ENGINEERING PHYSICS

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Core courses in the Engineering Physics plan provide the student with fundamental physical principles and theoretical tools for professional practice as well as a firm foundation in modern experimental techniques. To relate these abilities to the attitudes and knowledge of other engineering disciplines, the plan has four sub-plans: electrical, materials, mechanical, and computing. These sub-plans provide a sequence of courses in other engineering departments and thus provide career or graduate studies opportunities in both engineering and applied physics.

Note: **Students will not be registered in any core second year engineering physics courses until they have passed all the required first year mathematics and physics courses. It is strongly recommended that students have a grade of C- or better in the first year mathematics and physics courses.**

Fourth year elective courses must be chosen such that at the end of the academic plan each student meets or exceeds the Canadian Engineering Accreditation Board (CEAB) program requirements. A spreadsheet will be provided by the Undergraduate Chair to aid fourth year students with their course selection.
Options available:

- Electrical Option
- Materials Option
- Mechanical Option
- Computing Option

- Engineering Physics, B.A.Sc. (Class of 2025) (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/engineering-physics/engineering-physics-basc-class-2024/)
- Engineering Physics, B.A.Sc. (Class of 2026) (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/engineering-physics/engineering-physics-basc-class-2026/)
- Engineering Physics, B.A.Sc. (Class of 2027) (https://queensu-ca-public.courseleaf.com/engineering-applied-sciences/academic-plans/engineering-physics/engineering-physics-basc-class-2027/)

Courses

ENPH 211 Applied Physics Units: 3.50
This course stresses the creation of physical models for real systems. Applications of vibrational motion are developed and a basic description of the properties of elastic media given. The methods required to predict the performance of physical or engineering systems are demonstrated using examples drawn from various fields of science and engineering with emphasis on mechanics and vibrations, waves and optics.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 11
Complementary Studies 0
Engineering Science 31
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Identify systems exhibiting oscillatory behaviour.
2. Understand the difference between a generic oscillator and a harmonic one.
3. Linearize suitable oscillating systems.
4. Derive a wave equation.
5. Establish and use the laws of refraction.

ENPH 213 Computational Eng. Physics Units: 4.00
Introduction to the use of numerical methods in solving physics and engineering problems. A high-level language appropriate for engineering, such as Python, will be introduced and used throughout the course. Possible topics to be covered include numerical differentiation and integration (with applications in error propagation), root finding and optimization problems (including curve fitting), solution of linear systems of equations, finite-element modelling, fast Fourier transforms and Monte Carlo simulations.
(Lec: 2, Lab: 1.5, Tut: 0.5)
Requirements: Prerequisites: APSC 142 or APSC 143, MTHE 227 (MATH 227), MTHE 237 (MATH 237) or MTHE 225, ENPH 242 (PHYS 242) Corequisites: ENPH 211, ENPH 239 Exclusions: CMPE 271
Offering Term: W
CEAB Units:
Mathematics 12
Natural Sciences 0
Complementary Studies 0
Engineering Science 21
Engineering Design 15
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Use computational methods to analyze and model physics systems.
2. Apply a variety of computational algorithms, analyze limitations of the algorithms, and appropriately tailor them to suit particular problems or situations.
3. Select and apply appropriate analytical models and computational algorithms to problems in physics and engineering.
4. Analyze a multifaceted problem of computational analysis and design and develop an algorithmic solution that provides quantitative predictions of performance.

ENPH 225 Mechanics Units: 3.50
Extension of classical mechanics and engineering applications. Plane dynamics, relative motion and forces in moving and accelerated reference frames. Introduction to general three-dimensional motion of a rigid body, inertia tensor and steady-state precession. The laws of conservation of mass, momentum and energy.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 111, APSC 112, APSC 171, APSC 172, APSC 174 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 42
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Employ a variety of coordinate systems to describe the motion of particles (or system of particles, including rigid bodies) and select the most effective coordinate system for a particular problem
2. Analyze the motion of a particle (or system of particles) using the force-mass-acceleration approach to generate the equations of motion.
3. Apply the conservation laws (of energy, momentum, angular momentum) to aid in describing the motion of a particle or system of particles.
4. Understand the difference between inertial and non-inertial forces and be able to correctly identify them with the aid of free-body diagrams.
5. Apply the laws of motion and the conservation laws to describe general rigid-body motion (translation and rotation) in 1-, 2- and 3-dimensions.

ENPH 239 Eng. Electricity & Magnetism Units: 3.50
The experimental basis and mathematical description of electrostatics, magnetostatics and electromagnetic induction, together with a discussion of the properties of dielectrics and ferromagnetics, are presented. Both the integral and vector forms of Maxwell's equations are deduced.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 227 (MATH 227) or MTHE 280 (MATH 280); APSC 111 and APSC 112 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 17
Complementary Studies 0
Engineering Science 25
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a conceptual understanding of how to apply the methods of vector calculus to problems in electromagnetism.
2. Understand and apply the basic principles of electrostatics, including electric fields and potentials, work and energy.
3. Develop solutions for the electrical potential of systems of charges using methods involving Laplace's equation, image charges, separation of variables, multipole expansion
4. Model the behaviour of electric fields in matter, especially in the case of linear dielectrics.
5. Understand and apply the basic principles of magnetostatics, including the Lorentz force law, Biot-Savart law and Ampere's law.
6. Model the behaviour of magnetic fields in matter, for both linear and nonlinear (e.gferromagnetic) materials.
7. Understand the principles of electromagnetic induction and Faraday's law and the mathematical developments leading to Maxwell's equations.
8. Understand the experimental and theoretical developments leading to Maxwell's equations of electromagnetism.

ENPH 242 Relativity And Quanta Units: 3.50
Evidence for relativistic effects. Kinematics and dynamics in special relativity, Minkowski diagram, applications. Evidence for quanta, spectra, Bohr atom, quantum statistics. Descriptive nuclear physics, radioactivity, elementary particles.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: APSC 111, APSC 112 Corequisites: Exclusions: PHYS 342
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 42
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Understand the limitations of classical physics and the resulting need to introduce the principles of the Special Theory of Relativity.
2. Understand and apply basic transformations between different reference frames in Special Relativity.
3. Draw and read spacetime diagrams.
4. Calculate the results of collisions between relativistic particles.
5. Understand the key ideas of introductory equilibrium statistical mechanics.
6. Describe the key phenomena of thermal radiation and determine its effects, apply the mathematical laws relating to those phenomena to real-world problems and critically evaluate the results.
7. Describe different aspects of interaction of electromagnetic radiation with matter and make predictions for outcomes of related experiments based on the understanding and the mathematical models developed in this course.
8. Understand the atomic models of Bohr and Schrodinger and do basic calculations for Bohr's model.
9. Understand the connection between the quantum mechanical description of nature and non-intuitive phenomena like Heisenberg's Uncertainty Principle, Pauli-Exclusion principle and tunneling.

ENPH 252 Mangmt Of Experimental Data Units: 1.25
Error and uncertainties in experimental measurement, the propagation of errors. Probability and the Binomial, Poisson and Gaussian distribution functions, fitting of Poisson and Gaussian distributions to a sample population. Linear least-squares fitting, chi-squared. The graphical treatment and presentation of data; regression and power law analyses.
COURSE DELETED 2021-2022
(Lec: 1, Lab: 0, Tut: 0.25)
Offering Term: W
CEAB Units:
Mathematics 8
Natural Sciences 0
Complementary Studies 0
Engineering Science 6
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Determine and justify errors in measurements.
2. Propagate errors from measurements and understand the limitations in different methods to propagate errors.
3. Understand various statistical distributions and how they arise in physical processes.
4. Use statistical distributions to determine the confidence in a conclusion or measurement.
5. Use computers to analyze and visualize data.
6. Determine the parameters of a model from data and evaluate the goodness of fit of that model.

ENPH 253 Engineering Physics Laboratory Units: 3.50
The demonstration of the basic techniques of the engineering physicist in the measurement of electric, magnetic and mechanical properties. The emphasis is on correct measurement techniques, error analysis, treatment of results and the presentation of data.
K3.5(Lec: Yes, Lab: Yes, Tut: Yes)
Requirements: Prerequisites: Corequisites: ENPH 211, ENPH 239 Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 15
Complementary Studies 12
Engineering Science 15
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Operate common mechanical and electrical instrumentation in a physics lab in order to make measurements of physical systems
2. Recognize and record key information about the experiment and record it in a laboratory notebook that can easily be interpreted by others.
3. Analyze experimental data and infer the physical properties and behaviour of systems from that data, thereby acquiring a deeper understanding of the laws that govern those physical systems.
4. Estimate the uncertainty of experimental data acquired, propagate those error estimates and produce a credible assessment of the experimental results
5. Prepare graphs that clearly illustrate the relationship of the data that was collected to theories or to other observations.
6. Write reports that summarize the experimental work that was completed, the data that was collected, how the data were interpreted and the conclusions that were drawn.

ENPH 316 Mathematical Methods in Physics I Units: 3.50
Methods of mathematics important for physicists. Complex arithmetic, series expansions and approximations of functions, Fourier series and transforms, vector spaces and eigenvalue problems, and differential equations.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 227 (MATH 221 or MATH 280), MTHE 237 (MATH 225 or MATH 231) or MTHE 225 Corequisites: Exclusions: ENPH 312 (PHYS 312), MTHE 338 (MATH 338), MTHE 334 (MATH 334), MTHE 335 (MATH 335)
Offering Term: F
CEAB Units:
Mathematics 31
Natural Sciences 11
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Use functions of complex numbers in a wide variety of problems.
2. Apply methods of linear vector spaces to solve problems in classical and quantum mechanics
3. Develop a working knowledge of Fourier analysis and apply these methods to a wide range of problems in physics and engineering physics.
4. Develop the skills and tools to handle ordinary and partial differential equations

ENPH 317 Mathematical Methods in Physics II Units: 3.50
A continuation of PHYS 316. Partial differential equations, functions of a complex variable and contour integration, and special topics such as probability and statistics, group theory and non-linear dynamics
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 316 (PHYS 316) Corequisites: Exclusions: ENPH 312 (PHYS 312), MTHE 338 (MATH 338), MTHE 334 (MATH 334), MTHE 335 (MATH 335)
Offering Term: W
CEAB Units:
Mathematics 31
Natural Sciences 11
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Model differential equation eigenvalue problems with a discrete approximation
2. Develop linear algebra based approaches to ordinary differential equation problems
3. Solve boundary-value problems using separation of variables
4. Develop the differential and integral calculus of complex variables
5. Solve inhomogeneous differential equations by applying the residue theorem
6. Deliver a technical presentation with an organized, story format
7. Produce a clear, concise, and well-organized report of a technical computation
8. Assess gaps in your understanding and ask questions to help you fill them

ENPH 321 Advanced Mechanics Units: 3.50
An introduction to the equations of mechanics using the Lagrange formalism and to the calculus of variations leading to Hamilton's principle. The concepts developed in this course are applied to problems ranging from purely theoretical constructs to practical applications. Links to quantum mechanics and extensions to continuous systems are developed.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 211 (PHYS 211), MTHE 226 (MATH 226) or MTHE 237 (MATH 237) or MTHE 225, MTHE 227 (MATH 227) Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 11
Natural Sciences 20
Complementary Studies 0
Engineering Science 11
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a conceptual understanding of the role of Lagrangian and Hamiltonian mechanics.
2. Apply advanced Lagrangian and Hamiltonian methods to real world problems.
3. Understand the role of symmetries in mechanical systems.
4. Understand and apply variational methods to solve problems in a variety of contexts.
5. Develop an understanding of Poisson brackets and the construction of phase space constants.
6. Understand the technique of separation of variables.
7. Understand some of the global features of Lagrangian systems.
8. Understand some of the global features of Hamiltonian systems.

ENPH 334 Electronics For Applied Scientists Units: 5.00
The design of electronic circuits and systems, using commonly available devices and integrated circuits. The properties of linear circuits are discussed with particular reference to the applications of feedback; operational amplifiers are introduced as fundamental building blocks. Digital circuits are examined and the properties of the commonly available I.C. types are studied; their use in measurement, control and signal analysis is outlined. Laboratory work is closely linked with lectures and provides practical experience of the subjects covered in lectures.
(Lec: 3, Lab: 1.5, Tut: 0.5)
Requirements: Prerequisites: ELEC 221 Corequisites: Exclusions: ENPH 333 (PHYS 333)
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 27
Engineering Design 33
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a thorough understanding of current, voltage, resistance, and Ohm's law.
2. Analyze DC circuits using Kirchhoff's laws.
3. Analyze AC Circuits using complex representationsImpedance, RC filters, decibels, tuned filters.
4. Use an Arduino microcontroller to replicate the functionality of a multimeter and an oscilloscope, and to implement functional circuit designs;
5. Have a working knowledge of the Orcad circuit simulation software package.
6. Be knowledgeable of voltage and current sources, Thevenin's and Norton's theorems.
7. Analyze circuits containing operational amplifiers, and design complex circuits using operational amplifiers as a building block.
8. Analyze digital electronics: logic gates, flip-flops, counters, and memory with the aid of Truth tables, DeMorgan's theorems, and Boolean algebra.
9. Create figures and diagrams for the analogue and digital design project reports.
10. Use multiple strategies to solve an engineering problem as part of design projects.
11. Deliver short presentations on the design projects by speaking clearly and confidently and answering questions.
12. Works in teams of two to complete labs and design projects.

ENPH 336 Solid State Devices Units: 3.25
This course deals with the fundamental concepts of solid state materials and the principles of operation of modern electronic and optoelectronic devices. Topics in materials include crystal structure, energy bands, carrier processes and junctions. Topics in device operation include p-n junction diodes, bipolar junction transistors, field-effect junction transistors, metal-oxide-semiconductor field-effect transistors, and optoelectronic devices.
(Lec: 3, Lab: 0, Tut: 0.25)
Requirements: Prerequisites: ELEC 252, ELEC 280 or ENPH 239 (PHYS 239) Corequisites: Exclusions: PHYS 335
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 18
Complementary Studies 0
Engineering Science 21
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a conceptual understanding of semiconductor physics and semiconductor devices.
2. Apply semiconductor physics to a system with numerical results.
3. Apply basic quantum mechanics to semiconductor systems.
4. Determine the properties of a pn-junction with numerical results.
5. Understand the operation of a bipolar junction transistor and calculate expected performance with possible design enhancements.
6. Understand the operation of field effect transistors (i.e.MOSFETs), and calculate expected performance with possible design enhancements.

ENPH 344 Intro. To Quantum Mechanics Units: 3.50
Matter waves. Postulates of wave mechanics. Stationary states and one-dimensional potentials. Particle tunnelling and scattering states. Introduction to matrix mechanics and Dirac notation. Quantized angular momentum, and the H atom.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 237 (MATH 225 or MATH 231 or MATH 232) or MTHE 225, MTHE 227 (MATH 221 OR MATH 280), ENPH 242 (PHYS 242), ENPH 211 (PHYS 211) Corequisites: Exclusions: CHEM 313
Offering Term: F
CEAB Units:
Mathematics 11
Natural Sciences 31
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Assess whether classical mechanics can successfully describe the behaviour of atomic systems
2. Develop linear algebra based formalisms to describe systems at the atomic scale
3. Apply analytic or numerical techniques to compute the spectrum of physical systems
4. Deliver a technical presentation with an organized, story format
5. Produce a clear, concise, and well-organized report of a technical computation
6. Assess gaps in your understanding and ask questions to help you fill them

ENPH 345 Quantum Physics Of Atoms Units: 3.50
Spin. Addition of angular momentum. Many electron atoms and the periodic table. Introduction to perturbation theory and Fermi's golden rule. Time dependent perturbations, including stimulated emission. Introduction to nuclear and particle physics.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 344 (PHYS 344) Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 11
Natural Sciences 20
Complementary Studies 0
Engineering Science 11
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Apply the postulates of quantum mechanics to determine the outcomes of measurements on a variety of quantum systems.
2. Determine the quantum states of total angular momentum for different systems.
3. Use particle-exchange symmetry to characterize the energy levels of multi-particle systems.
4. Determine the quantum states of multielectron atoms and molecules.
5. Estimate the ground state energy of quantum systems using the variational method.
6. Determine the effects of perturbations on the energy levels of quantum systems.

ENPH 353 Engineering Physics Experiment Design Units: 2.50
A course on the design of advanced physics experiments. Students learn advanced measurement techniques in the context of modern physics experiments, including nanoscience, quantum physics, optics and particle physics. The lectures cover probability and the statistical interpretation of data, methods of measurement, and how to design an experiment. Students spend the majority of the term on an experimental project of their choosing, researching, assembling, carrying out the experiment, analyzing and presenting the results.
(Lec: 1, Lab: 1.5, Tut: 0)
Requirements: Prerequisites: ENPH 251 (PHYS 251) OR ENPH 253 Corequisites: ENPH 344 Exclusions: ENPH 351 (PHYS 351)
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 8
Complementary Studies 8
Engineering Science 14
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Research experiments and supporting models from the literature to propose a project of an appropriate scope.
2. Apply and develop models for physical phenomena and experimental apparatus that can be tested with an experiment.
3. Specify an experimental apparatus, assemble and test it to ensure it meets requirements.
4. Design an experimental procedure to measure one or more physical properties.
5. Use professional scientific instruments effectively and control them by computer.
6. Measure nuclear radiation through counting and spectroscopy experiments.
7. Use software to analyze experimental data including fitting data to a non-linear function.
8. Determine measurement and statistical uncertainties and use these to compare a model to data quantitatively.
9. Record data, settings, preliminary calculations in a laboratory notebook and/or electronic document following standard practices.
10. Present an experimental report orally and in written form using the formatting standards of professional scientists or engineers.
11. Work safely in a laboratory, including with radioactive sources, high voltages and other hazards.
12. Work collaboratively and professionally as a team, sharing

ENPH 354 Engineering Physics Design Project Units: 3.50
Students will apply technical knowledge, models, and computer-aided design tools to solve an open-ended design problem. The students will work in teams to design, built, and test a prototype device. The lectures provide background on the physics and engineering of the device and introduce the design tools and techniques that will be required to complete the project.
(Lec: 1, Lab: 2.5, Tut: 0)
Requirements: Prerequisites: APSC 200, APSC 293, ENPH 253
Corequisites: ENPH 213 or CMPE 271, ENPH 334 or ELEC 252
Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 11
Engineering Design 31
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Develop proficient LabVIEW programming skills.
2. Build a photodiode-based light meter to measure the light output of a white LED as a function of biasing voltage and duty cycles.
3. Understanding the physics and key characteristics of photodiodes, solar cells, light-emitting diodes and diode lasers.
4. Design a sturdy, motor-driven mechanical mount to vary the incident angle of a light source relative to the photodiode/solar cell.
5. Design circuits to generate a variable, program-controlled DC voltage bias that can be used to bias the photodiode or LED.
6. Design a current vsvoltage (I-V) tracer to measure the dark and light I-V curves of a photodiode/solar cell.
7. Write a LabVIEW program to perform automated I-V scans of the photodiode and display data in real time; write an evaluator program to automatically calculate key device parameters based on the measured I-V curves.
8. Be able to effectively communicate technical background, design ideas and test results in technical writing.
9. Be able to demonstrate professionalism, safe conduct and effective teamwork.
10. Demonstrate skills of self-education.

ENPH 372 Thermodynamics Units: 3.50
Temperature, equations of state, internal energy, first and second laws, entropy and response functions. Application to heat engines and refrigerators. Free energies, Legendre transformations, changes of phase. Introduction to the Boltzmann factor and statistical mechanics. First offering in winter 2013.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 242 (PHYS 242)
Corequisites: Exclusions: ENPH 274 (PHYS 274)
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 31
Complementary Studies 0
Engineering Science 11
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Apply a broad range of topics in thermodynamics including temperature, equations of state, internal energy, the first and second laws of thermodynamics.
2. Relate the basic principles of statistical mechanics to derive the underlying concepts of thermodynamics.
3. Use entropy and response functions, free energies to understand how system properties and state variables evolve, including phase changes.
4. Evaluate and compare practical applications of thermodynamics such as engines, refrigerators, and heat pumps.
5. Demonstrate proficiency in solving problems in thermodynamics, both individually and working in groups.
6. Investigate a specific topic in thermodynamics or statistical mechanics, and create a presentation that relates this topic to the material covered in class.

ENPH 414 Introducation to General Relativity Units: 3.00
Einstein's theory of gravity is developed from fundamental principles to a level which enables the student to read some of the current literature. Includes an introduction to computer algebra, an essential element of a modern introduction to Einstein's theory.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: ENPH 321 (PHYS 321), ENPH 316 (PHYS 316) and ENPH 317 (PHYS 317) or ENPH 312 (PHYS 312) or MTHE 338 (MATH 338) Corequisites: Exclusions:

Offering Term: F
CEAB Units:
Mathematics 12
Natural Sciences 24
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a conceptual understanding of the role of spacetime curvature in our understanding of gravitation (GR).
2. Apply GR to the Universe as a whole as we currently understand it (cosmology).
3. Understand the geodesic motion of particles in a gravitational field.
4. Develop simple models of non-rotating black holes and their observational consequences.
5. Develop simple models of gravitating objects in hydrostatic equilibrium including a study of their interior properties.
6. Understand the junction of one spacetime onto another in order to develop complete models of isolated systems.
7. Appreciate the complex role rotation plays in a background spacetime and understand some of the properties of real world black holes.
8. Understand some of the global features of a spacetime as represented in a Penrose diagram.

ENPH 431 Electromagnetic Theory Units: 3.50
An introduction to electromagnetic theory and some of its applications. Topics are: Maxwell's equations, properties of waves in free space, dielectrics, conductors and ionized media, reflection and refraction at the surfaces of various media, radiation of electromagnetic waves, antennae, wave-guides, and optical fibers.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: MTHE 226 (MATH 226) or MTHE 235 (MATH 235) or MTHE 237 (MATH 237) or MTHE 225 , MTHE 227 (MATH 227), ENPH 239 (PHYS 239) Corequisites: Exclusions: ENPH 332 (PHYS 332), PHYS 432
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 21
Complementary Studies 0
Engineering Science 21
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Implement Maxwell’s equations in vector form to analyse important charge and current structures.
2. Utilize linear response theory to describe the electromagnetic properties of materials.
3. Solve for harmonic waves propagating in a homogeneous medium.
4. Quantify energy flow of electromagnetic waves in physical systems.
5. Characterize the behaviour of the incident, reflected, and transmitted waves that arise when a uniform plane wave encounters a boundary between two simple media.
6. Describe the operation and application of waveguides, including filters and fibre optic cables.

ENPH 444 Advanced Quantum Physics Units: 3.00
Perturbation theory. Scattering theory. Addition of angular momentum. Special topics: Many electron systems. Path integral formulation of quantum mechanics. Entanglement and quantum computing.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: ENPH 345 (PHYS 345)
Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 36
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

ENPH 453 Advanced Physics Laboratory Units: 3.50
This course provides students in Engineering Physics with experience in a range of advanced experimental techniques and analysis. A balanced selection of experiments are performed from fields including nuclear physics, applied physics, solid state physics, low temperature physics, and optics.
(Lec: 0, Lab: 3.5, Tut: 0)
Requirements: Prerequisites: ENPH 344 (PHYS 344), ENPH 345 (PHYS 345), ENPH 351 (PHYS 351) or ENPH 353
Corequisites: Exclusions: ENPH 450 (PHYS 450), ENPH 453 (PHYS 453)
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 11
Complementary Studies 11
Engineering Science 20
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Propose an original research experiment that includes theoretical and instrumental contexts. You will evaluate the context of the experimental Science, and digest and construct knowledge related to the field addressed by the experiment through research proposals you would submit before performing the measurements. This involves mastering both the theoretical and instrumental contexts of the experiment enough to propose an original research direction. You will utilize your knowledge of Mathematics to estimate the expected results based on the theoretical context of the setup.
2. Describe and discuss models or theories as they relate to a particular physics experimental investigation. You will Identify the key underlying physics involved in the experiment, Formulate the connection between the theory and the experimental setup, and Evaluate your experimental investigation to test the models or theories.
3. Conduct the experiment based on your understanding of the experimental setup and procedure. You will adhere to the Safety code of the laboratory to prioritize the safety of you and your classmates. You will perform Analysis of the collected data, and Synthesis the results considering the statistical and systematical uncertainties of the setup.
4. Define the discrepancies between theoretical expectations and your lab results. You will evaluate different Stratergies to understand and resolve the discrepancies. You will evaluate different Solutions to verify your hypothesis and Assess the validity of your solutions through calculation or additional data collection.
5. Create the appropriate computing codes to build models based on the theory, analyze your lab results,

ENPH 454 Advanced Engineering Physics Design Project Units: 4.50
This course provides engineering physics students with a complete experience in advanced design and implementation. Working in groups, students undertake a large design project of their choice that reflects and further develops their knowledge of physics and engineering design. The students then build a prototype of their design to demonstrate the feasibility of project within the design constraints.
K4.5(Lec: No, Lab: No, Tut: No)
Requirements: Prerequisites: ENPH 354 Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 10
Engineering Science 0
Engineering Design 44
Offering Faculty: Smith Engineering
Course Learning Outcomes:

1. Work effectively as a team, Students should delegate tasks, manage their time, work with formal project planning, work as effective team leaders and members, support and learn from each other.; please refer to your course syllabus in the meantime.
2. Develop an engineering design project that meets a need for (a) stakeholder(s) This project should attempt to solve problems for a client (real or hypothetical), for the inventors, as an entrepreneur, or for society/the planet.
3. Use engineering and scientific/physics knowledge to quantitatively specify and design a device, process or system to solve the desired problem.
4. Give supportive, constructive and considerate feedback to teammates and peers through project review and teamwork.
5. Effectively document project progress through working documents and meetings (lab notebook, progress reports, team meetings).
6. Communicate project goals, design, results and prospects in formal written reports, visual and oral presentations.
7. Research background, alternatives, safety protocols, government regulations, and industry standards so that the chosen project meets needs, works effectively, and can be deployed.
8. Use technical, scientific and engineering tools (hardware, software) to draw, calculate, model, design, simulate, fabricate, modify, characterize and/or test the desired process/device/system.
9. Independently or as a team acquire new knowledge and

ENPH 455 Engineering Physics Thesis Units: 4.00
Students will be assigned individual design topics of the type a practicing engineering physicist might expect to encounter. They must develop a solution under the supervision of a faculty member, and give oral and written presentations to an examining committee. Grades will be based on the quality of the analysis of the problem, the proposed solution, and the written and oral presentations. The demonstration of effective written and oral communications skills is required.
K4(Lec: No, Lab: No, Tut: No)
Requirements: Prerequisites: ENPH 354 Corequisites: Exclusions:
Offering Term: FW
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 12
Engineering Science 0
Engineering Design 36
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Define and refine an engineering project, determining the objectives and constraints.
2. Use multiple strategies to solve an engineering problem.
3. Design a product, process or system to solve the problem, meeting the needs of the client and subject to appropriate iterations.
4. Assess the results, successes and limitations of your design.
5. Use appropriate tools and techniques to perform the design, including modelling, drawing, simulation and calculation.
6. Produce clear, concise, precise and well-organized written communication.
7. Create figures, diagrams and other visual aids to aid in communication.
8. Deliver formal oral presentations, speaking clearly and confidently, answering the audience's questions.
9. Perform independent research, acquiring new knowledge and properly organizing and citing sources.
10. Apply economic principles to your design, including costs for development, manufacturing, operation and capital.
11. Consider environmental effects, ethical considerations, cultural and equity issues throughout the designs as appropriate.
12. Involve safety of operation and manufacturing of the product or process in the design.

ENPH 456 Advanced Engineering Physics Thesis I: Units: 2.00
Students will be assigned individual research topics. Students must work under the supervision of a faculty member. Grade will be based on the progress in arriving at a solution to the assigned problem.
NOT OFFERED 2024-2025
(Lec: 0, Lab: 0, Tut: 2)
Offering Term: S
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 14
Engineering Design 10
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

ENPH 457 Advanced Engineering Physics Thesis II Units: 9.00
Continuation of ENPH 456. Upon completion of their thesis, students must give oral and written presentations to an examining committee. Grades will be based on the quality of the analysis of the problem, the proposed solution, and written and oral presentations. Demonstration of effective written and oral communications skills is required.
NOT OFFERED 2024-2025
(Lec: 0, Lab: 0, Tut: 9)
Requirements: Prerequisites: ENPH 456 Corequisites: Exclusions: ENPH 455
Offering Term: FW
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 28
Engineering Science 48
Engineering Design 32
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

ENPH 460 Laser Optics Units: 3.50
Topics and applications in modern physical optics, culminating with the development of the laser and its current applications. Topics include: Gaussian beam propagation, optical resonators, Fourier optics, fiber optics, holography, light-matter interaction using classical and semi-classical models, and the basic theory and types of lasers.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 239 (or PHYS 239), ENPH 344 (PHYS 344), or permission of the instructor Corequisites: ENPH 431 or permission of instructor Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 21
Complementary Studies 0
Engineering Science 21
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Apply Maxwell's formalism to determine the characteristics of spatially coherent light propagating through free space and simple optical elements.
2. Apply the Lorentz model, to characterize classical light-matter interaction, including dispersion and absorption.
3. Apply the postulates of quantum mechanics to model semiclassical light-matter interaction (Maxwell-Bloch theory) and quantify optical amplification for particular systems.
4. Characterize the performance of various gain media and laser cavities to generate laser light.
5. Identify an interesting technical problem and explain how optics solves it or may solve it.

ENPH 472 Statistical Mechanics Units: 3.50
Phase space, the ergodic hypothesis and ensemble theory. Canonical and grand canonical ensembles. Partition functions. Ideal quantum gases. Classical gases and the liquid vapour transition. Introduction to techniques for interacting systems, including Monte Carlo simulations.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 213 and ENPH 372
Corequisites: Exclusions: ENCH 412
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 31
Complementary Studies 0
Engineering Science 11
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Apply statistical reasoning to the analysis of physical systems.
2. Derive the standard ensemble distribution functions of equilibrium statistical mechanics.
3. Examine non-interacting quantum gases using ensemble statistical mechanics.
4. Examine non-interacting classical gases using ensemble statistical mechanics.
5. Examine simple models in interacting magnetic systems using exact and approximate methods.

ENPH 479 High Performance Computational Physics Units: 3.00
A course to teach students how to use the tools of high performance computing facilities, and to have them employ these tools and various common numerical algorithms in the solution of numerical physics and engineering physics projects.
(Lec: 2, Lab: 0, Tut: 2)
Requirements: Prerequisites: ENPH 213, ENPH 344
Corequisites: ENPH 431 Exclusions:
Offering Term: W
CEAB Units:
Mathematics 9
Natural Sciences 18
Complementary Studies 0
Engineering Science 9
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a detailed understanding and working knowledge of various numerical algorithms used in physics and engineering physics problems.
2. Use effective written communication skills and present a summary of results from various models and assignments throughout the course.
3. Be able to explain scientific results and ideas including critical analysis.

ENPH 480 Solid State Physics Units: 3.50
An introduction to the properties of insulators, semiconductors and metals. Topics include: crystal structure, X-ray and neutron scattering, the reciprocal lattice, phonons, electronic energy bands, and the thermal, magnetic, optical and transport properties of solids.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 239 (PHYS 239), ENPH 345 (PHYS 345) Corequisites: Exclusions: ENPH 380 (PHYS 380), ENPH 481 (PHYS 481)
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 31
Complementary Studies 0
Engineering Science 11
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a conceptual understanding of electrons (charge) and phonons (heat) in crystalline materials.
2. Describe crystal structures using a Bravais lattice and basis vectors and identify crystal structures from the results of x-ray diffraction measurements.
3. Apply quantum mechanics to describe electron energy levels in crystalline materials.
4. Apply quantum mechanics to describe vibrational energy levels in crystalline materials.
5. Apply quantum mechanics to describe the dynamics of electrons in externally applied electric and magnetic fields.

ENPH 481 Solid State Device Physics Units: 3.50
A course in the physics underlying solid state electronic and optical devices. The course presents an introduction to the electrical and optical properties of insulators, semiconductors and metals, including crystal structure, band theory, and electron transport. This is applied to obtain a physical understanding of the physics governing the behaviour of diodes, field effect and bipolar transistors, and other discrete optical and electronic devices.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 239 (PHYS 239), ENPH 344 (PHYS 344) Corequisites: Exclusions: ENPH 336 (PHYS 336), ENPH 380 (PHYS 380), ENPH 480 (PHYS 480)
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 12
Complementary Studies 0
Engineering Science 30
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

ENPH 483 Nanoscience & Nanotechnology Units: 3.50
An examination of the key ideas, techniques and technologies in the fields of nanoscience and nanotechnology. Emphasis will be placed on the physics involved, measurement techniques, and technological applications. Topics covered are selected from the following: electrical and optical properties of quantum dots, quantum wires and nanotubes; quantum information technology; mesoscopic electronics; nanostructures on surfaces; and scanning-probe and optical microscopy.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 344 (PHYS 344), ENPH 336 (PHYS 336) or ENPH 380 (PHYS 380) or ENPH 480 (PHYS 480) or ENPH 481 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 12
Complementary Studies 0
Engineering Science 30
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Have a fundamental understanding of the underlying physics and engineering as it connects to nanoscience and nanotechnologies.
2. Understand the limits and advantages of fabrication, analysis and characterization tools for nanoscale materials and devices.
3. Read and analyze papers from the current research literature in a variety of fields.
4. Use effective oral communication and present a summary of research scientific research.
5. Be able to explain scientific results and ideas including critical analysis.

ENPH 490 Nuclear And Particle Physics Units: 3.50
A systematic introduction to low energy nuclear physics for advanced physics students. Lecture topics are: nucleon-nucleon forces, structure of nuclei, nuclear models, radioactivity, detection of nuclear radiation, electromagnetic, weak and strong interactions and an introduction to particle physics.
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 345 (PHYS 345) Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 42
Complementary Studies 0
Engineering Science 0
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Conceptually understand low energy nuclear physics, including nuclear structure and basic interactions.
2. Conceptually understand particle physics including the quark model, the structure of mesons and hadrons, the fundamental forces and interactions.
3. Understand nuclear instability and calculate rates and properties for alpha, beta, and gamma decays, fusion and fission.
4. Understand the process for calculating particle interaction rates from first principles and the role of Feynman Diagrams.
5. Understand basic renormalization and how to calculate simple QED decay and annihilation processes from first principles.
6. Understand special relativity, particle kinematics, 4-vectors, and associated calculations relevant for nuclear and particle processes.
7. Understand the role of experiments in forming theories and the limitations of nuclear models and the standard model of particle physics and conceptually understand possible extensions to these models.
8. Understand the role of nuclear and particle physics in the modern age including nuclear power, nuclear medicine, and fundamental science.

ENPH 491 Physics Of Nuclear Reactors Units: 3.50
The fundamental physics associated with a nuclear reactor. Emphasis will be on the interaction of neutrons, reactor kinetics and calculations required in reactor design. Topics discussed include: brief review of basic nuclear physics, neutron interactions and cross-sections, neutron diffusion, neutron moderation, theory of reactors, changes in reactivity, control of reactors.
NOT OFFERED 2024-2025
(Lec: 3, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: 3rd or 4th year standing in Engineering Physics Corequisites: Exclusions:
Offering Term: F
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 0
Engineering Science 30
Engineering Design 12
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.

ENPH 493 Plasma Physics Units: 3.50
An introduction to plasma physics. The motions of single particles under the influence of various fields is considered first, followed by a fluid description of plasma. Topics also include plasma properties, waves in plasma, equilibrium and stability.
NOT OFFERED 2022-2023
(Lec: 3.0, Lab: 0, Tut: 0.5)
Requirements: Prerequisites: ENPH 239 (PHYS 239), MTHE 227, MTHE 237 Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 21
Complementary Studies 0
Engineering Science 21
Engineering Design 0
Offering Faculty: Smith Engineering
Course Learning Outcomes:

1. Have a working definition of what constitutes a plasma.
2. Be able to describe the motion of charged particles under the influence of various applied fields.
3. Be familiar with adiabatic invariants.
4. Develop a basic understanding of plasma as a fluid including the governing magnetohydrodynamics.
5. Be familiar with the propagation of waves in plasma.
6. Be able to describe diffusion processes, collision processes, and plasma resistivity.
7. Be aware of various plasma instabilities.

ENPH 495 Intro To Medical Physics Units: 3.00
Production and measurement of x-rays and charged particles for radiation therapy and nuclear medicine, interactions of radiation with matter and biological materials, interaction coefficients and radiation dosimetry, radiation safety, physics of medical imaging with examples from nuclear medicine ultrasound and magnetic resonance imaging.
(Lec: 3, Lab: 0, Tut: 0)
Requirements: Prerequisites: 3rd or 4th year standing in Engineering Physics Corequisites: Exclusions:
Offering Term: W
CEAB Units:
Mathematics 0
Natural Sciences 9
Complementary Studies 0
Engineering Science 27
Engineering Design 0
Offering Faculty: Faculty of Arts and Science
Course Learning Outcomes:

1. Estimate the biological effects on humans from different sources of ionizing radiation.
2. Describe the basic interactions of x-rays and charged particles with matter, and use this understanding to calculate radiation energy deposition in mater.
3. Describe some of the medical equipment used for radiation therapy and imaging from the perspective of the physical mechanisms involved in the radiation production and detection.
4. Derive and calculate some basic properties of x-ray images.
5. Use fundamental physical properties such as x-ray attenuation coefficients to explain the workings of conventional radiography and computed tomography.
6. Describe the physical basis for ultrasound and magnetic resonance imaging.
7. Describe different methods for radiation therapy.
8. Use basic dose calculation techniques to determine doses received from a simple radiation therapy treatment.
9. Perform independent reading and critical analysis of medical physics related topics.
10. Work as a group to create an in-depth poster presentation on a selected medical physics topic.
11. Give an oral presentation and answer questions on the selected medical physics topic.
12. Evaluate peer presentations.
13. Assess personal and team member contributions to a project.
14. Critically assess news articles related to radiation exposure and describe key institutions involved in radiation safety.

ENPH 555 Accelerated Engineering Physics Thesis Units: 4.00
Undergraduate thesis for students enrolled in the Accelerated Masters Program in Engineering Physics. They must develop an engineering solution to an assigned program under the supervision of a faculty member and give oral and written presentations to an examining committee. Grades will be based on the quality of the analysis of the problem, the proposed solution, and the written and oral presentations. The demonstration of effective written and oral communications skills is required. Students in the Accelerated Masters program are expected to work the summer before with the supervisor.
K4(Lec: No, Lab: No, Tut: No)
Requirements: Prerequisites: PREREQUISITE(S): ENPH 354 and acceptance in the Accelerated Masters Program Corequisites: Exclusions: Exclusions: ENPH 455, ENPH 456, ENPH 457
Offering Term: FW
CEAB Units:
Mathematics 0
Natural Sciences 0
Complementary Studies 12
Engineering Science 0
Engineering Design 36
Offering Faculty: Smith Engineering
Course Learning Outcomes:

1. CLOs coming soon; please refer to your course syllabus in the meantime.