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 231C or PHY 233B. Mechanics, Newton's laws, momentum, energy conservation laws, rotational motion, oscillation, gravity, and waves.

183B Physics for Scientists and Engineers II
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 183H or PHY 231C or PHY 233B. Mechanics, Newton's laws, momentum, energy conservation laws, rotational motion, oscillation, gravity, and waves. 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 193B) 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 234H or LB 274 or PHY 234B or concurrently)) Not open to students with credit in LB 273 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 183H or PHY 183B or PHY 231H or PHY 231C. Mechanics and waves.

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. 4(4-0) P: (PHY 184 or PHY 194H or PHY 294H or LB 273 or PHY 231C or PHY 232H or PHY 234B or PHY 294H). 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 (MTH 234 or concurrently)) Not open to students with credit in PHY 215B. 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 122 or concurrently) or (LB 116 or concurrently) 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.

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 PHY 184 or PHY 184B or PHY 232 or PHY 294H or LB 273. Kinematics, dynamics, applications of Newton's laws. This course is given in the competency based instruction format.

234B Calculus Concepts in Physics II
Spring. 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.

241 Physics for Cellular and Molecular Biologists I
Fall. 4(4-0) P: (MTH 124 or concurrently) or (MTH 132 or concurrently) or (MTH 152H or concurrently) or (LB 118 or concurrently) RB: CEM 141 and BS 161 R: Not open to students in the College of Engineering or in the Department of Physics and Astronomy. Not open to students with credit in LB 273 or PHY 183 or PHY 183B or PHY 193H or PHY 231 or PHY 231C or PHY 233B. Physics of cellular and molecular biology. Examples will be drawn from systems such as bacterial flagella, myosin and protein folding.

242 Physics for Cellular and Molecular Biologists II
Spring. 4(4-0) P: PHY 241 RB: CEM 141 and BS 161 R: Not open to students in the College of Engineering or in the Department of Physics and Astronomy. Not open to students with credit in PHY 184 or PHY 184B or PHY 294H or PHY 232 or PHY 234C or PHY 294H or LB 273. Physics of cellular and molecular biology. Examples will be drawn from systems such as ATPase and photosynthesis.
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) R: 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.

306 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.

321 Classical Mechanics I
Fall, Spring. 3(3-0) P: ((PHY 215 or concurrently) or (PHY 215B or concurrently) or (MTH 235 or concurrently) or (MTH 340 or concurrently) or (MTH 347H or concurrently)) and completion of Tier I writing requirement. Newtonian point particles. Oscillations. One-particle classical mechanics. 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.

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). R: (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, and completion of Tier I writing requirement.

421 Classical Mechanics II

431 Optics I
Spring. 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)). Not open to students with credit in PHY 802. Concepts of electronics used in investigating physical phenomena. Circuits, amplifiers, diodes, LEDs, transistors.

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. Lenses, aberrations, apertures, and stops. Diffraction, interference, spectroscopy, fiber optics.

441 Quantum Physics I
Fall. 3(3-0) P: (PHY 215 or concurrently) 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.

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

451 Advanced Laboratory
Fall, Spring. 3(1-6) P: (PHY 431 or PHY 440). Not open to students with credit in PHY 802. Not open to students with credit in PHY 803. Introduction to concepts and theory for elementary particle physics.

454 Advanced Laboratory
Fall, Spring. 3(1-6) P: (PHY 431 or PHY 440). Not open to students with credit in PHY 802. Not open to students with credit in PHY 803. Introduction to concepts and theory for elementary particle physics.

455 Advanced Laboratory
Fall, Spring. 3(1-6) P: (PHY 431 or PHY 440). Not open to students with credit in PHY 802. Not open to students with credit in PHY 803. Introduction to concepts and theory for elementary particle physics.

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 Mathematical course on Boundary-Value Problems. R: Open to 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.

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 R: 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.

500 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.
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.

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

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.

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.

Statistical Mechanics
Fall, 3(3-0)

Classical Electrodynamics I

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.

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.

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.

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.

Quantum Field Theory
Spring, 2(2-0) RB: PHY 862 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.

Beam Physics
Fall, Spring, Summer, 3(3-0) RB: PHY 820 and PHY 841 Particle accelerator theory and design.

Accelerator Systems
Fall, 2(2-0) RB: PHY 422 and PHY 482 R: Open to graduate students in the College of Engineering or in the College of Natural Science. Introduction to large accelerator systems, including the physics and engineering of accelerators and key components of accelerators.

Special Topics in Accelerator Physics
On Demand. 2(2-0) RB: PHY 841 and (PHY 810 or concurrently) Special topics in accelerator science.

Accelerator Technology
Spring, 3(3-0) RB: PHY 422 and PHY 482 R: Open to graduate students in the College of Engineering or in the College of Natural Science. Key technologies for modern accelerators such as magnets, the normal conducting and superconducting radio frequency cavities, charged particle sources, diagnostic instruments.

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.

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.
950 Data Analysis Methods for High-Energy and Nuclear Physics
Fall of even years. 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.
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 Department of Physics Major or approval of department.
Theory and phenomenology of high-energy collider physics. Quantum chromodynamics 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 12 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
On Demand. 3(3-0) A student may earn a maximum of 12 credits in all enrollments for this course.
Topics vary and may include quantum optics, scattering methods and Green's functions.

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

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

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.