DEPARTMENT OF PHYSICS AND ASTRONOMY

Why study physics and astronomy?
Because understanding the physical universe starts here.

Undergraduate Programs
The astronomy curriculum offers undergraduates a survey of modern astronomy and an introduction to physical science, gives science and engineering students an introduction to astronomy and astrophysics, and prepares students majoring in astronomy for graduate study in astronomy or related fields.

The physics curriculum includes course work for those who want a sound background in physics as part of their general education, for those who study physics as part of their training in other fields, and for those whose post-graduate plans include research or employment in physics or related fields.

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/archives/2017-18/engineering/engineering-physics), see the School of Engineering section of the online catalog.

Graduate Programs
At the graduate level, the Department of Physics and Astronomy offers Master of Science degrees in Physics and related fields. The department also offers a Master of Science degree with a subspecialty in computational physics and a Doctor of Philosophy degree in Physics and related fields.

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

ASTR 301. Undergraduate Research. 1-3 Hours AE61 / 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 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 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 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, astrobiology, 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 program 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. 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 211 or 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 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 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 with
a grade of C or better; co-requisite MATH 126; 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; co-requisite MATH 126; 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
211, PHSX 210 or PHSX 213. MATH 116 or MATH 125; concurrent or prior
enrollment in: MATH 126 or MATH 146. 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; co-requisite MATH 126; and permission of instructor. LEC.

PHSX 214. General Physics II Honors. 1-4 Hours 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. LEC.

PHSX 216. General Physics I Laboratory. 1 Hour N / LFE.
Experiments in classical mechanics and thermodynamics. 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. 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. 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. 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 AES2 / 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 EPHX 501.) Prerequisite: Junior/Senior standing in Astronomy,
Engineering Physics, or Physics. 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, 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 Schrödinger 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. (Same as EPHX 516.) Prerequisite: PHSX 313, PHSX 316 and PHSX 521. (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, electromodynamics, 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 528. Geodynamics and Plate Tectonics. 3 Hours N.
Study of physical processes in the solid Earth and of geophysical approaches to studying Earth systems at regional and global scales. Topics include global potential fields, thermal regime, rheology and Earth deformation, earthquakes and seismic structure, plate motions and global tectonics. (Same as GEOL 573.) Prerequisite: An introductory course in geology; MATH 116 or MATH 126; and PHSX 115, PHSX 214, or PHSX 212 and PHSX 236. 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 223; 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: PHSX 521. LEC.

PHSX 623. Physics of Fluids. 3 Hours N.
An introduction to basic fluid mechanics in which fundamental concepts and equations are covered. Topics include hydrostatics, hydrodynamics, wave propagation in fluids, and applications in the areas such as astrophysics, atmospheric physics, and geophysics. (Same as EPHX 623.) Prerequisite: MATH 127; MATH 290; PHSX 212 and PHSX 236 or PHSX 214 can replace PHSX 212 and PHSX 236. 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: PHSX 531. LEC.
PHSX 641. Introduction to Nuclear Physics. 3 Hours N.
Experimental methods and elementary concepts in nuclear physics,
including nuclear forces, alpha and beta decay, gamma radiation, nuclear
structure, and reaction systematics. (Same as EPHX 641.) Prerequisite:
PHSX 313 and PHSX 316. 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, semi-conductors, 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
Schwarzschild 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 or consent
instructor. 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 702. Potential Fields in Geophysics. 3 Hours.
Reduction and interpretation of gravity and magnetic data with emphasis
on exploration techniques. Spectral, analytical and modeling methods
of analysis of gravity and magnetic anomalies are emphasized. Prerequisite:
ME 250 and either GEO 572 or GEO 573 or PHSX 528. 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 724. Geophysical Data Analysis. 3 Hours.
Fourier analysis, sampling theory, prediction and interpolation of
geophysical data, filtering theory, correlation techniques, deconvolution.
Examples will be chosen from various fields of geophysics. (Same
as GEOL 772.) Prerequisite: MATH 250/ARCE 250/CE 250/CPE 250/
EECS 250/EPHX 250/ME 250 and either GEO 572 or GEO 573 or PHSX
528. LEC.

PHSX 723. Seismology. 3 Hours.
General theory of seismic waves, wave field extrapolation (migration)
by finite difference methods, construction of travel-time curves, reflection
and attenuation coefficients, earthquake source mechanism, distribution
and forecasting of earthquakes. (Same as GEOL 773.) Prerequisite: MATH
250/ARCE 250/EECS 250/CPE 250/ME 250 and either GEO 572 or GEO 573 or PHSX
528. 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
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, palaeomagnetism, geophysical inverse theory, and others upon sufficient demand. May be repeated for different topics. (Same as GEOL 771.) Prerequisite: PHSX 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, astrophysics, 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 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.
Inhomogenous 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.