The Violent Universe and the New Astronomy: 3 semester hours
A nontechnical course focusing on recent results which larger telescopes and the space program have made available. Pulsars, x-ray stars, and black holes; radio astronomy, our galaxy, and interstellar molecules; exploding galaxies and quasars; origin of the expanding universe. Three lecture hours and one observing session per week.

ASTRON 1050 Introduction to Astronomy I (MOTR ASTR 100): 3 semester hours
Prerequisites: MATH 1030 and MATH 1035. A survey of the history of astronomy from the ancient times to present. Theories for the formation and evolution of the solar system and the general features of the solar system and planetary motions are discussed. The physical concept of gravity is presented. The detailed properties of the planets, comets, and asteroids are reviewed, concentrating on recent results from space missions.

ASTRON 1051 Introduction to Astronomy II: 3 semester hours
Prerequisites: MATH 1030 and MATH 1035. A survey of astronomy beyond the solar system. Topics include stars and stellar evolution, neutron stars, and black holes. The physical concept of light and the design of telescopes is discussed in detail. The structure of the Milky Way Galaxy and the large scale structure of the universe are explored. Dark matter, quasars, and active galactic nuclei are discussed in the context of theories for the formation and evolution of the universe. Course does not need to be taken in sequence with ASTRON 1050.

ASTRON 4301 Astrophysics: 3 semester hours
Prerequisite: PHYSICS 3231 or consent of instructor. A moderately technical introduction to astrophysics. Topics will include: physics of stellar interiors and atmospheres; interpretation of stellar spectra; stellar evolution; radio astronomy; and cosmology.

ASTRON 4322 Observational Astronomy: 4 semester hours
Prerequisite: ASTRON 1050, ASTRON 1051 and PHYSICS 3231. Tools of the astronomer: telescopes, spectroscopy, photoelectric photometry. Students will work on a number of projects which will enable them to develop expertise in obtaining, reducing, and analyzing astronomical observations. Student night observing will be an important part of the course. This course is primarily for persons who are astronomy or physics majors or who have some equivalent background.

ASTRON 5322 Intermediate Observational Astronomy: 4 semester hours
Prerequisites: ASTRON 1050, ASTRON 1051, and PHYSICS 3231; or graduate standing. This course covers the tools of the astronomer: telescopes, spectroscopy, photoelectric photometry. Students will work on a number of intermediate projects, which will enable them to develop expertise in obtaining, reducing, and analyzing astronomical observations. Student night observing will be an important part of this course. This course is primarily for astronomy or physics majors. Students may not receive credit for both ASTRON 4322 and ASTRON 5322.

Atmospheric Science Courses

ATM SCI 1001 Elementary Meteorology: 3 semester hours
Prerequisites: MATH 1020 or equivalent. This course covers atmospheric phenomena, weather, and climate. Topics include temperature, pressure, and moisture distributions in the atmosphere and dynamical effects such as radiation, stability, storms, and general circulation.

ATM SCI 1001L Elementary Meteorology Laboratory: 1 semester hour
Prerequisite: Must be concurrently enrolled in ATM SCI 1001. An introductory meteorology laboratory to accompany ATM SCI 1001. The lab exercises consist of current weather studies to enhance the material in ATM SCI 1001.
ATM SCI 1002 Earth Climate Studies: 3 semester hours
Prerequisite: MATH 1020 or equivalent. This course covers the physical foundations of the Earth’s climate system, scientific evidence for climate change and its causes, and the effects of climate change on the ecosystem of the Earth. This course satisfies the information literacy general education requirement.

Geology Courses
GEOL 1001 General Geology: 3 semester hours
This course looks at earth materials and processes, including geological aspects of the resource/energy problem.

GEOL 1001L General Geology Lab: 1 semester hour
This geology laboratory involves identification of common rocks and minerals.

GEOL 1002 Historical Geology: 3 semester hours
This course is a study of changes in geography, climate, and life through geological time. This study includes the origin of the continents, ocean basins, and mountains in the light of continental drift.

GEOL 1002L Historical Geology Lab: 1 semester hour
Prerequisites: GEOL 1002 (may be taken concurrently). This course is a Geology laboratory, which primarily involves the description and identification of fossils.

GEOL 1053 Oceanography (MOTR PHYS 110): 3 semester hours
The atmospheric and ocean circulations; the chemistry and geology of the deep sea; and their effects on the distribution of marine organisms.

Physics Courses
PHYSICS 1001 How Things Work (MOTR PHYS 100): 3 semester hours
Can baseball players hit home runs more easily when the weather is hot and humid? This course provides a practical introduction to understanding common life experiences by using physical intuition and basic ideas of physics. Powerful scientific principles are demonstrated through topics ranging from airplane wings to compact disk players, from lightning strikes to lasers.

PHYSICS 1011 Basic Physics I: 3 semester hours
Prerequisites: MATH 1030 and MATH 1035 required, MATH 1100 or MATH 1800 strongly recommended, concurrent enrollment in PHYSICS 1011L recommended. This course is specifically designed for students in health and life sciences covering the topics in classical mechanics such as kinematics, Newton's laws, energy, momentum and oscillations. This course will not fulfill the PHYSICS 2111 requirement for physics, chemistry, and engineering majors.

PHYSICS 1011L Basic Physics I Laboratory: 1 semester hour
Prerequisite: PHYSICS 1011 (may be taken concurrently). This laboratory course accompanies PHYSICS 1011, which is specifically designed for students in health and life sciences covering electricity, magnetism, light, optics and waves. This course will not fulfill the PHYSICS 2112 requirement for physics, chemistry, and engineering majors.

PHYSICS 1012 Basic Physics II: 3 semester hours
Prerequisites: PHYSICS 1011, concurrent enrollment in PHYSICS 1012L recommended. This continuation of PHYSICS 1011 is specifically designed for students in health and life sciences covering electricity, magnetism, light, optics and waves. This course will not fulfill the PHYSICS 2112 requirement for physics, chemistry, and engineering majors.

PHYSICS 1012L Basic Physics II Laboratory: 1 semester hour
Prerequisites: PHYSICS 1012 (may be taken concurrently). This laboratory course accompanies PHYSICS 1012, which is specifically designed for students in health and life sciences, covering electricity, magnetism, light, optics and waves.

PHYSICS 1099 Windows on Physics: 1 semester hour
A seminar designed to introduce physics majors to research areas in physics and physics-related fields in the Department of Physics and Astronomy. In addition to fundamental areas of physics, the areas of astrophysics, biophysics, materials science, and nanotechnology will be included. Career opportunities for students with physics degrees will be discussed and the physics curriculum will be reviewed. The course meets weekly and is required of all physics majors and minors who are transfer students.

PHYSICS 2010 Introduction to Inquiry Approaches to STEM Education (STEP I): 1 semester hour
Same as CHEM 2010, BIOL 2010, MATH 2010, and SEC ED 2010. Prerequisites: Concurrent enrollment BIOL 1821, BIOL 1831, CHEM 1111, CHEM 1121, PHYSICS 2111, PHYSICS 2112, MATH 1800, or MATH 1900 or have a declared STEM major. Students who want to explore teaching careers become familiar with lesson plan development by writing, teaching and observing lessons in a local school class. Students build and practice inquiry-based lesson design skills and become familiar with and practice classroom management in the school setting. As a result of the STEP I experiences students should be able to decide whether to continue to explore teaching as a career and ultimately finishing the remainder of the WE TEACH MO curriculum leading to teacher certification. The classroom observations and teaching represent a major field component and requires at least one two hour block of free time during the school day once a week.

PHYSICS 2011 Designing Inquiry-Based STEM Experiences (STEP II): 1 semester hour
Same as CHEM 2111, BIOL 2111, MATH 2111, and SEC ED 2111. Prerequisites: BIOL 2010, CHEM 2010, PHYSICS 2110, MATH 2010, or SEC ED 2010. Students explore teaching careers, become familiar with STEM school setting through observing and discussing the school environment and by developing and teaching inquiry-based lessons.

PHYSICS 2111 Physics: Mechanics and Heat: 4 semester hours
Prerequisites: MATH 1900 (may be taken concurrently). This course introduces students to the phenomena, concepts, and laws of mechanics and heat for physics majors and students in other departments. Three classroom hours and one hour discussion per week.

PHYSICS 2111L Mechanics and Heat Laboratory: 1 semester hour
Prerequisites: PHYSICS 2111 (may be taken concurrently). This laboratory course accompanies PHYSICS 2111, which covers the phenomena, concepts, and laws of mechanics and heat.

PHYSICS 2112 Physics: Electricity, Magnetism, and Optics: 4 semester hours
Prerequisites: PHYSICS 2111 and MATH 2000 (MATH 2000 may be taken concurrently). This course provides a phenomenological introduction to the concepts and laws of electricity and magnetism, electromagnetic waves, optics and electrical circuits for physics majors and students in other departments. Three hours of lecture and one hour of discussion per week.
PHYSICS 2112L Electricity, Magnetism, and Optics Laboratory: 1 semester hour
Prerequisites: PHYSICS 2112 (may be taken concurrently). This laboratory course accompanies PHYSICS 2112, which covers the phenomena, concepts and laws of electricity and magnetism, electromagnetic waves, optics and electrical circuits.

PHYSICS 3200 Mathematical Methods of Theoretical Physics: 3 semester hours
Prerequisites: PHYSICS 2112 and MATH 2000. Mathematical techniques specifically used in the study of mechanics, electricity, magnetism, and quantum physics are developed in the context of various physical problems. Course includes the topics of vector calculus, coordinate systems, the Laplace equation and its solutions, elementary Fourier analysis, & complex variables. Applications to electrostatics, mechanics, and fluid dynamics are emphasized. Three hours of lecture per week.

PHYSICS 3221 Mechanics: 3 semester hours
Prerequisites: PHYSICS 3200 and MATH 2020 (MATH 2020 may be taken concurrently). Advanced course covering single and many particle dynamics, rigid-body dynamics, and oscillations. Variational principles and Hamiltonian formulations of mechanics are covered. Three hours of lecture per week.

PHYSICS 3223 Electricity and Magnetism: 3 semester hours
Prerequisites: PHYSICS 3200 and MATH 2020 (MATH 2020 may be taken concurrently). Advanced course covering the rigorous development, from basic laws, of Maxwell's equations for electromagnetic fields along with applications of these equations. Topics covered are electrostatics and electrodynamics including currents, magnetic fields, motion of charged particles in fields and an introduction to electromagnetic waves. Three hours of lecture per week.

PHYSICS 3231 Introduction to Modern Physics I: 3 semester hours
Prerequisites: PHYSICS 2111, PHYSICS 2112, and MATH 2020 (MATH 2020 may be taken concurrently). Advanced course covering single and many particle dynamics, rigid-body dynamics, and oscillations. Variational principles and Hamiltonian formulations of mechanics are covered. Three hours of lecture per week.

PHYSICS 3281 Directed Readings in Physics: 1-5 semester hours
Prerequisite: Consent of instructor. An independent study of special topics in physics. A paper may be required on an approved topic. Topics must be substantially different. Hours arranged.

PHYSICS 3390 Research: 1-10 semester hours
Prerequisite: Consent of department. Independent physics research projects arranged between student and instructor. Hours arranged.

PHYSICS 4304 Introduction to Nanotechnology: 3 semester hours
Prerequisites: PHYSICS 3231. This course presents a broad overview of the field of nanotechnology with an emphasis on physical phenomena involved with three main parts: Nanoscale Fabrication and Characterization (nano-lithography, self-assembly and self-organization, scanning probe microscopes); Nanomaterials and Nanostructures (low-dimensional materials, graphene, carbon nanotubes, quantum dots, nano-composites, etc); Select Applications (nanoscale and molecular electronics, nano-magnetism, nano-photronics, bio-inspired nanomaterials). The goal is to lay a foundation for a research career in the rapidly growing area of nanotechnology and to enhance student's competitiveness in the job market.

PHYSICS 4305 Bayesian Data Analysis for the Sciences: 3 semester hours
Prerequisites: Consent of instructor. This is a cross-disciplinary course in two parts. Part one covers Bayesian inference as applied to data analysis in general, with a special focus on the mathematics of model-selection in the physical and life sciences. Part two concentrates specifically on the Bayesian use of log-probability (i.e. information) measures to track order-disorder transitions in thermodynamics, and to track the evolution of subsystem correlations (via both digital and analog means) in a wide variety of complex systems. Expect weekly empirical observation exercises, and opportunities for asynchronous as well as synchronous collaboration.

PHYSICS 4306 Nanoscience Practicals: 1-3 semester hours
Studies of Nanoscience characterization, synthesis, modeling techniques designed for clients of these tools, as well as for technical users interested in a current overview. Course consists of a set of 1/3 semester modules. Check with the instructor on more specialized modules, (e.g, on materials microscopy), if interested. Each module will cover instrumentation, current applications, weaknesses, and will involve lab visits for hands-on experience, weekly web interaction and classroom hours.

PHYSICS 4310 Modern Electronics: 3 semester hours
Prerequisite: PHYSICS 2112. This course is an integrated recitation/laboratory study of modern analog and digital electronics with emphasis on integrated circuits, which consist of active and passive electrical circuit elements integrated on a single semiconductor substrate. This course includes the study of the properties of the various specialized electronic devices that are constructed with integrated circuits along with a study of the various circuit elements. This course has four contact hours of lecture/laboratory per week.

PHYSICS 4311 Advanced Physics Laboratory I: 3 semester hours
Prerequisite: Advanced standing with at least nine completed hours of Physics at or above the 3000 level. Physics majors are introduced to the experimental techniques used in research. A student will choose and do several special problems during the semester. Six hours laboratory per week.

PHYSICS 4323 Modern Optics: 3 semester hours
Prerequisite: PHYSICS 3223. A study of modern optics including diffraction theory, polarization, light propagation in solids, quantum optics, and coherence.

PHYSICS 4331 Intro to Quantum Mechanics: 3 semester hours
Prerequisites: PHYSICS 3200 and PHYSICS 3231. Photons and the wave nature of particles; wave mechanics, Schroedinger equation, with applications to atomic physics; and radiation; the physics of solids; elementary particles; special relativity; health physics. Three hours of lecture per week.

PHYSICS 4341 Thermal and Statistical Physics: 3 semester hours
Prerequisites: MATH 2000 and PHYSICS 3231. Introduction to statistical mechanics, classical thermodynamics, and kinetic theory.

PHYSICS 4343 Selected Topics in Physics I: 3 semester hours
Prerequisites: PHYSICS 3221, PHYSICS 3223, PHYSICS 3231, PHYSICS 3234. Topics include special phenomena for research areas such as physics of waves, biophysics, nonlinear physics, geophysical fluid dynamics and the atmospheric sciences treated by methods of advanced mechanics, electromagnetism, statistical mechanics, thermodynamics and quantum mechanics. Three hours of lecture per week.
**PHYSICS 4347 Introduction to Biophysics: 3 semester hours**
Prerequisites: PHYSICS 3231, BIOL 1821, and BIOL 1831; or permission of instructor. This course is an introduction to the application of physical principles to problems in biology. The course may cover topics such as molecular biophysics (e.g., ion transport, protein folding, molecular motors), collective dynamics and self-assembly of biological systems, nonlinear dynamics and electrophysiology in the heart and brain, and physics-based approaches to modeling gene networks and evolutionary dynamics. Students will complete a final project investigating a particular area of biophysics. Students may not receive credit for both PHYSICS 4347 and PHYSICS 5347.

**PHYSICS 4350 Computational Physics: 3 semester hours**
Prerequisites: PHYSICS 3221, PHYSICS 3223, PHYSICS 4331 and MATH 2450. This course explains how to solve physics-based problems using computational techniques. Mechanics, electrodynamics, and quantum physics problems are solved by (1) numerically solving ordinary and partial differential equations, (2) using Fourier analysis, and (3) solving eigenvalue problems.

**PHYSICS 4351 Elementary Solid State Physics: 3 semester hours**
Prerequisites: PHYSICS 4331. Theoretical and experimental aspects of solid state physics, including one-dimensional band theory of solids; electron emission from metals and semiconductors; electrical and thermal conductivity of solids.

**PHYSICS 4353 Physics of Fluids: 3 semester hours**
Prerequisites: PHYSICS 3221, PHYSICS 3223, and PHYSICS 4341, or consent of instructor. Dynamical theory of gases and liquids. Course covers the mathematical development of physical fluid dynamics with contemporary applications.

**PHYSICS 4358 Introduction to Global Geodynamics: 3 semester hours**
Prerequisites: PHYSICS 3221 and PHYSICS 3223. This advanced course covers the development, from basic laws, of equations describing the many geodynamic processes underpinning geological modeling and geological data. Topics covered are paleomagnetism, plate tectonics, viscoelastic media, heat transfer, gravity, fluid mechanics, rheology, faulting, and geochronology.

**PHYSICS 4370 Relativity and Cosmology: 3 semester hours**
Prerequisites: PHYSICS 3221, PHYSICS 3223 and PHYSICS 3231. An introduction to Einstein's general theory of relativity. Topics will include special relativity in the formalism of Minkowski's four dimensional spacetime, Principle of Equivalence, metric description of curved space, geodesic equation, Einstein Field Equation, black holes, and cosmology.

**PHYSICS 4381 Directed Readings in Physics: 1-10 semester hours**
Prerequisite: Consent of instructor. An independent study of special topics in physics for senior undergraduates or graduate students.

**PHYSICS 5306 Advanced Nanoscience Practicals: 1-3 semester hours**
Prerequisites: Graduate standing in physics or consent of instructor. Advanced studies of Nanoscience characterization, synthesis, and modeling techniques designed for clients of these tools, as well as for technical users interested in a current overview. The course consists of a set of 1/3 semester modules. Check with the instructor on more specialized modules, (e.g. on materials microscopy), if interested. Each module will cover instrumentation, current applications, and weaknesses and will involve lab visits for hands-on experience, weekly web interaction and classroom hours.

**PHYSICS 5345 Nonlinear Dynamics and Stochastic Processes: 3 semester hours**
Prerequisites: PHYSICS 3221 and PHYSICS 4341 and consent of instructor. Dynamical systems; theory of oscillations; introduction to bifurcation theory and chaos in dissipative systems with applications in physics and biology; introduction to stochastic processes with applications in physics, chemistry and biology; dynamics of nonlinear systems perturbed by noise; noise-induced phase transitions; linear and nonlinear time series analysis. Three classroom hours per week.

**PHYSICS 5347 Intermediate Biophysics: 3 semester hours**
Prerequisites: Graduate standing, PHYSICS 3231, BIOL 1821 and BIOL 1831 or permission of instructor. This course is applied physical principles to problems in biology. Topics may include molecular biophysics (e.g., ion transport, protein folding, molecular motors), collective dynamics and self-assembly of biological systems, nonlinear dynamics and electrophysiology in the heart and brain, and physics-based approaches to modeling gene networks and evolutionary dynamics. Students will complete a final project investigating a particular area of biophysics. Students will be expected to design projects containing a significant component of original research. Students may not receive credit for both PHYSICS 4347 and PHYSICS 5347.

**PHYSICS 5350 Intermediate Computational Physics: 3 semester hours**
Prerequisites: PHYSICS 3221, PHYSICS 3223, PHYSICS 4331 and MATH 2450; or graduate standing. This course explains how to solve physics-based, intermediate-level problems using computational techniques. Mechanics, electrodynamics, and quantum physics problems are solved by (1) numerically solving ordinary and partial differential equations, (2) using Fourier analysis, and (3) solving eigenvalue problems. Students may not receive credit for both PHYSICS 4350 and PHYSICS 5350.

**PHYSICS 5353 Intermediate Physics of Fluids: 3 semester hours**
Prerequisites: PHYSICS 3221, PHYSICS 3223, and PHYSICS 4341; or graduate standing. This course covers intermediate level dynamical theory of gases and liquids. This course examines mathematical fluid dynamics along with some contemporary applications. Students may not receive credit for both PHYSICS 4353 and PHYSICS 5353.

**PHYSICS 5357 Fundamental Particles and Forces: 3 semester hours**
Prerequisites: PHYSICS 3223, PHYSICS 3231, and PHYSICS 4331, may be taken concurrently Introduction to nuclear and particle physics. Nuclear phenomenology and models; high energy particle accelerators and detectors; phenomenology of strong, electromagnetic and weak interactions; symmetry principles; quark compositions of strongly interacting baryons and mesons; gauge theories and the standard model of particle interactions; grand unification.

**PHYSICS 5358 Intermediate Global Geodynamics: 3 semester hours**
Prerequisites: Graduate standing, PHYSICS 3221 and PHYSICS 3223 or permission of the Instructor. This course intermediate course covers the development of equations describing the many geodynamic processes underpinning geological modeling and geological data. Topics covered may include paleomagnetism, plate tectonics, viscoelastic media, heat transfer, gravity, fluid mechanics, rheology, faulting, and geochronology. Students will complete a final project investigating a particular area of geodynamics. Students will be expected to develop a more advanced project. Students may not receive credit for both PHYSICS 4358 and PHYSICS 5358.
PHYSICS 5370 Intermediate Relativity and Cosmology: 3 semester hours
Prerequisites: PHYSICS 3221, PHYSICS 3223, and PHYSICS 3231; or graduate standing. Topics will include special relativity in the formalism of Minkowski's four dimensional space-time, Principle of Equivalence, geodesic equation, Einstein Field Equation, black holes, and cosmology. Differential geometry from metric description to Riemann curvature tensor will be studied.

PHYSICS 5402 Introduction to Mathematical Physics: 3 semester hours
Prerequisites: Graduate standing in physics or consent of instructor. A course covering mathematical techniques as applied in advanced theoretical physics including generalized vector spaces and their dual spaces, linear operators and functionals, generalized functions, spectral decomposition of operators, tensor analysis, and complex variables. Three hours of lecture per week.

PHYSICS 5403 Principles of Mathematical Physics: 3 semester hours
Prerequisites: Graduate standing in physics or consent of instructor. Boundary value problems; Sturm-Liouville theory and orthogonal functions; Green's function techniques; and introduction to group theory with emphasis on representations of Lie Algebras. Three hours of lecture per week.

PHYSICS 6300 Master's Thesis: 3 semester hours
Prerequisite: Consent of instructor. Thesis work under the supervision of a faculty member. The course is designed for those students intending to present a thesis as part of their M.S. program. Students who do not write a thesis cannot apply PHYSICS 6300 to a degree. This course transfers to the Cooperative Ph.D. program as three research credits.

PHYSICS 6400 Special Problems: 1-5 semester hours
Must have faculty mentor and approval of Department Chairperson. A study of special topics in physics for graduate students.

PHYSICS 6401 Special Topics: 1-4 semester hours
Prerequisite: Consent of instructor. This course is designed to give the department an opportunity to test a new course.

PHYSICS 6409 Theoretical Mechanics I: 3 semester hours
Prerequisite: PHYSICS 3221. Classical mechanics, methods of Newton, Lagrange, and Hamilton applied to motion of particles and rigid bodies, elasticity, hydrodynamics.

PHYSICS 6410 Seminar: 1-3 semester hours
Prerequisite: Approval of Department Chair. Discussion of current topics.

PHYSICS 6411 Electrodynamics I: 3 semester hours
Prerequisite: PHYSICS 3223. A rigorous development of the fundamentals of electromagnetic fields and waves. Electrostatics, magnetostatics, Maxwell's equations, Green's functions, boundary value problems, multipoles, conservation laws.

PHYSICS 6413 Statistical Mechanics: 3 semester hours
Prerequisite: PHYSICS 4331, PHYSICS 4341. A study of statistical ensembles; Maxwell-Boltzmann, Fermi-Dirac and Einstein-Bose distribution laws, application to some physical systems.

PHYSICS 6423 Electrodynamics II: 3 semester hours

PHYSICS 6461 Quantum Mechanics I: 3 semester hours
Prerequisite: PHYSICS 4331. A study of the Schroedinger wave equation, operators and matrices, perturbation theory, collision and scattering problems.

PHYSICS 6463 Quantum Mechanics II: 3 semester hours
Prerequisite: PHYSICS 6461. Continuation of PHYSICS 6461. To include such topics as Pauli Spin-Operator Theory, classification of atomic states, introduction to field quantization, and Dirac Electron Theory.

PHYSICS 6481 Physics of Solid State: 3 semester hours
Prerequisite: PHYSICS 6461. Crystal symmetry, point and space groups, lattice vibrations, phonons, one-electron model, Hartee-Fock approximation, elementary energy band theory, transport properties, the Boltzmann equation, introduction to superconductivity, semiconductors and magnetism.

PHYSICS 6490 Research: 1-10 semester hours
Prerequisite: Must have a faculty mentor and approval of the department chair. Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

PHYSICS 6495 Continuous Registration: 1-6 semester hours
Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy.