PH 104. *DESCRIPTIVE ASTRONOMY. (4 Credits)
Historical and cultural context of discoveries concerning planets and stars and their motions. Topics include the solar system, the constellations, birth and death of stars, pulsars and black holes. An accompanying laboratory is used for demonstrations, experiments, and projects, as well as for outdoor observations. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Equivalent to: PH 104H

PH 104H. *DESCRIPTIVE ASTRONOMY. (4 Credits)
Historical and cultural context of discoveries concerning planets and stars and their motions. Topics include the solar system, the constellations, birth and death of stars, pulsars and black holes. An accompanying laboratory is used for demonstrations, experiments, and projects, as well as for outdoor observations. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science; HNRS – Honors Course Designator
Equivalent to: PH 104

PH 106. *PERSPECTIVES IN PHYSICS. (4 Credits)
A descriptive and non-mathematical study of the development of physical concepts and their historical and philosophical context. The emphasis is on the origin, meaning, significance, and limitations of these concepts and their role in the evolution of current understanding of the universe. Concepts to be covered include Copernican astronomy, Newtonian mechanics, energy, electricity and magnetism, relativity, and quantum theory. Intended primarily for non-science students. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science

PH 111. *INQUIRING INTO PHYSICAL PHENOMENA. (4 Credits)
Development of conceptual understandings through investigation of everyday phenomena. Emphasis is on questioning, predicting, exploring, observing, discussing, and writing in physical science contexts. Students document their initial thinking, record their evolving understandings, and write reflections upon how their thinking changed and what fostered their learning. Lec/lab. (Baccalaureate Core Course)
Attributes: CPPS – Core, Pers, Physical Science

PH 199. SPECIAL STUDIES. (1-16 Credits)
One-credit sections are graded pass/no pass. This course is repeatable for 99 credits.

PH 201. *GENERAL PHYSICS. (5 Credits)
Introductory survey course covering a broad spectrum of classical and modern physics with applications. Topics include dynamics, vibrations and waves, electricity and magnetism, optics, and modern physics. Laboratory and recitation sections accompany the lectures. Mathematical preparation should include college algebra and trigonometry. Lec/lab/rec. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Recommended: MTH 111 and MTH 112

PH 202. *GENERAL PHYSICS. (5 Credits)
Introductory survey course covering broad spectrum of classical and modern physics with applications. Topics include dynamics, vibrations and waves, electricity and magnetism, optics, and modern physics. Laboratory and recitation sections accompany the lectures. Mathematical preparation should include college algebra and trigonometry. Lec/lab/rec. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Recommended: MTH 111 and MTH 112 and PH 201

PH 203. *GENERAL PHYSICS. (5 Credits)
Introductory survey course covering broad spectrum of classical and modern physics with applications. Topics include dynamics, vibrations and waves, electricity and magnetism, optics, and modern physics. Laboratory and recitation sections accompany the lectures. Mathematical preparation should include college algebra and trigonometry. Lec/lab/rec. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Recommended: MTH 111 and MTH 112 and PH 202

PH 205. *SOLAR SYSTEM ASTRONOMY. (4 Credits)
History, laws, and tools of astronomy. Composition, motion, and origin of the sun, planets, moons, asteroids, and comets. An accompanying laboratory is used for demonstrations, experiments, and projects, as well as for outdoor observations. The courses in the astronomy sequence (PH 205, PH 206, PH 207) can be taken in any order. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science

PH 206. *STARS AND STELLAR EVOLUTION. (4 Credits)
Properties of stars; star formation, evolution, and death; supernovae, pulsars, and black holes. An accompanying laboratory is used for demonstrations, experiments, and projects, as well as for outdoor observations. The courses in the astronomy sequence (PH 205, PH 206, PH 207) can be taken in any order. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science

PH 207. *GALAXIES, QUASARS, AND COSMOLOGY. (4 Credits)
Nature and content of galaxies, properties of quasars, and the cosmic background radiation. Emphasis on the Big-Bang model and its features. An accompanying laboratory is used for demonstrations, experiments, and projects, as well as for outdoor observations. The courses in the astronomy sequence (PH 205, PH 206, PH 207) can be taken in any order. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science

PH 211. *GENERAL PHYSICS WITH CALCULUS. (4 Credits)
A comprehensive introductory survey course intended primarily for students in the sciences and engineering. Topics include mechanics, wave motion, thermal physics, electromagnetism, and optics. Elementary calculus is used. Laboratory work accompanies the lectures. Lec/lab/rec. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Equivalent to: PH 211H
Recommended: MTH 251 and concurrent enrollment in MTH 252 and a PH 221 recitation section

PH 211H. *GENERAL PHYSICS WITH CALCULUS. (4 Credits)
A comprehensive introductory survey course intended primarily for students in the sciences and engineering. Topics include mechanics, wave motion, thermal physics, electromagnetism, and optics. Elementary calculus is used. Laboratory work accompanies the lectures. Lec/lab/rec. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science; HNRS – Honors Course Designator
Equivalent to: PH 211
Recommended: MTH 251 and concurrent enrollment in MTH 252 and a PH 211 recitation section
PH 212. *GENERAL PHYSICS WITH CALCULUS. (4 Credits)
A comprehensive introductory survey course intended primarily for students in the sciences and engineering. Topics include mechanics, wave motion, thermal physics, electromagnetism, and optics. Elementary calculus is used. Laboratory work accompanies the lectures. Lec/lab. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Prerequisites: PH 211 with D- or better
Recommended: MTH 252 and concurrent enrollment in PH 222 and MTH 254

PH 213. *GENERAL PHYSICS WITH CALCULUS. (4 Credits)
A comprehensive introductory survey course intended primarily for students in the sciences and engineering. Topics include mechanics, wave motion, thermal physics, electromagnetism, and optics. Elementary calculus is used. Laboratory work accompanies the lectures. Lec/lab/rec. (Bacc Core Course)
Attributes: CPPS – Core, Pers, Physical Science
Recommended: MTH 254 and PH 212. Concurrent enrollment in a recitation section is strongly recommended.

PH 221. RECITATION FOR PHYSICS 211. (1 Credit)
One-hour weekly session for the development of problem-solving skills in calculus-based general physics. Lec/rec. Graded P/N.
Corequisites: PH 211
Equivalent to: PH 221H

PH 221H. RECITATION FOR PHYSICS 211. (1 Credit)
One-hour weekly session for the development of problem-solving skills in calculus-based general physics. Lec/rec. Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: PH 221
Recommended: Concurrent enrollment in PH 211 or PH 211H

PH 222. RECITATION FOR PHYSICS 212. (1 Credit)
One-hour weekly session for the development of problem-solving skills in calculus-based general physics. Graded P/N.
Corequisites: PH 212
Equivalent to: PH 222H

PH 222H. RECITATION FOR PHYSICS 212. (1 Credit)
One-hour weekly session for the development of problem-solving skills in calculus-based general physics. Lec/rec. Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: PH 222
Recommended: Concurrent enrollment in PH 212 or PH 212H

PH 223. RECITATION FOR PHYSICS 213. (1 Credit)
One-hour weekly session for the development of problem-solving skills in calculus-based general physics. Lec/rec. Graded P/N.
Corequisites: PH 213
Equivalent to: PH 223H

PH 223H. RECITATION FOR PHYSICS 213. (1 Credit)
One-hour weekly session for the development of problem-solving skills in calculus-based general physics. Lec/rec. Graded P/N.
Attributes: HNRS – Honors Course Designator
Corequisites: PH 213
Equivalent to: PH 223
Recommended: Concurrent enrollment in PH 213

PH 265. SCIENTIFIC COMPUTING. (3 Credits)
Basic computational tools and techniques for courses in science and engineering. Project approach to problem solving using symbolic and compiled languages with visualization. Basic computer literacy assumed. Recommended: Concurrent enrollment in MTH 251

PH 299. SPECIAL TOPICS. (1-16 Credits)
This course is repeatable for 16 credits.

PH 313. *ENERGY ALTERNATIVES. (3 Credits)
Exploration of the challenges and opportunities posed by dwindling resources; physical and technological basis of our current energy alternatives; new or controversial technologies such as nuclear or solar power; overview of resource availability, patterns of energy consumption, and current governmental policies. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Equivalent to: PH 313H
Recommended: Upper-division standing and 12 credits of introductory science.

PH 313H. *ENERGY ALTERNATIVES. (3 Credits)
Exploration of the challenges and opportunities posed by dwindling resources; physical and technological basis of our current energy alternatives; new or controversial technologies such as nuclear or solar power; overview of resource availability, patterns of energy consumption, and current governmental policies. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society; HNRS – Honors Course Designator
Equivalent to: PH 313
Recommended: Upper-division standing and 12 credits of introductory science.

PH 315. PHYSICS OF CONTEMPORARY CHALLENGES. (3 Credits)
An introduction to thermal and quantum physics in the context of contemporary challenges faced by our society, such as power generation, energy efficiency, and global warming.
Recommended: PH 211

PH 331. *SOUND, HEARING, AND MUSIC. (3 Credits)
Basic course in the physics, technology, and societal implications of sound. Intended for students in nontechnical majors. Topics include wave motion, hearing and the perception of sound, noise pollution, music and musical instruments, architectural acoustics, and sound recording and reproduction. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Recommended: Upper-division standing and one year of university science

PH 332. *LIGHT, VISION, AND COLOR. (3 Credits)
Basic physics of light, optical instruments (lenses, telescopes, microscopes), the eye and visual perception, colors, photography, environmental lighting, lasers and holography. For nontechnical majors. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Recommended: Upper-division standing and one year of university science

PH 335. TECHNIQUES OF THEORETICAL MECHANICS. (3 Credits)
Newtonian, Lagrangian, and Hamiltonian classical mechanics. Special relativity with relativistic mechanics.
Recommended: PH 212 and MTH 254

PH 365. COMPUTATIONAL PHYSICS LAB. (1 Credit)
A project-driven laboratory experience in computational physics. Includes the use of basic mathematical and numerical techniques in computer calculations leading to solutions for typical physical problems. Topics to be covered will coordinate with the Paradigms in Physics course sequence.
Prerequisites: PH 213 with C- or better
Recommended: Concurrent enrollment in Paradigms
PH 366. COMPUTATIONAL PHYSICS LAB. (1 Credit)
A project-driven laboratory experience in computational physics. Includes the use of basic mathematical and numerical techniques in computer calculations leading to solutions for typical physical problems. Topics to be covered will coordinate with the Paradigms in Physics course sequence.
Prerequisites: PH 213 with C- or better
Recommended: Concurrent enrollment in Paradigms

PH 367. COMPUTATIONAL PHYSICS LAB. (1 Credit)
A project-driven laboratory experience in computational physics. Includes the use of basic mathematical and numerical techniques in computer calculations leading to solutions for typical physical problems. Topics to be covered will coordinate with the Paradigms in Physics course sequence.
Prerequisites: PH 213 with C- or better
Recommended: Concurrent enrollment in Paradigms

PH 399. SPECIAL TOPICS. (1-16 Credits)
Equivalent to: PH 399H
This course is repeatable for 16 credits.

PH 399H. SPECIAL TOPICS. (1-16 Credits)
Attributes: HNRS – Honors Course Designator
Equivalent to: PH 399
This course is repeatable for 16 credits.

PH 401. RESEARCH. (1-16 Credits)
A research project under the supervision of a faculty member, whose approval must be arranged by the student in advance of registration. This course is repeatable for 16 credits.

PH 403. *THESIS. (1-16 Credits)
A research project leading to a thesis under the supervision of a faculty member, whose approval must be arranged by the student in advance of registration. (Writing Intensive Course)
Attributes: CWIC – Core, Skills, WIC
This course is repeatable for 16 credits.

PH 405. READING AND CONFERENCE. (1-16 Credits)
An independent study project under the supervision of a faculty member, whose approval must be arranged by the student in advance of registration. This course is repeatable for 16 credits.

PH 407. SEMINAR. (1-16 Credits)
Departmental seminars or colloquium. Graded P/N.
Equivalent to: PH 407H
This course is repeatable for 16 credits.

PH 407H. SEMINAR. (1-16 Credits)
Departmental seminars or colloquium.
Attributes: HNRS – Honors Course Designator
Equivalent to: PH 407
This course is repeatable for 16 credits.

PH 409. PHYSICS TEACHING PRACTICUM. (1-6 Credits)
Physics practicum experience for students assisting in Physics courses. Includes training in course content and development of instructional materials. Admission is by application. See the department office in Weniger 301 for details.
This course is repeatable for 6 credits.

PH 410. INTERNSHIP. (1-16 Credits)
This course is repeatable for 16 credits.

PH 411. ELECTRONICS. (3 Credits)
Covers how to build and analyze basic circuits. Topics include passive dc and ac circuits including filters, complex impedance, Fourier analysis, operational amplifiers, semiconductor diodes, and transistors.
Recommended: PH 213

PH 415. COMPUTER INTERFACING AND INSTRUMENTATION. (3 Credits)
Applications of computers as scientific instruments, with emphasis on hardware and instrumentation, online data acquisition, and computer control of experiments.
Recommended: Upper-division and PH 412/PH 512 or equivalent background in electronics

PH 422. PARADIGMS IN PHYSICS: STATIC FIELDS. (3 Credits)
Theory of static electric, magnetic, and gravitational potentials and fields using the techniques of vector calculus in three dimensions.
Recommended: PH 213 and MTH 255

PH 423. PARADIGMS IN PHYSICS: ENERGY AND ENTROPY. (3 Credits)
Thermodynamics and canonical statistical mechanics.
Recommended: PH 213

PH 424. PARADIGMS IN PHYSICS: OSCILLATIONS AND WAVES. (3 Credits)
Dynamics of mechanical and electrical oscillation using Fourier series and integrals; time and frequency representations for driven damped oscillators, resonance; one-dimensional waves in classical mechanics and electromagnetism; normal modes.
Recommended: PH 213 and PH 411 and MTH 256

PH 425. PARADIGMS IN PHYSICS: QUANTUM FUNDAMENTALS. (3 Credits)
Introduction to quantum mechanics through Stern-Gerlach spin measurements. Probability, eigenvalues, operators, measurement, state reduction, Dirac notation, matrix mechanics, time evolution. Quantum behavior of a one-dimensional well.
Recommended: PH 213 and concurrent enrollment in MTH 341

PH 426. PARADIGMS IN PHYSICS: CENTRAL FORCES. (3 Credits)
Gravitational and electrostatic forces; angular momentum and spherical harmonics, separation of variables in classical and quantum mechanics, hydrogen atom.
Recommended: PH 213 and PH 422 and PH 425 and concurrent enrollment in PH 335

PH 427. PARADIGMS IN PHYSICS: PERIODIC SYSTEMS. (3 Credits)
Quantum waves in position and momentum space; Bloch waves in one-dimensional periodic systems, and the reciprocal lattice; coupled harmonic oscillators; phonons.
Recommended: PH 424 and PH 425 and concurrent enrollment in PH 335

PH 431. CAPSTONES IN PHYSICS: ELECTROMAGNETISM. (3 Credits)
Static electric and magnetic fields in matter, electrodynamics, Maxwell equations, electromagnetic waves, wave guides, dipole radiation
Recommended: (PH 424 or 524) and (PH 426 or PH 526)

PH 441. CAPSTONES IN PHYSICS: THERMAL AND STATISTICAL PHYSICS. (3 Credits)
Entropy and quantum mechanics; canonical Gibbs probability; ideal gas; thermal radiation; Einstein and Debye lattices; grand canonical Gibbs probability; ideal Fermi and Bose gases; chemical reactions and phase transformations.
Recommended: (PH 423 or PH 523) and (PH 451 or PH 551)
PH 451. CAPSTONES IN PHYSICS: QUANTUM MECHANICS. (3 Credits)
Wave mechanics, Schroedinger equation, operators, harmonic oscillator, identical particles, atomic fine structure, approximation methods and applications.
Recommended: (PH 424 or PH 524) and (PH 425 or PH 525) and (PH 426 or PH 526)

PH 455. ASTROPHYSICS. (3 Credits)
Physics of stars and the cosmos.
Recommended: PH 213; PH 315 or equivalent junior-level background in modern physics and thermodynamics.

PH 461. CAPSTONES IN PHYSICS: MATHEMATICAL METHODS. (3 Credits)
Complex algebra, special functions, partial differential equations, series solutions, complex integration, calculus of residues.
Recommended: (PH 424 or PH 524) and (PH 426 or PH 526) and MTH 256

PH 464. SCIENTIFIC COMPUTING II. (3 Credits)
Mathematical, numerical, and conceptual elements forming foundations of scientific computing: computer hardware, algorithms, precision, efficiency, verification, numerical analysis, algorithm scaling, profiling, and tuning. Lec/lab.

PH 465. COMPUTATIONAL PHYSICS. (3 Credits)
The use of basic mathematical and numerical techniques in computer calculations leading to solutions for typical physical problems. Topics to be covered include models and applications ranging from classical mechanics and electromagnetism to modern solid state and particle physics.
Recommended: PH 464 or PH 564

PH 481. PHYSICAL OPTICS. (4 Credits)
Wave propagation, polarization, interference, diffraction, and selected topics in modern optics.
Recommended: PH 431 or PH 531

PH 482. OPTICAL ELECTRONIC SYSTEMS. (4 Credits)
Photodetectors, laser theory, and laser systems. Lec/lab. CROSSLISTED as ECE 482/ECE 582.
Equivalent to: ECE 482
Recommended: ECE 391 or (PH 481 or PH 581)

PH 483. GUIDED WAVE OPTICS. (4 Credits)
Optical fibers, fiber mode structure and polarization effects, fiber interferometry, fiber sensors, optical communication systems. Lec/lab. CROSSLISTED as ECE 483/ECE 583.
Equivalent to: ECE 483
Recommended: Completion or concurrent enrollment in ECE 391 or PH 481

PH 495. INTRODUCTION TO PARTICLE AND NUCLEAR PHYSICS. (3 Credits)
Elementary particles and forces, nuclear structure and reactions.
Recommended: PH 451 or PH 551

PH 499. SPECIAL TOPICS. (1-16 Credits)
Topics vary from year to year. May be repeated for credit. Not offered every year.
This course is repeatable for 16 credits.

PH 501. RESEARCH. (1-16 Credits)
Graded P/N.
This course is repeatable for 16 credits.

PH 503. THESIS. (1-16 Credits)
This course is repeatable for 999 credits.

PH 505. READING AND CONFERENCE. (1-16 Credits)
This course is repeatable for 16 credits.

PH 507. SEMINAR. (1-16 Credits)
Section 1: Departmental Colloquium. Section 3: Nuclear and Particle Physics. Section 5: Atomic, Molecular, and Optical Physics. Section 7: Solid State Physics. Section 9: Computational Physics. One-credit options are graded P/N.
This course is repeatable for 16 credits.

PH 510. INTERNSHIP. (1-16 Credits)
This course is repeatable for 16 credits.

PH 511. ELECTRONICS. (3 Credits)
Covers how to build and analyze basic circuits. Topics include passive dc and ac circuits including filters, complex impedance, Fourier analysis, operational amplifiers, semiconductor diodes, and transistors.
Recommended: PH 213

PH 512. ANALOG AND DIGITAL ELECTRONICS. (3 Credits)
Circuit theory. Passive dc and ac circuits including filters, resonance, complex impedance and Fourier analysis. Operational amplifiers, gates and combinational logic. Semiconductor principles, diodes, transistors, BJTs and FETs. Multiplexing, flip-flops and sequential logic, 555 timer, registers and memory, DAC, ADC.
Recommended: PH 511 and completion or concurrent enrollment in PH 314

PH 515. COMPUTER INTERFACING AND INSTRUMENTATION. (3 Credits)
Applications of computers as scientific instruments, with emphasis on hardware and instrumentation, online data acquisition, and computer control of experiments.
Recommended: PH 412 or PH 512 or equivalent background in electronics

PH 531. CAPSTONES IN PHYSICS: ELECTROMAGNETISM. (3 Credits)
Static electric and magnetic fields in matter, electrodynamics, Maxwell equations, electromagnetic waves, wave guides, dipole radiation.
Recommended: (PH 424 or PH 524) and (PH 426 or PH 526)

PH 541. CAPSTONES IN PHYSICS: THERMAL AND STATISTICAL PHYSICS. (3 Credits)
Entropy and quantum mechanics; canonical Gibbs probability; ideal gas; thermal radiation; Einstein and Debye lattices; grand canonical Gibbs probability; ideal Fermi and Bose gases; chemical reactions and phase transformations.
Recommended: (PH 423 or PH 523) and (PH 451 or PH 551)

PH 551. CAPSTONES IN PHYSICS: QUANTUM MECHANICS. (3 Credits)
Wave mechanics, Schroedinger equation, operators, harmonic oscillator, identical particles, atomic fine structure, approximation methods and applications.
Recommended: (PH 424 or PH 524) and (PH 425 or PH 525) and (PH 426 or PH 526)

PH 555. ASTROPHYSICS. (3 Credits)
Physics of stars and the cosmos.
Recommended: PH 213; PH 315 or equivalent junior-level background in modern physics and thermodynamics.

PH 561. MATHEMATICAL PHYSICS. (3 Credits)
Fundamental mathematical techniques needed for graduate students in physics. Topics include vector spaces and operators; fourier series, integrals, and transforms; partial differential equations; special functions, distributions, and delta functions; Green's functions; complex analysis.
PH 562. MATHEMATICAL PHYSICS. (3 Credits)
Fundamental mathematical techniques needed for graduate students in physics. Topics include vector spaces and operators; fourier series, integrals, and transforms; partial differential equations; special functions, distributions, and delta functions; Green's functions; complex analysis.

PH 564. SCIENTIFIC COMPUTING II. (3 Credits)
Mathematical, numerical, and conceptual elements forming foundations of scientific computing: computer hardware, algorithms, precision, efficiency, verification, numerical analysis, algorithm scaling, profiling, and tuning. Lec/lab.

PH 575. INTRODUCTION TO SOLID STATE PHYSICS. (3 Credits)
Introduction to condensed matter physics for majors in physics, chemistry, and engineering. Topics include band structure, free electron behavior, optical properties, magnetism, and lattice excitations.
Recommended: (PH 451 or PH 551) and concurrent enrollment in PH 427 or PH 527

PH 581. PHYSICAL OPTICS. (4 Credits)
Wave propagation, polarization, interference, diffraction, and selected topics in modern optics.
Recommended: PH 431 or PH 531

PH 582. OPTICAL ELECTRONIC SYSTEMS. (4 Credits)
Photodetectors, laser theory, and laser systems. Lec/lab. CROSSTLISTED as ECE 482/ECE 582.
Equivalent to: ECE 582
Recommended: PH 481 or PH 581

PH 583. GUIDED WAVE OPTICS. (4 Credits)
Optical fibers, fiber mode structure and polarization effects, fiber interferometry, fiber sensors, optical communication systems. Lec/lab. CROSSTLISTED as ECE 483/ECE 583.
Equivalent to: ECE 583
Recommended: Completion or concurrent enrollment in ECE 391 or PH 481/581

PH 585. ATOMIC, MOLECULAR, AND OPTICAL PHYSICS. (3 Credits)
Atomic and molecular structure, interaction with electromagnetic fields, atomic and molecular spectra, spectroscopic techniques, laser theory, nonlinear optics.
Recommended: (PH 431 or PH 531) or (PH 451 or PH 551)

PH 591. BIOLOGICAL PHYSICS. (3 Credits)
Basic physics principles applied to the kinetics and dynamics of molecular and cellular processes. Ion channels, two-state systems, dynamics of molecular motors, cell signalling, and multicellular phenomena.
Recommended: PH 320, PH 421, PH 422 and PH 423 or junior-level background in classical mechanics, electromagnetism, and thermodynamics

PH 595. INTRODUCTION TO PARTICLE AND NUCLEAR PHYSICS. (3 Credits)
Elementary particles and forces, nuclear structure and reactions.
Recommended: PH 451 or PH 551

PH 599. SPECIAL TOPICS. (1-16 Credits)
(See PH 499 for description.)
This course is repeatable for 16 credits.

PH 601. RESEARCH. (1-16 Credits)
This course is repeatable for 16 credits.

PH 603. THESIS. (1-16 Credits)
This course is repeatable for 999 credits.

PH 605. READING AND CONFERENCE. (1-16 Credits)
This course is repeatable for 16 credits.

PH 607. SEMINAR. (1-16 Credits)
Section 1: Departmental Colloquium. Section 3: Nuclear and Particle Physics. Section 5: Atomic, Molecular, and Optical Physics. Section 7: Solid State Physics. Section 9: Computational Physics. One-credit options are graded P/N.
This course is repeatable for 16 credits.

PH 621. DYNAMICS OF SINGLE- AND MULTI-PARTICLE SYSTEMS. (3 Credits)
Introduction to theory of non-linear systems, Chaos in Hamiltonian and dissipative systems. Lyapunov exponents, fractal geometries.
Recommended: PH 431 or PH 531

PH 631. ELECTROMAGNETIC THEORY. (3 Credits)
Electrostatics; multipole expansion; magnetostatics; radiation fields; dynamics of relativistic particles and electromagnetic fields.
Recommended: PH 431 or PH 531

PH 632. ELECTROMAGNETIC THEORY. (3 Credits)
Electrostatics; multipole expansion; magnetostatics; radiation fields; dynamics of relativistic particles and electromagnetic fields.
Recommended: PH 631 and (PH 431 or PH 531)

PH 633. ELECTROMAGNETIC THEORY. (3 Credits)
Electrostatics; multipole expansion; magnetostatics; radiation fields; dynamics of relativistic particles and electromagnetic fields.
Recommended: PH 632 and (PH 431 or PH 531)

PH 641. STATISTICAL THERMOPHYSICS. (3 Credits)
Macroscopic thermodynamics and kinetic theory. Classical and quantal statistical ensembles; partition functions. Applications to atoms and molecules, clustering, solids, radiation.
Recommended: PH 435 or PH 535

PH 642. STATISTICAL THERMOPHYSICS. (3 Credits)
Macroscopic thermodynamics and kinetic theory. Classical and quantal statistical ensembles; partition functions. Applications to atoms and molecules, clustering, solids, radiation.
Recommended: PH 641

PH 651. QUANTUM MECHANICS. (3 Credits)
Basic principles of nonrelativistic quantum theory and applications. Schroedinger theory, quantum theory of angular momentum, matrix mechanics, perturbation theory, identical particles, scattering.
Recommended: (PH 435 or PH 535) and (PH 451 or PH 551)

PH 652. QUANTUM MECHANICS. (3 Credits)
Basic principles of nonrelativistic quantum theory and applications. Schroedinger theory, quantum theory of angular momentum, matrix mechanics, perturbation theory, identical particles, scattering.
Recommended: (PH 435 or PH 535) and (PH 451 or PH 551) and PH 651

PH 653. QUANTUM MECHANICS. (3 Credits)
Basic principles of nonrelativistic quantum theory and applications. Schroedinger theory, quantum theory of angular momentum, matrix mechanics, perturbation theory, identical particles, scattering.
Recommended: (PH 435 or PH 535) and (PH 451 or PH 551) and PH 652

PH 654. ADVANCED QUANTUM THEORY. (3 Credits)
Scattering theory, second quantization and many body theory, relativistic quantum mechanics, quantization of fields, quantum electrodynamics, and elementary particles.
Recommended: PH 653
PH 671. SOLID STATE PHYSICS, ELECTRON TRANSPORT. (2 Credits)
Fundamentals of solid state physics, Boltzmann transport, phonon and
defect scattering, quantum transport, transport in magnetic field, localization, Mott-insulator transition, electron tunneling,
superconductivity. Offered in alternate years.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 672. SOLID STATE PHYSICS, THEORY. (2 Credits)
The many-body problem, density functional theory, excited states properties, BCS theory of superconductivity. Offered in alternate years.
Recommended: PH 575 and PH 654 and basic knowledge of electromagnetism and quantum mechanics.

PH 673. SOLID STATE PHYSICS, NANOSCIENCE AND NANOTECHNOLOGY. (2 Credits)
Introduction to nanoscience and nanotechnology; semiconductor quantum wells, wires, and dots; bulk metals vs nanoparticles; molecular ensembles vs single molecules; fabrication of nanoparticles and nanostructured materials; scanning probe microscopy; advanced optical imaging and manipulation. Offered in alternate years.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 674. SOLID STATE PHYSICS, MAGNETISM. (2 Credits)
Magnetism of atoms; interaction between magnetic atoms, magnetic ordering in crystalline solids; excitations in magnetic solids; temperature dependent phenomena in magnetic solids; magnetism of metals, alloys, insulators and semiconductors; topics of considerable interest in contemporary research.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 681. ATOMIC, MOLECULAR AND OPTICAL PHYSICS, MODERN OPTICS. (2 Credits)
Maxwell's equations in matter; refraction, phase and group indices; material and geometry dispersion; effective-medium regime. Not offered every year.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 682. ATOMIC, MOLECULAR, OPTICAL PHYSICS, SEMICONDUCTOR OPTICS. (2 Credits)
Linear response theory; polarization effects; interband excitations and emissions; low dimensional systems; excitons; phonons; semiconductor lasers; photovoltaics. Offered alternate years.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 683. ATOMIC, MOLECULAR AND OPTICAL PHYSICS, NONLINEAR OPTICS. (2 Credits)
Coherent nonlinear electromagnetic phenomena; harmonic generation and parametric mixing; quantum mechanical description of multi-photon interactions; incoherent multi-photon interactions; coherent nonlinear optical phenomena and spectroscopies. Offered in alternate years.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 684. ATOMIC, MOLECULAR AND OPTICAL PHYSICS, ULTRAFAST OPTICS. (2 Credits)
Introduction of ultrafast optical science; short pulse propagation in linear media; pulse stretching and compressing; Q-switching and mode-locking; characterization of femtosecond lasers; coherent optical effects. Offered in alternate years.
Recommended: Basic knowledge of electromagnetism and quantum mechanics.

PH 699. SPECIAL TOPICS: BIOLOGICAL PHYSICS. (3 Credits)
Topics vary from year to year. Not offered every year.
This course is repeatable for 9 credits.