Department of Physics, Astronomy and Geosciences

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Departmental Honors Program

The Department of Physics, Astronomy and Geosciences, under the direction of Towson University’s Honors Board, offers a departmental honors program for students who demonstrate exemplary abilities in their discipline. Such students will work closely with faculty mentors in an individual program of research, directed readings, independent study, and seminar. Departmental honors will be posted to the transcript shortly after the bachelor’s degree is conferred.

Criteria for Admission into the Department Honors Program

1. Completion of at least 60 units of courses.
2. Overall cumulative average of 3.25 or above and a 3.50 or above cumulative average in their major course requirements. Students below this threshold may appeal to the Department Honors Committee.

Contact the department for a list of detailed procedures for applying to the departmental honors program.

Department Activities and Awards

Research

Students are strongly encouraged to participate in research at TU or in summer research programs. Faculty advisers will assist students in finding a research project of interest. Undergraduate research and travel grants are awarded by TU and FCSM on a competitive basis to provide support for student research.

Internships

Majors are encouraged to participate in internship programs and receive academic credit. Internships may be undertaken in either the public or private sector. Internships must have a significant physics or geology component. At the completion of the internship, students are required to submit for evaluation a portfolio describing the work undertaken and give a public seminar. This portfolio and seminar will be evaluated by department faculty.

Student Organizations

Students in Physics, Astronomy, and Geosciences are encouraged to actively participate in the student based organizations within the department. These include the Geology Club, the Society of Physics Students, and the Secondary Education Club. For many of these organizations, students are permitted to join the national organization and to obtain publications, services at reduced rates, grants, and awards.

Departmental Awards

Departmental student awards are given annually for outstanding work in chemistry courses. These include:

- Edward L. Rubendall Physics Achievement Award - The awards were established in honor of Professor Emeritus Edward J. Rubendall by friends of the department. The awards are presented annually to outstanding junior and senior physics majors in the department.
- Geosciences Achievement Award - These awards are presented to two outstanding students in the Geosciences program. They must be of junior or senior standing.
- William F. Pelham Award - This award was established in honor of Professor Emeritus William F. Pelham by his friends at Towson University and in the greater Baltimore arts community. The award is presented to outstanding juniors in the department.
- Eddie Loh Graduate Scholarship - This award was established by Professor Emeritus Eddie Loh. It is given annually to two graduate students in the Masters in Applied Physics program.
- Eddie Loh Undergraduate Scholarship - This award was established by Professor Emeritus Eddie Loh. It is given annually to two undergraduate physics majors.
- American Mineralogist Undergraduate Award

- Major in Physics
  - General Physics Concentration
  - Applied Physics Concentration
  - Astrophysics Concentration
  - Computational Physics Concentration
- Major in Physics with Secondary Education Concentration
- Major in Earth-Space Science
- Major in Earth-Space Science with Secondary Education Concentration
- Major in Geology
- Accelerated B.S. in Physics and M.S. in Applied Physics
- B.S. in Physics and M.S. in Computer Science (individualized accelerated plan)
- Minor in Physics
- Minor in Astronomy
- Minor in Geology

Faculty

Professors: Rachel Burks, Phuoc Ha, Ronald Hermann, Rajeswari Kolagani (Graduate Program Director), Pamela Lottero-Perdue, Rommel Miranda, Joel Moore, James Overduin, Cody Sandifer, David Schaefer (Chairperson), Jennifer Scott, Jeffrey Simpson, Vera Smolyaninova

Associate Professors: Parviz Ghavamian, Thomas Krause, Wendy Nelson, Jia-An Yan

Assistant Professors: Michelle Casey, Peggy McNeal

Lecturers: Andrew Hawkins, Nicolas Kudsieh, Rajeh Mundle, Gary Pennington, Eriks Perkons, Christian Ready, Miguel Requena Torres
Astrophysics Courses

ASTR 161 THE SKY AND THE SOLAR SYSTEM (4)
A course for non-science majors covering observational astronomy, telescopes, Earth as a planet, the Moon, Solar System, Sun, general properties of stars. Development of enough algebra-based physics to understand these topics at a non-technical level. Three lecture hours and one two-hour laboratory period. Core: Biological & Physical Sciences.

ASTR 181 STARS, GALAXIES, AND THE EARLY UNIVERSE (4)
A course for non-science majors covering stellar evolution, galaxies, cosmology, and possibly other topics including life elsewhere in the universe. Emphasizes determination of the distance scale and modern trends in astronomy. Develop and use some algebra-based physics. Three lecture hours and one two-hour laboratory period. Students who have successfully completed ASTR 162 will not receive additional credit for ASTR 181. Prerequisite: high school algebra suggested. Core: Biological & Physical Sciences.

ASTR 261 INTRODUCTION TO ASTROPHYSICS (4)
Students will develop an understanding of the physical processes governing motions of celestial objects; the electromagnetic spectrum and the interaction of light and matter; star and planet formation and evolution; the extragalactic distance scale; and the early universe. Prerequisite: PHYS 211 or PHYS 241.

ASTR 301 COSMIC ORIGINS (3)
Origin and evolution of the universe, stars, and planets; the rise of life on Earth; social, technological and ethical issues raised by the scientific search for extraterrestrial life and its possible discovery on other worlds. Prerequisite: one Core 7 or Core 8 science course. Core: Ethical Issues & Perspectives.

ASTR 303 ASTROPHYSICAL TECHNIQUES (3)
Observational astronomy using the department's telescope and NASA archival data, emphasizing equipment operating principles, scientific methods, signal statistics, data reduction. Includes imaging and photometry with Charge-Coupled Devices in addition to spectroscopy, space observations, radio astronomy. Prerequisites: ASTR 161 and ASTR 162 and PHYS 212 (or PHYS 242 or PHYS 252). Lab/Class fee will be assessed.

ASTR 331 STELLAR ASTROPHYSICS (3)
Applications of physics in astronomy, spectroscopy, stellar interiors and evolution, the interstellar medium. Prerequisites: ASTR 261 or both ASTR 161 and ASTR 181; PHYS 242 or PHYS 252 (may be taken concurrently); PHYS 243 is recommended.

ASTR 371 PLANETARY ASTRONOMY (3)
A course for science majors and minors focusing on methods of scientific inquiry as well as specific topics. Planetary formation both around our Sun and around other stars, planetary interiors and surface processes, and atmospheres. Primitive surfaces, cratering, volcanism, tectonism, origin and evolution of planetary atmospheres. The course may include an observational segment (e.g., sketching the planets through a telescope) and field trips to local sites of geological interest. Prerequisites: ASTR 161 or GEOL 121 and PHYS 211 (or PHYS 241).

ASTR 385 ASTROPHYSICS SEMINAR (1)
Students learn to present technical material orally by attending and discussing presentations given by others and by giving presentations themselves on topics of current interest in astrophysics. Prerequisite: junior/senior standing as a Physics Major or Astronomy Minor.

ASTR 432 GALAXIES AND COSMOLOGY (3)
Stellar populations and the general properties of galaxies, including the Milky Way; galaxy formation and evolution; active galaxies; dark matter and dark energy; current topics in the study of the early universe; special and general relativity. Prerequisites: ASTR 162; PHYS 243; PHYS 311 may be taken concurrently.

ASTR 452 HIGH ENERGY ASTROPHYSICS (3)
An in-depth introduction to the physics of high energy phenomena in the universe, including emission from black holes, neutron stars, white dwarfs, supernova explosions/supernova remnants, active galactic nuclei and galaxy clusters. Introduction to high energy emission from these phenomena, including synchrotron radiation, Bremsstrahlung radiation and inverse Compton scattering. Prerequisites: PHYS 243 and PHYS 307 (required); ASTR 181 and PHYS 311 (recommended).

ASTR 470 SELECTED TOPICS IN CONTEMPORARY ASTROPHYSICS (3)
Special topics in the area of astrophysics. Special topics will be determined by current interests of the faculty and the needs of the curriculum. Special permission from the department is required. Prerequisites: ASTR 161 & ASTR 162.

ASTR 491 DIRECTED READINGS IN ASTROPHYSICS (1-4)
Directed readings required some advanced coursework in physics and/or astronomy. May be repeated for a maximum of six units. Prerequisites: At least junior status; one 300- or 400-level ASTR course; permission of instructor.

ASTR 495 CAPSTONE PROJECT IN ASTROPHYSICS (1-3)
Individual project in observational or theoretical astrophysics. May be completed over two semesters. Prerequisite: senior standing in Astrophysics Track or consent of instructor.

ASTR 496 RESEARCH PROBLEMS IN ASTROPHYSICS (1-3)
Individual projects in any branch of astrophysics, to be taken after a student has completed the Capstone Research course, ASTR 495. At the completion of a project, students must write a formal research paper on the work done. May be repeated for a maximum of six units. Prerequisite: permission of instructor who will direct the proposed work. Prerequisite: Permission of instructor.

ASTR 497 INDEPENDENT STUDY ASTR (1-3)
Individual and supervised examination of a topic in astronomy. Prerequisite: junior/senior standing and instructor consent.

ASTR 499 HONORS THESIS IN ASTRONOMY (1-4)
Writing of an honors thesis based on independent research done under the direction of a staff member. May be repeated for a maximum of 6 units. Prerequisites: Consent of instructor and open only to advanced honors candidates.

Geology Courses

GEOL 109 VOLCANOES AND EARTHQUAKES (3)
The geological origin, occurrence, and hazards of volcanoes and earthquakes. Plate tectonic theory, efforts at forecasting these events, and effects on human populations will be discussed. Core: Biological & Physical Sciences.
**GEOL 115 MARYLAND GEOLOGY IN THE FIELD (1)**
A field trip course open to any student, designed to introduce geology and geology-related career opportunities. Participation in a minimum of four field trips is required.

**GEOL 120 GEOLOGY OF NATIONAL PARKS (4)**
Uses an array of nationally preserved landscapes to explore introductory geology topics. Students will gain an understanding of how natural forces shape the world around them in the present, in the recent past (geologically speaking), and the more distant past. They will also gain an appreciation of landscapes that have for a variety of reasons been chosen by our society to be given a high level of preservation and protection. Not open to students who have completed GEOL 121 or GEOL 122. Core: Lab and Non-Lab Science.

**GEOL 121 PHYSICAL GEOLOGY (4)**
Composition and structure of the earth, the internal and external forces acting upon it, and the surface features resulting. Laboratory studies of common rocks and minerals, geologic and topographic maps, and aerial photographs. Field trips required. Three lecture hours and three laboratory hours per week. Prerequisite: GEOL 121. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

**GEOL 122 HONORS PHYSICAL GEOLOGY (4)**
Composition and structure of the earth, the internal and external forces acting upon it and the surface features resulting. Laboratory studies of common rocks and minerals, geologic and topographic maps and aerial photographs. Field trips required. Three lecture hours and three laboratory hours per week. Students who have successfully completed the non-honors version of this course will not receive additional credit for this course. Prerequisite: Honors College. Core: Biological & Physical Sciences and Science Lab. Lab/Class fee will be assessed.

**GEOL 123 HISTORICAL GEOLOGY (4)**
The history and development of the continents and ocean basins and the evolution of life on earth will be discussed based upon information obtained from the sedimentary rock record. Field trips required. Three lecture hours and three laboratory hours per week. Prerequisite: GEOL 121. Core: Biological & Physical Sciences and Science Lab. Lab/Class fee will be assessed.

**GEOL 301 SUSTAINABILITY AND THE USE OF NATURAL RESOURCES (3)**
Students will develop a scientific understanding of origin, use, and environmental impact of renewable and non-renewable natural resources. Examines the science behind the policies governing use and conservation of natural resources as well as the impacts associated with overuse of those resources. Topics will include exploration and development of both non-renewable and renewable energy resources and strategic mineral resources and the management and protection of water, air and soil. Prerequisite: GEOL 121.

**GEOL 305 ENVIRONMENTAL GEOLOGY (4)**
Earth's natural surface systems (hydrologic, atmospheric, and climatic): causes and extent of human modifications; effects and potential solutions to resulting problems. Introduction to standard field and laboratory methods in environmental geology. Field trips required. Three lecture hours and three lab hours. Prerequisite: GEOL 121. Lab/Class fee will be assessed.

**GEOL 321 STRUCTURAL GEOLOGY (4)**
The identification and analysis of tectonic forms to determine the physical conditions of formation and the context of historical geological events in which they occur. Field trips required. Three lecture hours and three laboratory hours. Prerequisites: GEOL 121 and PHYS 211 or equivalent. Lab/Class fee will be assessed.

**GEOL 331 MINERALOGY (4)**
The study of minerals with emphasis on crystallography, crystal chemistry, and chemical-structural classification. Laboratory identification of minerals in hand specimen, in thin section by application of principles of optical mineralogy, by chemical analysis, and by X-ray diffraction analysis. Three lecture hours and three laboratory hours. Prerequisites: GEOL 121 and CHEM 131/ CHEM 131L. Lab/Class fee will be assessed.

**GEOL 333 PETROLOGY OF IGNEOUS AND METAMORPHIC ROCKS (4)**
Study of the properties and genesis of two major rock groups. Megascopic and microscopic techniques in rock classification, Environments of formation. Case studies from the Maryland Piedmont. Field trips required. Three lecture hours and three laboratory hours. Prerequisite: GEOL 331. Lab/Class fee will be assessed.

**GEOL 357 PHYSICAL OCEANOGRAPHY (3)**
Physical, chemical, and geologic characteristics of ocean basins, boundaries, and sea water including origin and behavior of waves and currents. Prerequisites: PHYS 211 or PHYS 241 and CHEM 131/ CHEM 131L, or consent of the instructor.

**GEOL 410 METHODS FOR ENVIRONMENTAL GEOCHEMISTRY (4)**
Students will develop an understanding of fate, transport and cycling of geochemically important elements in the environment including natural and anthropogenic sources and their physical and chemical modes of transport in near surface environments. Students will learn basic geochemical and analytical methods applicable to investigations in soils and surface waters. Field trips required. Three lecture hours and three laboratory hours. Prerequisites: GEOL 121, CHEM 131, CHEM 132 or permission of the instructor. Lab/Class fee will be assessed.

**GEOL 415 HYDROGEOLOGY (4)**
Geologic aspects of groundwater: origin, occurrence, and movement. Field trips required. Three lecture hours and three laboratory hours. Prerequisites: CHEM 132/CHEM 132L (CHEM 111), PHYS 211 or PHYS 241. Lab/Class fee will be assessed.

**GEOL 421 TECTONICS (3)**
Motions and deformation of the earth on a regional to global scale; historical development of plate tectonic theory; case studies from the historic and current geological literature. Course pedagogy combines lecture and student-led discussions. Prerequisites: GEOL 121; GEOL 321; or consent of the instructor.

**GEOL 443 SEDIMENTOLOGY AND STRATIGRAPHY (4)**
Production, transport, and deposition of sediments and sedimentary bodies for the development of facies models useful in interpretation of the stratigraphic record. Three lecture hours and three laboratory hours. Field trips required. Prerequisites: GEOL 121, CHEM 131/CHEM 131L. Lab/Class fee will be assessed.

**GEOL 451 PETROLOGY OF SEDIMENTARY ROCKS (3)**
Macro-and microscopic analyses of sedimentary rocks. Classifications and diagenetic processes.
**PHYS 131 LIGHT AND COLOR (4)**

Some aspects of light and color and of vision will be examined on a factual and descriptive basis. Predominantly qualitative explorations will be made of the origin of light, of its wave and particular behavior, of the polarization of light, of lasers and holography, of the origin and physical basis of color and of the physics of vision. This course in liberal arts physics is offered for curious inquirers who have had minimal contact with physics. Three lecture hours and two laboratory hours. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

**PHYS 135 INTRODUCTION TO HOLOGRAPHY (4)**

Creative use of the holographic medium along with study of appropriate scientific principles and aesthetic values. Behavior of waves, including water, sound, and electromagnetic. Optics of lenses and mirrors. Lasers, holography, and experimental techniques of making holograms. Three lecture hours, two laboratory hours.

**PHYS 143 PHYSICS SOUND AND MUSIC (LAB) (4)**

Study of sound and its production by various instruments, including the human voice. Physical interpretations of concepts, such as noise, pitch, mechanical and acoustic waves and oscillations, loudness, harmonics and timbre, scales and temperament. Three lecture hours, two laboratory hours. Not open to students who have successfully completed PHYS 141. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

**PHYS 185 INTRODUCTORY HONORS SEMINAR IN PHYSICS (1)**

This seminar is intended for freshmen and sophomores who have demonstrated exceptional ability in the sciences and will involve them directly with current ideas and research in physics. Classical physics, quantum physics, relativity, and the new astronomy will be covered. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

**PHYS 202 GENERAL PHYSICS FOR THE HEALTH SCIENCES (5)**

Special emphasis on motion including kinematics and dynamics of linear and angular motion. Not intended for pre-medical, pre-dental or pre-physical therapy programs. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

**PHYS 203 TOPICS IN PHYSICS FOR BIOLOGY MAJORS (5)**

Topics may include mechanical and thermal properties of matter; forms of energy and conversion; optics; waves; electromagnetics. Students who may wish to seek advanced degrees in biology, dentistry, medicine, or related fields should enroll in PHYS 211 or PHYS 212 or PHYS 241, PHYS 242, PHYS 243.

**PHYS 205 PHYSICS FOR MIDDLE SCHOOL TEACHERS (3)**

Physics for middle school education majors, emphasizing development of principles from experiments and discussion. Topics include force and motion, energy, electricity, magnetism, and heat. Lab/Class fee will be assessed.

**PHYS 211 GENERAL PHYSICS I; NON CALCULUS-BASED (4)**

For Arts and Sciences, Biology and Geosciences majors: mechanics, heat, light, electricity, magnetism, and a brief introduction to modern physics. Three lecture units and one three-unit laboratory period. Prerequisite: MATH 115 or good standing in high school algebra and trigonometry. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.
PHYS 212 GENERAL PHYSICS II; NON CALCULUS-BASED (4)
For Arts and Sciences, Biology and Geosciences majors: mechanics, heat, light, electricity, magnetism, and a brief introduction to modern physics. Three lecture units and one three-unit laboratory period. Prerequisite: PHYS 211. Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

PHYS 220 ENGINEERING MECHANICS II (3)
Stress and deformation of solid-rods, beams, shafts, columns, tanks, and other structural, machine and vehicle members. Topics include stress transformation using Mohr’s circle; shear and moment diagrams; derivation of elastic curves; and Euler’s buckling formula. Prerequisite: PHYS 102. Core: Lab and Non-Lab Sciences.

PHYS 241 GENERAL PHYSICS I CALCULUS-BASED (4)
Calculus-based physics for science and engineering majors. Mechanics and the conservation laws, gravitation, simple harmonic motion. Prerequisite: MATH 273 (may be taken concurrently). Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

PHYS 242 GENERAL PHYSICS II CALCULUS-BASED (4)
Continuation of PHYS 241. Electricity, magnetism, DC and AC currents, geometric optics. Prerequisites: PHYS 241, MATH 274 (may be taken concurrently). Core: Biological & Physical Sciences. Lab/Class fee will be assessed.

PHYS 243 GENERAL PHYSICS III (4)
Special relativity, fluid kinematics and dynamics, waves, thermodynamics. Prerequisite: PHYS 242.

PHYS 251 HONORS GENERAL PHYSICS I CALCULUS-BASED (4)
Calculus based physics for science and engineering majors. Mechanics and the conservation laws, gravitation, simple harmonic motion, electricity, magnetism, DC and AC currents, geometric optics. Honors college course. Students who have successfully completed the non-honors version of this course will not receive additional credit for this course. Core: Biological & Physical Sciences.

PHYS 252 HONOR GENERAL PHYSICS II CALCULUS-BASED (4)
Continuation of PHYS 241. Electricity, magnetism, DC and AC currents, geometric optics. Prerequisites: PHYS 241, MATH 274 (may be taken concurrently). Students who have successfully completed the non-honors version of this course will not receive additional credit for this course. Core: Biological & Physical Sciences.

PHYS 270 COMPUTERS IN PHYSICS (4)
Introduction to hardware and software applications of computers in physics, including computer interfacing to experiments, computer aided design, LabView programming, data analysis, simulation and modeling techniques. Prerequisite: PHYS 241. Lab/Class fee will be assessed.

PHYS 295 RESEARCH PROBLEMS IN PHYSICS (1-3)
Individual project in any branch of physics. Students can choose either to work on projects or in areas suggested by physics faculty. At the completion of a project, the student must write a formal research paper on the work done. Repeatable for credit at different levels.

PHYS 296 RESEARCH PROBLEMS IN PHYSICS (1-3)
Individual project in any branch of physics. Students can choose either to work on projects or in areas suggested by physics faculty. At the completion of a project, the student must write a formal research paper on the work done. Repeatable for credit at different levels.

PHYS 307 INTRODUCTORY MATHEMATICAL PHYSICS (3)
Mathematical expressions for selected topics, such as forces and potentials, vector analysis, applications of Fourier series and complex variables, and solutions of the harmonic oscillator and wave equations.

PHYS 311 MODERN PHYSICS I (3)
A description of the the quantum theory, atomic structure, and spectra. Three lecture hours. Prerequisites: MATH 274, PHYS 242 or PHYS 252; or PHYS 212 with consent of instructor.

PHYS 312 MODERN PHYSICS II (3)
Required course for the Applied and General tracks of the Physics major. Applications of special relativity and quantum theory to the various disciplines in physics, including solid state, nuclear, elementary particles, and cosmology. Prerequisite: PHYS 311.

PHYS 335 BASIC ELECTRONICS (4)
Circuit components, characteristics of semi-conductors, electrical measurements, method of circuit analysis, electronic devices. Three lecture hours and one three-hour laboratory period. Lab/Class fee will be assessed.

PHYS 337 DIGITAL ELECTRONICS (4)
Subjects covered will be basic concepts of digital electronics such as gates, logic modules, truth tables, digital codes, sequential systems, semi-conductor memories, decade counters, etc. The laboratory program is designed to give students first hand experience on the material covered in lecture using integrated circuits and LED display systems. Two hours lecture, three hours laboratory. Lab/Class fee will be assessed.

PHYS 341 INTERMEDIATE PHYSICS LABORATORY I (3)
First Term: The measurement of several fundamental physical constants. Exploration of classical and modern research methods: lasers, holography, optical and nuclear spectroscopy. Second Term: Several advanced experiments, a research project. Familiarization with machine shop procedure, vacuum and other experimental techniques. Five laboratory units. Prerequisites: PHYS 270; PHYS 311 (may be taken concurrently). Lab/Class fee will be assessed.

PHYS 342 INTERMEDIATE PHYSICS LABORATORY II (3)
First Term: measurement of several fundamental physical constants. Exploration of classical and modern research methods: lasers, holography, optical and nuclear spectroscopy. Second Term: several advanced experiments, a research project. Familiarization with machine shop procedure, vacuum and other experimental techniques. Five laboratory hours. Lab/Class fee will be assessed.

PHYS 351 MECHANICS (4)
Systems of coordinates, kinematics, and transformations: Newtonian dynamics of particles and systems of particles; linear systems, oscillations, and series techniques; calculus of variations and the Lagrangian and Hamiltonian formulations; application of Lagrangians to gravitation/central force motion. Optional: non-linear oscillations.

PHYS 352 THERMODYNAMICS AND KINETIC THEORY (3)
Principles and laws of classical thermodynamics applied to simple irreversible processes, including chemical, elastic, electric and magnetic phenomena; thermodynamic functions and Maxwell’s relations; the conservation equations in elementary kinetic theory; fluctuations; and irreversible transfer effects. Three lecture hours. Prerequisites: PHYS 212 or PHYS 243, MATH 274 (may be taken concurrently with PHYS 243 or by permission).
PHYS 354 ELECTRICITY & MAGNETISM (4)
Electrostatics, magnetostatics and electromagnetic radiation, including Divergence Theorem and Stokes' Theorem, electrostatics in free space and dielectric materials, the Biot-Savart Law, the magnetic vector potential, inductance and electromotance, magnetic materials, Maxwell's Equation in free space and in materials, boundary value problems (Snell's and Fresnel's Law). Prerequisites: PHYS 243; PHYS 307 or consent of instructor.

PHYS 361 OPTICS FUNDAMENTALS (4)
Geometric, wave and quantum optics; lenses and mirrors, lens aberrations and design, optical instruments, interference diffraction, polarization, absorption and scattering, lasers, holography, and the dual nature of light. Three lecture hours and one three-hour laboratory each week. Prerequisites: PHYS 243, COSC 165, and PHYS 341 or consent of the instructor. Lab/Class fee will be assessed.

PHYS 385 PHYSICS SEMINAR (1)
Students participate in colloquia on topics of current interest in physics research under guidance of instructor. One lecture hour. Prerequisite: at least junior standing.

PHYS 391 INTERNSHIP IN PHYSICS (2-3)
Practical experience in industry, public and private agencies. Not for major or minor credit. Special permit and fee required. May be repeated for a maximum of 6 units. Graded S/U. Prerequisites: 2.70 GPA, junior or senior standing, major in Physics, consent of department.

PHYS 395 RESEARCH PROBLEMS IN PHYSICS (1-3)
Individual project in applied or theoretical physics research. May be repeated for a maximum of 6 units. Prerequisite: consent of instructor who will mentor the research project. Completed over two semesters. Prerequisite: Consent of instructor who will mentor the research project.

PHYS 454 ELECTRICITY AND MAGNETISM II (3)
Continuation of PHYS 354. Wave guides, retarded potentials, dipole radiation, relativistic electrodynamics. Prerequisite: PHYS 354.

PHYS 455 INTRODUCTORY QUANTUM MECHANICS (3)
Schrödinger equation, states of one particle in one dimension, potential barrier problems in one dimension, the harmonic oscillator, system of particles in one dimension, motion in three dimensions, angular momentum, spin, application to atomic physics. Prerequisites: PHYS 311, PHYS 351 (may be taken concurrently).

PHYS 456 INTRODUCTION TO STATISTICAL MECHANICS (3)
Distribution functions, microcanonical, canonical and grand canonical ensembles, the partition function and thermodynamics relations. Fermi-Dirac and Bose-Einstein statistics, some simple models and applications, the Maxwell-Boltzmann transport equation and the hydrodynamic equation, transport coefficients. Three lecture hours. Prerequisite: PHYS 455.

PHYS 457 SOLID STATE PHYSICS (3)
Prerequisites: PHYS 311, PHYS 351 and PHYS 354.

PHYS 458 MAGNETISM AND MAGNETIC MATERIALS (3)
It is impossible to imagine our modern technological society without magnetic materials. We use these materials and techniques virtually everywhere: in permanent magnets, sensors, information storage and processing. In this course, students will learn about the basic principles that govern different applications of magnetism and magnetic materials. We will discuss magnetic moments and their interactions, magnetic order and magnetic structures, implications of magnetism for real materials, experimental techniques and applications. Prerequisite: consent of Instructor.

PHYS 459 NUCLEAR AND PARTICLE PHYSICS (3)
Experimental and theoretical methods for the study of nuclear and particle physics. Topics include properties of nuclei, nuclear transitions, nuclear models, nuclear reactions, relativistic interactions, symmetry, fundamental interactions, and contemporary models. Offered in alternate years. Prerequisites: PHYS 311; PHYS 307 or consent of instructor.

PHYS 470 SPECIAL TOPICS IN PHYSICS (1-4)
Special topics in the area of physics. Special topics will be determined by current interests of the faculty and the needs of the curriculum. Prerequisite: department consent.

PHYS 486 PHYSICS SEMINAR II (1)
Students participate in colloquia on topics of current interests in physics research under guidance of instructor. One lecture hour. Prerequisite: senior standing or consent of instructor.

PHYS 490 INDEPENDENT STUDY IN PHYSICS (1-4)
May be repeated for a maximum of 6 units. Prerequisite: at least junior status and one course in the Department of Physics.

PHYS 491 DIRECTED READINGS (1-4)
May be repeated for a maximum of 6 units. Prerequisites: At least junior status and one course in the department.

PHYS 495 CAPSTONE PROJECT IN PHYSICS (1-4)
Individual project in applied or theoretical physics research. May be completed over two semesters. Prerequisite: Consent of instructor who will mentor the research project.
PHYS 496 RESEARCH PROBLEMS IN PHYSICS (1-3)
Individual projects in any branch of physics. Students can choose to work either on projects or in areas suggested by physics faculty. At the completion of a project, students must write a formal research paper on the work done. Repeatable for credit at different levels. Prerequisite: permission of the instructor who will direct the proposed work.

PHYS 497 RESEARCH PROBLEMS IN PHYSICS (1-4)
Individual projects in any branch of physics. Students can choose to work either on projects or in areas suggested by physics faculty. At the completion of a project, students must write a formal research paper on the work done. Repeatable for credit at different levels. Prerequisite: permission of the instructor who will direct the proposed work.

PHYS 499 HONORS THESIS IN PHYSICS (1-4)
Writing of an honors thesis based on independent research done under the direction of a staff member. May be repeated for a maximum of 6 units. Honors College course. Prerequisites: consent of instructor and open only to advanced honors candidates.