Department of Physics and Astronomy

Why study physics and astronomy?

Our goal is to understand the physical universe. The questions addressed by our department's research and education missions range from the applied, such as an improved understanding of the materials that can be used for solar cell energy production, to foundational questions about the nature of mass and space and how the Universe was formed and subsequently evolved, and how astrophysical phenomena affected the Earth and its evolution. We study the properties of systems ranging in size from smaller than an atom to larger than a galaxy on timescales ranging from billionths of a second to the age of the universe. Our courses and laboratory/research experiences help students hone their problem solving and analytical skills and thereby become broadly trained critical thinkers. While about half of our majors move on to graduate studies in STEM, many find employment in the private sector in diverse situations ranging from financial analysts to physicians. Graduates of all our degree programs can be found in key positions regionally, nationally, and internationally. In this way, our department is at the forefront of telling the academic story of the University of Kansas to people around the state and around the world.

Undergraduate Programs

We welcome all students curious about the universe around them. This includes not only students planning on graduate study in STEM, but also students from other disciplines where a background in foundational physical science and critical thinking can be useful – teaching, medicine, *e.g.* – and anyone seeking to include astronomy and physics as part of their general education. The department offers BA degrees in astronomy and physics and BS degrees in astronomy, physics, and engineering physics; degrees in astronomy and physics are granted through the College of Liberal Arts and Sciences whereas engineering physics degrees are granted through the School of Engineering. The BS physics degree includes an interdisciplinary track that allows students to take elective courses in other STEM disciplines and a pre-medicine emphasis for students interested in health professions. We also offer minors in astronomy and physics and a certificate in astrophysics of origins. We involve our undergraduate majors in cutting-edge research practically from the day they join the department; research is a requirement of both the BS Astronomy and BS Physics degrees. The breadth of our research program affords our students exposure to a number of different fields and we are justifiably proud of our undergraduate researchers who routinely publish papers, attend conferences, and/or conduct research abroad (in Antarctica, Chile, CERN, e.g.).

Courses for Nonmajors

ASTR 191 is a survey of contemporary astronomy, taught at a level using basic mathematics; ASTR 391 offers an introduction to physical astronomy at a calculus-based level. PHSX 111 provides a general introduction to important physics topics and is taught at a level using basic algebra. The department offers two introductory physics sequences that include laboratory work. PHSX 114 and PHSX 115 cover the major fields of physics without calculus. PHSX 211 and PHSX 212, with labs PHSX 216 and PHSX 236, provide a calculus-based foundation in physics for students in physical science, engineering, and mathematics. PHSX 313 and the laboratory course, PHSX 316, provide an introduction to modern physics for majors in physics and some engineering and physical science programs.

Students in biological sciences, health sciences, physical sciences, mathematics, engineering, and prospective elementary and secondary teachers should see appropriate sections of this catalog and major advisors for guidance about required physics course work. Chemistry majors should note that PHSX 211 and PHSX 212 are prerequisites to advanced work in chemistry.

For programs in engineering physics (http://catalog.ku.edu/engineering/engineering-physics), see the School of Engineering section of the online catalog.

Graduate Programs

The department offers two primary graduate programs: (i) an M.S. degree in Physics and (ii) a Ph.D. degree in Physics. The M.S. in Physics has the possibility of having a concentration in Computational Physics and Astronomy. This option requires a thesis, as does one of the M.S.-Physics options. The department does not offer a graduate-level degree in Astronomy, although students have obtained M.S. degrees in Physics by doing astronomy projects. In addition, the department has added flexibility in its course offerings to allow a student to obtain a Ph.D. in Physics while working on an astronomy or astrophysics multidisciplinary plan of study.

Information about admission, requirements, and graduate programs is also on the Department of Physics & Astronomy web page (https://physics.ku.edu/graduate-studies).

Courses

ASTR 177. First Year Seminar: _____. 3 Hours GE11 / U.
A limited-enrollment, seminar course for first-time freshmen, addressing current issues in Astronomy. Course is designed to meet the critical thinking learning outcome of the KU Core. First-Year Seminar topics are coordinated and approved by the Office of First-Year Experience. Prerequisite: First-time freshman status. LEC.

ASTR 190. Astronomy and Civilization. 3 Hours N.
A survey course that describes the interplay between the science of astronomy and cultural beliefs. It uses, among others, examples of how religious and philosophical tenets have enhanced or conflicted with scientific principles. Not for astronomy majors. LEC.

ASTR 191. Contemporary Astronomy. 3 Hours NP GE3N / N.
The structure and evolution of the universe, from nearby planets to distant quasars, are examined. Topics include recent discoveries concerning planets, stars, pulsars and black holes as well as their evolution, the structure of the universe today and how it will be in the future. The emphasis is descriptive rather than mathematical. Prerequisite: Eligibility for MATH 101. LEC.

ASTR 196. Contemporary Astronomy Laboratory. 1 Hour NP / N.
An introduction to astronomical observations and modern data analysis methods. Students will carry out independent investigations as well as standard exercises. This is an online course, delivered through Blackboard. Prerequisite: Corequisite: ASTR 191. LAB.

ASTR 293. Astronomy Bizarre. 3 Hours GE3N / N.
An exploration of physical phenomena found in astrophysical extremes. Topics may include the following: the most violent explosions in the Universe (supernovae and gamma ray bursts; the biggest collisions in nature (galaxy interactions; the densest and most bizarre forms of matter (white dwarfs, neutron stars); the strongest magnetic fields

(magnetars, pulsars); the amazing range of exo-planetary properties; and the mysteries of black holes. Prerequisite: Eligibility for MATH 101. LEC.

ASTR 390. Undergraduate Problems. 1-3 Hours AE61 / N.
Undergraduate observational or theoretical problems in astronomy. Maximum credit, six hours. Prerequisite: Permission of department. IND.

ASTR 391. Physical Astronomy, Honors. 3 Hours NP GE12/GE3N / N.
An honors, calculus-based introduction to astronomy and astrophysics, required for astronomy majors. Components of the Universe - from planetary systems, stellar systems, large scale structure and cosmology - are examined to illuminate the physics principles which govern their evolution. Prerequisite: MATH 125, and either permission of instructor, or participation in the University Honors Program. LEC.

ASTR 394. The Quest for Extraterrestrial Life. 3 Hours NP GE11 / N.
An introduction to the search for planets around other stars and for life in the universe beyond the earth. A discussion of the astronomical conditions under which life might form and the biological conditions of life formation and evolution. Methods of searching for extraterrestrial life. Prerequisite: An introductory course in biology, astronomy or geology. LEC.

ASTR 400. Topics in Astronomy: _____. 1-3 Hours N.
A course on special topics in astronomy. Course may be repeated for different topics. Each section may have additional prerequisites to be determined by the instructor. LEC.

ASTR 501. Honors Research. 1-4 Hours AE61 / N.
This course is for students seeking Departmental Honors in Astronomy, Engineering Physics, or Physics to fulfill the undergraduate research requirement. At the completion of the required four hours of total enrollment, a written and oral report of the research is required. (Same as EPHX 501 and PHSX 501.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor. IND.

ASTR 503. Undergraduate Research. 1-4 Hours AE61 / N.
This course is for students seeking to fulfill the undergraduate research requirement. Students are expected to participate in some area of ongoing research in the department, chosen with the help of their advisor. At the end of the term, students will present their results in a seminar to other students and faculty. (Same as EPHX 503 and PHSX 503.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor. IND.

ASTR 591. Stellar Astronomy. 3 Hours N.
Fundamentals of stellar astronomy including astronomical optics and techniques, coordinate and time systems, stellar spectroscopy, properties of normal, binary and variable stars. Prerequisite: PHSX 212 and PHSX 236. An introductory astronomy course is desirable. LEC.

ASTR 592. Galactic and Extragalactic Astronomy. 3 Hours N.
A study of stellar groups, the interstellar medium, galactic structure and dynamics, galaxies, and cosmology. Prerequisite: ASTR 591 or consent of instructor. LEC.

ASTR 596. Observational Astrophysics. 2 Hours AE61 / N.
Students acquire practical experience with astronomical equipment and data reduction techniques used in research and educational contexts. ASTR 596, combined with an independent research experience, provides a pathway for students to demonstrate creativity and integration of background knowledge. Prerequisite: Corequisite: ASTR 591. LEC.

ASTR 597. Analysis in Astrophysics. 1-3 Hours AE61 / N.
Individual students work on specialized research problems in the field of observational or theoretical astrophysics. Maximum credit, six hours. Prerequisite: ASTR 592. IND.

ASTR 691. Astrophysics I. 3 Hours N.
An introduction to radiation processes, thermal processes, and radiative transfer in stellar atmospheres and the interstellar medium. (Same as EPHX 691 and PHSX 691.) Prerequisite: PHSX 313 or consent of instructor. LEC.

ASTR 692. Astrophysics II. 3 Hours N.
The formation and evolution of stars, nucleosynthesis of the elements, and the physical processes of high energy physics. Prerequisite: ASTR 691 or consent of instructor. LEC.

ASTR 791. Seminar in Astrophysics. 1-3 Hours.
Seminar designed to cover current topics in the physics of the Universe beyond the solar system. Content will vary. Graduate students engaged in or preparing for research may repeat enrollments in this course. Open to undergraduates with twelve hours of physics/astronomy courses numbered 500 or above, or consent of instructor. LEC.

ASTR 792. Topics in Advanced Astrophyics. 3 Hours.
This course will address one or more of the following advanced topics in astrophysics: high energy astrophysics, nuclear astrophysics, galactic and extragalactic astrophysics, space physics, cosmology, astrobioyphysics, and the interstellar and intergalactic media (ISM/IGM.) This course may be repeated for credit if topical content differs. (Same as PHSX 792.) Prerequisite: ASTR 692 or permission of instructor. LEC.

ASTR 795. Space Plasma Physics. 3 Hours.
The physics of fully ionized gases in magnetic fields and their application to interplanetary processes, planetary radiation belts, and the surface of the sun. The motion of charged particles in magnetic fields, magnetohydrodynamic waves, the solar wind and the magnetosphere. (Same as PHSX 795.) Prerequisite: PHSX 621. Corequisite: PHSX 631. LEC.

ASTR 815. Computational Physics and Astronomy. 3 Hours.
Advanced computer applications in physics and astronomy. General discussion and illustration of problem organization and solution by numerical and other methods with examples from plasma, space, solid state, elementary particle, and nuclear physics and astronomy. Students will design, write, validate, and document a computer program to solve a physical problem. (Same as PHSX 815 and CHEM 914.) Prerequisite: Six hours of computer science courses numbered 300 or above, and six hours of physics and/or astronomy courses numbered 300 or above. LEC.

ASTR 897. Seminar in Plasma and Space Physics. 1-3 Hours.
Graduate students engaged in or preparing for research may repeat enrollments in this course. The content will vary. (Same as PHSX 897.) LEC.

Courses

PHSX 111. Introductory Physics. 3 Hours NP GE11/GE3N / N.
A one-semester survey of classical and modern physics, designed primarily for liberal arts students. Typical subjects include the laws of motion, gravity, electricity and magnetism, sound, light, quantum mechanics, atomic and subatomic physics. Subjects are treated mainly conceptually with some use of basic data. Prerequisite: Eligibility for MATH 104. LEC.

PHSX 112. Concepts in Physics, Honors. 3 Hours NP GE3N / N.
A discussion of important concepts in physics. While basic concepts such as force, energy, and mass will be introduced as needed, the emphasis will be on an understanding and appreciation of contemporary science. Prerequisite: Eligibility for MATH 104 and participation in the University Honors Program or permission of instructor. LEC.

PHSX 114. College Physics I. 1-4 Hours NP GE11/GE12/GE3N / N / LFE.
Principles and applications of mechanics, fluids, heat, thermodynamics, and sound waves. Three class hours and one laboratory per week. This course emphasizes the development of quantitative concepts and problem solving skills for students needing a broad background in physics as part of their preparation in other major programs, and for those who wish to meet the laboratory science requirement of the College. Students who enroll in this course are expected to have had 3.5 years of college-prep math, including trigonometry. In special circumstances, permission to enroll in less than four hours may be obtained from the department. Not open to students with credit in PHSX 211 or PHSX 216 or PHSX 212 or PHSX 236. Prerequisite: MATH 104 or a score of 25 or higher on ACT mathematics. LEC.

PHSX 115. College Physics II. 1-4 Hours N / LFE.
A continuation of PHSX 114. Principles and applications of electricity, magnetism, light, atomic physics, and nuclear physics. Three class hours and one laboratory per week. In special circumstances, permission to enroll in less than four hours may be obtained from the department. Not open to students with credit in PHSX 212 or PHSX 236. Prerequisite: PHSX 114. LEC.

PHSX 116. Introductory Physics Laboratory. 1 Hour U / LFE.
A laboratory exploring classical and modern physics, designed primarily for liberal arts students. Experiments in motion gravity, electricity and magnetism, sound, light, atomic and subatomic physics are designed to teach physics concepts and basic laboratory techniques. One two-hour lab period per week. Counts as a laboratory science when preceded or accompanied by PHSX 111. Prerequisite: Eligibility for MATH 104. Corequisite: PHSX 111. LAB.

PHSX 150. Seminar in Physics, Astronomy and Engineering Physics. 0.5 Hours N.
This course is intended for all students in physics, astronomy and engineering physics. Course content includes topics of current interest in all fields of physics and astronomy and an introduction to professional ethics and frameworks for ethical decision making. Topics covered include but are not limited to nanotechnology, cosmology, nuclear and high energy physics, galactic evolution, condensed matter physics, space physics, biophysics and plasma physics. Course will include hands on demonstrations, group in-class activities and general advising information. LEC.

PHSX 177. First Year Seminar: _____. 3 Hours GE11 / U.
A limited-enrollment, seminar course for first-time freshmen, addressing current issues in Physics. Course is designed to meet the critical thinking learning outcome of the KU Core. First-Year Seminar topics are coordinated and approved by the Office of First-Year Experience. Prerequisite: First-time freshman status. LEC.

PHSX 201. Calculus Supplement to College Physics I. 1 Hour N.
A calculus-based course in classical mechanics and thermodynamics for students who have had an algebra-based course in classical mechanics and thermodynamics. This course, combined with PHSX 114, covers the content of PHSX 211or PHSX 210. Prerequisite: PHSX 114 and MATH 116 or 125; co-requisite: MATH 126; and permission of the department. LEC.

PHSX 202. Calculus Supplement to College Physics II. 1 Hour N.
A calculus-based course in electricity and magnetism for students who have had a an algebra-based course in electricity and magnetism. This course, combined with PHSX 115, covers the content of PHSX 212. Prerequisite: PHSX 115 and permission of the department. Corequisite: MATH 126. LEC.

PHSX 210. General Physics I for Engineers. 3 Hours GE11/GE3N / N.
Introduction to classical mechanics and thermodynamics designed for students in the School of Engineering who have completed MATH 125 or MATH 145 with a grade of C or better. Students not admitted to the School of Engineering must receive permission from instructor. PHSX 210 and PHSX 211 cannot both be taken for credit. Prerequisite: MATH 125 or MATH 145 with a grade of C or better; co-requisite MATH 126 or MATH 146; courses in high school physics and/or chemistry recommended. LEC.

PHSX 211. General Physics I. 4 Hours NP GE11/GE12/GE3N / N / LFE.
Introduction to classical mechanics and thermodynamics. Designed for students in engineering and physical science majors. Prerequisite: MATH 116 or MATH 125 or MATH 145; co-requisite MATH 126 or MATH 146; courses in high school physics and/or chemistry are recommended. LEC.

PHSX 212. General Physics II. 3 Hours GE3N / N / LFE.
Study of electricity and magnetism, waves and sound. Prerequisite: PHSX 201, PHSX 210, PHSX 211 or PHSX 213; MATH 126 or MATH 146. Co-enrollment in MATH 127 or MATH 147 is strongly encouraged. LEC.

PHSX 213. General Physics I Honors. 1-5 Hours NP GE11/GE12/GE3N / N / LFE.
An honors section of PHSX 211 and PHSX 216. Credit for fewer than five hours requires permission of the department. Recommended for students with a strong math background who are either in the University Honors Program or intending to major in a physical science. Courses in high school physics and chemistry are strongly recommended. Prerequisite: MATH 125 or MATH 145; co-requisite MATH 126 or MATH 146; and permission of instructor. LEC.

PHSX 214. General Physics II Honors. 1-4 Hours GE3N / N / LFE.
An honors section of PHSX 212 and PHSX 236. Credit for fewer than four hours requires permission of the department. Recommended for students with a strong math background who are either in the University Honors Program or intending to major in a physical science. Prerequisite: PHSX 216 together with either PHSX 211 or PHSX 210; or PHSX 213, and permission of instructor. Co-requisite: MATH 127 or MATH 147. LEC.

PHSX 216. General Physics I Laboratory. 1 Hour N / LFE.
Experiments in classical mechanics and thermodynamics. The course includes practice on the ethics of recording and presentation of data. Counts as a laboratory science when accompanied by PHSX 210 or PHSX 211. Prerequisite: Corequisite: PHSX 210 or PHSX 211. LAB.

PHSX 236. General Physics II Laboratory. 1 Hour N / LFE.
Experiments in electricity and magnetism, waves and sound. Students will practice data reduction and error analysis in ways that are consistent with professional ethics. Prerequisite: Corequisite: PHSX 212. LAB.

PHSX 313. General Physics III. 3 Hours GE3N / N / LFE.
Introduction to modern physics. Topics include special relativity, optics, and introductions to quantum mechanics and solid state physics. Prerequisite: PHSX 212 and PHSX 236, or PHSX 214, or PHSX 202, or EECS 220 or EECS 221. Corequisite: MATH 320 or MATH 220 or MATH 221. LEC.

PHSX 316. Intermediate Physics Laboratory I. 1 Hour U / LFE.
Experiments in optics and modern physics. Development of experimental skills, data reduction, error analysis, and technical writing. One lab meeting per week and one lecture per week on topics including error analysis and experimental design, and the development of professional ethics in regard to citation and data presentation. Prerequisite: Corequisite: PHSX 313. LAB.

PHSX 400. Topics in Physics and Astronomy: _____. 1-3 Hours N.
A course on special topics in physics and astronomy, given as the need arises. Course may be repeated for different topics. Each section may have prerequisites to be determined by the instructor. LEC.

PHSX 420. Science and Policy. 3 Hours AE52 / N.
An introduction to the relationship between science and public policy. The mutual interactions between public policy and scientific practice are explored within an ethical framework with examples that include energy and sustainability issues. An experiential course where students will be asked to develop and implement ethical solutions and engage meaningfully on a practicum project for local, regional, national, or international partners who are working on policy decisions which have technology implications. Honors credit is available for this course. Prerequisite: Eligibility for MATH 101. LEC.

PHSX 500. Special Problems. 1-5 Hours AE61 / N.
Work in some area of physics beyond the topics or material covered in other courses. For some problems, continued enrollment in consecutive semesters may be appropriate. Prerequisite: One junior-senior course in science in an area related to the problem and consent of instructor. IND.

PHSX 501. Honors Research. 1-4 Hours AE61 / N.
This course is for students seeking Departmental Honors in Astronomy, Engineering Physics, or Physics to fulfill the undergraduate research requirement. At the completion of the required four hours of total enrollment, a written and oral report of the research is required. (Same as ASTR 501 and EPHX 501.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor. IND.

PHSX 502. Seminar in Physics and Astronomy Instruction. 1-3 Hours N.
One meeting per week to plan and report progress on projects which may include tutoring of students in personalized modes of study; developing, administering, and scoring test items; designing and improving demonstration and laboratory experiments. Amount of credit depends on projects contracted for and completed. (Distribution credit given for two-three hours only.) Prerequisite: Evidence of prior academic experience relevant to the student's proposed activities in the seminar and permission of instructor. LEC.

PHSX 503. Undergraduate Research. 1-4 Hours AE61 / N.
This course is for students seeking to fulfill the undergraduate research requirement. Students are expected to participate in some area of ongoing research in the department, chosen with the help of their advisor. At the end of the term, students will present their results in a seminar to other students and faculty. (Same as ASTR 503 and EPHX 503.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor. IND.

PHSX 511. Introductory Quantum Mechanics. 3 Hours N.
An introduction to quantum mechanics, emphasizing a physical overview. Topics should include the formalisms of non-relativistic quantum mechanics, the 3-dimensional Schrodinger equation with applications to the hydrogen atom; spin and angular momentum; multi-particle systems of Fermi-Dirac and Bose-Einstein particles; time-independent perturbation theory. (Same as EPHX 511.) Prerequisite: PHSX 313 and MATH 290. LEC.

PHSX 516. Physical Measurements. 4 Hours N / LFE.
A laboratory course emphasizing experimental techniques and data analysis, as well as scientific writing and presentation skills. Experiments will explore a range of classical and modern physics topics. Students will also practice ethical decision making using case studies appropriate for the discipline. (Same as EPHX 516.) Prerequisite: PHSX 313, EPHX 316 or PHSX 316 and EPHX 521 or PHSX 521. (EPHX 521 or PHSX 521 may be taken concurrently.) LAB.

PHSX 518. Mathematical Physics. 3 Hours N.
Applications of modern mathematical methods to problems in mechanics and modern physics. Techniques include application of partial differential equations and complex variables to classical field problems in continuous mechanics, unstable and chaotic systems, electrodynamics, hydrodynamics, and heat flow. Applications of elementary transformation theory and group theory, probability and statistics, and nonlinear analysis to selected problems in modern physics as well as to graphical representation of experimental data. Prerequisite: PHSX 313 and MATH 320 or permission of instructor. (Same as EPHX 518.) LEC.

PHSX 521. Mechanics I. 3 Hours N.
Newton's laws of motion. Motions of a particle in one, two, and three dimensions. Motion of a system of particles. Moving coordinate systems. (Same as EPHX 521.) Prerequisite: PHSX 211 and PHSX 216, or PHSX 213; MATH 127; MATH 290; and MATH 220 or MATH 320. LEC.

PHSX 531. Electricity and Magnetism. 3 Hours N.
The properties of electric and magnetic fields, including electrostatics, Gauss' Law, boundary value methods, electric fields in matter, electromagnetic induction, magnetic fields in matter, the properties of electric and magnetic dipoles, and of dielectric and magnetic materials. (Same as EPHX 531.) Prerequisite: PHSX 214, or PHSX 212 and PHSX 236; PHSX 521 or special permission; MATH 127; MATH 290; and MATH 220 or MATH 320. LEC.

PHSX 536. Electronic Circuit Measurement and Design. 4 Hours N / LFE.
A laboratory course that explores the theory and experimental techniques of analog and digital electronic circuit design and measurements. Topics include transient response, transmission lines, transistors, operational amplifiers, and digital logic. (Same as EPHX 536.) Prerequisite: PHSX 214 or PHSX 212 and PHSX 236; MATH 127; and MATH 290. PHSX 313 and 316 recommended. LAB.

PHSX 557. Topics in Mechanics, Properties of Materials, Thermodynamics. 1-3 Hours.
This course covers the principles and applications of classical mechanics, fluids, heat, thermodynamics and sound. Teaching of these topics is strongly emphasized. Some laboratory work is included. This course is intended for students accepted to the BS Education major in Physics. This course does not count towards Physics or Astronomy major requirements in the College of Liberal Arts and Sciences. Prerequisite: Math 115 and 116, and either PHSX 114 or PHSX 211. LEC.

PHSX 558. Topics in Electricity and Magnetism and Optics. 1-3 Hours.
This course covers the principles and applications of electricity, magnetism and optics. Teaching of these topics is strongly emphasized. Some laboratory work is included. This course is intended for students accepted to the BS Education major in physics. This course does not count towards Physics or Astronomy major requirements in the College of Liberal Arts and Sciences. Prerequisite: MATH 115 and 116, and either PHSX 115 or PHSX 212. LEC.

PHSX 559. Topics in Modern Physics. 1-3 Hours.
This course covers the principles and applications of quantum mechanics, atomic and nuclear physics. Teaching of these topics is strongly emphasized. Some laboratory work is included. This course is intended for students accepted to the BS Education major in physics. This course does not count towards Physics or Astronomy major requirements in the College of Liberal Arts and Sciences. Prerequisite: MATH 115 and 116, and either PHSX 115 or PHSX 313. LEC.

PHSX 594. Cosmology and Culture. 3 Hours AE42 / N.
A survey of modern physical cosmology, its recent historical roots, and creation myths from many world cultures. An examination of the effects of these stories on their parent cultures. LEC.

PHSX 600. Special Topics in Physics and Astrophysics: _____. 3 Hours N.
Different topics will be covered as needed. This course will address topics in physics and astrophysics not covered in regularly offered courses. May be repeated if topic differs. (Same as EPHX 600.) Prerequisite: Permission of instructor. LEC.

PHSX 601. Design of Physical and Electronic Systems. 4 Hours AE61 / N / LFE.
A laboratory course emphasizing the application of physical principles to the design of systems for research, monitoring, or control. Topics include the use of microcomputers as controllers, interfacing microcomputers with measurement devices, and use of approximations and/or computer simulation to optimize design parameters, linear control systems, and noise. (Same as EPHX 601.) Prerequisite: Twelve hours of junior-senior credit in physics or engineering, including one laboratory course. LAB.

PHSX 615. Numerical and Computational Methods in Physics. 3 Hours N.
An introduction to the use of numerical methods in the solution of problems in physics for which simplifications allowing closed-form solutions are not applicable. Examples are drawn from mechanics, electricity, magnetism, thermodynamics, and optics. (Same as EPHX 615.) Prerequisite: PHSX 313, MATH 320 or equivalent, and EECS 138 or equivalent. LEC.

PHSX 621. Mechanics II. 3 Hours N.
Continuation of PHSX 521. Lagrange's equations and generalized coordinates. Mechanics of continuous media. Tensor algebra and rotation of a rigid body. Special relativity and relativistic dynamics. (Same as EPHX 621.) Prerequisite: EPHX 521 or PHSX 521. LEC.

PHSX 631. Electromagnetic Theory. 3 Hours N.
Maxwell's equations, wave propagation, optics and waveguides, radiation, relativistic transformations of fields and sources, use of covariance and invariance in relativity. Normally a continuation of PHSX 531. (Same as EPHX 631.) Prerequisite: EPHX 531 or PHSX 531. LEC.

PHSX 641. Introduction to Nuclear Physics. 3 Hours N.
Experimental methods in nuclear physics, elementary concepts and simple considerations about nuclear forces, alpha and beta decay, gamma radiation, nuclear structure, and reaction systematics. (Same as EPHX 641.) Prerequisite: PHSX 313 and PHSX 511. LEC.

PHSX 655. Optics. 3 Hours N.
Geometric optics. Wave properties of light: interference, diffraction, coherence. Propagation of light through matter. Selected topics in modern optics, e.g., lasers, fibers. (Same as EPHX 655.) Prerequisite: PHSX 313 and PHSX 316. LEC.

PHSX 661. Introduction to Elementary Particle Physics. 3 Hours N.
Properties and interactions of quarks, leptons, and other elementary particles; symmetry principles and conservation laws; broken symmetry; gauge bosons; the fundamental interactions, grand unified theories of strong, electromagnetic, and weak interactions; the cosmological implications of elementary particle physics. (Same as EPHX 661.) Prerequisite: PHSX 511 and MATH 320. LEC.

PHSX 671. Thermal Physics. 3 Hours N.
Development of thermodynamics from statistical considerations. Techniques of calculating thermodynamic properties of systems. Application to classical problems of thermodynamics. Elementary kinetic theory of transport processes. Fermi-Dirac and Bose-Einstein systems. (Same as EPHX 671.) Prerequisite: PHSX 511. LEC.

PHSX 681. Concepts in Solids. 3 Hours N.
Properties of common types of crystals and amorphous solids. Lattice vibrations and thermal properties of solids. Electrons and holes in energy bands of metals, semiconductors, superconductors, and insulators. (Same as EPHX 681.) Prerequisite: PHSX 313 and PHSX 511. LEC.

PHSX 691. Astrophysics I. 3 Hours N.
An introduction to radiation processes, thermal processes, and radiative transfer in stellar atmospheres and the interstellar medium. (Same as ASTR 691 and EPHX 691.) Prerequisite: PHSX 313 or consent of instructor. LEC.

PHSX 693. Gravitation and Cosmology. 3 Hours N.
An overview of topics relevant to gravitation and modern cosmology: special relativity, tensor notation, the equivalence principle, the Schwarzchild solution, black holes, and Friedmann models. Cosmic black body radiation, dark matter, and the formation of large-scale structure. The idea of quantum gravity and an introduction to the current literature in cosmology. (Same as EPHX 693.) Prerequisite: PHSX 313 and MATH 320. LEC.

PHSX 700. Colloquium. 1 Hour.
Topics of current interest in physics, astronomy, and atmospheric science. Repeated enrollments are permitted. LEC.

PHSX 701. Major Experiments and Observations in Classical and Contemporary Physics. 1-3 Hours.
Critique, discussions, and interpretation of the most important discoveries and observations in physics. LEC.

PHSX 702. Introductory Physics Pedagogy. 1 Hour.
This course will address basic elements of pedagogy in specific relation to the teaching of physics and astronomy labs. It contains such elements as: peer and instructor evaluations of teaching, reading and discussion of pedagogical materials, development of online course material, and discussion of teaching methods. This course may be repeated for credit. Prerequisite: Permission of instructor. LEC.

PHSX 703. Proposal Writing. 1 Hour.
Means and methods for preparing a successful proposal. This course will discuss how to find funding and other award opportunities. Students will learn how to develop an effective application and will complete an application. Intended for early career graduate students and advanced undergraduate students. LEC.

PHSX 711. Quantum Mechanics I. 3 Hours.
Linear vector spaces. Postulates of quantum mechanics. Schrodinger equation. Harmonic oscillator and other problems in one dimension. Central forces and angular momentum. Symmetries and conservation laws. The hydrogen atom. Spin. Spin and statistics. Addition of angular momenta. Time independent approximation methods. Prerequisite: PHSX 511 and MATH 320. LEC.

PHSX 717. Graduate Seminar. 1 Hour.
First year graduate students meet to survey research opportunities in the department and develop skills in giving oral presentations in physics and related areas. Students will also learn about topics in responsible scholarship that may include: the origin of ideas and the allocation of credit, the treatment of data, scientific misconduct, intellectual property and entrepreneurship, the researcher in society, collaborative research, mentor/trainee responsibilities, and safe practices. LEC.

PHSX 718. Mathematical Methods in Physical Sciences. 3 Hours.
Review of complex variable theory; introduction to the partial differential equations of physical systems; Fourier analysis; special functions of

mathematical physics; and chemistry. (Same as CHEM 718.) Prerequisite: Two semesters of junior-senior mathematics. LEC.

PHSX 721. Chaotic Dynamics. 3 Hours.
Topics covered may include the following: dynamical systems, attractors, sensitive dependence on initial conditions, chaos, one-dimensional maps, strange attractors and fractal dimensions, fat fractals, the horseshoe map, symbolic dynamics, linear stability of periodic orbits, stable and unstable manifolds, Lyapunov exponents, topological entropy, quasiperiodicity, strange nonchaotic attractors, nonattracting chaotic sets, fractal basin boundaries, renormalization group analysis, intermittency, crisis and chaotic transients. Prerequisite: Mechanics (PHSX 521, or its equivalent), ordinary differential equations (MATH 320, or its equivalent), and some computer programming knowledge. LEC.

PHSX 727. Advanced Geophysics: _____. 1-3 Hours.
Topics to vary with demand and include heat flow, wave propagation, synthetic seismograms, groundwater exploration, geothermal exploration, electrical methods in exploration, rock mechanics-tectonophysics, rock magnetism, geomagnetism, paleomagnetism, geophysical inverse theory, and others upon sufficient demand. May be repeated for different topics. (Same as GEOL 771.) Prerequisite: GEOL 572 or GEOL 573/PHSX 528 or consent of instructor. LEC.

PHSX 731. Molecular Biophysics. 3 Hours.
Methods and concepts in contemporary molecular biophysics are discussed. Particular emphasis is placed on the thermodynamics of macromolecular interactions and quantitative methods of data analysis. Basic enzymology and biophysical spectroscopy will also be reviewed. Prerequisite: PHSX 212, MATH 125, and either CHEM 135 or CHEM 175. LEC.

PHSX 741. Nuclear Physics I. 3 Hours.
Experimental methods in nuclear physics, elementary concepts and simple considerations about nuclear forces, alpha and beta decay, gamma radiation, nuclear structure, and reaction systematics. Prerequisite: PHSX 511. LEC.

PHSX 761. Elementary Particles I. 3 Hours.
Particle accelerators and detectors; quarks and leptons; invariance principles and conservation laws; strong, electromagnetic, and weak interactions of elementary particles; unification of electroweak and other interactions. Prerequisite: Corequisite: PHSX 711. LEC.

PHSX 781. Solid State Physics I. 3 Hours.
Classification of solids, structure and symmetry of crystals; lattice vibrations and thermal properties of solids; electric and magnetic properties; electron theory of metals and semiconductors; electronic and atomic transport processes; theory of ionic crystals. Prerequisite: PHSX 511 (or CHEM 648) and PHSX 671 (or CHEM 646). LEC.

PHSX 791. Seminar in Astrophysics. 1-3 Hours.
Seminar designed to cover current topics in the physics of the Universe beyond the solar system. Content will vary. Graduate students engaged in or preparing for research may repeat enrollments in this course. Open to undergraduates with twelve hours of physics/astronomy courses numbered 500 or above, or consent of instructor. LEC.

PHSX 792. Topics in Advanced Astrophysics. 3 Hours.
This course will address one or more of the following advanced topics in astrophysics: high energy astrophysics, nuclear astrophysics, galactic and extragalactic astrophysics, space physics, cosmology, astrobiophysics, and the interstellar and intergalactic media (ISM/IGM). This course may be repeated for credit if topical content differs. (Same as ASTR 792.) Prerequisite: ASTR 692 or permission of instructor. LEC.

PHSX 793. Physical Cosmology. 3 Hours.
Discussion of how fundamental laws of physics govern the evolution of the universe as a whole along with its structure. Survey of cosmogenic clues in the observable universe, including observed structures, cosmic background radiation and evidence for dark matter. Development of the universe, including theories of initial conditions; cosmological phase transitions; generation of possible relics and dark matter; symmetry breaking; baryon asymmetry; nucleosynthesis; recombination, gravitational instability and the formation of structure; current experimental techniques. Prerequisite: PHSX 718. Recommended: PHSX 593. LEC.

PHSX 795. Space Plasma Physics. 3 Hours.
The physics of fully ionized gases in magnetic fields and their application to interplanetary processes, planetary radiation belts, and the sun. The motion of charged particles in magnetic fields, magnetohydrodynamic waves, the solar wind, the ionosphere, and the magnetosphere. (Same as ASTR 795.) Prerequisite: PHSX 621. Corequisite: PHSX 631. LEC.

PHSX 800. Graduate Problems. 1-5 Hours.
Advanced laboratory problems, special research problems, or library reading problems. Repeated enrollments are permitted. RSH.

PHSX 801. Advanced Topics. 1-3 Hours.
Lectures on advanced material not covered by regular courses. The topics are not limited but generally address recent experimental or theoretical developments in subjects such as superconductivity, nuclear physics, elementary particle physics, quantum field theory, gauge and unified theories, nonlinear or chaotic systems, space plasma physics, and astrophysics and cosmology. Repeated enrollments are permitted. LEC.

PHSX 811. Quantum Mechanics II. 3 Hours.
Time dependent perturbation theory. Gauge invariance and electromagnetic interactions. Quantization of the electromagnetic field and applications. The Dirac equation, its transformation properties and applications to relativistic problems. Scattering theory, elementary applications, and formal properties. Prerequisite: PHSX 711. LEC.

PHSX 815. Computational Methods in Physical Sciences. 3 Hours.
Advanced computer applications in physical science. General discussion and illustration of problem organization and solution by numerical and other methods with examples from physics, astronomy, and other physical sciences. Students will design, write, validate, and document a computer program to solve a physical problem. (Same as ASTR 815 and CHEM 914.) Prerequisite: Six hours of computer science courses numbered 300 or above, and six hours of physics and/or astronomy courses numbered 300 or above. LEC.

PHSX 817. Graduate Seminar. 1 Hour.
First year graduate students meet to survey research opportunities in the department and develop skills in giving oral presentations in physics and related areas. Prerequisite: Only one hour of 817 can count toward required hours for degree. LEC.

PHSX 821. Classical Mechanics. 3 Hours.
Vector and tensor notation; review of Newtonian mechanics; Lagrangian mechanics; linear vector spaces and matrix theory with applications to the theory of small oscillations; rigid bodies; Hamiltonian formalism. Special relativity. Prerequisite: Twelve hours of junior-senior courses in physics. LEC.

PHSX 831. Electrodynamics I. 3 Hours.
Electrostatics and magnetostatics; Maxwell's equations; plane waves; waveguides. Prerequisite: PHSX 718 and PHSX 821. LEC.

PHSX 841. Nuclear Physics II. 3 Hours.
Nuclear forces and the two-body problem; nuclear models; phenomenological treatment of nuclear reactions and decay processes. Prerequisite: PHSX 741 and PHSX 811. LEC.

PHSX 855. Advanced Optics. 3 Hours.
Advanced topics in optics that may include: Laser principles and techniques, light propagation in dielectrics, absorption and luminescence, interaction of light with free electrons and phonons, nonlinear optics, photonic devices, and optical spectroscopy. LEC.

PHSX 861. Elementary Particles II. 3 Hours.
Theoretical analysis of the standard model of strong and electroweak interactions. Applications to decay and scattering processes with comparison to experiments. Selected topics in non-perturbative physics. Examples of tests to probe beyond the standard model. Prerequisite: PHSX 761. Corequisite: PHSX 911. LEC.

PHSX 871. Statistical Physics I. 3 Hours.
Review of and advanced topics in thermodynamics; the Maxwell relations; the third law; phase transitions. Kinetic theory: the Boltzmann equation; transport phenomena. Statistical mechanics: ideal Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein gases; ensemble theory; derivation of the laws of thermodynamics. Prerequisite: PHSX 711 and PHSX 821. PHSX 671 is recommended. LEC.

PHSX 881. Solid State Physics II. 3 Hours.
More advanced topics in solid state physics that may include: diamagnetism, paramagnetism, ferromagnetism, and antiferromagnetism; electron and nuclear spin magnetic resonance; dielectric properties and ferroelectricity; photoconductivity and luminescence. Prerequisite: PHSX 631 and PHSX 711 (or CHEM 915). LEC.

PHSX 895. Plasma Physics. 3 Hours.
Magnetohydrodynamics, including discussion of shocks, waves, and stability theory; statistical mechanical foundations; kinetic theory; microstability; non-linear phenomena. Prerequisite: PHSX 795. LEC.

PHSX 897. Seminar in Plasma and Space Physics. 1-3 Hours.
Graduate students engaged in or preparing for research may repeat enrollments in this course. The content will vary. (Same as ASTR 897.) LEC.

PHSX 899. Master's Research/Thesis. 1-10 Hours.
Research work (either experimental or theoretical) in physics for students working toward the master's degree. Repeated enrollments are permitted. Graded on a satisfactory progress/limited progress/no progress basis. THE.

PHSX 911. Quantum Mechanics III. 3 Hours.
Path integral formulation of quantum mechanics. Introduction to quantum field theory using the canonical approach and using the path integral approach. Application of perturbation theory in quantum electrodynamics. Selected applications in condensed matter, nuclear, and particle physics. Prerequisite: PHSX 811. LEC.

PHSX 912. Quantum Field Theory. 3 Hours.
Survey of problems in quantum field theory. Functional methods. Renormalization and renormalization group. Role of symmetries. Gauge field theories. Symmetry breaking. Prerequisite: PHSX 911. LEC.

PHSX 915. Relativity. 3 Hours.
Reviews of special relativity, manifolds, tensors, and geometry. General coordinate covariance and general relativity. Applications to classical theory of gravitation: weak field tests, isotropic, homogeneous cosmology, Schwarzschild solution. Selected advanced topics. Prerequisite: A total of 10 hours of junior/senior work in physics and mathematics, including at least concurrent enrollment in MATH 646. LEC.

PHSX 917. Seminar in Theoretical Physics. 1-3 Hours.
Graduate students engaged in or preparing for research may repeat enrollments in this course. Content will vary. LEC.

PHSX 931. Electrodynamics II. 3 Hours.
Inhomogenious Maxwell's equations and multipole radiation fields; special theory of relativity; radiation from accelerated charges: scattering and dispersion. Prerequisite: PHSX 831. LEC.

PHSX 947. Seminar in Nuclear Physics. 1-3 Hours.
Graduate students engaged in or preparing for research may repeat enrollments in this course. The content will vary. LEC.

PHSX 967. Seminar in Particle Physics. 1-3 Hours.
Graduate students engaged in or preparing for research may repeat enrollments in this course. The content will vary. LEC.

PHSX 971. Advanced Statistical Mechanics. 3 Hours.
Advanced equilibrium statistical mechanics and introduction to nonequilibrium statistical mechanics. Topics include: the theory of liquids, critical phenomena, linear response theory and time correlation functions, Langevin dynamics, and molecular hydrodynamics. (Same as CHEM 950.) Prerequisite: PHSX 871 or CHEM 917. LEC.

PHSX 987. Seminar in Solid State Physics. 1-3 Hours.
Graduate students engaged in or preparing for research may repeat enrollments in this course. The content will vary. LEC.

PHSX 999. Ph.D. Dissertation Research. 1-10 Hours.
Research work (either experimental or theoretical) in physics for students working toward the Ph.D. degree. Repeated enrollments are permitted. Graded on a satisfactory progress/limited progress/no progress basis. THE.