PHYSICS (PHYS)

PHYS 101 Conceptual Physics (Units: 3)
Prerequisite: Category I or II placement for QR/Math, or completion of GE Area B4, or MATH 197.

Conceptual introduction to Newton's Laws of Motion, properties of matter and energy, heat, sound, light, electricity, magnetism, and atoms.
Course Attributes:

- B1: Physical Science

PHYS 102 Conceptual Physics Laboratory (Unit: 1)
Prerequisite: Concurrent enrollment in PHYS 101.

Laboratory exercises in basic physics.
Course Attributes:

- B3: Lab Science

PHYS 111 General Physics I (Units: 3)
Prerequisites: MATH 198 or MATH 199 or equivalent with a grade of C-minus or higher. Concurrent enrollment in PHYS 112 required. If pre-calculus was completed in high school, the online Math Preparation for Physics mini-course is required; see the Department of Physics & Astronomy website for details.

Introduction to mechanics, waves, sound, fluids, thermodynamics, with applications to biology, life, and health sciences.
Course Attributes:

- B1: Physical Science

PHYS 112 General Physics I Laboratory (Unit: 1)
Prerequisite: Concurrent enrollment in PHYS 111.

Mechanics, heat, and sound. Extra fee required.
Course Attributes:

- B3: Lab Science

PHYS 121 General Physics II (Units: 3)
Prerequisites: PHYS 111; concurrent enrollment in PHYS 122.

Light, electricity, magnetism, atoms, and modern physics.

PHYS 122 General Physics II Laboratory (Unit: 1)
Prerequisite: Concurrent enrollment in PHYS 121.

Light, electricity, magnetism, atoms, and modern physics. Extra fee required.

PHYS 220 General Physics with Calculus I (Units: 3)
Prerequisites: High school physics or equivalent; satisfactory score on physics placement examination; MATH 226 with a grade of C or better; concurrent enrollment in PHYS 222, MATH 227.

Basic mechanics. Calculus is used in examples and problems. Optional tutorial discussion.
Course Attributes:

- B1: Physical Science

PHYS 222 General Physics with Calculus I Laboratory (Unit: 1)
Prerequisite: Concurrent enrollment in PHYS 220.

Experiments in mechanics. Extra fee required.
Course Attributes:

- B3: Lab Science

PHYS 230 General Physics with Calculus II (Units: 3)
Prerequisites: PHYS 220, MATH 227, with grades of C or better; concurrent enrollment in PHYS 232, MATH 228 recommended.

Introduction to electricity and magnetism. Calculus is used in examples and problems.

PHYS 232 General Physics with Calculus II Laboratory (Unit: 1)
Prerequisite: Concurrent enrollment in PHYS 230.

Experiments in electricity and magnetism. Extra fee required.

PHYS 240 General Physics with Calculus III (Units: 3)
Prerequisites: PHYS 220, MATH 227, with grades of C or better; concurrent enrollment in PHYS 242, MATH 228 recommended; recommended for Physics majors.

Wave motion, optics, and thermodynamics.

PHYS 242 General Physics with Calculus III Laboratory (Unit: 1)
Prerequisite: Concurrent enrollment in PHYS 240.

Experiments in wave motion, optics, and thermodynamics.

PHYS 320 Modern Physics I (Units: 3)
Prerequisites: PHYS 230, PHYS 240, MATH 228, with grades of C or better.

Introduction to special relativity, quantum phenomena, the Bohr model of the hydrogen atom, and the Schrödinger equation.

PHYS 321 Modern Physics Laboratory (Units: 2)
Prerequisite: Concurrent enrollment in PHYS 320.

Experiments on quantum physics and other phenomena of modern physics. Methods of data and error analysis. Classwork, 1 unit; laboratory, 1 unit.

PHYS 325 Modern Physics II (Units: 3)
Prerequisite: PHYS 320 with a grade of C- or better.

Physics of multi-electron atoms including L and S coupling schemes and optical spectra; elementary concepts of nuclear and elementary particle physics; use of four-vectors to analyze particle collisions and decays.

PHYS 330 Analytical Mechanics I (Units: 3)
Prerequisites: PHYS 230, MATH 245 or MATH 376, with grades of C- or better.

Vector analysis, fundamentals of statics, kinematics, and dynamics of rigid bodies and systems of particles.

PHYS 360 Electricity and Magnetism I (Units: 3)
Prerequisites: PHYS 230, PHYS 330, PHYS 385, with grades of C- or better.

Electrostatics, including boundary-value problems, fields in polarizable media, magnetostatics.

PHYS 370 Thermodynamics and Statistical Mechanics (Units: 3)
Prerequisites: PHYS 240, PHYS 320, MATH 228, with grades of C or better.

Classical thermodynamics, kinetic theory, and elementary statistical mechanics. Applications may include quantum statistics, black-body radiation, paramagnetic spin systems, and low-temperature phenomena.

PHYS 385 Introduction to Theoretical Physics I (Units: 3)
Prerequisites: PHYS 240/PHYS 242 with grades of C- or better; concurrent enrollment in PHYS 330.

Principles of theoretical physics. Theoretical techniques applied throughout mechanics, electricity and magnetism, optics, relativity, quantum mechanics, etc. Applications of vector and tensor spaces, coordinate systems, and group theory.

PHYS 430 Quantum Mechanics I (Units: 3)
Prerequisites: PHYS 320, PHYS 360 (may be taken concurrently), PHYS 385, and MATH 245 or MATH 376, with grades of C- or better.

Postulates of quantum mechanics, one-dimensional problems, barriers and the WKB approximation, angular momentum, and hydrogen atom.

PHYS 431 Quantum Mechanics II (Units: 3)
Prerequisite: PHYS 430 with a grade of C- or better.

Problems in three dimensions, matrix mechanics, spin, application to atomic and molecular physics, perturbation theory, and scattering.

PHYS 440 Computational Physics (Units: 4)
Prerequisites: MATH 245 or MATH 376; PHYS 320; and CSC 210 or CSC 309 or ENGR 213.

Analysis and development of numerical algorithms with a focus on computer simulations of physical systems. Topics may include: finite difference methods for nonlinear ordinary differential equations and chaos theory, N-body gravitational systems and molecular dynamics; numerical linear algebra; Fast Fourier Transforms, finite difference and spectral methods for partial differential equations; Monte Carlo methods for integration, Markov chains, statistical mechanics and spin systems; introduction to parallel programming. Lecture, 3 units; laboratory, 1 unit. (PHYS 740/PHYS 440 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

PHYS 450 Introduction to Solid State Physics (Units: 3)
Prerequisites: PHYS 320, MATH 245 or MATH 376, with grades of C- or better.

Crystal structure, x-ray diffraction, lattice vibrations, models of electrical conductivity; electron energy bands in crystals; electrons and holes in semiconductors.

PHYS 457 Introduction to Analog Electronics (Units: 4)
Prerequisites: PHYS 121 or PHYS 230, MATH 226, with grades of C- or better.

Linear network analysis techniques; phasors; diodes; bipolar junction transistors; field-effect transistors; operational amplifiers. Classwork, 3 units; laboratory, 1 unit.

PHYS 460 Electricity and Magnetism II (Units: 3)
Prerequisite: PHYS 360 with a grade of C- or better.

Maxwell's equations; waves in free space and in dielectrics; reflection and refraction; radiation; special-relativistic transformation of the electromagnetic field.

PHYS 480 Introduction to Optics & Photonics (Units: 3)
Prerequisites: PHYS 230 and PHYS 240, PHYS 320 and PHYS 385 recommended, with grades of C- or better.

Ray optics, including optical fibers and instruments. Wave optics, including interference, diffraction, electromagnetic waves and polarization. Selected topics including beam optics, Fourier optics, photonic-crystal optics, laser basics, holography.

PHYS 490 Physics Project Laboratory (Units: 2)
Prerequisite: PHYS 321 with a grade of C- or better.

Experiments from the fields of atomic, nuclear, solid-state, and optical physics with emphasis on electronic instrumentation and computer-assisted data acquisition. Lecture, 1 unit; laboratory, 1 unit. (Completion of PHYS 490 and PHYS 491GW with a grade of C or better culminates in the satisfaction of GWAR.) (ABC/NC grading only)

PHYS 491GW Advanced Laboratory II - GWAR (Unit: 1)
Prerequisites: GE Area A2; PHYS 490 with a grade of C or better.

Advanced laboratory work in atomic, nuclear, solid state, and optical physics. Preparation of publication-quality reports and oral presentations on experiments. (ABC/NC grading only)
Course Attributes:

- Graduation Writing Assessment

PHYS 495 Introduction to Apparatus Fabrication (Unit: 1)
Prerequisites: Physics majors; PHYS 490 with a grade of C- or better; consent of the instructor.

Laboratory work with materials, machine tools (lathe, mill, etc.), and fabrication methods for the production of experimental research apparatus. Safety considerations.

PHYS 685 Instructional Methods in Teaching Physics (Unit: 1)
Prerequisite: Upper-division standing.

Pedagogical strategies and principles of teaching and learning in STEM. Seminar for students in their first Learning Assistant (LA) or Supplemental Instruction (SI) position.

PHYS 686 Experiences in Teaching Physics (Unit: 1)
Prerequisite: Upper-division standing.

Activity practicum for students serving as Learning Assistants (LAs) in STEM courses. LAs will directly assist STEM instructors in facilitating active learning in their classrooms. May be repeated for a total of 6 units.

PHYS 695 Culminating Experience in Physics (Unit: 1)
Prerequisite: Final semester of a Physics degree program.

Preparation of a portfolio of work completed in classes required for the degree. The final examination will be the ETS physics major field test.

PHYS 697 Senior Project (Units: 1-3)
Prerequisite: PHYS 490; consent of the faculty adviser.

Participation in experimental or theoretical project under the direction of faculty member. Written report of specific observations and calculations required. May be repeated with consent of the advisor.

PHYS 699 Independent Study (Units: 1-3)
Prerequisite: Approval of department and consent of instructor.

Study in the laboratory or library under the direction of a member of the department. For students majoring or minoring in physics. Student must present a detailed written report of the work accomplished to the department. May be repeated for a total of 12 units.

PHYS 701 Classical Mechanics (Units: 3)
Prerequisites: Graduate standing; PHYS 460 (may be taken concurrently), PHYS 785 recommended.

Lagrangian and Hamiltonian mechanics; motion in arbitrary central force potentials; canonical transformation theory; Liouville's theorem; computer visualizations of phase space trajectories and topologies; collisionless Boltzmann equation applied to stellar dynamics; Jeans theorems, orbital anisotropy, and phase space distribution functions.

PHYS 704 Electricity and Magnetism I (Units: 3)
Prerequisites: PHYS 785, PHYS 460, PHYS 701 recommended.

Boundary-value problems in electrostatics, magnetostatics; Maxwell's equations and the causal structure of electrodynamics; plane waves and wave propagation.

PHYS 706 Quantum Mechanics (Units: 3)
Prerequisites: PHYS 701, PHYS 785.

Bound states, collision theory, matrix mechanics, symmetry and groups, perturbation theory.

PHYS 710 Advanced Laboratory Techniques (Units: 3)
Prerequisite: PHYS 490.

Techniques of electronic instrumentation, computerized data acquisition, digital signal processing, and data analysis designed to prepare the student for experimental research work in academic and industrial laboratories. Classwork, 2 units; laboratory, 1 unit.

PHYS 711 Semiconductor Devices and Technology (Units: 3)
Prerequisite: PHYS 450 with a grade of C or better.

Physical principles of semiconductor devices based upon mestructures. Introduction to integrated circuit fabrication technology structures.

PHYS 712 Physics of Plasmas (Units: 3)
Prerequisites: Graduate standing; PHYS 460; PHYS 701 or PHYS 785 recommended.

Fundamental properties of plasmas. Motion of charged particles in electromagnetic fields. Kinetic theory of plasmas, including the Boltzmann and Vlasov equations. Fluid theory of plasmas, including magnetohydrodynamics. Waves and instabilities. Applications to controlled thermonuclear fusion and space physics.

PHYS 714 Low-Temperature Physics (Units: 3)
Prerequisites: PHYS 360, PHYS 430, with grades of C or better.

Low temperature thermal and electrical behavior of materials; theories of superconductivity and superfluidity; superconducting devices including Josephson junctions, quantum interference devices and cryogenic phonon.

PHYS 715 Lasers and Quantum Optics (Units: 3)
Prerequisites: PHYS 430, PHYS 460.

Atom-field interaction, stimulated emission, dipole oscillations, the ammonia maser, semi-classical laser theory, coherent states, quantum laser theory, Fourier optics, and holographic interferometry.

PHYS 725 Special and General Relativity (Units: 3)
Prerequisites: Graduate standing; PHYS 701 (may be taken concurrently); PHYS 785 recommended.

Tensor formulation of special relativity with astrophysical applications. Riemannian geometry. The Einstein field equations applied to Mercury's orbit, black holes, gravitational lensing, cosmology, and interstellar travel. Computer visualizations of spacetimes and orbits.

PHYS 726 Quantum Field Theory (Units: 3)
Prerequisites: PHYS 430, PHYS 431, PHYS 706.

Relativistic wave equations; quantization of the scalar, Dirac, and Maxwell fields. The LSZ reduction formula for S-matrix elements. Path-Integral evaluation of time-ordered products. Tree-level Feynman diagrams in quantum electrodynamics, and an introduction to non-abelian gauge theory.

PHYS 730 Photonics and Nano Materials (Units: 3)
Prerequisites: PHYS 320 and PHYS 360 or consent of the instructor. Non-Physics majors should consult with the instructor.

Introduction to light-matter interactions in nanostructures, including: basic properties of electromagnetic waves and quantum particles, wave optics and wave mechanics, electrons in periodic structures and quantum confinement effects, semiconductor nanocrystals (quantum dots), nanoplasmonics, multilayer structures, metamaterials, photonic crystals, photonic circuitry. Applications to microscopy, optical antennas, devices for opto-mechanics, energy conversion, biomedicine, nanophotonics for communication and quantum information science.

PHYS 740 Computational Physics (Units: 4)
Prerequisites: MATH 245 or MATH 376; PHYS 320; and CSC 210 or CSC 309 or ENGR 213.

Analysis and development of numerical algorithms with a focus on computer simulations of physical systems. Topics may include: finite difference methods for nonlinear ordinary differential equations and chaos theory, N-body gravitational systems and molecular dynamics; numerical linear algebra; Fast Fourier Transforms, finite difference and spectral methods for partial differential equations; Monte Carlo methods for integration, Markov chains, statistical mechanics and spin systems; introduction to parallel programming. Lecture, 3 units; laboratory, 1 unit. (PHYS 740/PHYS 440 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

PHYS 775 Statistical Physics (Units: 3)
Prerequisites: PHYS 370, MATH 376, PHYS 385.

Statistical methods in physics: probability, phase space, distribution functions, partition functions. Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics. Phase transitions, Monte Carlo method, transport theory. (Plus-minus letter grade only)

PHYS 785 Theoretical Physics (Units: 3)
Prerequisites: PHYS 360, PHYS 460 (may be taken concurrently).

Advanced concepts and techniques in mathematics applied to problems in physics. Applications in mechanics, electricity and magnetism, and fluids. (Plus-minus letter grade only)

PHYS 832 Instructional Methods in Physics (Units: 2)
Prerequisites: Graduate standing or consent of the instructor; concurrent GTA appointment.

Instructional methods for the teaching of physics laboratories including the introductory lecture, laboratory safety procedures, supervision of laboratory students, proper handling of equipment and demonstrations, and best practices in maintaining lab logbooks and writing lab reports. May be repeated for a total of 4 units. (CR/NC grading only)

PHYS 885 Projects in Teaching Physics and Astronomy (Units: 3)
Prerequisite: Graduate standing.

Learning experience and pedagogical strategies and principles of teaching and learning physics and/or astronomy. Required of students in their first GTA position. (Plus-minus letter grade only)

PHYS 890 Introduction to Physics Research (Units: 1-3)
Prerequisite: Graduate standing.

Introduction to methods of physics research. May be repeated for a total of 5 units. (CR/NC only)

PHYS 891 Physics Research Design (Units: 1-3)
Prerequisites: Passed Level 1 Written English Proficiency Requirement and have research project approved.

Elements of Physics/Astronomy research proposals: literature review, project significance, and feasibility, materials and methods, budget, data analysis and presentation, statistical significance, reference notation. May be repeated for a total of 4 units.

PHYS 896 Directed Reading in Physics (Units: 1-3)
Prerequisite: Graduate standing.

Readings/tutorials to achieve better understanding of specific topics based on individual student need. Focus on review and integration of core concepts in preparation for the comprehensive oral examination. (Does not count toward MS degree requirements.) (CR/NC only)

PHYS 896EXM Culminating Experience Examination (Units: 0-3)
Prerequisites: Consent of the instructor, committee chair, and approval of Advancement to Candidacy (ATC) and Culminating Experience (CE) forms by Graduate Studies. ATC and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration.

Enrollment in 896EXAM required for students whose culminating experience consists of an examination only. Not for students enrolled in a culminating experience course numbered PHYS 898 (or in some cases, course number PHYS 890 - see program's graduate advisor for further information). (CR/NC, RP))

PHYS 897 Research (Units: 1-3)
Prerequisite: Completed undergraduate major in physics.

Independent and original laboratory investigation under supervision of a staff member. May be repeated. (Plus-minus letter grade, CR/NC, RP)

PHYS 898 Master's Thesis (Units: 3)
Prerequisites: Consent of the instructor and approval of Advancement to Candidacy (ATC) and Culminating Experience (CE) forms by Graduate Studies.

Advancement to Candidacy and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration. (CR/NC, RP grading only)

PHYS 899 Independent Study (Units: 1-3)
Prerequisite: Approval of department and consent of instructor.

Study in the laboratory or library under the direction of a member of the department. For graduate students in physics. The student must present a detailed written report of the work accomplished to the department. May be repeated.