# PHYSICS    PHY

**Department of Physics
and Astronomy
College of Natural Science**

**101    Concepts in Physics**
Fall. 1(1-0)
Conceptual foundations of physics emphasizing key experiments.

**102    Physics Computations I**
Spring. 1(0-3) P: (PHY 183 or concurrently) or (PHY 183B or concurrently) or (PHY 193H or concurrently) or (LB 273 or concurrently) RB: CSE 101 or CSE 231
Use of Mathematica to solve, analyze and graph equations and data from mechanics.

**105C    Preparatory - Physics**
Summer. 1(1-0) Interdepartmental with Lyman Briggs. Administered by Lyman Briggs. RB: College Algebra
Preparation for the introductory physics sequence: mathematical concepts, notations, representations, effective problem solving techniques and study strategies.

**170    Investigations in Physics**
Fall. 3(0-6) R: Open to freshmen in the Department of Physics and Astronomy. Approval of department.
Experiments in optics, electronics, sound and mechanics; analysis of data using computers, library research and oral presentations.

**183    Physics for Scientists and Engineers I**
Fall, Spring. 4(5-0) P: MTH 132 or MTH 152H or LB 118 Not open to students with credit in LB 273 or PHY 193H or PHY 231 or PHY 231C.
Mechanics, Newton's laws, momentum, energy conservation laws, rotational motion, oscillation, gravity, and waves.

**183B    Physics for Scientists and Engineers I**
Fall, Spring, Summer. 4 credits. P: MTH 132 or MTH 152H or LB 118 Not open to students with credit in LB 273 or PHY 183 or PHY 193H or PHY 231 or PHY 231C.
Mechanics, Newton's laws, momentum, energy conservation laws, rotational motion, oscillation, gravity, waves.

**184    Physics for Scientists and Engineers II**
Fall, Spring. 4(5-0) P: {(PHY 183 or PHY 183B or PHY 193H or LB 273) or (PHY 231 and (PHY 233B or concurrently)) or (PHY 231C and (PHY 233B or concurrently))} and (MTH 133 or MTH 153H or LB 119) Not open to students with credit in LB 274 or PHY 184B or PHY 232 or PHY 234B or PHY 294H or PHY 232C.
Electricity and magnetism, electromagnetic waves, light and optics, interference and diffraction.

**184B    Physics for Scientists and Engineers II**
Fall, Spring, Summer. 4 credits. P: {(PHY 183 or PHY 183B or PHY 193H or LB 273) or (PHY 231 and PHY 233B) or (PHY 231C and PHY 233B)} and (MTH 133 or MTH 153H or LB 119) Not open to students with credit in LB 274 or PHY 184 or PHY 232 or PHY 232C or PHY 294H.
Electricity and magnetism, electromagnetic waves, light and optics, interference and diffraction.

**191    Physics Laboratory for Scientists, I**
Fall. 1(0-3) P: ((PHY 183 or concurrently) or PHY 183B or (PHY 193H or concurrently)) or (PHY 231 and (PHY 233B or concurrently)) or (PHY 231C and (PHY 233B or concurrently)) Not open to students with credit in LB 273 or PHY 251.
Error analysis, exercises in motion, forces, conservation laws and some electricity and magnetism studies.

**192    Physics Laboratory for Scientists, II**
Spring. 1(0-3) P: {PHY 191 and ((PHY 184 or concurrently) or PHY 184B or (PHY 294H or concurrently))} or (PHY 232 and (PHY 234B or concurrently)) or (PHY 232C and (PHY 234B or concurrently)) Not open to students with credit in LB 274 or PHY 252.
Electric and magnetic fields, circuits, wave optics, modern physics.

**193H    Honors Physics I-Mechanics**
Spring. 4(4-0) P: (MTH 133 or concurrently) or (MTH 153H or concurrently) or (LB 119 or concurrently) Not open to students with credit in LB 273 or PHY 231C or PHY 183 or PHY 231.
Mechanics and waves.

**201    Physics Computations II**
Fall. 1(0-3) P: (PHY 184 or concurrently) or (PHY 184B or concurrently) or (PHY 294H or concurrently) RB: MTH 133 and PHY 102
Computer methods to analyze and visualize physics problems. Tools used will include programming languages (Fortran) and mathematical software (Mathematica, etc.).

**205    Directed Studies**
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 3 credits in all enrollments for this course. R: Approval of department.
Guided individualized study in an area of physics.

**215    Thermodynamics and Modern Physics**
Fall, Spring. 3(4-0) P: ((PHY 184 or concurrently) or PHY 184B or (PHY 294H or concurrently) or (LB 274 or concurrently)) or (PHY 232 and (PHY 234B or concurrently)) or (PHY 232C and (PHY 234B or concurrently)) Not open to students with credit in PHY 215B.
Thermodynamics, atomic physics, quantized systems, nuclear physics, solids, elementary particles.

**215B    Thermodynamics and Modern Physics**
Fall, Spring, Summer. 3 credits. P: (PHY 184 or (PHY 184B or concurrently) or PHY 294H or LB 274) or (PHY 232 and PHY 234B) or (PHY 232C and PHY 234B) Not open to students with credit in PHY 215.
Thermodynamics, atomic physics, quantized systems, nuclear physics, solids, elementary particles. This course is given in the competency based instruction format.

**231    Introductory Physics I**
Fall, Spring. 3(4-0) P: MTH 103 or MTH 116 or LB 118 or MTH 124 or (MTH 132 or concurrently) Not open to students with credit in LB 271 or PHY 183 or PHY 183B or PHY 193H or PHY 231C.
Mechanics, Newton's Laws, momentum, energy, conservation laws, thermodynamics, waves, sound.

**231C    Introductory Physics I**
Fall, Spring. 3 credits. P: MTH 103 or MTH 116 or MTH 124 or (MTH 132 or concurrently) or LB 118 RB: MTH 116 Not open to students with credit in LB 271 or PHY 183 or PHY 183B or PHY 193H or PHY 231.
Mechanics, Newton's Laws, momentum, energy, conservation laws, thermodynamics, waves, sound. This course is an internet based course.

**232    Introductory Physics II**
Fall, Spring. 3(4-0) P: PHY 231 or PHY 231C or PHY 183 or PHY 183B or PHY 193H or LB 273 Not open to students with credit in LB 274 or PHY 184 or PHY 184B or PHY 232C or PHY 234B.
Electricity and magnetism; optics; atomic, nuclear, and subnuclear physics.

**232C    Introductory Physics II**
Fall, Spring. 3 credits. P: PHY 183 or PHY 183B or PHY 193H or PHY 231 or PHY 231C or LB 273 Not open to students with credit in LB 274 or PHY 184 or PHY 184B or PHY 232 or PHY 294H.
Electricity and magnetism; optics; atomic, nuclear, and subnuclear physics. This course is an internet based course.

**233B    Calculus Concepts in Physics I**
Fall, Spring, Summer. 2 credits. P: (PHY 231 or PHY 231C) and (MTH 132 or MTH 152H or LB 118) Not open to students with credit in PHY 183 or PHY 193H.
Kinematics, dynamics, applications of Newton's laws. PHY 231B plus PHY 233B is equivalent to PHY 183B. This course is given in the competency based instruction format.

**234B    Calculus Concepts in Physics II**
Fall, Spring, Summer. 2 credits. P: (PHY 232 or PHY 232C) and ((MTH 133 or concurrently) or (MTH 153H or concurrently) or (LB 119 or concurrently)
Electricity and magnetism. PHY 232 (or PHY232C) plus PHY 234B equals PHY 184. This course is given in the competency based instruction format.

**251    Introductory Physics Laboratory I**
Fall, Spring, Summer. 1(0-2) P: (PHY 183 or concurrently) or (PHY 183B or concurrently) or (PHY 193H or concurrently) or (PHY 231 or concurrently) or (PHY 231C or concurrently) RB: MTH 103 Not open to students with credit in LB 273 or PHY 191.
Laboratory exercises involving simple mechanical systems.

**252    Introductory Physics Laboratory II**
Fall, Spring, Summer. 1(0-2) P: (PHY 251 or PHY 191 or LB 273) and ((PHY 232 or concurrently) or (PHY 232C or concurrently) or (PHY 184 or concurrently) or (PHY 184B or concurrently) or (PHY 294H or concurrently)) Not open to students with credit in LB 274 or PHY 192.
Laboratory exercises involving simple electromagnetic and optical systems.

**294H    Honors Physics II-Electromagnetism**
Fall. 4(4-0) P: PHY 193H and ((MTH 234 or concurrently) or (MTH 254H or concurrently) or (LB 220 or concurrently)) Not open to students with credit in LB 274 or PHY 184 or PHY 184B or PHY 232 or PHY 232C.
Electricity and magnetism, electromagnetic waves and optics.

# Physics—PHY

**305 Directed Studies**
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 3 credits in all enrollments for this course. P: (PHY 184 or concurrently) or (PHY 184B or concurrently) or (PHY 294H or concurrently) R: Open to undergraduate students. Approval of department.
Guided individualized study in an area of physics.

**321 Classical Mechanics I**
Spring, Summer. 3(3-0) P: (PHY 184 or PHY 184B or PHY 294H or LB 274) and ((PHY 215 or concurrently) or (PHY 215B or concurrently)) and ((MTH 234 or concurrently) or (MTH 254H or concurrently) or (LB 220 or concurrently))
Newtonian point particles. Oscillations. One-particle chaos. Central-force motion. Systems of particles.

**390 Physics Journal Seminar**
Spring. 1(3-0) P: Completion of Tier I writing requirement. R: Open only to juniors or seniors in the Department of Physics and Astronomy or Lyman Briggs School.
Written and oral reports on selected articles in the current literature. Critique of presentations by peers.

**405 Directed Studies**
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 5 credits in all enrollments for this course. P: PHY 184 or PHY 184B or PHY 232 or PHY 232C or PHY 294H or LB 274 R: Approval of department.
Guided independent study of special topics.

**410 Thermal and Statistical Physics**
Spring. 3(3-0) P: PHY 471
Equilibrium statistical mechanics and thermodynamics, kinetic theory, phase transformations.

**415 Methods of Theoretical Physics**
Spring. 4(4-0) Interdepartmental with Lyman Briggs. Administered by Lyman Briggs. P: ((MTH 234 or concurrently) or (LB 220 or concurrently) or (MTH 254H or concurrently)) and (LB 273 or PHY 183 or PHY 193H) and (LB 274 or PHY 184 or PHY 294H) RB: (MTH 235 or concurrently) or (MTH 255H or concurrently) or (MTH 340 or concurrently) SA: LBS 415
Mathematical methods applied to physical problems in mechanics, electromagnetism, and thermodynamics. Multiple integration, vector calculus, Fourier series, ordinary and partial differential equations, eigenvector problems, coordinate transformations, and complex analysis. Newtonian mechanics, rigid body dynamics, heat flow, electrostatics, harmonic motion, and waves.

**422 Classical Mechanics II**
Fall. 3(3-0) P: PHY 321
Hamiltonian and Lagrangian mechanics. Non-inertial frames. Coupled oscillations. Continuous systems.

**431 Optics I**
Fall. 3(2-3) P: (PHY 192 or LB 274) and (PHY 184 or PHY 184B or PHY 294H) and ((MTH 235 or concurrently) or (MTH 255H or concurrently) and Completion of Tier I Writing Requirement
Lenses, aberrations, apertures, and stops. Diffraction, interferometry, spectroscopy, fiber optics.

**440 Electronics**
Spring. 4(3-3) P: {{(PHY 192 or LB 274) and (PHY 184 or PHY 184B or PHY 294H)} or (PHY 232 and PHY 234B) or (PHY 232C and PHY 234B)} and ((MTH 235 or concurrently) or (MTH 255H or concurrently) or (LB 220 or concurrently) or (MTH 340 or concurrently))
Concepts of electronics used in investigating physical phenomena. Circuits, amplifiers, diodes, LEDs, transistors.

**451 Advanced Laboratory**
Fall. 3(1-6) P: (PHY 440) and completion of Tier I writing requirement
General research techniques, design of experiments, and the analysis of results based on some historical experiments in modern physics.

**471 Quantum Physics I**
Fall. 3(3-0) P: (PHY 215 or PHY 215B) and (PHY 321 or concurrently) and (MTH 235 or MTH 255H or LB 220)
Schroedinger equation, hydrogen atom, harmonic oscillator, and other one-dimensional systems.

**472 Quantum Physics II**
Spring. 3(3-0) P: PHY 471 RB: A Mathematics course on Boundary-Value Problems
Matrix formulation of quantum mechanics, perturbation theory, scattering.

**480 Computational Physics**
Spring of even years. 3(3-0) RB: CSE 131 or CSE 230
Applications of scientific computational techniques to solutions of differential equations, matrix methods, and Monte Carlo methods used in physics.

**481 Electricity and Magnetism I**
Fall. 3(3-0) P: MTH 234 or MTH 254H or LB 220 R: Open to juniors or seniors or graduate students.
Electrostatics, dielectrics, magnetic fields of steady state currents, Faraday law of induction.

**482 Electricity and Magnetism II**
Spring. 3(3-0) P: PHY 481 RB: A Mathematics course on Boundary-Value Problems. R: Open to juniors or seniors or graduate students.
Maxwell's equations, scalar and vector potentials, electromagnetic plane waves.

**490 Senior Thesis**
Fall, Spring, Summer. 1 to 4 credits. A student may earn a maximum of 5 credits in all enrollments for this course. P: (PHY 390) and completion of Tier I writing requirement R: Open to seniors in the Department of Physics and Astronomy. Approval of department.
Design, carry out, and analyze an original experiment or computation. A written and oral report is required.

**491 Atomic, Molecular, and Condensed Matter Physics**
Fall. 3(3-0) P: (PHY 471 and PHY 410) and completion of Tier I writing requirement
Many-electron atoms. Molecules, crystal structure, lattice dynamics. Band models of metals and semiconductors. Transport properties.

**492 Nuclear and Elementary Particle Physics**
Spring. 3(3-0) P: (PHY 471) and completion of Tier I writing requirement RB: PHY 472
Properties of nuclei, nuclear models, nuclear reactions. High-energy accelerators. Weak, electromagnetic and strong interactions. Symmetries and conservation laws. Elementary particle spectrum, quarks, gluons.

**800 Research Methods**
Fall, Spring, Summer. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course.
Design and setup of experiments in various faculty research areas. Data collection and analysis. Study and practice of theoretical methods.

**810 Methods of Theoretical Physics**
Fall. 3(3-0)
Theoretical methods used in classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics.

**820 Classical Mechanics**
Fall. 3(3-0)
Two-body central force problem, Hamilton's principle, Lagrangian and Hamiltonian equations of motion, variational methods, small oscillations, classical fields.

**831 Statistical Mechanics**
Spring. 3(3-0)
Equilibrium statistical mechanics and thermodynamics. Boltzmann transport equations and hydrodynamics. Brownian and Langevin motion.

**832 Special Topics in Statistical Mechanics**
Fall, Spring. 3(3-0) A student may earn a maximum of 12 credits in all enrollments for this course. RB: PHY 831 and PHY 841 and PHY 852
Topics vary and may include superfluidity and superconductivity, magnetism, non-linear dynamics and chaos, phase transitions and critical phenomena, transport theory, disordered systems, and computational physics.

**841 Classical Electrodynamics I**
Spring. 3(3-0) RB: PHY 810
Electrostatics, magnetostatics, time-varying fields and Maxwell's equations. Gauge transformations. Poynting's theorem and conservation laws.

**842 Classical Electrodynamics II**
Fall. 3(3-0) RB: PHY 841 and (PHY 810 or concurrently)
Plane electromagnetic waves, polarization states, reflection, refraction. Wave guides and resonant cavities. Radiating systems, dipole fields, radiated power. Special theory of relativity.

**850 Electrodynamics of Plasmas**
Spring of odd years. 3(3-0) Interdepartmental with Astronomy and Astrophysics and Electrical and Computer Engineering. Administered by Electrical and Computer Engineering. RB: ECE 835 or PHY 488 SA: EE 850
Plasma kinetic and macroscopic plasma transport theory. Electromagnetic wave propagation and charged particle diffusion processes in plasma. Electromagnetic energy absorption via elastic and inelastic collisions. Dc, rf, and microwave discharges.

**851    Quantum Mechanics I**
Fall. 3(3-0) R: Open only to graduate students in the College of Engineering or College of Natural Science.
Axioms of quantum and wave mechanics, applications to spherically symmetric potentials. Hydrogen atom, harmonic oscillator, matrix mechanics, angular momentum theory, rotations.

**852    Quantum Mechanics II**
Spring. 3(3-0) RB: PHY 851
Approximation methods, perturbation theory, atomic physics applications, scattering theory, identical particles, Pauli principle, Bose and Einstein statistics, Hartree-Fock approximation, collisions of identical particles, radiation.

**853    Advanced Quantum Mechanics**
Fall. 3(3-0) RB: PHY 852
Quantum description of relativistic particles and fields. Dirac equation, interpretation of negative energy states, Lagrangian field theory, quantization of free fields, interactions, perturbation theory, S-matrix, and Feynman rules.

**854    Quantum Electrodynamics**
Spring of odd years. 3(3-0) RB: PHY 853
Application of quantum field theory to the interaction of electrons and photons: pair annihilation, Compton scattering. Bound states, renormalization theory.

**861    Beam Physics**
Spring of odd years. 3(3-0) RB: PHY 820 and PHY 841
Particle accelerator theory and design.

**891    Elementary Particle Physics**
Spring. 3(3-0) RB: PHY 853
Nonabelian gauge theory, spontaneously broken gauge theory, electroweak interaction, QCD, W and Z boson coupling to quarks and leptons, charm, top and bottom quarks, particle generations.

**899    Master's Thesis Research**
Fall, Spring, Summer. 1 to 6 credits. A student may earn a maximum of 36 credits in all enrollments for this course. R: Open only to graduate students in the Physics major.
Master's thesis research.

**901    Frontiers in Physics and Astronomy**
Spring. 1(1-0)
Seminar and discussions in physics. Attendance at weekly colloquium.

**905    Special Problems**
Fall, Spring. 1 to 4 credits. A student may earn a maximum of 9 credits in all enrollments for this course. R: Open only to graduate students in the Department of Physics and Astronomy.
In-depth study of a topic in physics or in astrophysics and astronomy.

**911    Group Theory and Symmetry in Physics**
Fall of odd years. 2(2-0) P: PHY 810 and PHY 851 or approval of department
Group representation theory as the general framework to formulate fundamental symmetries in physics. Irreducible states and tensors, projection operator techniques, rotation and translation, Lie groups, Lorentz and Poincare groups. Offered first half of semester.

**912    Modern Nonlinear Dynamics**
Spring of even years. 2(2-0) P: PHY 820 or approval of department
Nonlinear dynamics of Hamiltonian and dissipative systems; method of averaging; adiabatic invariants; KAM theorem; invariant manifolds; bifurcation theory; dynamical chaos. Offered first half of semester.

**913    Foundations of Nanoscience and Nanotechnology**
Fall of odd years. 2(2-0) P: PHY 851 or approval of department RB: PHY 971
The self-assembly process and unusual phenomena occurring in nanostructures of carbon. Magnetic aggregates in different size ranges. Finite size and low-dimension effects. Fractional conductance quantization. Response in nanostructures to mechanical stress, high temperature, and electric fields. Offered first half of semester.

**916    Quantum Transport and Quantum Optics**
Spring of odd years. 2(2-0) P: PHY 831 and PHY 852 or approval of department
Photon counting statistics. Atom-photon interaction. Electron scattering in metals and semiconductors. Low-dimensional systems. Anderson localization. Weak localization.

**917    Introduction to Elementary Particle Physics**
Spring of odd years. 2(2-0) P: PHY 851 or approval of department RB: PHY 853
The phenomenology of elementary particle physics, emphasizing the experimental evidence for the Standard Model. Role of elementary particle physics in the development of the early universe.

**961    Non-Linear Beam Dynamics**
Fall, Spring. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course. RB: PHY 861
Dynamics of particle beams.

**962    Particle Accelerators**
Fall, Spring, Summer. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course. RB: PHY 861
Theory of particle accelerator design.

**963    U.S. Particle Accelerator School**
Fall, Spring. 3(3-0) A student may earn a maximum of 12 credits in all enrollments for this course. RB: PHY 861 SA: PHY 962C
Participation in suitable courses offered by the U.S. Particle Accelerator School.

**964    Seminar in Beam Physics Research**
Fall, Spring. 3(3-0) A student may earn a maximum of 12 credits in all enrollments for this course. RB: PHY 861 SA: PHY 962D
Presentation of current research topics in beam physics or accelerator design.

**971    Atomic and Electronic Structure of Matter**
Spring. 3(3-0) RB: PHY 491 and PHY 852 and PHY 841 and PHY 831 SA: PHY 871
Atomic structure, bravais lattices, x-ray scattering. Vibrations, phonons, neutron scattering. Electron in solids, electron gas. Bloch's theorem. Metals, semiconductors and insulators. Introduction to cooperative phenomena.

**973    Special Topics in Condensed Matter Physics**
Fall, Spring. 3(3-0) A student may earn a maximum of 12 credits in all enrollments for this course. RB: PHY 971 and PHY 972
Topics vary and may include quantum optics, scattering methods and Green's functions.

**980    Advanced Reading in Physics**
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 4 credits in all enrollments for this course. R: Approval of department.

**981    Nuclear Structure**
Fall, Spring. 3(3-0) RB: PHY 492 and PHY 831 and PHY 841 and PHY 852
Nuclear forces, nuclear matter, nuclear-structure models, few-nucleon systems, electromagnetic and weak transitions.

**982    Nuclear Dynamics**
Spring. 3(3-0) RB: PHY 492 and PHY 831 and PHY 841 and PHY 852
Scattering theory, resonance reactions, compound nuclear decay and fission, direct and breakup reactions, time-dependent Hartree-Fock, Vlasov equation, nuclear transport equations, particle production, nuclear liquid-gas phase transition, quark-gluon plasma.

**983    Nuclear Astrophysics**
Fall, Spring. 3(3-0) RB: PHY 410 and PHY 472 and PHY 482
Low energy reaction theory, survey of astrophysics, physics of nuclei and reaction relevant to astrophysics, nuclear reaction rates in stellar environments, stellar evolution, solar neutrinos, big bang nucleosynthesis, dark matter, supernova explosions, r-process, hot CNO and rp-process, cosmochronology

**999    Doctoral Dissertation Research**
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 120 credits in all enrollments for this course. R: Open only to graduate students in the Physics major.
Doctoral dissertation research.