

# EN.615 (APPLIED PHYSICS)

## EN.615.611. Classical Physics. 3 Credits.

This course provides the graduate student in Applied Physics with a review of the basic core topics in classical physics, presented at an entry graduate level. The basic subfields covered are classical mechanics (including fluids and acoustics), thermal (and statistical) physics, electromagnetism (including plasmas and relativity), and optics. The four major core topics (in italics) are treated in roughly equal depth. For each topic covered, the fundamental physical laws are introduced to establish a rigorous but intuitive understanding of the basic physics, which is reinforced with hands-on demonstrations and relevant homework assignments. A final exam will also cover the core concepts and principles to check the student's understanding of the key concepts presented. In addition, each student will delve into one subtopic of their own choosing, according to their interest and needs, treating it in more depth as an extended homework assignment, which will be submitted in written form and given as a brief oral presentation before the end of the semester. This course will complement the modern physics course as well as the advanced mathematical methods course offered in the Applied Physics program. Prerequisite(s): An undergraduate degree in physics, engineering, or a related field.

## EN.615.621. Electric Power Principles. 3 Credits.

This is an introductory course on electric power, its distribution, and its applications. The first half of the course focuses on the physics of electric power and its generation, with an emphasis on distribution and distribution systems. Topics to be covered include AC voltages and currents, transmission lines, mono- and poly-phase systems, and losses due to electromagnetic forces. The second half of the course is directed toward applications. Specific applications covered include system analysis and protection, power electronics, induction and permanent magnet motors, transformers, etc. At least one lecture will be used to bring all the concepts together by studying the implementation of an alternative power generation system using wind turbines. During the course of the term, several research papers on power generation and distribution will be read and summarized by the students. A term paper on an electric power subject may be required. Prerequisite(s): An undergraduate degree in physics, engineering, or a related field.

## EN.615.641. Mathematical Methods for Physics and Engineering. 3 Credits.

This course covers a broad spectrum of mathematical techniques essential to the solution of advanced problems in physics and engineering. Topics include ordinary and partial differential equations, contour integration, tabulated integrals, saddlepoint methods, linear vector spaces, boundary-value problems, eigenvalue problems, Green's functions, integral transforms, and special functions. Application of these topics to the solution of problems in physics and engineering is stressed. Prerequisite(s): Vector analysis and ordinary differential equations (linear algebra and complex variables recommended).

## EN.615.642. Electromagnetics. 3 Credits.

Maxwell's equations are derived and applied to the study of topics including electrostatics, magnetostatics, propagation of electromagnetic waves in vacuum and matter, antennas, wave guides and cavities, microwave networks, electromagnetic waves in plasmas, and electric and magnetic properties of materials. Prerequisite(s): Knowledge of vector analysis, partial differential equations, Fourier analysis, and intermediate electromagnetics.

## EN.615.644. Space Systems I. 3 Credits.

This course is intended for the physicist or engineer interested in the design of space experiments and space systems. This class presents the fundamental technical background, current state of the art, and example applications in the development of space systems. Topics include systems engineering, space environment, astrodynamics, propulsion and launch vehicles, attitude determination and control, and space power systems. This course is team taught by experts in their respective fields. Prerequisite(s): An undergraduate degree in physics or engineering or the equivalent. Course Note(s): This course may be taken for 700-level credit with the additional requirement of a research paper. See EN.615.744 Fundamentals of Space Systems and Subsystems I.

## EN.615.645. Space Systems II. 3 Credits.

This course is intended for the physicist or engineer interested in the design of space experiments and space systems. The course presents the technical background, current state of the art, and example applications in the development of space systems. Topics include spacecraft thermal control, spacecraft configuration and structural design, space communications, risk analysis, command and telemetry systems, spacecraft computer systems, systems integration and test, and space mission operations. This course is team taught by experts in their respective fields. Prerequisite(s): An undergraduate degree in physics or engineering or the equivalent. Although preferable, it is not necessary to have taken EN.615.644 Fundamentals of Space Systems and Subsystems I or EN.615.744 Fundamentals of Space Systems and Subsystems I. Course Note(s): This course may be taken for 700-level credit with the additional requirement of a research paper. See EN.615.745 Fundamentals of Space Systems and Subsystems II.

## EN.615.646. Physics of Magnetism. 3 Credits.

This is an introductory course on the magnetic properties of materials and magnetic systems. The emphasis of the course is a mastery of the physics of magnetism along with detailed examples and applications. A basic review of magnetic fields and various classical applications is given. Topics include the physics of paramagnetism, diamagnetism, and ferromagnetism. The magnetism of metals is presented along with discussion of Landau levels and the quantum Hall effect. Various applications are presented in detail, including: magnetic resonance, spectroscopic techniques, magnetoresistance, and spintronics. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline. Prior knowledge of electromagnetic interactions would be helpful but is not required.

## EN.615.647. Fundamentals of Sensors. 3 Credits.

Students will receive an overview of sensors and methods to build networks and systems using sensors. The physics of detectors including fundamental technologies and sampling interfaces will be discussed. Sensor technologies for chemical, biological, nuclear, and radiological detection will be studied in detail. Evaluation methods will be presented for sensor selection based on application-specific information including sensor performance, environmental conditions, and operational impact. DODAF 2.0 methods will be taught and a project based on several viewpoints will be required and presented. Additional studies will include methods for combining results from various sensors to increase detection confidence. As part of the course, students will be given a threat scenario and will be required to select a sensor suite and networking information to design a hypothetical system considering the threat, sensor deployment cost, and logistics. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline.

**EN.615.648. Alternate Energy Technology. 3 Credits.**

Energy availability and its cost are major concerns to every person. Fossil fuels in general and oil in particular are limited and the world's reserves are depleting. The question asked by many is, "Are there alternatives to the fossil fuel spiral (dwindling supplies and rising costs)?" This course addresses these alternative energy sources. It focuses on the technology basis of these alternate energy methods, as well as the practicality and the potential for widespread use and economic effectiveness. Energy technologies to be considered include photovoltaics, solar thermal, wind energy, geothermal and thermal gradient sources, biomass and synthetic fuels, hydroelectric, wave and tidal energy, and nuclear. The associated methods of energy storage will also be discussed. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline.

**EN.615.651. Statistical Mechanics and Thermodynamics. 3 Credits.**

After a brief historical review of thermodynamics and statistical mechanics, the basic principles of statistical mechanics are presented. The classical and quantum mechanical partition functions are discussed and are subsequently used to carry out derivations of the basic thermodynamic properties of several different systems. Topics discussed include Planck's black body radiation derivation and the Einstein-Debye theories of the specific heats of solids. The importance of these topics in the development and confirmation of quantum mechanics is also examined. Other topics discussed include Fermi Dirac and the Bose-Einstein statistics and the cosmic background radiation. The importance of comparisons between theory and data is stressed throughout.

**EN.615.653. Classical Mechanics. 3 Credits.**

This is an advanced course in classical mechanics that introduces techniques that are applicable to contemporary pure and applied research. The material covered provides a basis for a fundamental understanding of not only quantum and statistical mechanics but also nonlinear mechanical systems. Topics include the Lagrangian and Hamiltonian formulation of classical mechanics, Euler's rigid body equations of motion, Hamilton-Jacobi theory, and canonical perturbation theory. These methods are applied to force-free motion of a rigid body, oscillations of systems of coupled particles, and central force motion including the Kepler problem and scattering in a Coulomb potential. Applications are emphasized through in-class examples and homework. Prerequisite(s): Intermediate mechanics and EN.615.641 Mathematical Methods for Physics and Engineering.

**EN.615.654. Quantum Mechanics. 3 Credits.**

This course presents the basic concepts and mathematical formalism of quantum mechanics. Topics include the mathematics of quantum mechanics, the harmonic oscillator and operator methods, quantum mechanics in three dimensions and angular momentum, quantum mechanical spin, quantum statistical mechanics, approximation methods, and quantum theory of scattering. Prerequisite(s): EN.615.641 Mathematical Methods for Physics and Engineering or the equivalent.

**EN.615.662. Intro to Astrophysics. 3 Credits.**

The objective of the course is to understand the formation, structure, evolution and final fate of stars. Our emphasis will be on the fundamental physics, namely the physical properties of matter and radiation under conditions of extreme temperature and pressure and the various physical processes that take place under these conditions. Topics include: basic astrophysical concepts (gravitational contraction, and free fall, and hydrostatic equilibrium, stellar spectra, classification of stars, stellar nucleosynthesis, H-R diagram, main sequence stars, red giant phase, the sun), thermodynamics of matter and radiation, radiative and convective heat transport, energy production in stars and thermonuclear fusion (p-p chain and CNO cycle, helium burning and beyond), theory of stellar structure, endpoint of stellar evolution (relativistic degenerate Fermi gas, Chandrasekhar mass limit for white dwarfs, neutron stars and pulsars, black holes), Helioseismology. Prerequisite(s): Familiarity with thermodynamics, quantum and statistical mechanics at the undergraduate level is required.

Prerequisite(s): EN.615.642 Electromagnetics, or the equivalent, and EN.615.654 Quantum Mechanics.

**EN.615.665. Modern Physics. 3 Credits.**

This course covers a broad spectrum of topics related to the development of quantum and relativity theories. The understanding of modern physics and its applications is essential to the pursuit of advanced work in materials, optics, and other applied sciences. Topics include the special theory of relativity, particle-like properties of light, wave-like properties of particles, wave mechanics, atomic and nuclear phenomena, elementary particles, statistical physics, solid state, astrophysics, and general relativity. Prerequisite(s): Undergraduate degree in physics or engineering.

**EN.615.671. Principles Of Optics. 3 Credits.**

This course teaches the student the fundamental principles of geometrical optics, radiometry, vision, and imaging and spectroscopic instruments. It begins with a review of basic, Gaussian optics to prepare the student for advanced concepts. From Gaussian optics, the course leads the students through the principles of paraxial ray-trace analysis to develop a detailed understanding of the properties of an optical system. The causes and techniques for the correction of aberrations are studied. The course covers the design principles of optical Instruments, telescopes, microscopes, etc. The techniques of light measurement are covered in sessions on radiometry and photometry. Prerequisite(s): Undergraduate degree in physics or engineering.

**EN.615.680. Materials Science. 3 Credits.**

This course covers a broad spectrum of materials-related topics designed to prepare the student for advanced study in the materials arena. Topics include atomic structure, atom and ionic behavior, defects, crystal mechanics, strength of materials, material properties, fracture mechanics and fatigue, phase diagrams and phase transformations, alloys, ceramics, polymers, and composites. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline.

**EN.615.681. Polymeric Materials. 3 Credits.**

This is a comprehensive course in polymeric materials. Topics include natural (biological) polymers, polymer synthesis, polymer morphology, inorganic polymers, ionomers, and polymeric materials applications. Composite materials containing polymers will also be discussed. A portion of the course will be devoted to the evaluation of polymer properties by physical methods. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline.

**EN.615.731. Photovoltaic & Solar Thermal Energy Conversion. 3 Credits.**

This is an advanced course in the application of science and technology to the field of solar energy in general and photovoltaic and solar thermal energy systems in particular. The foundations of solar energy are described in detail to provide the student with the knowledge to evaluate and/or design complete solar thermal or photovoltaic energy systems. Topics range from the theoretical physical basics of solar radiation to the advanced design of both photovoltaic and solar thermal energy collectors. A major feature of the course is the understanding and design of semiconducting photovoltaic devices (solar cells). Solar cell topics include semiconductors, analysis of p-n junction, Shockley-Queisser limit, non-radiative recombination processes, antireflection coating, crystalline silicon solar cells, thin-film solar cells, and rechargeable batteries. Solar thermal energy topics include solar heat collectors, solar water heaters, solar power systems, sensible heat energy storage, phase transition thermal storage, etc. The course will also present optimizing building designs for a solar energy system. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline.

**EN.615.744. Space Systems I. 3 Credits.**

This course is intended for the physicist or engineer interested in the design of space experiments and space systems. This class presents the fundamental technical background, current state of the art, and example applications in the development of space systems. Topics include systems engineering, space environment, astrodynamics, propulsion and launch vehicles, attitude determination and control, and space power systems. This course is team taught by experts in their respective fields and requires a research paper. Prerequisite(s): An undergraduate degree in physics or engineering or the equivalent. Course Note(s): This course may be taken for 600-level credit with the additional requirement of a research paper. See EN.615.644 Fundamentals of Space Systems and Subsystems I

**EN.615.745. Space Systems II. 3 Credits.**

This course examines the fundamentals necessary to design and develop space experiments and space systems. The course presents the theoretical background, current state of the art, and examples of the disciplines essential to developing space instrumentation and systems. Experts in the field will cover the following topics: spacecraft attitude determination and control, space communications, satellite command and telemetry systems, satellite data processing and storage, and space systems integration and testing. This course requires the completion of a research paper. Prerequisite(s): An undergraduate degree in physics or engineering or the equivalent. Although preferable, it is not necessary to have taken EN.615.644 Fundamentals of Space Systems and Subsystems I or EN.615.744 Fundamentals of Space Systems and Subsystems I. Course Note(s): This course is also offered for 600-level credit and does not require completion of a research paper. See EN.615.645 Fundamentals of Space Systems and Subsystems II.

**EN.615.746. Nanoelectronics:Physics,Devices. 3 Credits.**

This course provides an introduction to state-of-the-art and potential future electronics technologies. The first part of the course focuses on the physics of advanced silicon technology and on its scaling limits. The treatment includes a discussion of future electronics as projected to the year 2012 by the Semiconductor Industry Association's National Technology Roadmap for Semiconductors. This understanding of conventional technology then motivates the second part of the course, which covers some of the "new" physics currently being explored for going "beyond the roadmap." Topics range from the reasonably practical to the highly speculative and include tunneling transistors, single-flux quantum logic, single-electronics, spin-based electronics, quantum computing, and perhaps even DNA-based computing. An overview is also given of the prospects for advances in fabrication technology that will largely determine the economic viability for any of these possible electronic futures. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline. Familiarity with semiconductor device physics would be helpful.

**Prerequisite(s):** EN.615.454 Quantum Mechanics AND EN.615.760 Physics of Semiconductor Devices

**EN.615.747. Sensors and Sensor Systems. 3 Credits.**

The primary objective of this course is to present recent advances made in the field of sensors. A broad overview includes optical, infrared, hyperspectral, terahertz, biological, magnetic, chemical, acoustic, and radiation sensors. The course will examine basic sensor operation and the implementation of sensors in measurement systems. Other topics to be covered are physical principles of sensing, interface electronic circuits, and sensor characteristics. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline.

**EN.615.748. Introduction to Relativity. 3 Credits.**

After a brief review of the theory of special relativity, the mathematical tools of tensor calculus that are necessary for understanding the theory of general relativity will be developed. Relativistic perfect fluids and their stress-energy-momentum tensor will be defined, and Einstein's field equations will be studied. Gravitational collapse will be introduced, and the Schwarzschild Black Hole solution will be discussed.

**EN.615.751. Modern Optics. 3 Credits.**

This course covers the fundamental principles of modern physical optics and contemporary optical systems. Topics include propagation of light, polarization, coherence, interference, diffraction, Fourier optics, absorption, scattering, dispersion, and image quality analysis. Special emphasis is placed on the instrumentation and experimental techniques used in optical studies.

**Prerequisite(s):** EN.615.642 Electromagnetics or the equivalent completed or taken concurrently.

**EN.615.753. Plasma Physics. 3 Credits.**

This course is an introduction to the physical processes that govern the “fourth state of matter”, also known as plasma. Plasma physics is the study of ionized gas, which is the state of the matter for 99.9% of the apparent universe, from astrophysical plasmas, to the solar wind and Earth’s radiation belts and ionosphere. Plasma phenomena are also relevant to energy generation by controlled thermonuclear fusion. The challenge of plasma physics comes from the fact that many plasma properties result from the long-range Coulomb interaction, and therefore are collective properties that involve many particles simultaneously. Topics to be covered during class include motion of charged particles in electric and magnetic fields, dynamics of fully ionized plasma from both microscopic and macroscopic points of view, magneto-hydrodynamics, equilibria, waves, instabilities, applications to fusion devices, ionospheric, and space physics. .

**Prerequisite(s):** EN.615.642 Electromagnetics or the equivalent

**EN.615.755. Space Physics. 3 Credits.**

This course studies the physics and the history of our utilization of space, the challenges and mitigation of making in situ observations in space. Topics include the history of solar system exploration; the solar cycle; the electrodynamics of the solar upper atmosphere responsible for the solar wind; and the solar wind interaction with unmagnetized and magnetized bodies—how this leads to planetary bow shocks, comets, and magnetospheres and how they are studied. Practical issues include penetrating radiation and its effects on spacecraft and man in space, magnetospheric storm disruptions of ground power distribution and spacecraft charging in the presence and absence of solar illumination with particular reference to applying this knowledge in exploring the outer solar system and beyond.

**Prerequisite(s):** EN.615.642 Electromagnetics or the equivalent.

**EN.615.757. Solid State Physics. 3 Credits.**

Students examine concepts and methods employed in condensed matter physics with applications in materials science, surface physics, and electronic devices. Topics include atomic and electronic structure of crystalline solids and their role in determining the elastic, transport, and magnetic properties of metals, semiconductors, and insulators. The effects of structural and chemical disorder on these properties are also discussed.

**Prerequisite(s):** EN.615.654 Quantum Mechanics or the equivalent.

**EN.615.758. Modern Topics in Applied Optics. 3 Credits.**

This course deals with optical system design involving state-of-the-art concepts. In particular, we will analyze the impact of nonlinearity in the propagation of laser beams and also the stochastic nature of light propagation in some commonly encountered situations such as atmospheric and undersea light propagation. Nonlinear interactions of light and matter play a significant role in a large portion of modern optical systems. In most situations, the optical system designer needs linear regime. In other situations, the optical system takes advantage of the nonlinear interaction to produce significantly new operating conditions that are a significant key to the performance of modern optical systems. Similarly, taking into account the stochastic nature of light emission, detection, and propagation is important in the design and analyses of modern optical systems. The course reviews random processes involved in optical systems and applies statistical tools to identify the impact of such processes to the optical system performance.

**Prerequisite(s):** EN.615.642 Electromagnetics and EN.615.782 Optics and MATLAB. A knowledge of laser fundamentals would also be helpful.

**EN.615.760. Physics of Semiconductor Devices. 3 Credits.**

This course examines the physical principles underlying semiconductor device operation and the application of these principles to specific devices. Emphasis is placed on understanding device operation, rather than on circuit properties. Topics include elementary excitations in semiconductors such as phonons, photons, conduction electrons, and holes; charge and heat transport; carrier trapping and recombination; effects of high doping; contacts; the pn junction; the junction transistor; surface effects; the MIS diode; and the MOSFET. Nanotechnology as applied to electronics will be discussed. Prerequisite(s): An undergraduate degree in engineering, physics, or a related technical discipline. Some familiarity with quantum mechanics would be helpful.

**EN.615.761. Intro To Oceanography. 3 Credits.**

This course covers the physical concepts and mathematics of the exciting field of oceanography and can be taken as an elective. It is designed for the student who wants to learn more about oceanography. Topics range from fundamental small waves to planetary-scale ocean currents. There will be a strong emphasis on understanding the basic ocean processes. Initial development gives a description of how the ocean system works and the basic governing equations. Additional subjects include boundary layers, flow around objects (seamounts), waves, tides, Ekman flow, and the Gulf Stream. Also studied will be the ocean processes that impact our climate such as El Nino and the Thermohaline Conveyor Belt. Prerequisite(s): Mathematics through calculus.

**EN.615.762. Applied Computational Electromagnetics. 3 Credits.**

This course introduces the numerical methods and computer tools required for the practical applications of the electromagnetic concepts covered in EN.615.642 to daily-life engineering problems. It covers the methods of calculating electromagnetic scattering from complex air and sea targets (aircraft, missiles, ships, etc.), taking into account the effects of the intervening atmosphere and natural surfaces such as the sea surface and terrain. These methods have direct applications in the areas of radar imaging, communications, and remote sensing. Methods for modeling and calculating long-distance propagation over terrain and in urban areas, which find application in the areas of radar imaging, radio and TV broadcasting, and cellular communications, are also discussed. The numerical toolkit built in this course includes the method of moments, the finite difference frequency and time domain methods, the finite element method, marching numerical methods, iterative methods, and the shooting and bouncing ray method. Prerequisite(s): Knowledge of vector analysis, partial differential equations, Fourier analysis, basic electromagnetics, and a scientific computer language.

**EN.615.765. Chaos and Its Applications. 3 Credits.**

The course will introduce students to the basic concepts of nonlinear physics, dynamical system theory, and chaos. These concepts will be studied by examining the behavior of fundamental model systems that are modeled by ordinary differential equations and, sometimes, discrete maps. Examples will be drawn from physics, chemistry, and engineering. Some mathematical theory is necessary to develop the material. Practice through concrete examples will help to develop the geometric intuition necessary for work on nonlinear systems. Students conduct numerical experiments using provided software, which allows for interactive learning. Prerequisite(s): Mathematics through ordinary differential equations. Familiarity with MATLAB is helpful. Consult instructor for more information. Course Note(s): Access to Whiting School computers is provided for those without appropriate personal computers.

**EN.615.769. Physics of Remote Sensing. 3 Credits.**

This course exposes the student to the physical principles underlying satellite observations of Earth by optical, infrared, and microwave sensors, as well as techniques for extracting geophysical information from remote sensor observations. Topics will include spacecraft orbit considerations, fundamental concepts of radiometry, electromagnetic wave interactions with land and ocean surfaces and Earth's atmosphere, radiative transfer and atmospheric effects, and overviews of some important satellite sensors and observations. Examples from selected sensors will be used to illustrate the information extraction process and applications of the data for environmental monitoring, oceanography, meteorology, and climate studies.

**EN.615.772. Cosmology. 3 Credits.**

This course begins with a brief review of tensor calculus and principles of the General theory of relativity, the Friedmann equation and the Robertson-Walker metric. Cosmological models including radiation, matter, and the cosmological constant and their properties are discussed. Observational parameters, the role of dark matter, and the cosmic microwave background, and nucleosynthesis in the early universe are studied. The flatness and the horizon problems are introduced and the role of inflation in the early universe is discussed. Finally, we discuss the origins and the role of density fluctuations in formation of large structures leading to the current Cosmological constant Cold Dark Matter model of the universe.

**Prerequisite(s):** EN.615.748 Introduction to Relativity.

**EN.615.775. Physics of Climate. 3 Credits.**

To understand the forces that cause global climate variability, we must understand the natural forces that drive our weather and our oceans. This course covers the fundamental science underlying the nature of the Earth's atmosphere and its ocean. This includes development of the basic equations for the atmosphere and ocean, the global radiation balance, description of oceanic and atmospheric processes, and their interactions and variability. Also included will be a description of observational systems used for climate studies and monitoring, fundamentals underlying global circulation, and climate prediction models. **Prerequisite(s):** Undergraduate degree in physics or engineering or equivalent, with strong background in mathematics through the calculus level.

**EN.615.778. Computer Optical Design. 3 Credits.**

In this course, students learn to design and analyze optical systems. Students will use a full-function optical ray-trace program (CODE V, OSLO, or ZEMAX), to be installed on their personal computers or those in the computer lab, to complete their assignments and design project. We will begin with simple lenses for familiarization with the software and then move onto more complicated multi-element lenses and reflective systems. Emphasis is placed on understanding the optical concepts involved in the designs while developing the ability to use the software. Upon completion of the course, students are capable of independently pursuing their own optical designs.

**Prerequisite(s):** EN.615.671 (471) Principles of Optics

**EN.615.780. Optical Detectors & Applications. 3 Credits.**

This course examines the physics of detection of incoherent electromagnetic radiation from the infrared to the soft X-ray regions. Brief descriptions of the fundamental mechanisms of device operation are given. A variety of illumination sources are considered to clarify detection requirements, with emphasis on solar illumination in the visible and blackbody emission in the infrared. Practical devices, elementary detection circuits, and practical operational constraints are described. An introduction to solid-state and semiconductor physics follows and is then applied to the photodiode, and later to CCD and CMOS devices. A description and analysis of the electronics associated with photodiodes and their associated noise is given. Description of scanning formats leads into the description of spatially resolving systems (e.g., staring arrays). Emphasis is placed on Charged-Coupled Device and CMOS detector arrays. This naturally leads into the discussion of more complex IR detectors and Readout Integrated Circuits that are based on the CMOS pixel. In addition, descriptions of non-spatially resolving detectors based on photoemission and photo-excitation are provided, including background physics, noise, and sensitivity. Selection of optimum detectors and integration into complete system designs are discussed. Applications in space-based and terrestrial remote sensing are discussed, from simple radiometry and imaging to spectrometry. **Prerequisite(s):** Undergraduate degree in physics or engineering, preferably with studies in elementary circuit theory, solid-state physics, and optics. Students are expected to be proficient using spreadsheets and/or a programming language such as MATLAB or IDL.

**EN.615.781. Quantum Information Processing. 3 Credits.**

This course provides an introduction to the rapidly developing field of quantum information processing. In addition to covering fundamental concepts such as two-state systems, measurements uncertainty, quantum entanglement, and nonlocality, the course will emphasize specific quantum information protocols. Several applications of this technology will be explored, including cryptography, teleportation, dense coding, computing, and error correction. The quantum mechanics of polarized light will be used to provide a physical context to the discussion. Current research on implementations of these ideas will also be discussed.

**Prerequisite(s):** EN.615.654 (454) Quantum Mechanics

**EN.615.782. Optics and Matlab. 3 Credits.**

This course provides hands-on experience with MATLAB by performing weekly computer exercises revolving around optics. Each module explores a new topic in optics, while simultaneously providing experience in MATLAB. The goal is to bridge the gap between theoretical concepts and realworld applications. Topics include an introduction to MATLAB, Fourier theory and E&M propagation, geometrical optics, optical pattern recognition, geometrical optics and ray tracing through simple optical systems, interference and wave optics, holography and computer-generated holography, polarization, speckle phenomenon, and laser theory and related technology. Students are also expected to complete weekly exercises in MATLAB and a semester project that will allow the student to investigate a particular topic of interest not specifically covered in the course. **Course Note(s):** No prior experience with MATLAB is required. While a background in optics is helpful, it is not required.

**EN.615.800. Applied Physics Project. 3 Credits.**

This course is an individually tailored, supervised project that offers the student research experience through work on a special problem related to his or her field of interest. The research problem can be addressed experimentally or analytically, and a written report is produced. It is recommended that all required Applied Physics courses be completed. Open only to candidates in the Master of Science in Applied Physics program. Prerequisite(s): It is recommended that all required Applied Physics courses be completed. The Applied Physics project proposal form ([ep.jhu.edu/student-forms](http://ep.jhu.edu/student-forms)) must be approved prior to registration. Course Note(s): Open only to candidates in the Master of Science in Applied Physics program.

**EN.615.802. Directed Studies in Applied Physics. 3 Credits.**

In this course, qualified students are permitted to investigate possible research fields or to pursue problems of interest through reading or non-laboratory study under the direction of faculty members. Open only to candidates in the Master of Science in Applied Physics program. Prerequisite(s): The directed studies program proposal form (available from the EP website) must be completed and approved prior to registration. Course Note(s): Open only to candidates in the Master of Science in Applied Physics program.