PHYS - Physics

PHYS 101N Conceptual Physics (4 Credit Hours)
An introductory descriptive course which develops and illustrates the concepts of physics in terms of phenomena encountered in daily life. Topics include mechanics, electricity and magnetism. (offered fall, summer)

PHYS 102N Conceptual Physics (4 Credit Hours)
An introductory descriptive course which develops and illustrates the concepts of physics in terms of phenomena encountered in daily life. Topics include sound, light, fluids and heat. (offered spring)
Prerequisites: PHYS 101N

PHYS 103N Introductory Astronomy of the Solar System (4 Credit Hours)
A study of the physical principles and scientific investigation of objects in our solar system. Emphasis on how we acquire knowledge of celestial objects to develop models of our universe.

PHYS 104N Introductory Astronomy of Galaxies and Cosmology (4 Credit Hours)
Emphasizes the study of stars, star systems, cosmology and relativity. Emphasis on how we acquire knowledge of celestial objects to develop models of our universe.

PHYS 109 Introductory Astronomy Laboratory (1 Credit Hour)
An introductory laboratory course in astronomy dealing with experiments about the laws of nature that apply to objects in our solar system.
Prerequisites: written permission of the chief departmental advisor of the Physics Department

PHYS 111N Introductory General Physics (4 Credit Hours)
Emphasizes mechanics, wave motion and heat and will also cover the needed elements of trigonometry and vectors. Students receiving credit for PHYS 111N cannot receive credit for PHYS 102N either simultaneously or subsequently. (offered fall, spring, summer)
Prerequisites: MATH 102M or MATH 103M or MATH 162M or MATH 166

PHYS 112N Introductory General Physics (4 Credit Hours)
Emphasizes electricity, light, and introduction to modern physics. (offered fall, spring, summer)
Prerequisites: PHYS 111N and MATH 102M (or MATH 103M) or MATH 162M or MATH 166

PHYS 113 Physics Laboratory (1 Credit Hour)
Available for pass/fail grading only. An introductory laboratory covering experiments from mechanics, wave motion, heat and sound.
Prerequisites: written permission of the chief departmental advisor of the Physics Department

PHYS 114 Physics Laboratory (1 Credit Hour)
Available for pass/fail grading only. An introductory laboratory covering experiments from electricity, magnetism, and optics.
Prerequisites: written permission of the chief departmental advisor of the Physics Department

PHYS 120 Physics in the 21st Century (1 Credit Hour)
This seminar will provide students with a broad introduction to the cutting edge of physics research and its applications in diverse areas of contemporary physics. Recommended for incoming students interested in physics and the natural sciences.

PHYS 126N Honors: Introductory Astronomy (4 Credit Hours)
Open only to students in the Honors College. A special honors version of PHYS 103N.

PHYS 127N Honors: Introductory Astronomy (4 Credit Hours)
Open only to students in the Honors College. A special honors version of PHYS 104N.

PHYS 137T Introduction to Quantum Science and Technology (3 Credit Hours)
Quantum mechanics has had an enormous impact on society since its discovery nearly a century ago and has been instrumental in developing technology such as transistors and lasers. This course will explore the potential benefits of emerging quantum technologies, how they will impact present and future society, and the technical challenges posed in implementing them. Students will develop a conceptual understanding of these technologies and their fundamental underlying principles of superposition, interference, and entanglement. Topics include quantum computing, quantum communications, and quantum sensing. These ideas will be explored quantitatively using basic algebra. It is strongly recommended that students have passed a college-level math class.

PHYS 197 Undergraduate Research Experience in Physics (0 Credit Hours)
Student participation in a supervised, undergraduate research experience for which credit will not apply to the degree. Experience must be related to the student's major, minor or career area of interest.
Prerequisites: permission of the instructor

PHYS 226N Honors: University Physics I (4 Credit Hours)
Open only to students in the Honors College. A special honors version of PHYS 231N. This course also includes a Recitation Section for more in-depth discussion of advanced problems.
Prerequisites: MATH 211 with a grade of C or better
Pre- or corequisite: MATH 212

PHYS 227N Honors: University Physics II (4 Credit Hours)
Open only to students in the Honors College. A special honors version of PHYS 232N, including a recitation section for discussion of advanced problems.
Prerequisites: PHYS 231N or PHYS 226N or PHYS 261N with a grade of C or better, and both MATH 211 and MATH 212 each with a grade of C or better

PHYS 231N University Physics I (4 Credit Hours)
A general introduction to physics in which the principles of classical and modern physics are applied to the solution of physical problems. The reasoning through which solutions are obtained is stressed. Topics include mechanics, fluids, and thermodynamics. This course is designed for majors in the physical sciences, engineering, mathematics, and computational sciences. Students receiving credit for PHYS 231N and PHYS 232N cannot simultaneously or subsequently receive credit for PHYS 101N and PHYS 102N or PHYS 111N and PHYS 112N. (offered fall, spring, summer) Pre- or
Prerequisites: MATH 211 with a grade of C or better
Corequisites: MATH 212 or permission of instructor

PHYS 232N University Physics II (4 Credit Hours)
A general introduction to physics in which the principles of classical and modern physics are applied to the solution of physical problems. The reasoning through which solutions are obtained is stressed. This course is designed for majors in the physical sciences, engineering, mathematics, and computational sciences. Topics include electricity and magnetism, and optics. Students receiving credit for PHYS 231N and PHYS 232N cannot simultaneously or subsequently receive credit for PHYS 101N and PHYS 102N or PHYS 111N and PHYS 112N. (offered fall, spring, summer)
Prerequisites: PHYS 231N or PHYS 226N or PHYS 261N with a grade of C or better, and both MATH 211 and MATH 212 with each a grade of C or better

PHYS 261N Advanced University Physics I (4 Credit Hours)
This calculus-based course is the required introductory course for Physics majors. In addition to the physics curriculum of PHYS 231N, this course has a recitation section for advanced problems and additional mathematical preparation for advanced courses in physics.
Prerequisites: MATH 211, with a grade of C or better
Pre- or corequisite: MATH 212

PHYS 262N Advanced University Physics II (4 Credit Hours)
This calculus-based course is the required introductory course for Physics majors. In addition to the physics curriculum of PHYS 232N, this course has a recitation section for advanced problems and additional mathematical preparation for advanced courses in physics.
Prerequisites: PHYS 261N with a grade of C or better; MATH 211 and MATH 212, each with a grade of C or better

PHYS 297 Undergraduate Research I (1-3 Credit Hours)
This course offers students at the Freshman and Sophomore levels their first opportunity to work one-on-one with a research mentor to acquire and develop skills in research techniques, information literacy, research planning, proposal preparation and report writing. Research experiences may include but are not limited to hands-on instrument control to collect and analyze data, including graphical, statistical and error analysis of their data. Students will also be instructed on accepted methods for dissemination of data, including written, oral and poster presentation, as well as procedures for research proposal preparation and submission. Students will be required to deliver to their peers and department faculty at the end of semester an oral and written presentation of their research, as well as a poster presentation at an annual department or university event including the ODU Undergraduate Research Symposium.
Prerequisites: Permission of the instructor
Pre- or corequisite: PHYS 226N or PHYS 231N or PHYS 261N

PHYS 303 Intermediate Experimental Physics (3 Credit Hours)
A laboratory-oriented course designed to provide students with a broad introduction to instrumentation and techniques used in modern physics laboratories. Topics to be covered include: basic electronics with an introduction to diode, transistor and op-amp circuitry, and an introduction to physical computing using LabView and Arduino micro controllers.
Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N

PHYS 309 Physics on the Back of an Envelope (1 Credit Hour)
Physicists should be able to estimate the order-of-magnitude of anything. How many atoms of Julius Caesar do you eat every day? How much waste does a nuclear power plant generate? Will develop concepts, relations and numbers useful for estimation. Will cover little new material, emphasizing already acquired knowledge. Will help students apply physics to real-life questions and understand which physical effects are appropriate on which scales. Seminar course.
Prerequisites: PHYS 102N or PHYS 112N or PHYS 232N or PHYS 227N or PHYS 262N

PHYS 311 Color in Nature and Art (3 Credit Hours)
Explores the relationship between light as stimulus and color perceived by us. Develops underlying concept of technology of art and applied art. Describes basis for optical phenomena involved in many facets of daily life. Topics include: the interaction of light and the visual perception it produces; the basic concept of spectra; wave, ray, and quantum optics; polarized light; photography; paintings; pigments; rainbows and mirages; color theory systems; formation of images; optical instruments. There is no physics prerequisite for this course.
Prerequisites: MATH 102M (or MATH 103M)

PHYS 319 Analytical Mechanics (3 Credit Hours)
Fundamentals of Newtonian mechanics. Topics include kinematics, dynamics, energy and momentum, central forces and planetary motion, and resonance phenomena. (Offered Spring)
Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N
Pre- or corequisite: MATH 307 or MATH 280

PHYS 323 Modern Physics (3 Credit Hours)
Introduction to the wave nature of matter, with applications in materials science, atomic, and nuclear physics. Introduction to relativity, including applications in mechanics and electrodynamics. (Offered Fall)
Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 212

PHYS 350 Light and Lasers (3 Credit Hours)
An analysis of those concepts of geometrical physical optics needed for the understanding of laser resonators, optical propagation, and radiation detection. A study of laser diodes, molecular, neutral and ion gas lasers, tuneable dye and excimer lasers. Laser applications in medicine, communications, information processing, holography, pollution detection, and material testing and fabrication are stressed.
Prerequisites: PHYS 102N or PHYS 112N or PHYS 232N

PHYS 355 Mathematical Methods of Physics (3 Credit Hours)
This course will provide a strong foundation in the mathematical methods and applications necessary for undergraduate study of physics beyond the introductory level. The course contains a mandatory recitation section. (Offered Fall)
Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 212
Pre- or corequisite: MATH 312 or MATH 285

PHYS 367 Cooperative Education (1-3 Credit Hours)
May be repeated for credit. Available for pass/fail grading only. Student participation for credit based on the academic relevance of the work experience, criteria, and evaluative procedures as formally determined by the department and Career Development Services prior to the semester in which the work experience is to take place.
Prerequisites: approval of the chief departmental advisor and Career Development Services in accordance with the policy for granting credit for Cooperative Education programs

PHYS 368 Internship (1-3 Credit Hours)
Available for pass/fail grading only. Academic requirements will be established by the department and will vary with the amount of credit desired. Allows students to gain short duration career-related experience.
Prerequisites: approval by the chief departmental advisor and Career Development Services

PHYS 397 Undergraduate Research II (1-3 Credit Hours)
This course offers students at the Sophomore and Junior levels an opportunity to work one-on-one with a research mentor on a self-designed research project of mutual interest, and typically within the research field of their mentor. The student will demonstrate their knowledge of the research skills covered in PHYS 297 by formulating their own research plan and then collecting and analyzing their data. Students will also be instructed in research publication skills as well as conference standard presentation techniques. Students will be required to attend at least two conferences, within and outside the university.
Prerequisites: PHYS 297, and PHYS 226N or PHYS 231N or PHYS 261N, and permission of instructor

PHYS 408/508 Astronomy for Teachers (3 Credit Hours)
A course in astronomy dealing with stars and stellar systems. Topics will include observational astronomy, the electromagnetic spectrum, relativity, stellar and galactic structures, cosmology, and the search for extraterrestrial intelligence.
Prerequisites: junior standing

PHYS 411 Introduction to Atomic Physics (3 Credit Hours)
The hydrogen atom, radiative transitions, two-electron systems, many-electron atoms, interaction with external fields, theory of atomic spectra.
Prerequisites: PHYS 452 and MATH 307

PHYS 413/513 Methods of Experimental Physics (3 Credit Hours)
Experiments in classical and modern physics, designed to develop skills in the collection, analysis, and interpretation of experimental data. (Offered Spring)
Prerequisites: PHYS 303 or ECE 287, and PHYS 323

PHYS 415/515 Introduction to Nuclear and Particle Physics (3 Credit Hours)
An introduction to the structure of the atomic nucleus, natural and artificial radioactivity, nuclear decay processes and stability of nuclei, nuclear reactions, properties of nuclear forces, and nuclear models. Also, particle phenomenology, experimental techniques and the standard model. Topics include the spectra of leptons, mesons, and baryons; strong, weak, and electromagnetic interactions.
Prerequisites: PHYS 452
Pre- or corequisite: MATH 307

PHYS 416/516 Introduction to Solid State Physics (3 Credit Hours)
Introduction to solid state physics and materials science, with emphasis placed on the applications of each topic to experimental and analytical techniques. Topics include crystallography, thermal and vibrational properties of crystals and semiconductors, metals and the band theory of solids, superconductivity and the magnetic properties of materials.
Prerequisites: PHYS 452 and MATH 307

PHYS 417/517 Introduction to Particle Accelerator Physics (3 Credit Hours)
Fundamentals of relativistic particle dynamics including particle acceleration; weak and strong focusing; linear beam optics and particle transfer matrices; linear and non-linear synchrotron motion; introduction to the statistical descriptions of particle beams; and radiation production by accelerated relativistic particles. Examples relevant to betatrons, cyclotrons, synchrotrons, and linear accelerators will be given.
Prerequisites: PHYS 319 or MAE 205, and PHYS 425 or ECE 323

PHYS 420/520 Introductory Computational Physics (3 Credit Hours)
Introduction of computational methods and visualization techniques for problem solving in physics.
Prerequisites: PHYS 319, PHYS 323, CS 150, and MATH 212

PHYS 425/525 Electromagnetism I (3 Credit Hours)
A study of the classical theory and phenomena of electricity and magnetism. Topics include the calculation of electric and magnetic fields, magnetic and dielectric properties of matter, and an introduction to Maxwell's equations. The course contains a mandatory recitation section.
Prerequisites: PHYS 232N or PHYS 227N or PHYS 262N and MATH 312 or MATH 285
Pre- or corequisite: PHYS 355

PHYS 451/551 Theoretical Mechanics (3 Credit Hours)
A mathematical study of the concepts of mechanics. Vector calculus methods are used. Topics include mechanics of a system of particles, Lagrangian mechanics, Hamilton's canonical equations, and motion of a rigid body.
Prerequisites: PHYS 319, PHYS 355 and MATH 312

PHYS 452/552 Introduction to Quantum Mechanics (3 Credit Hours)
Introduction to the physical and mathematical structure of quantum theory, including the historical and experimental origins of the subject. The subject matter includes techniques for solving the Schrodinger equation in one, two, and three dimensions. Both coordinate and momentum space representations are used. The harmonic oscillator and the Hydrogen atom receive particular attention. The course contains a mandatory recitation section.
Prerequisites: PHYS 319, PHYS 323, and PHYS 355

PHYS 453/553 Electromagnetism II (3 Credit Hours)
A course in electrodynamics developed from Maxwell's Equations. Topics include Maxwell's Equations, Conservation Laws, Electromagnetic Waves, Potentials and Fields, Radiation, and the interplay of electrodynamics and special relativity. The course contains a mandatory recitation section.
Prerequisites: PHYS 425 or ECE 323 and MATH 312

PHYS 454/554 Thermal and Statistical Physics (3 Credit Hours)
A study of the fundamental concepts of thermodynamics, kinetic theory, and statistical mechanics. Topics include the thermodynamics of simple systems, kinetic theory of gases, statistical mechanics of gases and an introduction to quantum statistics.
Prerequisites: PHYS 319 and PHYS 323

PHYS 456/556 Intermediate Quantum Mechanics (3 Credit Hours)
This course follows directly from PHYS 452. It includes a more detailed study of simple systems, an introduction to abstract quantum mechanics and Dirac notation, and applications to operator methods. Particular attention is paid to electron spin, angular momentum theory, operator treatment of the harmonic oscillator, the Pauli exclusion principle, perturbation theory, and scattering. The course contains a mandatory recitation section.
Prerequisites: PHYS 323 and PHYS 452 or permission of the instructor

PHYS 460 Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab (3 Credit Hours)
Explores the historical development of accelerators and their past and present applications. Principles of acceleration, including the physics of linear accelerators, synchrotrons, and storage rings. Magnet design; machine lattice design and particle beam optics. Longitudinal and transverse beam dynamics, including synchrotron and betatron particle motion. Special topics will be reviewed, including synchrotron radiation, injection techniques, and collective effects and beam instabilities.
Prerequisites: PHYS 319 and PHYS 425

PHYS 467 Preparing for the Physics GRE (1 Credit Hour)
This course will review the style and scope of problems likely to be found on the Physics Graduate Record Exam (GRE). Emphasis is on quick solving of problems based on foundational knowledge and intuition. This course is particularly intended for students preparing to apply for graduate school, but may be of interest to all students.
Prerequisites: PHYS 323 and PHYS 319

PHYS 468W Research Methods in Mathematics and Sciences (3 Credit Hours)
Emphasizes the tools and techniques used to solve scientific problems. Topics include use and design of experiments, use of statistics to interpret experimental results, mathematical modeling of scientific phenomena, and oral and written presentation of scientific results. Students will perform four independent inquiries, combining skills from mathematics and science to solve research problems. Required for Physics teaching licensure track; not available as upper-division elective in content area. This is a writing intensive course.
Prerequisites: Admission to the Monarch Teach Program; PHYS 232N or MATH 212; and a grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C

PHYS 489W Senior Thesis I (1 Credit Hour)
Part one of a two-semester option for completing the Senior Thesis. This is a writing intensive course. PHYS 489W plus PHYS 490W is equivalent to PHYS 499W.
Prerequisites: permission of the instructor and a grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C

PHYS 490W Senior Thesis II (2 Credit Hours)
Part two of a two-semester option for completing the Senior Thesis. PHYS 489W plus PHYS 490W is equivalent to PHYS 499W. This is a writing intensive course.
Prerequisites: PHYS 489W

PHYS 495/595 Special Topics in Physics (1-3 Credit Hours)
In-depth study of a selected topic in physics at the advanced undergraduate level. May include a laboratory or computational component.
Prerequisites: permission of the instructor

PHYS 497/597 Special Problems and Research (1-3 Credit Hours)
These courses afford the student an opportunity to pursue individual study and research.
Prerequisites: senior standing or permission of the instructor

PHYS 499W Senior Thesis (3 Credit Hours)
Each student will undertake a research experience under the supervision of a department faculty member. The experience can be of an experimental, theoretical, or calculational type. A final oral and written report are required. The research may be completed on campus or at one of the department affiliated research organizations. This is a writing intensive course.(offered fall, spring, summer)
Prerequisites: grade of C or better in ENGL 211C or ENGL 221C or ENGL 231C and permission of the instructor

PHYS 503 Electronic Instrumentation (3 Credit Hours)

PHYS 508 Astronomy for Teachers (3 Credit Hours)
A course in astronomy dealing with stars and stellar systems. Topics will include observational astronomy, the electromagnetic spectrum, relativity, stellar and galactic structures, cosmology, and the search for extraterrestrial intelligence.

PHYS 513 Methods of Experimental Physics (3 Credit Hours)
Experiments in classical and modern physics, designed to develop skills in the collection, analysis, and interpretation of experimental data.

PHYS 515 Introduction to Nuclear Particle Physics (3 Credit Hours)
An introduction to the structure of the atomic nucleus, natural and artificial radioactivity, nuclear decay processes and stability of nuclei, nuclear reactions, properties of nuclear forces, and nuclear models. Also, particle phenomenology, experimental techniques and the standard model. Topics include the spectra of leptons, mesons, and baryons; strong, weak, and electromagnetic interactions.

PHYS 516 Introduction to Solid State Physics (3 Credit Hours)
Introduction to solid state physics and materials science, with emphasis placed on the applications of each topic to experimental and analytical techniques. Topics include crystallography, thermal and vibrational properties of crystals and semiconductors, metals and the band theory of solids, superconductivity and the magnetic properties of materials.

PHYS 517 Introduction to Particle Accelerator Physics (3 Credit Hours)
Fundamentals of relativistic particle dynamics including particle acceleration; weak and strong focusing; linear beam optics and particle transfer matrices; linear and non-linear synchrotron motion; introduction to the statistical descriptions of particle beams; and radiation production by accelerated relativistic particles. Examples relevant to betatrons, cyclotrons, synchrotrons, and linear accelerators will be given.
Prerequisites: PHYS 319 or MAE 205, and PHYS 425 or ECE 323

PHYS 520 Introductory Computational Physics (3 Credit Hours)
Introduction of computational methods and visualization techniques for problem solving in physics.

PHYS 525 Electromagnetism I (3 Credit Hours)
A study of the classical theory and phenomena of electricity and magnetism. Topics include the calculation of electric and magnetic fields, magnetic and dielectric properties of matter, and an introduction to Maxwell's equations. The course contains a mandatory recitation section.

PHYS 551 Theoretical Mechanics (3 Credit Hours)
A mathematical study of the concepts of mechanics. Vector calculus methods are used. Topics include mechanics of a system of particles, Lagrangian mechanics, Hamilton’s canonical equations, and motion of a rigid body.

PHYS 552 Introduction to Quantum Mechanics (3 Credit Hours)
Introduction to the physical and mathematical structure of quantum theory, including the historical and experimental origins of the subject. The curriculum includes techniques for solving the Schrodinger wave equation, particularly for the harmonic oscillator and the hydrogen atom. The course contains a mandatory recitation section.
Prerequisites: PHYS 319 and PHYS 323

PHYS 553 Electromagnetism II (3 Credit Hours)
A course in electrodynamics developed from Maxwell’s Equations. Topics include Maxwell’s Equations, Conservation Laws, Electromagnetic Waves, Potentials and Fields, Radiation, and the interplay of electrodynamics and special relativity. The course contains a mandatory recitation section.

PHYS 554 Thermal and Statistical Physics (3 Credit Hours)
A study of the fundamental concepts of thermodynamics, kinetic theory, and statistical mechanics. Topics include the thermodynamics of simple systems, kinetic theory of gases, statistical mechanics of gases and an introduction to quantum statistics.

PHYS 556 Intermediate Quantum Mechanics (3 Credit Hours)
This course follows directly from PHYS 552. It includes a more detailed study of simple systems, an introduction to abstract quantum mechanics and Dirac notation, and applications to operator methods. Particular attention is paid to electron spin, angular momentum theory, operator treatment of the harmonic oscillator, the Pauli exclusion principle, perturbation theory, and scattering. The course contains a mandatory recitation section.

PHYS 595 Special Topics in Physics (1-3 Credit Hours)
In-depth study of a selected topic in physics at the graduate level. May include a laboratory or computational component.
Prerequisites: Permission of the instructor

PHYS 597 Special Problems and Research (1-3 Credit Hours)
These courses afford the student an opportunity to pursue individual study and research.
Prerequisites: permission of the instructor

PHYS 601 Mathematical Methods of Physics I (3 Credit Hours)
Basic mathematical methods with applications: vector analysis, linear algebra, series and series of functions, Hilbert spaces, complex variable theory.

PHYS 602 Mathematical Methods of Physics II (1 Credit Hour)
Continuation of PHYS 601. Basic mathematical methods with applications: integral transforms, ordinary differential equations and partial differential equations.
Prerequisites: PHYS 601

PHYS 603 Classical Mechanics (3 Credit Hours)
Particle in a central-force field. Dynamics in a rotating reference frame. Lagrangian and Hamiltonian formulations. Small oscillations. Kinematics and dynamics of a rigid body. Canonical transformation, Hamilton-Jacobi theory.

PHYS 604 Classical Electrodynamics I (3 Credit Hours)
Electrostatics: Gauss' Law and Poisson and Laplace equations. Methods for the solution of boundary-value problems with rectangular, cylindrical, and spherical symmetry. Expansion in multipoles. Dielectrics. Magnetostatics and Faraday's law.

PHYS 621 Quantum Mechanics I (3 Credit Hours)
Mathematical foundations of Hilbert spaces. Background on Hamiltonian mechanics and electro-magnetism. Postulates of Quantum Mechanics, measurements and Schroedinger equation. Simple systems. Schroedinger Equation in 1-3 dimensions and solutions for specific systems. Symmetries and angular momentum. Time-independent perturbation theory.

PHYS 695 Selected Topics in Pure and Applied Physics (1-3 Credit Hours)
These courses afford the student an opportunity to pursue individual study.
Prerequisites: permission of the instructor

PHYS 696 Special Topics in Accelerator Physics (3 Credit Hours)
Special topics related to particle accelerators and their applications. Departmental approval required.

PHYS 698 Research (1-9 Credit Hours)
M.S. level research supervised by the student's thesis advisor.

PHYS 699 Thesis (1-9 Credit Hours)
M.S. level research supervised by the student's thesis advisor.

PHYS 704 Classical Electrodynamics II (3 Credit Hours)
Electrodynamics: Maxwell equations, plane electromagnetic waves and wave propagation, waveguides, radiating systems, special theory of relativity, including the dynamics of relativistic particles and electromagnetic fields.
Prerequisites: PHYS 604

PHYS 707 Statistical Mechanics (3 Credit Hours)
Review of thermodynamics. Classical statistical mechanics and applications. The virial expansion. Quantum statistical mechanics and the micro-canonical, canonical, and grand-canonical ensembles. The Fermi and Bose gases, and applications. Special topics in statistical mechanics.
Prerequisites: PHYS 603

PHYS 711 Computational Physics (3 Credit Hours)
Studies of high level computer languages. Computational techniques used in physics. Numerical techniques for differential and integral problems. Algebraic processing languages. Introduction to scientific visualization techniques.

PHYS 721 Quantum Mechanics II (3 Credit Hours)
Further development of quantum mechanics. Multi-particle states, bosons and fermions. Classical Limit. Variational principle, time-dependent perturbation theory and scattering. Path integral formulation. Symmetry and groups, addition of angular moments. Examples from solid state, atomic, nuclear, and particle physics.
Prerequisites: PHYS 621

PHYS 722 Nuclear and Particle Physics I (3 Credit Hours)
Nuclear forces, models of nuclear structure and reactions, hadron and lepton scattering, introduction to constituent quark model and hadron spectroscopy.
Prerequisites: PHYS 621

PHYS 723 Nuclear and Particle Physics II (3 Credit Hours)
Discrete and continuous symmetries and application to particle physics, SU(2) and SU(3) symmetries and static properties of hadrons. Klein-Gordon and Dirac equations, quantum electrodynamics and Feynman rules, strong and weak interactions, Standard Model and physics beyond the Standard Model.
Prerequisites: PHYS 722 or PHYS 822

PHYS 724 Condensed Matter Physics I (3 Credit Hours)
Electronic and lattice properties of solids, band structures of metals, semiconductors and insulators, dynamics of electron and phonons, electromagnetic and optical properties of metals and doped semiconductors, phenomenology of superconductivity and magnetism, and selected experimental methods of solid state physics.
Prerequisites: PHYS 621, and PHYS 721 or PHYS 821

PHYS 727 Atomic Physics (3 Credit Hours)
Irreducible tensor methods. Radiative excitation and ionization processes. Atom-atom scattering. Time-evolution of atomic observables in external fields. Multiple channel quantum defect theory and complex atomic and molecular spectra.
Prerequisites: permission of the instructor

PHYS 754 Accelerator Physics (3 Credit Hours)
Overview of the underlying physics of modern particle accelerators. Beam acceleration, coupled and uncoupled beam transport, nonlinear dynamics, collective effects, phase space cooling, and free-electron lasers will be covered. Depending on the instructor, additional topics of current interest such as coherent synchrotron radiation, wakefields and impedances, and novel methods of acceleration will be discussed.

PHYS 755 Experimental and Computational Techniques in Accelerator Physics (3 Credit Hours)
Measurements related to particle accelerators. Both accelerator instrumentation and methods of measurements will be covered, as well as analysis and presentation of measurement results. Examples of topics are microwave instrumentation and measurements, superconducting RF measurements, beam losses, and beam-based diagnostics.

PHYS 759 Classical Mechanics and Electromagnetism in Accelerator Physics (3 Credit Hours)
Further developments in classical mechanics and electromagnetism and their application to accelerator physics: Lagrangian and Hamiltonian formulation of equations of motion, canonical transformations, adiabatic invariants, linear and nonlinear resonances. Louisville's theorem, solutions of Maxwell's equation in cavities and waveguides, wakefields, radiation and retarded potentials, and synchrotron radiation.
Prerequisites: PHYS 601, PHYS 603, and PHYS 704 or PHYS 804

PHYS 760 Low Temperature Physics (3 Credit Hours)
Properties and behavior of materials and systems at low temperature with emphasis on particle accelerator and microwave applications. Macroscopic quantum phenomena in condensates. Superfluidity, electrodynamic properties of superconductors.
Prerequisites: PHYS 825

PHYS 765 Design and Operating Principles of Particle Accelerators (3 Credit Hours)
This course will introduce design and general operating principles for particle accelerators, including acceleration methods for particles and beams. Topics will include the evolution and descriptions of particle beams under acceleration, physics of accelerated particle beams, as well as the effects of space charge, high-order modes (HOMs), and other collective effects. Aspects of both normal conducting (RF) and superconducting (SRF) particle beam acceleration will be covered.
Prerequisites: PHYS 603, PHYS 604, and PHYS 754 or PHYS 854

PHYS 790 Introduction to the Processes of Quantum Chromodynamics (3 Credit Hours)
An introduction to basic Quantum Chromodynamics (QCD) methods in hadron-scattering experiments. Focus will be placed on perturbative methods and partonic interpretations of specific processes. The course will begin with a general overview of QCD, and specific processes will be studied in detail to illustrate the general features of patronic physics and their QCD interpretations. The course will close with a summary of questions of current research interest.
Prerequisites: PHYS 871

PHYS 791 Seminar I (1 Credit Hour)
This seminar is designed to enhance both written and oral communication skills as applied to physics. Topics include effective display of data, preparation of scientific reports and preparation and delivery of scientific talks.

PHYS 795 Special Topics in Physics (1-3 Credit Hours)
Thorough coverage of areas selected to meet special needs and interests.
Prerequisites: Permission of the instructor

PHYS 796 Special Topics in Accelerator Physics (3 Credit Hours)
Special topics related to particle accelerators and their applications.
Prerequisites: Department approval required

PHYS 797 Research (1-6 Credit Hours)

PHYS 804 Classical Electrodynamics II (3 Credit Hours)
Electrodynamics: Maxwell equations, plane electromagnetic waves and wave propagation, waveguides, radiating systems, special theory of relativity, including the dynamics of relativistic particles and electromagnetic fields.
Prerequisites: PHYS 604

PHYS 807 Statistical Mechanics (3 Credit Hours)
Review of thermodynamics. Classical statistical mechanics and applications. The virial expansion. Quantum statistical mechanics and the micro-canonical, canonical, and grand-canonical ensembles. The Fermi and Bose gases, and applications. Special topics in statistical mechanics.
Prerequisites: PHYS 603

PHYS 811 Computational Physics (3 Credit Hours)
Studies of high level computer languages. Computational techniques used in physics. Numerical techniques for differential and integral problems. Algebraic processing languages. Introduction to scientific visualization techniques.

PHYS 821 Quantum Mechanics II (3 Credit Hours)
Further development of quantum mechanics. Multi-particle states, bosons and fermions. Classical Limit. Variational principle, time-dependent perturbation theory and scattering. Path integral formulation. Symmetry and groups, addition of angular moments. Examples from solid state, atomic, nuclear and particle physics.
Prerequisites: PHYS 621

PHYS 822 Nuclear and Particle Physics I (3 Credit Hours)
Nuclear forces, models of nuclear structure and reactions, hadron and lepton scattering, introduction to constituent quark model and hadron spectroscopy.
Prerequisites: PHYS 621

PHYS 823 Nuclear and Particle Physics II (3 Credit Hours)
Discrete and continuous symmetries and application to particle physics, SU(2) and SU(3) symmetries and static properties of hadrons. Klein-Gordon and Dirac equations, quantum electrodynamics and Feynman rules, strong and weak interactions. Standard Model and physics beyond the Standard Model.
Prerequisites: PHYS 722 or PHYS 822

PHYS 824 Condensed Matter Physics I (3 Credit Hours)
Electronic and lattice properties of solids, band structures of metals, semiconductors and insulators, dynamics of electron and phonons, electromagnetic and optical properties of metals and doped semiconductors, phenomenology of superconductivity and magnetism, and selected experimental methods of solid state physics.
Prerequisites: PHYS 621, and PHYS 721 or PHYS 821

PHYS 825 Condensed Matter Physics II (3 Credit Hours)
Many body and collective effects in condensed matter, including phase transitions, Bose and Fermi quantum liquids, superfluidity, superconductivity and magnetism, and properties of mesoscopic and low-dimensional systems.
Prerequisites: PHYS 707 or PHYS 807, and PHYS 724 or PHYS 824

PHYS 827 Atomic Physics (3 Credit Hours)
Irreducible tensor methods. Radiative excitation and ionization processes. Atom-atom scattering. Time-evolution of atomic observables in external fields. Multiple channel quantum defect theory and complex atomic and molecular spectra.
Prerequisites: permission of the instructor

PHYS 842 Advanced Quantum Mechanics (3 Credit Hours)
Introduction to relativistic quantum mechanics; symmetries in relativistic wave equations; solutions to relativistic wave equations for bound states and scattering processes; classical field theory and role of symmetries in construction of conserved currents; introduction to second quantization of fields.
Prerequisites: PHYS 704 or PHYS 804, PHYS 721 or PHYS 821

PHYS 853 Atomic & Molecular Physics (3 Credit Hours)
Theory of atomic and diatomic molecular structure, including coupling of angular momenta and tensor operators. Influence of external static fields and interaction of atomic and molecular systems with both classical and quantized radiation fields. Contemporary topics such as degenerate Fermion and Boson gases, quantum sensors, mesoscopic quantum physics, squeezed light, resonance fluorescence, cold atoms and atom interferometry are also included.
Prerequisites: PHYS 621 and either PHYS 721 or PHYS 821 or permission of the instructor

PHYS 854 Accelerator Physics (3 Credit Hours)
Overview of the underlying physics of modern particle accelerators. Beam acceleration, coupled and uncoupled beam transport, nonlinear dynamics, collective effects, phase space cooling, and free-electron lasers will be covered. Depending on the instructor, additional topics of current interest such as coherent synchrotron radiation, wakefields and impedances, and novel methods of acceleration will be discussed.

PHYS 855 Experimental and Computational Techniques in Accelerator Physics (3 Credit Hours)
Measurements related to particle accelerators. Both accelerator instrumentation and methods of measurements will be covered, as well as analysis and presentation of measurement results. Examples of topics are microwave instrumentation and measurements, superconducting RF measurements, beam losses, and beam-based diagnostics.

PHYS 857 Plasma Physics (3 Credit Hours)
Motion of charged particles in electromagnetic fields. Coulomb collisions and transport processes. Collisional Boltzmann equation. Generation of various forms of plasma in the laboratory. Basic plasma diagnostic methods including plasma and laser spectroscopy, measurements of electron and ion density and energy distribution.
Prerequisites: PHYS 603, PHYS 604, PHYS 704/PHYS 804, PHYS 727/PHYS 827 or permission of the instructor

PHYS 859 Classical Mechanics and Electromagnetism in Accelerator Physics (3 Credit Hours)
Further development in classical mechanics and electromagnetism and their application to accelerator physics: Lagrangian and Hamiltonian formulation of equations of motion, canonical transformations, adiabatic invariants, linear and nonlinear resonances. Louisville's theorem, solutions of Maxwell's equation in cavities and waveguides, wakefields, radiation and retarded potentials, and synchrotron radiation.
Prerequisites: PHYS 601, PHYS 603, and PHYS 704 or PHYS 804

PHYS 860 Low Temperature Physics (3 Credit Hours)
Properties and behavior of materials and systems at low temperature with emphasis on particle accelerator and microwave applications. Macroscopic quantum phenomena in condensates. Superfluidity, electrodynamic properties of superconductors.
Prerequisites: PHYS 825

PHYS 861 Nuclear Physics (3 Credit Hours)
The Yukawa potential in classical and quantum mechanics. One- and two-meson exchange amplitudes. Pion-exchange interactions: one- and two-pion exchange two-nucleon potentials, and two-pion exchange three-nucleon potentials. Electromagnetic interactions. Nucleon-nucleon scattering. Realistic models of two- and three-nucleon potentials. Relativistic corrections to the nuclear Hamiltonian. Electro-weak currents of nucleons and nuclei.
Prerequisites: PHYS 621 and either PHYS 721 or PHYS 821

PHYS 865 Design and Operating Principles of Particle Accelerators (3 Credit Hours)
This course will introduce design and general operating principles for particle accelerators, including acceleration methods for particles and beams. Topics will include the evolution and descriptions of particle beams under acceleration, physics of accelerated particle beams, as well as the effects of space charge, high-order modes (HOMs), and other collective effects. Aspects of both normal conducting (RF) and superconducting (SRF) particle beam acceleration will be covered.
Prerequisites: PHYS 603, PHYS 604, and PHYS 754 or PHYS 854

PHYS 871 Introduction to Quantum Field Theory I (3 Credit Hours)
Quantization of the Klein-Gordon field, interactions in quantum field theory and Feynman diagrams, quantization of the Dirac field, quantization of the electromagnetic field, quantum electrodynamics, renormalization, quantum chromodynamics and asymptotic freedom.
Prerequisites: PHYS 842

PHYS 872 Introduction to Quantum Field Theory II (3 Credit Hours)
Further development of topics in quantum field theory. The course addresses renormalization, non-abelian gauge theories, and advanced calculation techniques.
Prerequisites: PHYS 871

PHYS 890 Introduction to the Processes of Quantum Chromodynamics (3 Credit Hours)
An introduction to basic Quantum Chromodynamics (QCD) methods in hadron-scattering experiments. Focus will be placed on perturbative methods and partonic interpretations of specific processes. The course will begin with a general overview of QCD, and specific processes will be studied in detail to illustrate the general features of patronic physics and their QCD interpretations. The course will close with a summary of questions of current research interest.
Pre- or corequisite: PHYS 871

PHYS 891 Seminar I (1 Credit Hour)
This seminar is designed to enhance both written and oral communication skills as applied to physics. Topics include effective display of data, preparation of scientific reports and preparation and delivery of scientific talks.

PHYS 892 Seminar II (1 Credit Hour)
A continuation of PHYS 891 at an advanced level. This seminar is designed to enhance both written and oral communication skills as applied to physics. Topics include effective display of data, preparation of scientific reports and preparation and delivery of scientific talks.

PHYS 895 Special Topics in Physics (1-3 Credit Hours)
Thorough coverage of areas selected to meet special needs and interests.
Prerequisites: Permission of the instructor

PHYS 896 Special Topics in Accelerator Physics (3 Credit Hours)
Special topics related to particle accelerators and their applications.
Prerequisites: Departmental approval required

PHYS 898 Doctoral Research (1-12 Credit Hours)

PHYS 899 Dissertation (1-9 Credit Hours)