# 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 concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently) Not open to students with credit in LB 273 or PHY 193H or PHY 231 or PHY 231C or PHY 233B.
Mechanics, Newton's laws, momentum, energy conservation laws, rotational motion, oscillation, gravity, and waves.

**183B Physics for Scientists and Engineers I**
Summer. 4 credits. P: (MTH 132 or concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently) 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. This course is given in the competency based instruction format.

**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 (PHY 231C and PHY 233B)} and ((MTH 133 or concurrently) or (MTH 153H or concurrently) or (LB 119 or concurrently)) Not open to students with credit in LB 274 or PHY 184B or PHY 232 or PHY 232C or PHY 234B or PHY 294H.
Electricity and magnetism, electromagnetic waves, light and optics, interference and diffraction.

**184B Physics for Scientists and Engineers II**
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 concurrently) or (MTH 153H or concurrently) or (LB 119 or concurrently)) Not open to students with credit in LB 274 or PHY 184 or PHY 232 or PHY 232C or PHY 234B or PHY 294H.
Electricity and magnetism, electromagnetic waves, light and optics, interference and diffraction. This course is given in the competency based instruction format.

**191 Physics Laboratory for Scientists, I**
Fall. 1(0-3) P: ((PHY 183 or concurrently) or (PHY 193H or concurrently) or PHY 183B) 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 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**
Fall. 4(4-0) P: (MTH 132 or concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently) Not open to students with credit in LB 273 or PHY 183 or PHY 183B or PHY 231 or PHY 231C.
Mechanics and waves.

**201 Physics Computations II**
Fall. 1(0-3) P: (PHY 184 or concurrently) or PHY 184B or PHY 294H 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 PHY 294H or LB 274 or PHY 184B) or (PHY 232 and PHY 234B) or (PHY 232C and PHY 234B)} and ((MTH 234 or concurrently) or (MTH 254H or concurrently) or (LB 220 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**
Summer. 3 credits. P: {(PHY 184 or PHY 294H or LB 274 or (PHY 184B or concurrently)) or (PHY 232 and (PHY 234B or concurrently)) or (PHY 232C and (PHY 234B or concurrently))} and ((MTH 234 or concurrently) or (MTH 254H or concurrently) or (LB 220 or concurrently)) 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 114 or MTH 116 or MTH 124 or (MTH 132 or concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently) Not open to students with credit in LB 273 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, Summer. 3 credits. P: MTH 114 or MTH 116 or MTH 124 or (MTH 132 or concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently) RB: MTH 116 Not open to students with credit in LB 273 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, Summer. 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 PHY 184 or PHY 184B or PHY 232 or PHY 294H or LB 274.
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 concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently)) Not open to students with credit in LB 273 or PHY 183 or PHY 183B or PHY 193H.
Kinematics, dynamics, applications of Newton's laws. This course is given in the competency based instruction format.

**234B Calculus Concepts in Physics II**
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)) Not open to students with credit in LB 274 or PHY 184 or PHY 184B.
Electricity and magnetism. 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**
Spring. 4(4-0) P: (PHY 193H or PHY 183 or PHY 183B) and ((MTH 133 or concurrently) or (MTH 153H or concurrently) or (LB 119 or concurrently)) Not open to students with credit in PHY 184 or PHY 184B or PHY 232 or PHY 232C or LB 274.
Electricity and magnetism, electromagnetic waves and optics.

**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**
Fall, Spring. 3(3-0) P: ((PHY 215 or concurrently) or (PHY 215B or concurrently)) and ((MTH 235 or concurrently) or (MTH 340 or concurrently) or (MTH 347H or concurrently))
Newtonian point particles. Oscillations. One-particle chaos. Central-force motion. Systems of particles.

**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**
Fall. 4(4-0) P: (MTH 234 or LB 220 or MTH 254H) 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) R: Open to undergraduate students or approval of department. SA: LB 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 184 or PHY 184B or PHY 294H) and PHY 192} or LB 274} and (((MTH 235 or concurrently) or (MTH 340 or concurrently) or (MTH 347H or concurrently)) and completion of Tier I writing requirement)
Lenses, aberrations, apertures, and stops. Diffraction, interferometry, spectroscopy, fiber optics.

**440 Electronics**
Fall, Spring. 4(3-3) P: {{(PHY 184 or PHY 184B) or (PHY 232 and PHY 234B) or (PHY 232C and PHY 234B)} and PHY 192} or LB 274 and (((MTH 235 or concurrently) or (MTH 340 or concurrently) or (MTH 347H or concurrently)) and completion of Tier I writing requirement)
Concepts of electronics used in investigating physical phenomena. Circuits, amplifiers, diodes, LEDs, transistors.

**451 Advanced Laboratory**
Fall, Spring. 3(1-6) P: (PHY 431 or 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 340 or MTH 347H)
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. 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 Physics 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 471) 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 Introduction to Condensed Matter Physics**
Fall. 3(3-0) P: (PHY 471 and PHY 410) and completion of Tier I writing requirement Not open to students with credit in PHY 801.
Many-electron atoms. Molecules, crystal structure, lattice dynamics. Band models of metals and semiconductors, transport properties.

**492 Introduction to Nuclear Physics**
Spring. 3(3-0) P: (PHY 471) and completion of Tier I writing requirement RB: PHY 472 Not open to students with credit in PHY 802.
Survey of phenomena and conceptual foundations of nuclear physics.

**493 Introduction to Elementary Particle Physics**
Spring. 3(3-0) P: (PHY 471) and completion of Tier I writing requirement RB: PHY 472 R: Open to undergraduate students in the Department of Physics and Astronomy or approval of department. Not open to students with credit in PHY 803.
Introduction to concepts and theory for elementary particle physics.

**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.

**801 Survey of Atomic and Condensed Matter Physics**
Spring. 3(3-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department. Not open to students with credit in PHY 491.
Survey of physics phenomena related to atomic, liquid and solid systems. Describe underlying microscopic principles responsible for properties of matter.

**802 Survey of Nuclear Physics**
Spring. 3(3-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department. Not open to students with credit in PHY 492.
Survey of phenomena and conceptual foundations of nuclear physics.

**803 Survey of Elementary Particle Physics**
Spring. 3(3-0) RB: students should have completed undergraduate degree in physics R: Open to graduate students in the Department of Physics and Astronomy or approval of department. Not open to students with credit in PHY 493.
Overview of high-energy physics, including the standard model, quark composition of hadrons, collider physics and the role of elementary particle physics in cosmology.

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

**812 Advanced Methods of Theoretical Physics**
Fall of even years. 3(3-0) RB: PHY 810
Advanced mathematical tools for theoretical physics. Group theory, advanced Green's functions and asymptotic methods.

**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.

**822 Advanced Classical Mechanics**
Fall of odd years. 2(2-0) RB: PHY 820 R: Open to graduate students in the Physics Major.
Formal methods of mechanics along with a variety of modern topics including formal treatments of fluids, chaos and non-linear dynamics. Offered first half of semester.

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

**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.

**855 Quantum Field Theory**
Spring. 2(2-0) RB: PHY 852 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Introduction to field theory as it pertains to numerous problems in particle, nuclear and condensed matter physics. Second quantization, applications to different fields based on perturbation theory. Offered first half of semester.

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

**862 Physics and Applications of Accelerators and Beams**
Spring of odd years. 2(2-0) RB: PHY 842
Physics and design of particle accelerators used in various subfields of physics.

**863 Special Topics in Accelerator Physics**
On Demand. 2(2-0) A student may earn a maximum of 6 credits in all enrollments for this course. R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Advanced topics in accelerator science.

**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.

**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.

**909 Experimental Techniques for Condensed Matter Physics**
Fall of even years. 2(2-0) RB: PHY 491 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Methods for sample preparation and measurement in context of condensed matter physics.

**910 Quantum Fluids**
Fall of odd years. 2(2-0) P: PHY 831 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Theory and phenomenology of Bose Einstein condensates, superconductivity and superfluidity.

**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.

**915 Computational Condensed Matter Physics**
Spring of odd years. 2(2-0) RB: PHY 831 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Computational techniques for addressing problem in theoretical condensed matter physics

**918 Quantum and Non-linear Optics**
Fall of even years. 2(2-0) RB: PHY 852 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Interaction of light with atoms and semiconductors. Theory and experimental techniques for non-linear optics.

**919 Modern Electronic Structure Theory**
Spring of even years. 2(2-0) RB: PHY 852 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Electronic structure theory using modern computational methods

**921 Quantum Transport and Mesoscopic Physics**
Fall of odd years. 2(2-0) P: PHY 831 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Quantum properties of mesoscopic systems. Quantum dots and large molecules and complex materials. Linear response theory for finite systems.

**922 Ultrafast Phenomena**
Fall of odd years. 2(2-0) RB: PHY 842 or concurrently R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Theoretical and experimental tools for addressing ultrafast phenomena, such as femtoscopic lasers

**925 Topics in Molecular and Biophysics**
On Demand. 2(2-0) RB: PHY 851 R: Open to graduate students in the College of Natural Science or approval of department.
Advanced topics in molecular and biophysics.

**950 Data Analysis Methods for High-Energy and Nuclear Physics**
Fall. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Tools and methods used for analyzing data in large experiments.

**951 Concepts and Calculations for the Standard Model**
Fall. 3(3-0) RB: PHY 852 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Concepts, phenomena and calculations the standard model for particle physics

**955 Relativistic Quantum Field Theory**
Spring. 2(2-0) RB: PHY 855 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Theory of relativistic quantum fields and renormalization with emphasis on applications for particle physics. Offered second half of semester.

**956 Collider Phenomenology**
Spring of odd years. 2(2-0) RB: PHY 955 R: Open to graduate students in the Physics Major or approval of department.
Theory and phenomenology of high-energy collider physics. Quantum chromo dynamics evolution, structure functions and higher-order calculations.

**959 Special Topics in High-Energy Physics**
On Demand. 2(2-0) A student may earn a maximum of 6 credits in all enrollments for this course. RB: PHY 951 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Topics in high-energy physics.

**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.

**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. 2(2-0) 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. 2(2-0) RB: PHY 492 and PHY 831 and PHY 841 and PHY 852 R: Open to graduate students in the Department of Physics and Astronomy.
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. Offered second half of semester.

**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

**988 Few-body Methods and Nuclear Reactions**
Spring of odd years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Basic nuclear reactions based on few-body methods.

**989 Special Topics in Nuclear Physics**
On Demand. 2(2-0) A student may earn a maximum of 6 credits in all enrollments for this course. R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Topics in nuclear physics not covered in regularly scheduled courses

**990 Nuclear Forces and Their Impact in Nuclear Structure**
Spring of even years. 2(2-0)
Overview of strong interaction between nucleons. This includes two- and three-body nuclear forces and nucleon-nucleon scattering, along with the implications for light nuclei and nuclear matter.

**991 Many-Body Methods for Nuclear Physics**
Spring of odd years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Calculation of nuclei properties from first principles, nucleon-nucleon force.

**993 Density Functional Theory and Self-Consistent Methods for Nuclear Physics**
Fall of even years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Application of density-functional techniques in the context of nuclear physics.

**994 Theory for Exploring Nuclear Structure Experiments**
Fall of even years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Phenomenological methods for modeling structure and dynamics of nuclei.

**995 Theory for Exploring Nuclear Reaction Experiments**
Fall of odd years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Modeling direct nuclear reactions from low to high energy.

**996 Nuclear Theory for Astrophysics**
Fall of even years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Theory for nucleosynthesis in stellar evolution and stellar explosions, with an emphasis on the role of nuclei far from stability.

**997 Theoretical Approaches to Describe Exotic Nuclei**
Spring of odd years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Techniques specific for modeling nuclei far from stability, especially halo nuclei.

**998 High-Performance Computing and Computational Tools for Nuclear Physics**
Spring of even years. 2(2-0) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.
Knowledge and skills for problems in nuclear structure involving high-performance computing.

**999 Doctoral Dissertation Research**
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 36 credits in all enrollments for this course. R: Open to graduate students in the Physics major.
Doctoral dissertation research.