

# Physics and Astronomy

## Chair

- Frederick N. Skiff

## Associate Chair

- Craig E. Pryor

**Undergraduate majors:** physics (B.A., B.S.); applied physics (B.S.); astronomy (B.A., B.S.)

**Undergraduate minors:** physics; astronomy

**Graduate degrees:** M.S. in physics; M.S. in astronomy; Ph.D. in physics

**Faculty:** <https://physics.uiowa.edu/people>

**Website:** <https://physics.uiowa.edu/>

The Department of Physics and Astronomy provides comprehensive and rigorous instruction in all basic aspects of its subjects. It also provides research facilities and guidance in selected specialties for advanced individual scholarly work.

In addition to its undergraduate and graduate programs of study, the department offers several courses that undergraduate students in all majors may use to satisfy the General Education Program Natural Sciences requirement. Look for courses with prefixes ASTR and PHYS under "Natural Sciences" in the General Education Program section of the Catalog. The department also offers a First-Year Seminar designed for entering undergraduates.

The department also participates in an interdisciplinary doctoral program, the Program in Applied Mathematical and Computational Sciences (Graduate College).

All of the department's courses and advanced laboratories are taught by faculty members. Faculty members also supervise associated laboratories taught by graduate students. Enrollment in courses beyond the elementary level is typically 15 to 20 students; there is ample opportunity for individual work. Special introductory courses are offered for students majoring in physics and astronomy and for others with a special interest in these subjects.

Total enrollment in physics and astronomy courses is approximately 2,200 each semester of the academic year and 150 during the summer session. The department has around 120 undergraduate majors, half of whom are honors students, and 75 graduate students.

## Programs

### Undergraduate Programs of Study

#### Majors

- Major in Physics (Bachelor of Arts)
- Major in Astronomy (Bachelor of Arts)
- Major in Physics (Bachelor of Science)
- Major in Applied Physics (Bachelor of Science)
- Major in Astronomy (Bachelor of Science)

#### Minors

- Minor in Physics

- Minor in Astronomy

### Graduate Programs of Study

#### Majors

- Master of Science in Physics
- Master of Science in Astronomy
- Doctor of Philosophy in Physics

#### Facilities

The department has a number of well-equipped laboratories and observatories. Faculty, students, and staff access national supercomputers via the Internet, and have access to high performance computing clusters on campus. The central machine shop is fully equipped and staffed by skilled instrument makers and machinists, and there are electronics and machine shops for use by advanced students and research staff.

Experimental research is conducted in astronomy (optical, radio, and X-ray), atomic and molecular physics, condensed matter physics, elementary particle physics, laser physics, medical physics, plasma physics, and space physics. Extensive facilities are available for construction of specialized research equipment and for data processing and analysis.

State-of-the-art semiconductor materials and devices are grown in two molecular beam epitaxy machines. Ultrafast laser techniques are developed and used to probe electron transport, energy relaxation, recombination, and spin dynamics in the novel nanostructures grown in these machines. Experiments also are conducted on laser-induced coherent phenomena and coherent control of charge carriers in semiconductor nanostructures. The experimental condensed matter program is closely coordinated with the condensed matter theory group.

Plasma physics is an active area of experimental and theoretical research. Laboratory experiments studying plasma processes of importance in various space and astrophysical plasmas are performed in a Q machine, including experiments on waves and instabilities in dusty plasmas. Additional laboratory and microgravity experiments with dusty plasmas include studies of Coulomb crystals, shocks, and complex fluids. Glow discharges for plasma processing applications are studied using laser diagnostics and numerical simulations. Wave propagation and plasma particle dynamics also are studied in collisionless plasmas through laboratory experiments. Laser techniques are developed for measuring plasma flow and following particle orbits. Plasma theory efforts include analytical and numerical investigations of magnetic reconnection and turbulence in space and astrophysical plasmas; collaboration with laboratory and space plasma experimental groups in strongly coupled dusty plasmas, waves, and instabilities; and free electron lasers and hydrodynamic turbulence.

State-of-the-art laser systems are available for high-resolution spectroscopic measurement and ultrafast studies of molecular structure, for collisional relaxation and nonlinear optical effects in atomic and molecular systems, and for plasma diagnostics.

Experimental research in elementary particle physics is carried out at Fermi National Accelerator Laboratory, Stanford Linear Accelerator Center, CERN in Switzerland, and other international laboratories. The present generation of high-

energy experiments has been designed to probe both the strong nuclear force and the weak interactions.

The department is well-equipped for research and instruction in observational astronomy. The primary optical instrument is a fully automated 15-inch telescope at a dark-sky site in Arizona. The telescope is equipped with CCD cameras and a variety of filters. There are 3-meter and 4.5-meter radio telescopes on the roof of Van Allen Hall, which are used for instruction and student research projects.

Research programs in galactic and extragalactic radio astronomy are carried out using the facilities of the National Radio Astronomy Observatory, including the Very Large Array and the Very Long Baseline Array, one element of which is 10 miles north of campus. Current long-term research activities include studies of the center of the Milky Way galaxy; investigations of extragalactic radio sources; the formation of powerful winds in young, luminous stars; radio-wave scattering in the interstellar and interplanetary media; and interacting binary stars. A research program in X-ray astronomy has been established, and there is a laboratory for instrument development. Research topics in X-ray astronomy concentrate on observations of X-ray emission from black holes and supernova remnants, using existing spacecraft.

Active theoretical research is carried on in astrophysics; atomic, molecular, and optical physics; condensed matter physics; elementary particle physics; laser physics; mathematical physics; nuclear physics; plasma physics; and space physics. An active mathematical physics seminar fosters the exchange of ideas between mathematics and physics.

The primary emphasis of Iowa's program in experimental and theoretical space physics is on studies of cosmic and heliospheric physics, magnetospheric physics, and magnetosphere-ionosphere interactions. Facilities are available for designing and constructing spaceflight instruments. Investigators in the department have flown instruments for studying plasmas, energetic charged particles, auroral images, plasma waves, and radio emissions on a wide variety of terrestrial and planetary spacecraft, including Pioneer 10 and 11, Dynamics Explorer, Voyager 1 and 2, Galileo, Polar, Cassini, and Mars Express.

## Courses

### Physics Courses

**PHYS:1000 First-Year Seminar** 1 s.h.

Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities). Requirements: first- or second-semester standing.

**PHYS:1100 From Quarks to Quasars** 3-4 s.h.

Conceptual explanation of the latest discoveries in physics—from the smallest objects, such as quarks and atoms, to the largest, such as galaxies, black holes, and quasars. Requirements: nonscience major. GE: Natural Sciences with Lab; Natural Sciences without Lab.

**PHYS:1200 Physics of Everyday Experience** 3 s.h.

Principles of physics for nonscience majors; basic motion, behavior of fluids, waves, temperature and heat, gravity and planetary motion, electricity and magnetism, optics, nuclear energy, radioactivity, and medical imaging technology; examples from everyday experience. GE: Natural Sciences without Lab.

**PHYS:1300 Nanoscience** 3 s.h.

Properties of very small materials and structures; unique properties emerging at a length scale of one billionth of a meter, or one nanometer. GE: Natural Sciences without Lab.

**PHYS:1400 Basic Physics** 3-4 s.h.

Quantitative treatment of mechanics, electricity, heat, liquids, gases, and atomic, nuclear, and elementary particle physics. Requirements: must have completed high school trigonometry or achieved a minimum ALEKS score of 75%. GE: Natural Sciences with Lab; Natural Sciences without Lab.

**PHYS:1409 Basic Physics Lab** 1 s.h.

Laboratory for PHYS:1400.

**PHYS:1410 Physics of Sound** 3-4 s.h.

Acoustical foundations of music; production of sound by vibrating objects, properties of sound waves, vocal acoustics, hearing, room acoustics, principles of electroacoustics. GE: Natural Sciences with Lab; Natural Sciences without Lab.

**PHYS:1511 College Physics I** 4 s.h.

Mechanics, waves, thermodynamics, special relativity. Requirements: must have completed high school trigonometry or achieved a minimum ALEKS score of 75%. GE: Natural Sciences with Lab.

**PHYS:1512 College Physics II** 4 s.h.

Continuation of PHYS:1511; electricity, magnetism, light, modern physics. Prerequisites: PHYS:1611 or PHYS:1511. GE: Natural Sciences with Lab.

**PHYS:1611 Introductory Physics I** 4 s.h.

Mechanics, waves, thermodynamics. Corequisites: MATH:1550 or MATH:1850. GE: Natural Sciences with Lab.

**PHYS:1612 Introductory Physics II** 3-4 s.h.

Continuation of PHYS:1611; electricity, magnetism, light. Prerequisites: PHYS:1611. Corequisites: MATH:1560 or MATH:1860. GE: Natural Sciences with Lab; Natural Sciences without Lab.

**PHYS:1619 Introductory Physics II Lab** 1 s.h.

Laboratory for PHYS:1612. Requirements: 3 s.h. in PHYS:1612. GE: Natural Sciences Lab only.

**PHYS:1701 Physics I** 4 s.h.

Newtonian mechanics for point particles and rigid bodies; conservation laws. Offered fall semesters. Corequisites: MATH:1850. Requirements: physics or astronomy major. GE: Natural Sciences with Lab.

**PHYS:1702 Physics II** 4 s.h.

Continuation of PHYS:1701; introduction to fluid mechanics, electricity, magnetism (Maxwell's equations). Offered spring semesters. Prerequisites: PHYS:1701. Corequisites: MATH:1860. Requirements: physics or astronomy major. GE: Natural Sciences with Lab.

**PHYS:1999 Undergraduate Seminar** arr.

Selected topics in physics and astronomy; discussion, presentations.

**PHYS:2703 Physics III** 4 s.h.

Continuation of PHYS:1702; electromagnetic waves, optics; mechanical and sound waves; thermal physics. Offered fall semesters. Prerequisites: PHYS:1702.

**PHYS:2704 Physics IV** 3-4 s.h.

Introduction to quantum mechanics and other topics in modern physics, including special relativity, atomic and solid state physics. Offered spring semesters. Prerequisites: (PHYS:1612 or PHYS:2703) and (MATH:1860 or MATH:1550). Requirements: for 3 s.h. option—nonmajor.

- PHYS:2990 Reading in Physics** arr. **3 s.h.**  
Selected topics in physics.
- PHYS:3710 Intermediate Mechanics** **3 s.h.**  
Newtonian mechanics; noninertial reference systems; central forces, celestial mechanics; rigid body motion; Lagrangian, Hamiltonian equations of motion; small oscillations. Prerequisites: (PHYS:1611 or PHYS:1511 or PHYS:1701) and (MATH:1860 or MATH:1560).
- PHYS:3730 Statistical Physics** **3 s.h.**  
Integrated introduction to subjects of thermodynamics, statistical mechanics, kinetic theory; emphasis on applications. Prerequisites: PHYS:2704.
- PHYS:3741 Introduction to Quantum Mechanics I** **3 s.h.**  
Superposition principle, Stern-Gerlach experiment, linear operators, measurement theory, time evolution, angular momentum, wave mechanics in one dimension, one-dimensional harmonic oscillator, two-body problems with central forces, the hydrogen atom. Prerequisites: MATH:2850 and PHYS:2704 and MATH:2700.
- PHYS:3742 Introduction to Quantum Mechanics II** **3 s.h.**  
Perturbation theory, variational methods, WKB approximation, scattering, Helium atom, periodic table, atomic spectroscopy, transition rates, other selected applications. Prerequisites: PHYS:3741.
- PHYS:3750 Fundamentals of Micro and Nanofabrication** **3 s.h.**  
Fundamentals of micro- and nano-fabrication processes; physical principles of photo and electron beam lithography, alternative nano-lithography techniques, thin film deposition, molecular beam epitaxy, atomic layer deposition, self-assembly; metrology methods; physical and chemical processes of wet and plasma etching; cleanroom science, operations, safety protocols; sequential micro- and nano-fabrication processes involved in manufacture of semiconductor, photonic, nanoscale devices; imaging and characterization of micro- and nano-structures; scientific and technological applications of emerging micro- and nano-devices and systems. Prerequisites: BIOL:1141 or CHEM:1120 or PHYS:1612 or CHEM:1110 or CHEM:1060 or PHYS:1702 or PHYS:1611. Requirements: undergraduate lab course in chemistry, biology, physics, or engineering. Same as OSTC:3750.
- PHYS:3756 Intermediate Laboratory** **3 s.h.**  
Electricity; electronics; magnetism; optics; atomic, nuclear, solid state physics; techniques in data analysis, including error analysis. Corequisites: PHYS:3811.
- PHYS:3811 Electricity and Magnetism I** **3 s.h.**  
Electrostatics, magnetic fields, introduction to Maxwell's equations. Prerequisites: (MATH:3550 or MATH:2850) and (PHYS:1612 or PHYS:1702 or PHYS:1512).
- PHYS:3812 Electricity and Magnetism II** **3 s.h.**  
Continuation of PHYS:3811; magnetism, electromagnetic waves, A.C. circuits, applications of Maxwell's equations to wave guides, antennas, optics, plasma physics, other topics. Prerequisites: PHYS:3811.
- PHYS:3850 Electronics** **4 s.h.**  
Design and construction of small circuits; use of measurement instruments—oscilloscope, multimeter, function generator; circuits, including transistors, operational amplifiers, digital, analog-to-digital conversion. Prerequisites: PHYS:1512 or PHYS:1612 or PHYS:1702. Requirements: physics or astronomy major.
- PHYS:4720 Introductory Optics** **3 s.h.**  
Geometrical and physical optics; interference; diffraction; polarization; microscopic origins of macroscopic optical properties of matter; optical activity; electro-optical, magneto-optical, acousto-optical phenomena; spontaneous Brillouin, Raman, Rayleigh scattering. Prerequisites: (PHYS:1512 or PHYS:2703 or PHYS:1612) and (MATH:1560 or MATH:1860). Same as ECE:4720.
- PHYS:4726 Electro Optics** **3 s.h.**  
Wave equation solutions; optical birefringence; finite beam propagation in free space, dielectric waveguides and fibers; optical resonators; nonlinear phenomena; electro-optic, acousto-optic modulation; optical detection, noise; application to communication systems. Requirements: for ECE:5790—ECE:3700; for PHYS:4726—PHYS:3812. Same as ECE:5790.
- PHYS:4728 Introductory Solid State Physics** **3 s.h.**  
Phenomena associated with solid state; classification of solids and crystal structures, electronic and vibrational properties in solids; thermal, optical, magnetic, dielectric properties of solids. Prerequisites: PHYS:3741. Same as ECE:4728.
- PHYS:4731 Plasma Physics I** **3 s.h.**  
Physics of ionized gases, including orbit theory, guiding center motion, adiabatic invariants, ionization balance description of plasmas by fluid variables and distribution functions; linearized wave motions, instabilities; magnetohydrodynamics. Prerequisites: PHYS:3812.
- PHYS:4740 Elementary Particles and Nuclear Physics** **3 s.h.**  
Accelerators, particle detectors, passage of radiation through matter; nuclear structure, nuclear reactions; quark model of hadrons; strong, electromagnetic, weak interactions of elementary particles; gauge theories, intermediate vector bosons; unification of electromagnetic and weak interactions. Prerequisites: PHYS:3741.
- PHYS:4750 Advanced Laboratory** **3 s.h.**  
Topics in electricity; electronics; magnetism; atomic, nuclear, plasma, solid state physics; techniques in data analysis, including error analysis.
- PHYS:4761 Mathematical Methods of Physics I** **3 s.h.**  
Functions of complex variables, integration methods, linear vector spaces, tensors, matrix algebra. Prerequisites: MATH:2850.
- PHYS:4762 Mathematical Methods of Physics II** **3 s.h.**  
Continuation of PHYS:4761; Hilbert space, special functions, Fourier transform and expansions in orthogonal polynomials, differential equations, Green's functions. Prerequisites: PHYS:4761.
- PHYS:4820 Optical Signal Processing** **3 s.h.**  
Linear systems description of optical propagation; diffraction and angular plane wave spectrum; lenses as Fourier transformers, lens configurations as generalized optical processors; lasers, coherence, spatial frequency analysis; holography; convolvers, correlators, matched filters; synthetic aperture radar; optical computing. Requirements: for ECE:5780—ECE:3700; for PHYS:4820—PHYS:3812. Same as ECE:5780.
- PHYS:4860 Computational Physics** **3 s.h.**  
Introduction to contemporary use of computers by physicists; topics such as numerical solutions of ordinary differential equations in classical mechanics, boundary value problems in electricity and magnetism, eigenvalue problems in quantum mechanics, Monte Carlo simulations in statistical mechanics, methods of data analysis. Prerequisites: PHYS:3741 and PHYS:3811 and PHYS:3710.

- PHYS:4905 Special Topics in Physics** arr. **3 s.h.**  
**PHYS:4990 Reading in Physics** arr.  
 Selected topics in physics.
- PHYS:4999 Undergraduate Research** arr.  
 Supervised research leading to written report or oral presentation.
- PHYS:5000 Workshops and Special Training in Physics** arr.  
 Workshops and special training opportunities for postbaccalaureate students; may include collaborations with other departments, institutions, or externally funded research organizations.
- PHYS:5710 Classical Mechanics** 3 s.h.  
 Dynamics of mass points; Lagrange multipliers, small oscillations, Hamilton's equations; canonical transformations, Hamilton-Jacobi theory; chaos. Prerequisites: PHYS:3710.
- PHYS:5729 Fluid Mechanics** 3 s.h.  
 Basic equations of fluid mechanics and solutions of these equations for various cases of special interest; compressible and incompressible flows in two- and three-dimensions, rotational and irrotational flows, self-similar solutions, instabilities, turbulence; relate solutions to application of general interest to physicist and engineers; subsonic and supersonic flows around wings and bodies, gravity waves in oceans and atmospheres, transition to supersonic flow in a rocket nozzle, supersonic outflow of gas from the Sun and other stars, and physics of high energy explosions. Prerequisites: PHYS:3710. Requirements: knowledge of vector calculus at level used in PHYS:3811 and PHYS:3812.
- PHYS:5730 Statistical Mechanics I** 3 s.h.  
 Probability concepts; kinetic equations; classical and quantum equilibrium statistical mechanics with applications, including ideal and imperfect gases and phase transitions, irreversible processes, fluctuation-dissipation theorems. Prerequisites: PHYS:3730 and PHYS:3741.
- PHYS:5741 Quantum Mechanics I** 3 s.h.  
 Nonrelativistic quantum mechanics, Schrödinger wave mechanics, Hilbert space methods, perturbation theory, scattering, spin and angular momentum, identical particles, selected applications, introduction to relativistic theory. Prerequisites: PHYS:3741 and PHYS:3742.
- PHYS:5742 Quantum Mechanics II** 3 s.h.  
 Continuation of PHYS:5741. Prerequisites: PHYS:5741.
- PHYS:5811 Classical Electrodynamics I** 3 s.h.  
 Advanced electrostatics, boundary value problems, Green's functions, Maxwell's equations, radiation theory, physical optics, multipole expansion of radiation field.
- PHYS:5812 Classical Electrodynamics II** 3 s.h.  
 Special relativity, motion of charges in fields, theories of radiation reaction, special topics. Prerequisites: PHYS:5811.
- PHYS:6710 Nonlinear Dynamics** 3 s.h.  
 Deterministic approach of turbulence and chaotic dynamical systems; qualitative theory of ordinary differential equations, perturbation in classical mechanics, ergodicity, bifurcation, universal properties of discrete maps, intermittency, fractals, quantitative characterizations of chaos.
- PHYS:6720 Nonlinear Optics** 3 s.h.  
 Classical treatment of second- and third-order optical nonlinearities; phase matching, harmonic generation, three- and four-wave mixing, self-focusing, self-phase modulation, stimulated scattering of light, applications. Requirements: for PHYS:6720—PHYS:3812; for ECE:6720—ECE:5700 or PHYS:3812. Same as ECE:6720.
- PHYS:6723 Advanced Optics** 3 s.h.  
 Classical theory of absorption and emission; laser theory, threshold, rate equations, saturation, spectral and spatial hole burning; multimode and pulsed operation; laser resonators and Gaussian beam optics; dispersion, pulse propagation, light scattering; interaction of light with two level atoms. Prerequisites: PHYS:3812.
- PHYS:6726 Laser Principles** 3 s.h.  
 Laser theory, stimulated emission, dispersion theory, broadening mechanisms, rate equations, gain saturation, optical resonators, mode-locking, Q-switching techniques, survey of laser types, modes of operation. Requirements: for PHYS:6726—PHYS:3812; for ECE:6726—ECE:5700. Same as ECE:6726.
- PHYS:7270 Ethics in Physics for Graduate Students** arr.  
 Responsible conduct and ethics training.
- PHYS:7604 Ethics in Physics for Postdocs** 0 s.h.  
 Responsible conduct and ethics training.
- PHYS:7720 Semiconductor Physics** 3 s.h.  
 Electronic, optical, and materials properties of semiconductors. Prerequisites: PHYS:4728 and PHYS:5742. Same as ECE:7720.
- PHYS:7722 Advanced Condensed Matter** 3 s.h.  
 Elementary excitations, plasmonics, exchange/magnetism, hyperfine interactions, resonance, superconductivity, topological materials. Prerequisites: PHYS:7720.
- PHYS:7725 Special Topics in Condensed Matter** 3 s.h.  
 Current topics, such as superconductivity and magnetism. Prerequisites: PHYS:7820.
- PHYS:7729 Plasma Physics II** 3 s.h.  
 Continuation of PHYS:4731; cold plasma waves, MHD stability, kinetic theory of plasmas, including Landau damping and velocity space instabilities; nonlinear evolution. Prerequisites: PHYS:4731.
- PHYS:7730 Advanced Plasma Physics I** 3 s.h.  
 Microscopic plasma behavior: statistical mechanics of plasmas; Liouville equation; BBGKY hierarchy; Fokker-Planck equation and relaxation processes; Balescu-Lenard equation; Vlasov equation and linearized wave motion; shocks, nonlinear plasma motions, and instabilities; fluctuations and radiation processes; topics from recent literature.
- PHYS:7731 Physics of Strongly Coupled Plasmas** 3 s.h.  
 Nonequilibrium thermodynamics, equation of state, transport properties, structure factors, integral equation theories, BBGKY hierarchy, linear response theory, kinetic theories, Chapman-Enskog method, one-component plasma model, and selected topics from recent literature.
- PHYS:7740 Introduction to Quantum Field Theory** 3 s.h.  
 Quantization of relativistic and nonrelativistic field theories, covariant perturbation theory, theory of renormalization, dimensional regularization, renormalization group theory, introduction to gauge theories and anomalies. Prerequisites: PHYS:5742.
- PHYS:7745 Special Topics in Quantum Mechanics** arr.  
 Current topics in quantum mechanics, such as string theory, relativistic quantum mechanics, quantum gravity, axiomatic quantum field theory.
- PHYS:7746 Particle Physics** 3 s.h.  
 Elementary particle properties and phenomenology, quark-parton models, quantum chromodynamics, unified theory of weak and electromagnetic interactions.

**PHYS:7760 General Relativity and Cosmology** 2-3 s.h.  
Einstein's theory of gravitation; applications to astrophysics and cosmology.

**PHYS:7820 Theoretical Solid State Physics I** 3 s.h.  
Central principles of the quantum theory of solids; lattice dynamics, electronic structure, optical properties, superconductivity, magnetism; emphasis on viewpoint of elementary excitations. Prerequisites: PHYS:4728 and PHYS:5742.

**PHYS:7840 Quantum Gauge Theories** 3 s.h.  
Gauge invariance, introductory group theory, Yang-Mills theories, electroweak theory, quantum chromodynamics, running coupling constants, operator product expansions, Ward identities, spontaneous symmetry breaking, chiral anomalies, instantons, monopoles, effective Lagrangians, supersymmetry, quantum gravity, introduction to string theory. Prerequisites: PHYS:7740.

**PHYS:7905 Special Topics in Physics** arr.

**PHYS:7920 Seminar: Solid State Physics** arr.  
Current research.

**PHYS:7930 Seminar: Plasma Physics** arr.  
Current research. Same as ECE:7930.

**PHYS:7936 Seminar: Space Physics** arr.  
Current research.

**PHYS:7940 Seminar: Nuclear Physics** arr.  
Current research.

**PHYS:7945 Seminar: Math/Physics** arr.  
Current research.

**PHYS:7946 Seminar: Elementary Particle Physics** arr.  
Current research.

**PHYS:7990 Research: Physics** arr.

**PHYS:7992 Individual Critical Study** arr.  
Essay on topic chosen in consultation with faculty member. Requirements: candidacy for M.S. with critical essay.

## Astronomy Courses

**ASTR:1000 First-Year Seminar** 1 s.h.  
Small discussion class taught by a faculty member; topics chosen by instructor; may include outside activities (e.g., films, lectures, performances, readings, visits to research facilities).

**ASTR:1060 Big Ideas: Origins of the Universe, Earth, and Life** 3 s.h.  
Fundamental questions (How old is the universe? What is the nature of life? How has life evolved on Earth? What are our human origins? Are there other habitable planets in the universe?) that revolve around understanding origins from different perspectives (i.e., astronomy, physics, geoscience, biology, chemistry, anthropology); work with faculty from several departments to investigate these questions; inquiry-based activities to build success in critical thinking, teamwork, effective written and oral communication; origin of the universe, biochemistry of life, and origin of life on Earth; first of a two-part sequence. Recommendations: first-year or sophomore standing. GE: Natural Sciences without Lab. Same as BIOL:1060, EES:1060.

**ASTR:1061 Big Ideas: Evolution of Life on Earth and the Search for Life in the Universe** 4 s.h.

How has life evolved on Earth? What are our human origins? Are there other habitable planets in the universe? These fundamental questions revolve around understanding the origins of life from different perspectives—astronomy and physics, geoscience, biology, chemistry, and anthropology; students will work together with faculty from across four different departments to investigate these questions using inquiry-based activities to build success in critical thinking, teamwork, and effective written and oral communication; second half of the origins sequence (though either course also may be taken alone). GE: Natural Sciences with Lab. Same as ANTH:1061, BIOL:1061, EES:1061.

**ASTR:1070 Stars, Galaxies, and the Universe** 3-4 s.h.

Survey of stars, galaxies, and the universe; life cycles of stars, including black holes and pulsars; diversity of galaxies, including the Milky Way and distant quasars; cosmology—the history, structure, and fate of the universe; current results from recent astronomical observations; night sky observation. Recommendations: closed to physics and astronomy majors. GE: Natural Sciences with Lab; Natural Sciences without Lab.

**ASTR:1079 Introductory Astronomy Laboratory** 1 s.h.

Laboratory for ASTR:1070 or ASTR:1080. GE: Natural Sciences Lab only.

**ASTR:1080 Exploration of the Solar System** 3-4 s.h.

Survey of the solar system; physical properties of the planets, comets, and asteroids; origin of the solar system; search for extrasolar planetary systems; search for life in the universe; current results of recent planetary space missions; night sky observation. Recommendations: closed to physics and astronomy majors. GE: Natural Sciences with Lab; Natural Sciences without Lab.

**ASTR:1085 Citizen Astronomy** 3 s.h.

Exploration of the Universe, not as spectators, but as active participants in the scientific process; survey of important environments in astronomy and astrophysics, ranging from the very local solar system to nearby stars in the galaxy, to distant galaxies and unseen black holes; focus on a growing number of citizen science projects that allow students to examine real data, make real discoveries, and in some cases, get scientific credit for their contributions; goes beyond the superficial exploration of pretty pictures as students make real contributions to understanding the universe; science and math background not required, just curiosity.

**ASTR:1771 General Astronomy I** 4 s.h.

Qualitative and quantitative introduction to the development of astronomy, celestial mechanics, time, electromagnetic radiation, telescopes and astronomical instrumentation, planets, smaller solar system objects; laboratory emphasis on observation with telescopes. Requirements: four years of high school math. GE: Natural Sciences with Lab.

**ASTR:1772 General Astronomy II** 4 s.h.

Continuation of ASTR:1771; qualitative and quantitative introduction to properties and evolution of sun, stars, interstellar matter, galaxies; cosmology; laboratory emphasis on observation with telescopes. Requirements: four years of high school math. GE: Natural Sciences with Lab.

**ASTR:2991 Reading in Astronomy** arr.

Selected topics in astronomy.

**ASTR:3771 Introduction to Astrophysics I 3 s.h.**

Fundamentals of astrophysical processes in solar system objects, stars, nebulae, interstellar medium, galaxies, cosmology; topics include stellar spectra, binary stars, interstellar gas and dust, stellar and galactic kinematics, stellar evolution, HII regions, radiation processes in galaxies and quasars, mathematical descriptions of the universe. Prerequisites: PHYS:2704 and ASTR:1772 and ASTR:1771 and (MATH:2850 or MATH:3550) and (MATH:2700 or MATH:2550). Recommendations: computer programming experience.

**ASTR:3772 Introduction to Astrophysics II 3 s.h.**

Continuation of ASTR:3771. Prerequisites: ASTR:3771.

**ASTR:4770 Radio Astronomy 3 s.h.**

Survey of radio astronomy, emphasizing technical aspects; radiation, antennas, receivers, radio spectroscopy, interferometer arrays and aperture synthesis; emission mechanisms, pulsars, supernova remnants, radio galaxies.

**ASTR:4850 Astronomical Laboratory 3 s.h.**

Techniques and instrumentation in optical and radio astronomy. Prerequisites: PHYS:2704 and ASTR:1772 and ASTR:1771.

**ASTR:4906 Special Topics in Astronomy arr.****ASTR:4996 Reading in Astronomy arr.****ASTR:6781 Galactic Astronomy 3 s.h.**

Structure of the Milky Way galaxy; distance indicators, orbits in the galaxy, spiral structure; evidence for dark matter in the Milky Way, the galactic center; comparison of Milky Way with nearby galaxies.

**ASTR:6782 Extragalactic Astronomy 3 s.h.**

Normal and active galaxies, large scale structure, the early Universe, cosmology.

**ASTR:6785 The Interstellar Medium 3 s.h.**

The interstellar medium: optical properties of small interstellar grains, radiative processes in interstellar gas, structure of HII regions, interstellar shock waves, supernova remnants, modification of interstellar medium by luminous stars, molecular clouds.

**ASTR:6790 Stellar Astrophysics 3 s.h.**

Stellar interiors, nuclear astrophysics; advanced topics.

**ASTR:6870 Radiative Processes in Astrophysics 3 s.h.**

Physical mechanisms for generation of electromagnetic radiation in astrophysics; continuum mechanisms (bremsstrahlung, Compton scattering, synchrotron radiation); spectral line radiation from atoms, molecules, and nuclei, including fine structure effects; fundamental physics of processes; application to astronomical observations.

**ASTR:6880 High Energy Astrophysics 3 s.h.**

Detection of X-rays and gamma-rays, analysis of X-ray data, black holes and neutron stars, accretion onto compact objects, pulsars, supernova remnants, cosmic rays, gamma-ray bursts.

**ASTR:7775 Special Topics in Astrophysics 1-3 s.h.**

Advanced lectures.

**ASTR:7830 Space and Astrophysical Plasma Physics 3 s.h.**

Dynamics and evolution of space and astrophysical plasmas; heliosphere, planetary magnetospheres, accretion disks; plasma waves, shock waves, turbulence.

**ASTR:7970 Seminar: Astrophysics arr.**

Current research.

**ASTR:7991 Research: Astronomy arr.**

Original research in observational, theoretical astronomy.