173  Studio Physics for Scientists and Engineers I
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 234B or concurrently) or (MTH 153H or concurrently) or (MTH 152H 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.
Electromany and magnetism, electromagnetic waves, light, and optics, interference and diffraction.

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 234B) or (PHY 232 and PHY 234B 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. This course is given in the competency based instruction format.

191  Physics Laboratory for Scientists, I
Fall, 1(0-3) P: (PHY 183 or PHY 193H or LB 273) or (PHY 231 and PHY 233B) or (PHY 231C and PHY 234B) or (PHY 232 and PHY 234B or concurrently) or (PHY 231C and PHY 234B 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 PHY 184B) or (PHY 232 and PHY 234B or concurrently)) or (PHY 232C 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-Mechnics
Fall, 4(4-0) P: (MTH 132 or concurrently) or (MTH 152H or concurrently) or (LB 119 or concurrently) Not open to students with credit in LB 273 or PHY 183 or PHY 231 or PHY 231C or PHY 232 or PHY 234B or PHY 242 or PHY 294H.
Basic principles of electricity and magnetism, development of scientific skills and problem-solving through integrated physics laboratory and discussion.

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 individual study in an area of physics.

215  Thermodynamics and Modern Physics
Fall, Spring. 3(4-0) P: (PHY 184 or PHY 294H or PHY 184B) or (PHY 232 and PHY 234B or PHY 232C and PHY 234B) or (MTH 152H or concurrently) or (LB 119 or concurrently) Not open to students with credit in PHY 215B.
Thermodynamics, atomic physics, quantized systems, nuclear physics, solids, elementary particles.
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 234H 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.

234  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) and PHY 184B.  
Not open to students in the Department of Physics and Astronomy. Not open to students with credit in PHY 184 or PHY 184B or PHY 232 or PHY 234B or PHY 294H or LB 274.  
Physics of cellular and molecular biology. Examples will be drawn from systems such as bacterial flagella, myosin and protein folding.

241  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.

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 234B or PHY 294B or LB 274.  
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) or (PHY 241 or concurrently) or (PHY 193H or concurrently) or (PHY 193B or concurrently) or (PHY 184 or concurrently) or (PHY 184B or concurrently) or (PHY 232 or concurrently) or (PHY 232C or concurrently) or (PHY 242 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.

252  Introductory Physics Laboratory II  
Fall, Spring, Summer. 1(0-2) P: (PHY 251 or PHY 191 or LB 273) and (PHY 184 or concurrently) or (PHY 184B or concurrently) or (PHY 232 or concurrently) or (PHY 232C or concurrently) or (PHY 242 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 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 234C or PHY 294B 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) or (PHY 294C or concurrently) Not 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) or (MTH 235 or concurrently) or (MTH 340 or concurrently) or (MTH 347H or concurrently)) and CMSE 201 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 234C 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 PHY 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) or (MTH 347H 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, eigenvalue 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  
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)) and completion of Tier I writing requirement) Lenses, aberrations, apertures, and stops. Diffraction, interferometry, spectroscopy, fiber optics.

440  Electronics  
Fall, Spring. 3(3-1) P: ((PHY 184 or PHY 184B) or (PHY 232 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 215B 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) R: 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 491.

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. Not open to students with credit in PHY 492.

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. Not open to students with credit in PHY 493.

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) R: 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) R: Open to graduate students in the Department of Physics and Astronomy or approval of department.

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) R: 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.

831 Statistical Mechanics
Fall, 3(3-0)


841 Classical Electrodynamics I
Spring, 3(3-0) R: PHY 810


842 Classical Electrodynamics II
Fall, 3(3-0) R: PHY 841 and (PHY 810 or concurrently)


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


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) R: PHY 851


855 Quantum Field Theory
Spring, 2(2-0) R: 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
Fall, Spring, Summer. 3(3-0) R: PHY 820 and PHY 841

Particle accelerator theory and design.

862 Accelerator Systems
Fall, 3(3-0) R: 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.

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.

864 Accelerator Technology
Spring, 3(3-0) R: 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.

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.

910 Quantum Fluids
Fall, Spring, Summer. 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.

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.

918 Quantum and Non-linear Optics
Fall of even years. 2(2-0) R: PHY 852 R: Open to graduate students in the Department of Physics and Astronomy or approval of department.


919 Modern Electronic Structure Theory
Spring of even years. 2(2-0) R: 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. Concepts and phenomena and calculations the standard model for particle physics.

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 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. Offered second half of semester.

955 Relativistic Quantum Field Theory
Spring. 2(2-0) RB: PHY 955 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.

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. Offered second half of semester.

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, 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 r-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.