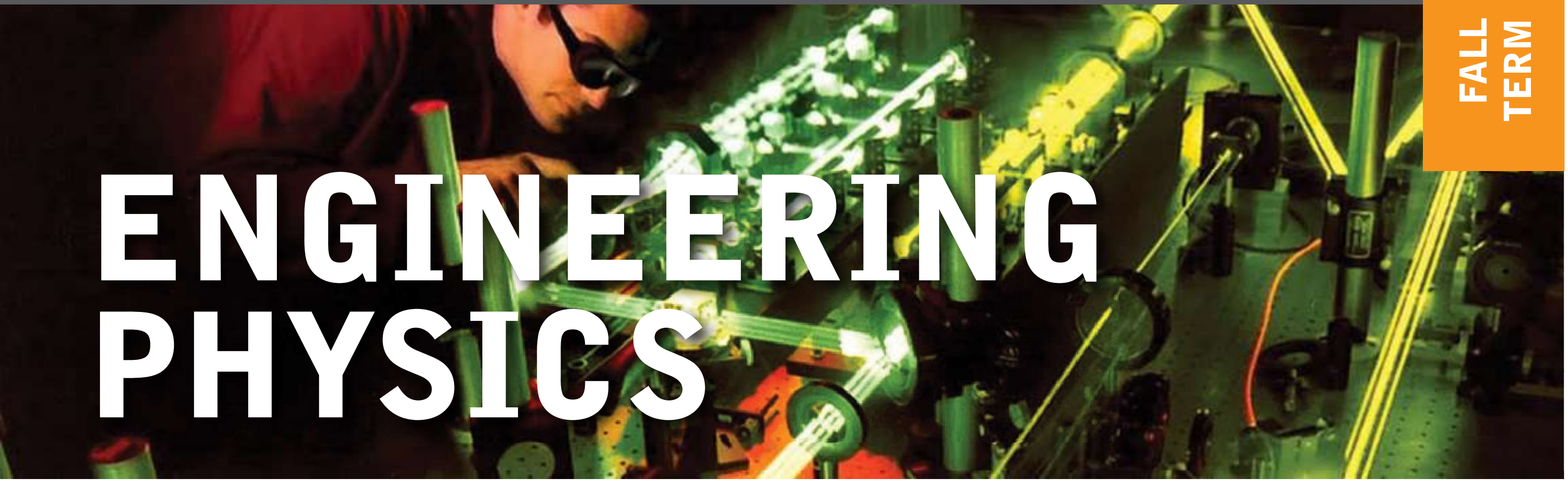

FALL TERM

ENGINEERING PHYSICS

Engineering physics bridges the gap between physics and engineering by utilizing fundamental principles and phenomena for the development of radically new technologies solving outstanding challenges in the fields of energy, communications and processing, and biomedicine.

Students must take 12 to 15 credits among the following :

PHS8205E // Guided Waves in Photonics (3 cr.)

Wave approach to optical waveguides. Hamiltonian formulation of Maxwell's equations and fundamental properties of guided modes. Transfer matrix method. Guided modes, leaky modes, surface waves. Modal excitation and coupling efficiency. Optical fiber communications. Metamaterial waveguides and anti-resonant waveguides. Perturbation Theory and Coupled Mode Theory. Waveguide components. Optical systems. Numerical modeling of the behavior of guided optical devices using the finite element method.

Prerequisites: Principles of quantum mechanics and numerical computing.

PHS8310E // Microfabrication (3 cr.)

Introduction to micro- and nano-fabrication. Photolithography: optical technology and photoresists. Thin films: physical processes (evaporation, sputtering and laser), chemical processes, electrochemical processes and oxidation. Etching: wet and dry (plasma). Fundamentals of nanofabrication. Processes for microelectronics, for photonics, for micro-electro-mechanical systems, and bio sensors. Applications of microfabrication. Laboratory of microfabrication.

PHS8604E // Direct Energy Conversion (3 cr.)

Classification of energy conversion systems. Introduction to energy conversion limitations. Limitations imposed by our planet: sensitivity study. Thermodynamic limitations. Electromagnetic energy conversion. Magneto hydrodynamic (MHD) energy conversion: efficiency of Faraday and Hall MHD systems. Thermoelectric, photovoltaic and fuel cell systems. Comparative study of different energy conversion technologies. Analyses of advanced energy conversion cycles.

GBM8810E // Biomedical Nanotechnologies (3 cr.)

Physical concepts of nanotechnology. Fabrication and functionalization of nanomaterials. Bionanoplasmonics: concept of plasmons, Mie theory, nanophotothermy and therapeutic applications. Optical nanobiosensors: Theory and application of plasmonics. Biomedical nanophotonics: quantum dots, optical tweezers and laser nanosurgery. Biomedical nanomagnetism: properties of magnetic nanomaterials and applications in biosensing and therapy. Ethics and social issues of nanotechnologies in biomedical.

Prerequisites: Notions of optics, quantum mechanics, thermodynamics.

SL803E // Research Internship or Final Project (3 cr.)
SL806E // Research Internship or Final Project (6 cr.)

Exchange students can pursue a research internship in one of Polytechnique laboratories. These serve as introduction to research through the execution of a project in a research environment.

French Language Course (3 cr.)

Exchange students have access to the Université de Montréal credited French language course offer and will receive by email several weeks before the beginning of classes the detailed application procedure. For more information regarding the French as a second language course offer *click here*.

Back to Cover Page

INTERNATIONAL THEMATIC CLUSTERS IN ENGINEERING

POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

For more information: *point@polymtl.ca* // 514 340-4975
POLYMTL.CA/INTERNATIONAL

The above courses offer may vary slightly from year to year.

POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

COURSE SYLLABUS

CODE

PHS8205E

NAME	HOURS/WEEK (in class / practical work / individual work)	CREDITS
Guided waves in photonics	3 / 1,5 / 4,5	3
PREREQUISITES	**COREQUISITES**	**SEMESTER**
PHS2108, MTH2210 and 70 credits for undergraduate students	None	☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

Wave approach to optical waveguides. Hamiltonian formulation of Maxwell equations and fundamental properties of guided modes. Transfer matrix method: planar waveguides and circular optical fibers. Guided modes, leaky modes, surface waves. Modal excitation and coupling efficiency. Optical fiber communications. Metamaterial waveguides and anti-resonant waveguides. Perturbation Theory and Coupled Mode Theory.
Waveguide components: couplers, Bragg gratings, tapered fibers. Optical systems. Numerical modeling of the behavior of guided optical devices using the finite element method.

COURSE AND LAB OBJECTIVES

By the end of the course, the student will be able to:

- analyze the guidance and propagation phenomena in optical waveguides;
- apply waveguide design, analysis, and characterization techniques;
- master several types of optical waveguides and their practical applications;
- explain the operation of components in integrated optics and fiber optics;

After having completed practical work sessions, the student will be able to:

- master modern methods of numerical modeling of optical properties of waveguides and optical components;
- apply the theoretical concepts introduced in class;
- master digital design methods for optical components in the presence of constraints and compromises;
- design optical components for specific applications;

COURSE STRUCTURE (CONTENT AND HOURS) – 1st SECTION

Subjects	Hours
Week 1	3
Introduction to guided waves and waveguides Hamiltonian formulation of Maxwell's equations Notions of waveguide modes, band diagram	
Week 2	4
Fundamental properties of modes: orthogonality, phase velocity, group velocity, dispersion chromatic and geometric dispersion, Poynting vector Waveguides planes Transfer matrix method	
Week 3	3
Fundamental properties of a plane dielectric waveguide Flat waveguide with a porous metamaterial core Study of a band diagram of a plane dielectric waveguide	
Week 4	3
Mode excitation and coupling efficiency Study of the efficiency of fundamental mode excitation by a Gaussian beam in a plane dielectric waveguide as a function of the core-cladding index contrast	
Week 5	4
Surface waves, surface polaritons and surface plasmons Flat waveguide with a metallic core Long-range plasmon modes Slotted metallic waveguide	
Week 6	4
Circular optical fibers. Transfer matrix method Classification of modes Fundamental properties of a circular step index optical fiber Single-mode fiber with low index contrast Optical communication	
Week 7	2
Information transmission through dispersive modes in single-mode and multimode waveguides	
Week 8	3
Leaky modes Anti-resonant reflecting optical waveguide (ARROW) Study of band diagrams of leakage mode	

Week 9	3
Theory of disturbances: absorption losses, dispersion of polarization modes Introduction to COMSOL, toolbox 1 Comparison with the transfer matrix method	
Week 10	2
Coupled mode theory and supermode theory: directional coupler with two guides	
Week 11	3
Coupled mode theory: fiber Bragg grating Introduction à COMSOL, toolbox 2	
Week 12	3
Theory of coupled modes : tapered fiber. Adiabatic regime Introduction to COMSOL, toolbox 3	
Week 13	2
Optical systems, integration and analysis	
Total:	**39 h**

STRUCTURE OF PRACTICAL WORK (CONTENT AND HOURS) – 2nd SECTION

Subjects	Hours
Introductory Class Introduction to the calculation of the modes by the transfer matrix method and by a software with finite elements (Software - TMT, Matlab, COMSOL)	2
Design project 1 Design of a wide modal area single-mode waveguide using porous waveguides Optimization of the geometric parameters of a waveguide in order to maximize the efficiency of excitation of the fundamental mode by a Gaussian beam (Software - TMT, Matlab, COMSOL)	4
Design project 2 Design of a step-index optical fiber to maximize the transmitted information rate as well as of coupling efficiency (Software - TMT, Matlab, COMSOL)	3
Design project 3 Design of a hollow core chalcogenide glass waveguide for average infrared guidance with minimized absorption loss (Software - TMT, Matlab, COMSOL)	2
Design project 4 Design of a two-fiber coupler. Calculation of the band diagram of a directional coupler with two circular fibers (Software - COMSOL, toolbox 1) Design of a coupler with two plane waveguides (Software - TMT, Matlab)	5
Design project 5 Design of a fiber Bragg grating for telecommunication applications in the near infrared (low index contrast silica fiber, IR) (COMSOL software, toolbox 2)	2
Design project 6 Design of an essentially adiabatic tapered tapered fiber for near infrared telecommunications applications (high index contrast step index fiber) (COMSOL software, toolbox 3)	2
Total:	**20 h**

ASSESSMENT METHODS

Nature	Individual	In groups	Number	Weight
Homework *Homework 1: Fundamental properties of a flat dielectric waveguide* *Homework 2: Surface waves and their absorption losses* *Homework 3: Fundamental properties of a circular step-index optical fiber* *Homework 4: Escape Modes*	☐	☒	4	20 %
Projects *Each of the 6 mini design projects will be assessed by the quality of the associated project report*	☐	☒	6	60 %
Final exam *The final exam is in the form of a report of approximately 10 pages as well as an oral presentation on one of the subjects suggested by the course's educational team*	☒	☐	1	20 %
	Individual: 20%	**In groups: 80%**		**Total : 100 %**

RATIONALE FOR ASSESSMENTS

One of the important objectives of this course is to promote a collaborative environment for solving complex numerical problems in guided optics. Therefore, practical work as well as digital homework are designed for teamwork

POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

CODE

PHS8310E

COURSE SYLLABUS

NAME	**HOURS/WEEK** (in class / practical work / individual work)	**CREDITS**
Microfabrication	3 / 1.5 / 4.5	3
PREREQUISITES	**COREQUISITES**	**SEMESTER**
80 cr. for bachelors' students	None	☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

Introduction to micro- and nano-fabrication. Photolithography: optical technology and photoresists. Thin films: physical processes (evaporation, sputtering and laser), chemical processes, electrochemical processes and oxidation. Etching: wet and dry (plasma). Fundamentals of nanofabrication. Processes for microelectronics, for photonics, for micro-electro-mechanical systems, and bio sensors.
Applications of microfabrication. Laboratory of microfabrication.

COURSE AND LAB OBJECTIVES

By the end of the course, the student will be able to:

- describe the principles, advantages and disadvantages of basic lithography, thin film deposition and etching techniques;

- determine an appropriate sequence of steps in order to design a microsystem that can be used in microelectronics, micromechanics, microelectromechanics, photonics, biosystems etc.

General objectives of lab sessions:

The four lab sessions will allow students to familiarize themselves with the various stages of microfabrication (deposition of thin films, lithography, etching). The laboratories will take place in a clean room (LMF - Microfabrication Lab) in teams of four under the supervision of lab assistants. After having completed these labs, the student should be able to elaborate on and detail the different steps of microfabrication.

COURSE STRUCTURE (CONTENT AND HOURS) – 1st SECTION

Subjects	Hours
Introduction	2
Microfabrication environment	3
Lithography Introduction –Contamination Principles of optical lithography Photomasks Pattern transfers by contact and proximity Projection lithography Photoresists Evolution of lithography New optical technologies Nanolithography	9
Deposition of thin films Introduction Physical and chemical bases of thin film fabrication Physical processes Chemical processing Comparison of deposition techniques	9
Etching Introduction Dry etching Wet etching	4
Microelectronic processes	2
Micro-machining Surface micro-machining, LIGA Electro-Discharge-Machining Bonding, Replication Sticking of structures during release MUMPS Micro-machining by LASER	4
Student presentations	6
Total:	**39 h**

STRUCTURE OF PRACTICAL WORKS (CONTENT AND HOURS) 2ND SECTION

Subjects	Hours
Lab sessions	18
Total:	**18 h**

ASSESSMENT METHODS

Nature	Individual	In groups	Number	Weight
Homework	☒	☐	3	30 %
Oral presentations	☐	☒	1	20 %
Practical work	☒	☐	3	25 %
Final exam	☒	☐	1	25 %
	Individual: 80 %	**In groups: 20%**	**Total:**	**100 %**

POLYTECHNIQUE MONTRÉAL

TECHNOLOGICAL UNIVERSITY

CODE

PHS8604E

COURSE SYLLABUS

NAME	HOURS/WEEK (in class / practical work / individual work)	CREDITS
Direct Energy Conversion	3 / 0 / 6	3
PREREQUISITES	**COREQUISITES**	**SEMESTER**
PHS1102, PHS1105 and 70 credits for undergraduate students	None	☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

Classification of energy conversion systems. Introduction to energy conversion limitations. Limitations imposed by our planet: sensitivity study. Thermodynamic limitations. Electromagnetic energy conversion. Magneto hydrodynamic (MHD) energy conversion: efficiency of Faraday and Hall MHD systems. Thermoelectric, photovoltaic and fuel cell systems. Comparative study of different energy conversion technologies. Analyses of advanced energy conversion cycles.

COURSE AND LAB OBJECTIVES

By the end of the course, the student will be able to:

- identify and calculate the thermodynamic and planetary limits that must be observed in the design of new methods of energy conversion;
- write and evaluate the advantages and disadvantages of one energy conversion technique compared to anotherin a given context;
- explain the operation of magnetohydrodynamic, thermoelectric, photovoltaic, and fuel cell converters;
- calculate theoretical limits and energy efficiency of various energy conversion technologies;
- write the effects of current R&D programs on the implementation of new conversion techniques;
- criticize various energy conversion choices in a given context by justifying the approach used by qualitative and quantitative analyze.

COURSE STRUCTURE (CONTENT AND HOURS) – 1ST SECTION

Subjects	Hours
Class 1: INTRODUCTION	5
Energy and society; energy resources	
Various direct energy conversion techniques; classification	
Class 2: THE PLANET'S LIMITATIONS	1.5
The planet as an ecosystem	
The thermal equilibrium between the sun and the earth; Sensitivity study	
Class 3: THERMODYNAMIC LIMITS	3
Perpetual mobiles of the first and second types; limitations in energy conversion	
Characteristic functions; application to the conversion of chemical energy	
Class 4: ELECTROMAGNETISM APPLIED TO ENERGY CONVERSION	6
Conversion of electrical energy into thermal energy	
Conversion of mechanical energy into electrical energy	
Conversion of electrical energy into mechanical energy	
Class 5: MAGNETOHYDRODYNAMIC CONVERTER (MHD)	6
The fundamental equation of the converter to MHD	
Various possible types of MHD converters	
Faraday and Hall converters, their efficiency	
Combined cycles; their performance; The state of the art	
Class 6: THERMOELECTRIC CONVERTERS	6
Thermodynamics and the thermoelectric effect; Kelvin's relations	
Analysis of a thermoelectric converter; yield calculation	
Thermoelectric converters in the "SNAP" program	
Class 7: PHOTOVOLTAIC CONVERTERS	6
The equation of the diode; dark current	
Effects due to temperature and recombinants	
Yield analysis, manufacturing techniques	
State of the art; aerospace industry, pumping systems, etc.	
Class 8: FUEL CELLS	4
Energy balance in chemical reactions; Gibbs function	
Energy analysis of a typical fuel cell	
Polarization phenomena; energetic efficiency	
Manufacturing techniques, applications: aerospace industry, high density electrical energy generation	
Oral presentations	4
Periodic tests	2
Total:	**39 h**

ASSESSMENT METHODS

Nature	Individual	In groups	Number	Weight
Periodic testing	☒	☐	1	30 %
Project (s)	☒	☐	1	30 %
Final exam	☒	☐	1	40 %
	Individual: 100 %	**In groups: 0 %**	**Total:**	**100%**

POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

CODE

GBM8810E

COURSE SYLLABUS

NAME	HOURS/WEEK (in class / practical work / individual work)	CREDITS
Biomedical Nanotechnologies	3 / 1 / 5	3
PREREQUISITES	**COREQUISITES**	**SEMESTER (INFORMATION ONLY)**
70 credits	None	☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

Physical concepts nanotechnology and applications in the biomedical realm. Different approaches to nanotechnology: Fabrication and functionalization of metallic and semiconductor nanomaterials used in biomedical applications. Functionalization bioplasmonics: concept of plasmon, Mie theory, nanophotothermy and therapeutic applications. Optical nano-sensors: theory and application of plasmonics, biosensors based on surface plasmon resonance. Biomedical nanophotonics: quantum dots, laser nano-surgery. Biomedical nano-magnetism: properties of magnetic nanomaterials and applications in biodetection, imaging and therapy. Ethics and social impact of biomedical nanotechnologies.

COURSE AND LAB OBJECTIVES

By the end of the course, the student will be able to:

- discuss the specifics and the various approaches to nanotechnology, particularly those associated with the biomedical field;
- discuss the various techniques for manufacturing and functionalizing nanomaterials used in the biomedical field; know which one is most appropriate for a particular biomedical application
- describe the optical and magnetic properties of nanomaterials and discuss the principles of their applications in biosensing/biodetection and therapy;
- know how to choose which type or set of optical and magnetic nanomaterials is most appropriate for a particular biomedical application;
- solve theoretical, analytical, and numeric/digital problems involving optical and magnetic nanomaterials in a

particular biomedical application;

- describe the operating principles of various types of optical and electronic nanobiosensors; know which type of nanobiosensor is most appropriate for a particular biomedical application;
- solve theoretical, analytical, and numeric/digital problems involving biosensors;
- discuss the ethical and social challenges of biomedical nanotechnology.

Specific objectives of practical work:

During hands-on sessions led by the professor or teaching assistant, problems brought forth by students will enable them to achieve the objectives described in the previous section.

COURSE STRUCTURE (CONTENT AND HOURS) – 1ST SECTION

Subjects	Hours
Introduction nanotechnology Class plan Historical aspects of the development of nanotechnology. Orders of magnitude (mass). Convergence of fields (chemistry, physics, and biology). New phenomena at the nanoscale. Various fields of nanotechnology for biomedical use: nanomaterials, nanobiosensors/detectors, nanophotonics, and nanomagnetism	3
Manufacturing of nanomaterials for biomedical uses Various types of nanomaterials and an overview of applications for biomedical use. Development and growth of nanoparticles. Chemical (chemical reduction, sonochemistry, electrochemistry, photoreduction) and physical (laser ablation) synthesis methods of metallic and semiconductor nanomaterials. Functionalization of nanomaterials, cytotoxicity of nanomaterials.	5
Biomedical Nanoplasmonics Reminder of the permittivity and optical properties of metals; the concept of plasmon; dipolar approximation of nanospheres; Mie theory, localized plasmons in plasmonic nanostructures nanospheres, nanobatons, etc.). Biomedical applications: nanophotothermia; cancer treatment, molecular probes, imaging, SERS (Surface Enhanced Raman Spectroscopy).	9
Nanobiosensors Theory and applications of surface plasmons, local amplification of surface plasmons, nanoplasmonics; coupling and excitation; surface plasmon propagation; phase detection; optical design of SPR (Surface plasmon Resonance) biosensors	6
Test	2
Nanophotonics in biomedical usage Optical properties of quantum dots and applications in imaging; near-field microscopy; optical tweezers of biological elements; laser nanosurgery, PDT.	4
Biomedical Nanomagnetism Review of magnetism in the materials, and the magnetic properties of nanomaterials; applications of magnetic nanoparticles in the biomedical field: hyperthermia, imaging, magnetic separation	4
Ethics and social challenges of biomedical nanotechnology use	2
Student Presentations	4

Note: There will be approximately 2-3 visiting researchers during the semester who will give one-to-two-hour presentations on one of the hot topics in the field of biomedical nanotechnology

Total: 39 h

STRUCTURE OF PRATICAL WORK (CONTENT AND HOURS) – 2ND SECTION

Subjects	Hours
Introduction to nanotechnology	1
Manufacturing of nanomaterials for biomedical uses	1
Biomedical Nanoplasmonics	3
Nanobiosensors	2
Biomedical Nanophotonics	2
Biomedical Nanomagnetism	1
Ethics and social challenges of biomedical nanotechnology use	1
Student Presentations	2
Total:	**13 h**

ASSESSMENT METHODS

Nature	Individual	In a group	Number	Weight
Homework	☒	☐	10	25 %
Period testing	☒	☐	1	20 %
Oral presentations *Oral presentations will be made in a team of two students, and will cover a topic related to the course and approved by the professor*	☐	☒	1	20 %
Final exam	☒	☐	1	35 %
	Individual: 80 %	**In a group: 20 %**	**Total:**	**100 %**