Physics

Physics is devoted to the discovery and exploration of the most basic physical laws governing our material universe. The working physicist attempts to express these laws in their most elegant mathematical form, so that they can be applied to predict the behavior of all forms of matter and energy, in physical systems that range from the subatomic level of quarks, gluons, nuclei, and atoms, all the way out to the astrophysical level of planets, stars, black holes, galaxies, and larger scale structures of the universe. The knowledge obtained in various experimental and theoretical investigations of physical phenomena forms the foundation for many modern technologies. For example there are lasers used in high-speed communications and micro-surgery, the plastic electronics used in modern computer displays, the magnetic behavior of the thin films used for computer hard drives, and the radiation detectors and optical elements used in the Hubble space telescope. The fundamental knowledge gained by physicists helps to shape and improve the quality of modern life.

The Missouri S&T physics department is dedicated to providing opportunities for undergraduates to participate in cutting-edge, nationally funded scientific research programs supervised by department faculty. Topics currently being investigated by Missouri S&T undergraduates include collisions between electrons, atoms, and ions; the magnetic properties of nanoscale thin films and other highly magnetic materials; transparent conducting oxides; photonic materials; quantum phase transitions; and atmospheric changes induced by manmade pollutants, such as those found in acid rain or in the exhaust generated by high altitude aircraft and space vehicle launches.

The department encourages its undergraduates to get involved in the many research projects available, and many students who participate in research go on to present their work at research competitions throughout the state and at national scientific meetings. Missouri S&T physics students regularly win prizes for their research accomplishments in the annual Fuller competitions.

After receiving a solid foundation in the basic physics governing the behavior of matter, energy, and radiation, the undergraduate physics major is able to choose among many advanced level courses to satisfy their particular interests in various fields of modern physics. Courses available to upper level physics majors include optics, astrophysics, subatomic physics, general relativity, solid state physics, laser physics, chaos, and computational physics. The curriculum also includes advanced laboratory courses where students design and participate in original research with other physics majors. Many additional technical courses are available to Physics majors in applied areas of other disciplines, such as computer science, electrical engineering, and the biological sciences.

Your undergraduate program will cover a range of fundamental topics and will include substantial laboratory training. In addition, the program is designed with many electives that allow physics majors to tailor their undergraduate education to their own particular interests. As a physics major you will have the flexibility to develop a program that best suits your interest and needs. There are 50 credit hours in physics, 23 in mathematics, 9 in chemistry, and 3 in computer science. Also required are 24 credit hours in communication, humanities, and social sciences. The rest of the 128 required hours, 19 hours, are free electives that you select in consultation with your advisor.

Many physics majors choose to use their electives to study other technical areas, such as mathematics, computer science, or electrical engineering. Some students get dual bachelor's degrees, for example, with their second degree in computer science, chemistry, or mathematics. Because there is considerable overlap in degree requirements between physics and other technical and scientific disciplines, a dual degree usually requires no more than one extra semester of undergraduate study. The best curriculum for each student seeking a dual degree is determined in planning sessions with his or her advisor.

An undergraduate degree in physics provides opportunities for a wide range of careers. About two-thirds of our graduates go on to graduate school, many at some of the most prestigious first-tier schools in the country. In addition many of those who complete their physics education with a bachelor's degree have been very successful in finding exciting employment opportunities in today's high-tech industries. Missouri S&T physics graduates have gone on to lead and manage major research efforts at leading industrial companies, to be professors and chairmen at leading academic universities, and to work in areas ranging from law and medicine to ecophysics and astrophysics.

All interested or prospective students considering a career in physics are invited to visit the campus and tour our research laboratories and classrooms to obtain a better picture of the exciting opportunities available.

Bachelor of Science Physics

A minimum of 128 credit hours is required for a bachelor of science degree in physics and an average of at least two grade points per credit hour must be obtained. These requirements for the B.S. degree are in addition to credit received for algebra, trigonometry, and basic ROTC.

The physics curriculum requires twelve semester hours in humanities, exclusive of foreign language, and must include ENGLISH 1160 or ENGLISH 3560. A minimum of nine semester hours is required in social sciences, including either HISTORY 1300, HISTORY 1310, HISTORY 1200, or POL SCI 1200. Specific requirements for the bachelor degree are outlined in the sample program listed below.

**Freshman Year**

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Credits</th>
<th>Second Semester</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1310</td>
<td></td>
<td>CHEM 1320</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 1319</td>
<td>1</td>
<td>HISTORY 1200, or 1300, or 1310, or POL SCI 1200</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 1100</td>
<td>1</td>
<td>MATH 1221</td>
<td>5</td>
</tr>
<tr>
<td>ENGLISH 1210</td>
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<td>PHYSICS 1111 &amp; PHYSICS 1119</td>
<td>5</td>
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<tr>
<td>MATH 1200</td>
<td>5</td>
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<tr>
<td>PHYSICS 1101</td>
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<tr>
<td><strong>Total</strong></td>
<td>15</td>
<td><strong>Total</strong></td>
<td>16</td>
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**Sophomore Year**

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Credits</th>
<th>Second Semester</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>ENGLISH 1160</td>
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<td>MATH 3304</td>
<td>3</td>
</tr>
<tr>
<td>MATH 2222</td>
<td>4</td>
<td>PHYSICS 2311</td>
<td>3</td>
</tr>
<tr>
<td>PHYSICS 2111</td>
<td>5</td>
<td>PHYSICS 2129</td>
<td>3</td>
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</tbody>
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2016-2017
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Note:

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Electives, in addition to the math/stat electives and Physics electives, shall include six hours of social studies and nine hours of humanities, at least three of which must be literature and at least three of which must be at the 3000 level or above not including Special Problems courses (PHILOS 4345 recommended). 19 hours of free electives may be used to develop an emphasis area. 18 hours of elective credit shall be in courses at the 3000 level or above.

Six hours of mathematics or statistics beyond MATH 3304 are required. MATH 3108, MATH 5222, MATH 5325, or MATH 5351 are recommended.

In addition to the specific physics courses listed (PHYSICS 3311, PHYSICS 3201, PHYSICS 4311, PHYSICS 4211, PHYSICS 3119, PHYSICS 3129, and PHYSICS 4301) two other physics 3000 level or higher courses are required.

Alternatively COMP SCI 1971 and COMP SCI 1981; note that this will require one less credit hour than the option listed in the sample schedule.

Alternatively students may substitute Math 1214 for Math 1208. Note that this is one less credit hour than Math 1208.

Alternatively students may substitute Math 1215 for Math 1221. Note that this is one less credit hour than Math 1221.

Alternatively students may substitute Physics 1135 for the combination of Physics 1111 and 1119. Note that this is one less credit hour than Physics 1111/1119.

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The physics minor consists of PHYSICS 2305 or PHYSICS 2311 and 12 additional hours of physics courses at the 2000-level or above. The program will be designed to conform to the individual's interests and needs.

Aleksandr Chernatynskiy, Assistant Professor
PHD University of Louisville

Daniel Fischer, Assistant Professor
PHD Heidelberg University

Yew San Hor, Associate Professor
PHD Rutgers University
Ulrich Jentschura, Professor  
PHD Dresden University of Technology

Cihan Kurter, Assistant Professor  
PHD Illinois Institute of Technology

David Edward Lay, Lecturer  
MS University of Missouri-St. Louis

Don H Madison, Curators Professor  
PHD Florida State University

Ioulia Y. Medvedeva, Professor  
PHD Russian Academy of Science

James Musser, Assistant Teaching Professor  
PHD Texas A&M University

Paul E Parris, Professor  
PHD University of Rochester

Jerry L Peacher, Professor  
PHD Indiana University Bloomington

Joel Peacher, Lecturer  
MS University of Missouri-Rolla

Michael Schulz, Curators Professor  
PHD University of Heidelberg

John G Story, Associate Professor  
PHD University of Southern California

Steffen Thomas Vojta, Curators Distinguished Professor  
PHD Chemnitz University of Technology, Germany

Agnes Vojta, Associate Teaching Professor  
PHD Technical University Dresden

George D Waddill, Professor  
PHD Indiana University Bloomington

Gerald Wilemski, Professor  
PHD Yale University

Alexey Georgiyevich Yamilov, Associate Professor  
PHD The City University of New York

**PHYSICS 1001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**PHYSICS 1101 Introduction To Physics** (LEC 1.0)  
An introduction to the study of physics and its intellectual and professional opportunities. The student will be acquainted with the various areas of physics and with departmental and campus facilities useful to their future studies. Required of all freshman majors.

**PHYSICS 1111 General Physics I** (LEC 4.0)  
An introduction to the fundamental ideas of physics, including mechanics, heat, and sound. Prerequisite: Preceded by Math 1208 or Math 1214.  
PHYSICS 1111 - MOTR PHYS 150L: Physics I with Lab  
PHYSICS 1111 - MOTR PHYS 150: Physics I

**PHYSICS 1119 General Physics Laboratory** (LAB 1.0)  
Experiments related to topics studied in Physics 1111 and Physics 1145. Prerequisites: Preceded or accompanied by either Physics 1111 or Physics 1145.  
PHYSICS 1119 - MOTR PHYS 150L: Physics I with Lab

**PHYSICS 1135 Engineering Physics I** (LAB 1.0 and RSD 1.5 and LEC 1.5)  
An introduction to mechanics, with an emphasis on topics needed by engineering students, including kinematics, dynamics, statics, and energetics. Prerequisite: Math 1208 or 1214.  
PHYSICS 1135 - MOTR PHYS 200L: Advanced Physics I with Lab

**PHYSICS 1145 College Physics I** (LEC 3.0)  
An introduction to the ideas of physics, including mechanics, heat, and sound. Prerequisites: Math 1160 and either of Math 1120 or Math 1140.  
PHYSICS 1145 - MOTR PHYS 150L: Physics I with Lab  
PHYSICS 1145 - MOTR PHYS 150: Physics I

**PHYSICS 1505 Introductory Astronomy** (LEC 3.0)  
An introductory course in basic astronomy designed primarily for students other than those in science and engineering. Topics include history, the sky, the solar system, stars, stellar evolution, galaxies and the origin and evolution of the universe. Credit will not be given for both Physics 1505 and Physics 1515.  
PHYSICS 1505 - MOTR ASTR 100L: Astronomy with Lab  
PHYSICS 1505 - MOTR ASTR 100: Astronomy

**PHYSICS 1509 Astronomy Laboratory** (LAB 1.0)  
A science laboratory course in which the student analyzes and interprets astronomical data and makes observations with a telescope. Prerequisite: Preceded or accompanied by Physics 1505 or 1515.  
PHYSICS 1509 - MOTR ASTR 100L: Astronomy with Lab

**PHYSICS 1605 Environmental Physics I** (LEC 3.0)  
A course for non-science majors which will consider, without mathematics, the production of energy and the environmental consequences of its use, and the physical problems associated with pollution.

**PHYSICS 1609 Laboratory For Environmental Physics** (LAB 1.0)  
A laboratory course to accompany the Environmental Physics lecture course as an option. A set of experiments will be performed related to environmental impacts studied in Environmental Physics 1605. To be taken simultaneously with Environmental Physics 1605. Prerequisite: Corequisite Physics 1605.

**PHYSICS 2001 Special Topics** (IND 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**PHYSICS 2111 General Physics II** (LEC 4.0)  
An introduction to the fundamental ideas of physics including electricity, magnetism, and light. Prerequisites: Preceded by Physics 1111 or Physics 1135 and preceded or accompanied by Math 1221 or Math 1215.
PHYSICS 2119 General Physics Laboratory (LAB 1.0)
Experiments related to topics studied in Physics 2111 and Physics 2145. Prerequisite: Preceded or accompanied by either Physics 2111 or Physics 2145.

PHYSICS 2129 Intermediate Physics Laboratory (LAB 2.0 and LEC 1.0)
A laboratory study of the principles of instrumentation used in all modern branches of physics. Analog and digital methods of data gathering are surveyed. Laboratory practice evolves from elementary operations to the design and assembly of a simple instrument.

PHYSICS 2135 Engineering Physics II (LEC 1.5 and RSD 1.5 and LAB 1.0)
An introduction to electricity, magnetism, and light, with emphasis on topics needed by engineering students. Prerequisites: Physics 1135 or Physics 1111, Math 1221 or Math 1215.

PHYSICS 2145 College Physics II (LEC 3.0)
An introduction to the ideas of physics, including electricity, magnetism, and light. Prerequisites: Math 1160, Physics 1145.

PHYSICS 2305 Introduction To Modern Physics (LEC 3.0)
An elementary survey of the modern concepts in physics and their applications; relativity, quantum mechanics, atomic physics, solid state physics, nuclear and particle physics. Prerequisites: Math 2222 and Physics 2135 or 2111.

PHYSICS 2311 Modern Physics I (LEC 3.0)
An introduction to quantum mechanics, atomic physics, and solid state physics. Topics include historically important experiments and interpretations. Prerequisites: Physics 2135 or 2111, preceded or accompanied by Math 3304 or 3329.

PHYSICS 2401 Introduction To Theoretical Physics (LEC 3.0)
Fundamental physical concepts are elaborated in mathematical terms emphasizing the coherence and economy of Physics. Topics include elementary vector analysis, introduction to physical mechanics (motion of a point mass, conservation laws, relativity), Fourier series, and introduction to partial differential equations. Prerequisites: Math 3304 corequisite; Physics 2135 or 2111.

PHYSICS 3000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

PHYSICS 3001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

PHYSICS 3119 Advanced Physics Laboratory I (LAB 3.0)
A laboratory study of the principles of basic experiments in all major branches of physics. The experiments stress design of apparatus, and procedures and analysis in projects involving electronic, optical, mechanical, and vacuum techniques. Prerequisite: Physics 2129.

PHYSICS 3129 Advanced Physics Laboratory II (LAB 3.0)
A senior laboratory involving experimental design. The student must specify his objectives, assemble apparatus, take measurements, analyze the results, form conclusions, write a report, and deliver an oral presentation of the results. Prerequisite: Physics 2129.

PHYSICS 3201 Physical Mechanics (LEC 3.0)
This course covers topics of rigid body motion in three dimensions, moving coordinate frames, two body collisions, conservation laws, small oscillations, generalized coordinates, and LaGrange's and Hamilton's equations. Prerequisite: Physics 2401.

PHYSICS 3201H Physical Mechanics-H (LEC 3.0)
A study of electric and magnetic fields, leading to Maxwell's equations. Topics covered include the electrostatic field, the electric potential, and the electrostatic field in matter. Prerequisite: Physics 2401.

PHYSICS 3311 Modern Physics II (LEC 3.0)
A continuation of Physics 2311. An introduction to nuclear and particle physics. Topics include nuclear models, decays, and reactions, and elementary particles and fundamental forces. Prerequisites: Math 3304 or 3329, and either Physics 2305 with consent of instructor or Physics 2311.

PHYSICS 4001 Special Topics (LEC 3.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

PHYSICS 4099 Undergraduate Research (IND 0.0-6.0)
This course is designed for the undergraduate student who wishes to engage in research. It is not to be used for graduate credit nor for more than six credit hours of undergraduate credit. The subject and credit are to be arranged with the instructor.

PHYSICS 4203 Introduction To General Relativity (LEC 3.0)
An introduction to the theory of general relativity. Topics covered include the formalism of general relativity, Einstein's gravitational field equations, the Schwarzschild solution, black holes, and cosmological models of the universe. Prerequisite: Physics 2401.

PHYSICS 4211 Electricity And Magnetism II (LEC 3.0)
A continuation of Physics 3211. Topics covered include the magnetostatic field, the magnetic vector potential, the magnetostatic field in matter, electrodynamics, and electromagnetic waves. Prerequisite: Physics 3211.

PHYSICS 4301 Introduction To Quantum Mechanics (LEC 3.0)
The fundamental concepts, postulates and methods of quantum mechanics and their applications to physical systems. Topics include solutions of the Schrodinger equation for simple systems and operator methods. Prerequisites: Physics 2305 or 2311, 2401.
**PHYSICS 4311 Thermal Physics** (LEC 3.0)
A study of the equilibrium states of matter as governed by the first and second laws of thermodynamics. Emphasis is placed on the microscopic approach with an introduction to statistical mechanics. Topics include the kinetic theory of (uniform) gases, phase equilibria in pure systems, and an introduction to quantum statistics. Prerequisite: Physics 2305 or 2311.

**PHYSICS 4323 Elementary Solid State Physics** (LEC 3.0)
An introductory study of the structure and physical properties of crystalline solids. Included are topics in crystal structure, x-ray diffraction, crystal binding, thermal properties of solids, free electron theory and elementary energy band theory. Prerequisites: Math 3304 and Physics 2305 or 2311.

**PHYSICS 4503 Classical Optics** (LEC 3.0)
Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 2222 and Physics 2135 or 2111. (Co-listed with Elec Eng 5200).

**PHYSICS 4513 Laser Physics** (LEC 3.0)
The generation of coherent radiation by lasers and the interaction of laser radiation with matter. Topics include stimulated emission, population inversion, optical cavities, optical gain, properties of laser media and other applications. Prerequisite: Physics 2305 or 2311.

**PHYSICS 4523 Principles Of Engineering Materials** (LEC 3.0)
Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Met Eng 5810, Cer Eng 5810).

**PHYSICS 4533 Transport in Nanostructures: An Introduction** (LEC 3.0)
The course overviews how wave interference, energy quantization and tunneling phenomena influence the wave (electron and light) transport in modern nanostructured materials and devices such as quantum dots, quantum wells, quantum wires, and photonic crystals. Prerequisite: Physics 2305 or 2311.

**PHYSICS 4543 Plasma Physics I** (LEC 3.0)
Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Aero Eng 5570, Mech Eng 5570, Nuc Eng 4370).

**PHYSICS 4553 Astrophysics** (LEC 3.0)
The structure, physical characteristics and evolution of stars, binary systems, nebulae and galaxies. Prerequisite: Physics 2305.

**PHYSICS 4563 Astrophysical Concepts** (LEC 3.0)
A comprehensive course in modern astrophysics. Topics include: Earth and sky, planetary science, stellar structure and evolution, galaxies, and structure and evolution of the universe. The course includes hands-on computer simulation and telescope use. (For secondary teachers or Master of Science for Teachers candidates.) Prerequisite: Math 2222 or admission to the MST program.

**PHYSICS 4605 Physics For Elementary School Teachers** (LEC 2.0 and LAB 1.0)
A nonmathematical review of the fundamental ideas of physics, including mechanics, matter, energy, sound, electricity, magnetism, astronomy, and light. Emphasis is placed on the development of hands-on activities. (For elementary school teachers or Master of Science for Teachers candidates only).

**PHYSICS 4615 Physics For Secondary School Teachers** (LEC 3.0)
A review of the fundamental ideas of physics, including mechanics, matter, energy, sound, electricity, magnetism, and light with an emphasis on how mathematics can be used to help understand the underlying concepts. (For secondary teachers or Masters of Science Teachers candidates only) Prerequisites: Math 2222 and admission to the MST program.

**PHYSICS 4625 Science Education and Quantitative Literacy for Middle School Teachers** (LEC 3.0)
An integrated science-mathematics course for middle school teachers. Course covers selected science/mathematics topics/skills specified in Missouri standards for grades 5-7. Inquiry based methods of teaching these topics in an integrated manner will be emphasized. Prerequisite: Current enrollment in a Teacher Education Program or a full or part-time teacher in a K-12 school. (Co-listed with Stat 5904).

**PHYSICS 4635 Physics, Energy, and the Environment** (LEC 3.0)
Applications of physics to the environment, including energy, its conservation and transformation, environmental consequences of energy use; world energy resources; atmospheric physics; sources of air, water, and land pollution, and the role physics plays in controlling those resources. May not be used as a 3000- or 4000-level elective for a B.S. in Physics. Prerequisite: Admissions to the Master of Science for Teachers program.

**PHYSICS 5000 Special Problems** (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**PHYSICS 5001 Special Topics** (IND 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

**PHYSICS 5201 Classical Mechanics I** (LEC 3.0)
Methods of Newton, Lagrange, and Hamilton applied to the motion of particles and rigid bodies. Introduction to canonical transformations and Poisson brackets. Classical scattering and small oscillations. Prerequisites: Math 3304, Physics 3201.
PHYSICS 5211 Electrodynamics I (LEC 3.0)
A rigorous development of the fundamentals of electromagnetic fields and waves. Electrostatics, magnetostatics, Maxwell's equations—Green's function, boundary value problems, multipoles, conservation laws. Prerequisites: Physics 4211.

PHYSICS 5301 Quantum Mechanics I (LEC 3.0)
Basic formalism applied to selected problems. Schroedinger equation and one dimensional problems, Dirac notation, matrix mechanics, harmonic oscillator, angular momentum, hydrogen atom, variational methods, introduction to spin. Prerequisite: Physics 4301 or equivalent.

PHYSICS 5333 Subatomic Physics (LEC 3.0)
An introduction to elementary particles. Topics include particle properties, nuclear forces, particle interactions, the Standard Model for quarks and leptons, fundamental forces in gauge field theory models, and the role of elementary particle interactions in cosmology. Prerequisite: Physics 3311.

PHYSICS 5403 Computational Physics (LEC 3.0 and LAB 1.0)
An introduction to modern computer simulations for solving physics problems. The course will be project-oriented with examples including planetary motion, chaotic dynamics, quantum scattering, structure of atoms and clusters, molecular dynamics, and Monte-Carlo simulations. Prerequisites: Physics 2305 or Physics 2311; Math 3304; programming experience.

PHYSICS 5413 Chaos, Fractals, and Nonlinear Dynamics (LEC 3.0)
An introduction into nonlinear dynamics, deterministic chaos, and fractals. Topics covered include phase plane analysis, iterated maps, routes to chaos, Lyapunov exponents, strange attractors and pattern formation with applications to chaotic vibrations, population dynamics, chemical oscillations and lasers. Prerequisites: Math 3304; Physics 2135 or Physics 2111.

PHYSICS 5503 Fourier Optics (LEC 3.0)
Applications of Fourier analysis and linear system theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both Elec Eng 3430 and Elec Eng 3600 or both Physics 2401 and Physics 4211 (Co-listed with ELEC ENG 5210).

PHYSICS 5513 Fiber And Integrated Optics (LEC 3.0)
Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: Elec Eng 3600 or Physics 4211. (Co-listed with Elec Eng 5220).

PHYSICS 5603 Advanced Physics Laboratory Teaching Methods (LEC 3.0)
Objectives, methods and problems related to teaching of introductory physics, with an emphasis on laboratory instruction, the development of educational laboratory experiments and techniques, student learning styles, student assessment, student work groups, computer-based data acquisition, and communication techniques. Prerequisite: Graduate standing.