The Engineering Physics curriculum is a flexible program that combines a firm foundation in physics and mathematics with the freedom to choose from a diverse range of technical options. The curriculum is designed to prepare students for a wide variety of technical and professional careers, including graduate study in physics or a closely allied field.

**Undergraduate Programs:**
- major: Physics, BS ([http://catalog.illinois.edu/undergraduate/bs_engr_phys](http://catalog.illinois.edu/undergraduate/bs_engr_phys))

**Graduate Programs:**
- degree: Physics, MS ([http://catalog.illinois.edu/graduate/graduate-majors/physics/physics-ms](http://catalog.illinois.edu/graduate/graduate-majors/physics/physics-ms))
- degree: Teaching of Physics, MS ([http://catalog.illinois.edu/graduate/graduate-majors/physics/physics-teaching-ms](http://catalog.illinois.edu/graduate/graduate-majors/physics/physics-teaching-ms))
- degree: Physics, PhD ([http://catalog.illinois.edu/graduate/graduate-majors/physics/#doctoraltext](http://catalog.illinois.edu/graduate/graduate-majors/physics/#doctoraltext))

**Graduate Degree Programs**
The Department of Physics is actively developing a new paradigm for graduate physics education and research for the 21st century, aimed at enhancing interdisciplinary interactions and creating an integrated approach to educational and research training. Advanced degrees offered in physics are the Master of Science and the Doctor of Philosophy. Outstanding graduate research opportunities are available in many subdisciplines of physics, including:
- condensed matter physics
- high energy and nuclear physics
- astrophysics
- atomic
- molecular and optical physics
- complex systems
- quantum information
- biological physics
- physics education research

Students may select experimental, theoretical, or computational thesis projects. Multidisciplinary projects are especially encouraged, and, with the consent of other departments, students may earn master's degrees in areas such as materials science and engineering, or computer science, simultaneously with their Ph.D. degrees in physics. Opportunity also exists for specializing in:

1. computational science and engineering via the Computational Science and Engineering (CSE) ([http://www.cse.illinois.edu](http://www.cse.illinois.edu)) transcriptable Concentration
2. energy and sustainability engineering via the Energy and Sustainability Engineering (EaSE) Option ([http://ease.illinois.edu](http://ease.illinois.edu)).

**Admission**
Admission to the physics graduate program requires an outstanding record of accomplishment in an undergraduate physics program and clear evidence of considerable academic promise, as judged by test scores, letters of recommendation, and strong intellectual achievements. A bachelor's degree or its equivalent from an accredited college or university in the U.S. or an approved institution of higher learning abroad, with at least 20 semester hours (30 quarter hours) of intermediate and advanced undergraduate physics course work, is required for admission. Course preparation in electricity and magnetism, optics, mechanics, atomic and nuclear physics, quantum mechanics, mathematical physics, differential equations, and analysis is essential. Any deficiency in these areas may delay degree completion by as much as a year. (Students are expected to make up deficiencies during the first graduate year.)

A minimum GPA of 3.00 (A = 4.00) for the last two years of undergraduate work is required; however, because of space limitations, applicants with GPAs below 3.50 are rarely admitted. Students with prior graduate course work must have a minimum GPA of 3.50 for those courses. All applicants must provide test scores from both the general and the physics tests of the Graduate Record Examination (GRE) ([http://www.ets.org](http://www.ets.org)).

Graduates of curricula in the physical and biological sciences, mathematics, or computer science may be admitted with limited standing if they are judged to have the necessary aptitudes to profit from graduate work in physics. Such students are admitted to full standing after completing course work to remove deficiencies in physics preparation.

All applicants whose native language is not English must submit a minimum TOEFL ([http://www.toefl.org](http://www.toefl.org)) score of 79 (iBT), 213 (CBT), or 550 (PBT); or minimum International English Language Testing System (IELTS) ([http://www.ielts.org](http://www.ielts.org)) academic exam scores of 6.5 overall and 6.0 in all subsections. Applicants may be exempt from the TOEFL if certain criteria ([http://grad.illinois.edu/admissions/instructions/04c](http://grad.illinois.edu/admissions/instructions/04c)) are met. For those taking the TOEFL or IELTS, full admission status ([http://grad.illinois.edu/admissions/instructions/04c](http://grad.illinois.edu/admissions/instructions/04c)) is granted for scores greater than 102 (TOEFL iBT), 253 (TOEFL CBT), 610 (TOEFL PBT), or 6.5 (IELTS). Limited status ([http://grad.illinois.edu/admissions/instructions/04c](http://grad.illinois.edu/admissions/instructions/04c)) is granted for lesser scores and requires enrollment in English as a Second Language (ESL) courses ([http://grad.illinois.edu/admissions/instructions/04c](http://grad.illinois.edu/admissions/instructions/04c)).
linguistics.illinois.edu/students/esl/guidelines) based on an ESL Placement Test (EPT) taken upon arrival to campus.

A few applicants may be admitted for the spring semester, in addition to the customary fall semester admissions. See the Physics graduate admissions Web site (http://physics.illinois.edu/grad/apply.asp) for lists of deadlines and application materials.

Faculty Research Interests
The research specialties of Physics faculty fall into the broad categories described in the graduate programs section of this document. Details of each individual's specific interests are available at the department's faculty research Web site. (http://physics.illinois.edu/research) Included are faculty whose primary appointments are in other departments but who supervise Physics students.

Facilities and Resources
The Department of Physics offers world-class research facilities in traditional areas of physics, including condensed matter, nuclear, particle, and optical physics, as well as state-of-the-art instruments for quantum information, nanoscale science and engineering, and biological physics. For a complete description of physics facilities, please consult the department's facilities Web site (http://physics.illinois.edu/research/shops.asp).

Financial Aid
Fellowships, research assistantships, and teaching assistantships (all of which include waivers of tuition and some fees) are available for the majority of admitted students. All applicants, regardless of U.S. citizenship, whose native language is not English and who wish to be considered for teaching assistantships must demonstrate spoken English language proficiency (http://grad.illinois.edu/admissions/taengprof.htm) by achieving a minimum score of 24 on the speaking subsection of the TOEFL iBT or 8 on the speaking subsection of the IELTS. For students who are unable to take the iBT or IELTS, a minimum score of 4CP is required on the EPI test (http://cte.illinois.edu/testing/oral_eng/epi_overview.html), offered on campus. All new teaching assistants are required to participate in the Graduate Academy for College Teaching (http://cte.illinois.edu/programs/ta_train.html) conducted prior to the start of the semester.

PHYS Class Schedule (https://courses.illinois.edu/schedule/DEFAULT/DEFAULT/PHYS)

Courses

PHYS 100 Thinking About Physics credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/100)
Conceptual and problem solving skills in preparation for PHYS 211: analysis and mathematical descriptions of physical situations understanding the meaning of the solutions Prerequisite: Credit or concurrent registration in MATH 220 or MATH 221.

PHYS 101 College Physics: Mech & Heat credit: 5 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/101)
Newton's Laws, work and energy, rotational motion, fluids, thermodynamics, and waves. A noncalculus-based approach for majors in the life sciences, preprofessional health programs, agriculture, and veterinary medicine. Credit is not given for both PHYS 101 and either PHYS 211 or PHYS 213. Prerequisite: Trigonometry.
This course satisfies the General Education Criteria for: Nat Sci Tech - Phys Sciences Quantitative Reasoning II

PHYS 102 College Physics: E&M & Modern credit: 5 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/102)
Electric forces and fields, electric potential, electric circuits, magnetic forces and fields, geometrical optics, relativity, and modern physics. A noncalculus-based approach for majors in the life sciences, preprofessional health programs, agriculture, and veterinary medicine. Credit is not given for both PHYS 102 and either PHYS 212 or PHYS 214. Prerequisite: PHYS 101.
This course satisfies the General Education Criteria for: Nat Sci Tech - Phys Sciences Quantitative Reasoning II

PHYS 110 Physics Careers credit: 0 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/110)
Exploration of careers founded on physics undergraduate training. Introduction to the Physics Department, faculty, research and curricula. Outside speaker presentations. Approved for S/U grading only.

PHYS 123 Physics Made Easy credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/123)
Inquiry-based, nonmathematical, hands-on study of physics for elementary school teachers. Coverage of most of the National Science Education K-4 Content Standards. Additional fees may apply. See Class Schedule.
This course satisfies the General Education Criteria for: Nat Sci Tech - Phys Sciences

PHYS 140 How Things Work credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/140)
Nonmathematical approach underscoring the generality and ubiquity of basic physical laws in understanding commonplace phenomena: musical instruments, photography, electric and electronic circuits, television, motors, engines, etc. Credit is not given to engineering majors.
This course satisfies the General Education Criteria for: Nat Sci Tech - Phys Sciences

PHYS 150 Physics of Societal Issues credit: 3 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/150)
Physics topics and applications relevant in the modern world: energy, quantum mechanics, electricity and magnetism, nuclear physics, waves, light, and outer space. Application to satellites, alternative energy, medical imaging, radiation, nuclear weapons, climate change, and electronics. Emphasis on analytical thinking and the applicability to modern societal issues.
This course satisfies the General Education Criteria for: Nat Sci Tech - Phys Sciences
Quantitative Reasoning II

Information listed in this catalog is current as of 04/2019
PHYS 192  Science and Pseudoscience  credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/PHYS/192)

Extra-sensory perception, alien abduction, and psychic crime-solving from the standpoint of scientific inquiry and exploration; the scientific method, how science progresses, and the types of argumentative fallacies that pervade the pseudoscientific community; examples of good science and how the scientific method is self-correcting.

PHYS 193  Physics of Music  credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/193)

Physics of music and musical instruments: acoustical physics, propagation of sound waves, the biological physics of human hearing, and the acoustical physics associated with all types of musical instruments.

PHYS 194  Behavior of Complex Systems  credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/PHYS/194)

Exploration of systems with simple rules that nevertheless exhibit complex behavior. Lecture demonstrations on fractal growth, chaos, catastrophes, self-assembly, lightning, turbulence, explosions, and human rhythms. Simple computer models which exhibit regular, irregular, symmetric, and self-similar patterns and dynamics. Dynamics of isolated and coupled complex systems and mathematical tools for quantifying complex behavior.

PHYS 199  Undergraduate Open Seminar  credit: 0 to 5 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/199)

Approved for letter and S/U grading. May be repeated.

PHYS 211  University Physics: Mechanics  credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/211)

Newton's Laws, work and energy, static properties and fluids, oscillations, transverse waves, systems of particles, and rotations. A calculus-based approach for majors in engineering, mathematics, physics and chemistry. Credit is not given for both PHYS 211 and PHYS 101. Prerequisite: Credit or concurrent registration in MATH 231.

This course satisfies the General Education Criteria for:
Nat Sci Tech - Phys Sciences
Quantitative Reasoning II

PHYS 212  University Physics: Elec & Mag  credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/212)

Coulomb's Law, electric fields, Gauss' Law, electric potential, capacitance, circuits, magnetic forces and fields, Ampere's law, induction, electromagnetic waves, polarization, and geometrical optics. A calculus-based approach for majors in engineering, mathematics, physics, and chemistry. Credit is not given for both PHYS 212 and PHYS 102. Prerequisite: PHYS 211; credit or concurrent registration in MATH 241.

This course satisfies the General Education Criteria for:
Nat Sci Tech - Phys Sciences
Quantitative Reasoning II

PHYS 213  Univ Physics: Thermal Physics  credit: 2 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/213)

First and second laws of thermodynamics including kinetic theory of gases, heat capacity, heat engines, introduction to entropy and statistical mechanics, and introduction to application of free energy and Boltzmann factor. A calculus-based approach for majors in engineering, mathematics, physics and chemistry. Credit is not given for both PHYS 213 and PHYS 101. Prerequisite: PHYS 211; credit or concurrent registration in MATH 241.

This course satisfies the General Education Criteria for:
Nat Sci Tech - Phys Sciences
Quantitative Reasoning II
PHYS 298  Freshmen/Sophomore Special Topics in Physics  credit: 0 to 4 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/298)
Topical offerings of technical interest, skills, and knowledge in physics, and its practice, intended to augment the existing curriculum at the introductory level. Approved for Letter and S/U grading. May be repeated in separate terms up to 12 credit hours if topics vary. Prerequisite: See Class Schedule or departmental course information for topics and prerequisites. For students with freshman or sophomore standing.

PHYS 325  Classical Mechanics I  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/325)
Kinematics and dynamics of classical systems, including a review of Newtonian kinematics and dynamics. Three dimensional motion, variable mass, and conservation laws; damped and periodically driven oscillations; gravitational potential of extended objects and motion in rotating frames of reference; Lagrangian and Hamiltonian mechanics. Prerequisite: PHYS 225; credit or concurrent registration in MATH 285.

PHYS 326  Classical Mechanics II  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/326)
Continuation of PHYS 325. Central force motion, collisions and scattering, rotational motion, coupled oscillations, continuous media, and fluid dynamics. Prerequisite: PHYS 325.

PHYS 329  Atmospheric Dynamics I  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/329)
Same as ATMS 302. See ATMS 302.

PHYS 330  Atmospheric Dynamics II  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/330)
Same as ATMS 312. See ATMS 312.

PHYS 398  Sophomore/Junior Special Topics in Physics  credit: 1 to 4 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/398)
Topical offerings of technical interest, skills, and knowledge in physics, and its practice, intended to augment the existing curriculum at the intermediate level. Approved for Letter and S/U grading. May be repeated in separate terms up to 12 hours if topics vary. Prerequisite: See Class Schedule or departmental course information for topics and prerequisites. For students with sophomore or junior standing.

PHYS 401  Classical Physics Lab  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/401)
Experiments and techniques in classical mechanics and electromagnetism. Dynamics of electrical and mechanical oscillators in the linear domain. Fourier analysis of system response. Measurements of electrostatic fields, transmission lines, waves, and radiation. Electromagnetic phenomena in dielectrics, conductors, and magnetic materials. Instruction in data analysis and report writing. 3 undergraduate hours. 3 graduate hours. Prerequisite: Credit or concurrent enrollment in PHYS 325.

PHYS 402  Light  credit: 3 or 4 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/402)
Wave kinematics; geometrical optics: basic concepts, ray-tracing and matrix formalism, Gaussian imaging by thick lenses, stops, apertures, and intensity relations; interference; interference spectroscopy and coherence; diffraction: Fresnel-Kirchhoff formulation, Fraunhofer case, Fresnel case, and holography; polarized light. 4 undergraduate hours. 3 or 4 graduate hours. (3 hours without lab). Prerequisite: MATH 285; PHYS 102 or PHYS 214.

PHYS 403  Modern Experimental Physics  credit: 4 or 5 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/403)
Techniques and experiments in the physics of atoms, atomic nuclei, molecules, the solid state, and other areas of modern physical research. 5 undergraduate hours. 4 graduate hours. Prerequisite: Credit or concurrent registration in PHYS 486.

PHYS 404  Electronic Circuits  credit: 4 or 5 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/404)
Physics of semiconductor devices; theory and application of discrete and integrated devices in linear circuits; use of operational amplifiers and feedback; regulation, oscillators, and modulation; emphasizes practical experience. 5 undergraduate hours. 4 graduate hours. Prerequisite: PHYS 325.

PHYS 406  Acoustical Physics of Music  credit: 4 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/406)
Acoustical physics associated with music and musical instruments, propagation of sound waves in and from musical instruments, and the biological physics of human hearing. Investigation of topics via advanced laboratory and data acquisition techniques. 4 undergraduate hours. 4 graduate hours. Prerequisite: PHYS 213 and PHYS 214.

PHYS 419  Space, Time, and Matter-ACP  credit: 3 or 4 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/419)
Identical to PHYS 420 except for the additional writing component including a final term paper. Same as PHIL 419. 3 undergraduate hours. 4 graduate hours. Credit is not given for both PHYS 419 and PHYS 420. Prerequisite: PHIL 101; PHYS 101 or PHYS 211. This course satisfies the General Education Criteria for: Advanced Composition

PHYS 420  Space, Time, and Matter  credit: 2 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/420)
Philosophical examination of some fundamental concepts and theories of the physical world, such as time, matter, space, and geometry; interpretation of quantum theory. Same as PHIL 420. 2 undergraduate hours. 2 graduate hours. Credit is not given for both PHYS 420 and PHYS 419. Prerequisite: PHIL 101; PHYS 101 or PHYS 211.

PHYS 427  Thermal & Statistical Physics  credit: 4 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/427)
Equilibrium thermodynamics, statistical mechanics, and kinetic theory of gases. A unified treatment is used in that the principles of heat and thermodynamics are discussed along with statistical postulates and the microscopic approach of introductory quantum mechanics. 4 undergraduate hours. 4 graduate hours. Credit is not given for both PHYS 427 and any of ME 404, CHEM 444, MSE 500. Prerequisite: PHYS 213, PHYS 214, and PHYS 325.

PHYS 435  Electromagnetic Fields I  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/435)
Static electric and magnetic fields, their interactions with electric charge and current, and their transformation properties; the effect of special relativity is incorporated. Macroscopic fields in material media are described. 3 undergraduate hours. 3 graduate hours. Prerequisite: MATH 285; credit or concurrent enrollment in PHYS 325.

PHYS 436  Electromagnetic Fields II  credit: 3 Hours.  (https://courses.illinois.edu/schedule/terms/PHYS/436)
Time-dependent fields. Electromagnetic induction, Maxwell's equations, electromagnetic wave propagation in various media and structures, and electromagnetic radiation from charge and current distributions. Relativistic covariance of Maxwell's equations. Course Information:3 undergraduate hours. 3 graduate hours. Prerequisite: PHYS 435.
Advanced Composition
This course satisfies the General Education Criteria for credit.
and oral-presentation activities. 3 undergraduate hours. No graduate credit.

Examination of current research topics through extensive reading, writing, and oral-presentation activities. 3 undergraduate hours. No graduate credit. This course satisfies the General Education Criteria for:

Department of Physics

Information listed in this catalog is current as of 04/2019
**PHYS 510** Nonlinear Dynamics credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/510)
Broad introduction to nonlinear dynamics of physical systems with varying degrees of complexity; survey of a variety of concepts associated with bifurcation phenomena, mappings, nonlinear oscillations, chaotic behavior, strange attractors, and solitons. Topics of current interest. Prerequisite: PHYS 326.

**PHYS 513** Quantum Optics & Information credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/513)
Experimental and theoretical fundamentals of quantum information, using nonclassical features of quantum physics (wave-particle duality, superposition, and entanglement) to surpass the information-processing capabilities of classical systems. Underlying fundamental quantum phenomena, including tests of nonlocality, quantum erasers, the quantum Zeno effect, squeezed light, multi-particle interference, state transformations of the Bloch sphere, and decoherence; quantum cryptography and teleportation; quantum information theory; quantum computation algorithms and techniques for error correction; experimental "qubit" systems. Prerequisite: Recommended: PHYS 580.

**PHYS 514** Modern Atomic Physics credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/514)
Rigorous survey of modern atomic, molecular, and optical physics, including a functional approach to theory and an overview of experimental techniques. Atomic structure, including fine and hyperfine structure, multi-electron atoms, and relativistic effects; interaction of single atoms with dynamic and static electromagnetic fields, ultracold collisions between atoms; laser cooling, evaporative cooling, and magnetic trapping; Paul and Penning traps; quantum degenerate gases; atom interferometry. Prerequisite: PHYS 427, PHYS 436, and PHYS 487.

**PHYS 515** General Relativity I credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/515)
Systematic introduction to Einstein's theory, with emphasis on modern coordinate-free methods of computation. Review of special relativity, modern differential geometry, foundations of general relativity, laws of physics in the presence of a gravitational field, linearized theory, and experimental tests of gravitation theories. Same as ASTR 515. Prerequisite: PHYS 436.

**PHYS 516** General Relativity II credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/516)
Continuation of PHYS 515 with emphasis on applications to astrophysics and cosmology. Relativistic stars, gravitational collapse, black holes, gravitational waves, numerical relativity, and cosmology. Same as ASTR 516. Prerequisite: PHYS 515.

**PHYS 540** Astrophysics credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/540)
Fundamental aspect of astrophysics and cosmology and new developments in these fields. Basic physical concepts and principles, the key observational evidence, and illustrative calculations. Relativistic cosmological models, inflation, Big-Bang nucleosynthesis, and the cosmic microwave background; formation and evolution of galaxy clusters, galaxies, and stars; formation, structure, and evolution of white dwarfs, neutron stars, and black holes; rotation- and accretion-powered pulsars, X-ray and y-ray stars, and gravitational radiation. Same as ASTR 540. Prerequisite: PHYS 435; PHYS 485 or PHYS 486.

**PHYS 541** Physics of Compact Objects credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/541)

**PHYS 542** Theoretical Stellar Physics credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/542)
Same as ASTR 504. See ASTR 504.

**PHYS 550** Biomolecular Physics credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/550)
Physical concepts governing the structure and function of biological macromolecules; general properties, spatial structure, energy levels, dynamics and functions, and relation to other complex physical systems such as glasses; recent research in biomolecular physics; physical techniques and concepts from theoretical physics emphasized. Same as BIOP 550 and MCB 550. Prerequisite: CHEM 485 or PHYS 487.

**PHYS 552** Optical Spectroscopy credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/552)
Theoretical and experimental fundamentals of optical spectroscopy. Light-matter interaction (absorption of UV, visible, IR), emission spectroscopy (fluorescence, Raman and light scattering), theoretical backgrounds of molecular electronic and vibrational transitions, modern experimental techniques, and data analysis of the optical spectroscopy experiments. Laboratory exercises applying spectroscopy to a broad spectrum of disciplines, including biophysical examples. Prerequisite: PHYS 427 and PHYS 487.

**PHYS 554** Nonequilibrium Stat Mechanics credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/554)
Mathematical description of classical and quantum stochastic systems, thoroughly addressing the tools and the mode of thinking of nonequilibrium statistical mechanics. Equilibrium statistical mechanics (review); Einstein and Smoluchowski diffusion equation; generalized moment expansion of correlation functions; noise-induced limit cycles; time series analysis; diffusion-controlled reactions; classical dynamics under the influence of stochastic forces; observables connected with Brownian transport, echoes, and hysteresis; spin-boson model. Examples from biological physics and theoretical condensed matter physics. Prerequisite: PHYS 504.

**PHYS 560** Condensed Matter Physics I credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/560)
Crystalline perfection, free-electron gas, screening, plasma oscillations, and dielectric response; Bloch electrons, Brillouin zones, and band structure; semiconductors, intrinsic and extrinsic, with applications; phonons, elasticity, and anharmonicity; ferromagnetism and second-order phase transitions; superconductivity. Prerequisite: PHYS 427 and PHYS 580.

**PHYS 561** Condensed Matter Physics II credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/561)
Hartree-Fock theory and electron-electron interactions; electron-phonon interactions; electron dynamics and transport; BCS theory of superconductivity; elastic properties; thermal properties due to anharmonicity; defects in solids. Prerequisite: PHYS 560 and PHYS 581.
PHYS 580  Quantum Mechanics I  credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/580)
Second course in quantum mechanics. Operators, state vectors, and the formal structure of quantum theory; operator treatments of simple systems; angular momentum and vector addition coefficients; stationary state perturbation theory; introduction to scattering theory for particles without spin, partial wave analysis, and Born approximation; examples taken from atomic, nuclear, and elementary particle physics. Prerequisite: PHYS 485 or PHYS 487.

PHYS 581  Quantum Mechanics II  credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/581)
Spin and identical particles, simple many-particle systems and elements of second-quantization theory; time-dependent processes, radiative transitions, and quantization of the electromagnetic field; scattering of particles with spin; polarization; introduction to the Klein-Gordon and Dirac equations and properties of simple relativistic systems. Prerequisite: PHYS 580.

PHYS 582  General Field Theory  credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/582)
Standard techniques of field theory as used by experimenters and theorists; relativistic quantum mechanics of a single particle; Lagrangian field theories, perturbation theory, and calculation of lowest-order processes; introduction to Feynman diagrams and higher order processes; examples taken from quantum electrodynamics, solid-state and elementary particle physics, and many-body theory. Prerequisite: PHYS 581.

PHYS 583  Advanced Field Theory  credit: 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/583)
Quantization and Feynman path integral; gauge theories and renormalization; renormalization group with applications to particle physics and critical phenomena; approximation methods and recent developments. Prerequisite: PHYS 582.

PHYS 596  Graduate Physics Orientation  credit: 1 Hour. (https://courses.illinois.edu/schedule/terms/PHYS/596)
Introduction to research in the Department of Physics. Advice on choosing a field of research and finding a research advisor. Faculty-presented overviews of the major areas of research available in the Physics Department. General discussions on instructional topics as well as ethics in teaching and sciences.

PHYS 597  Individual Study  credit: 1 to 16 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/597)
Individual study in a subject not covered in course offerings may be arranged for credit by registration under this number. May be repeated. 2 to 16 hours for full term; 1 to 8 hours for half-term. Prerequisite: Consent of instructor.

PHYS 598  Special Topics in Physics  credit: 1 to 4 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/598)
Subject offerings of new and developing areas of knowledge in physics intended to augment the existing curriculum. See Class Schedule or departmental course information for topics and prerequisites. May be repeated in the same or separate terms if topics vary.

PHYS 599  Thesis Research  credit: 0 to 16 Hours. (https://courses.illinois.edu/schedule/terms/PHYS/599)
Approved for S/U grading only. May be repeated.