Appendix C: Course Outlines

Core Graduate Courses to be offered by the School of Energy Systems and Nuclear Science

Course Title: NUCL 5001G – MASc Thesis

- **Course Description and Content Outline:** The thesis is the major component of the MASc program and is carried out under the direction of the student's supervisor. The thesis may involve an investigation which is fundamental in nature or applied, and may incorporate elements of analysis, design and development. Through the thesis, candidates are expected to give evidence of competence in research and a sound understanding of the area of specialization involved.
- **Delivery Mode and Teaching Method:** N/A
- **Student Evaluation:** The student is required to write a research thesis. Upon completion, the student must defend the thesis in front of an examination committee comprised of his or her supervisory committee plus an external examiner.
- **Textbook requirements:** None
- **Learning Outcomes:** Students who successfully complete the MASc thesis have reliably demonstrated the ability to:
  Outcome 1: understand and explain the essential facts, concepts, principles, and theories relating to their research topic.
  Outcome 2: effectively use advanced tools for research.
  Outcome 3: apply the principles of effective data management, information organization, and information-retrieval skills to data of various types.
  Outcome 4: critically evaluate advanced information and knowledge and their implementation.
  Outcome 5: understand, explain and solve problems using quantitative and qualitative methods.
  Outcome 6: design and conduct experiments, analyze and interpret experimental data, and/or computational results.
  Outcome 7: prepare and present, orally and in writing, to peers and experts, a systematic report on a significant research topic.

- **Information About Course Designer/Developer:**
  Course designed by G. Bereznai, PhD, School of Energy Systems and Nuclear Science

- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  All Core Faculty Members of SESNS.

- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering or science and relevant experience in teaching and research.

Course Title: NUCL 5003G – Seminar

- **Course Description and Content Outline:** Students are required to participate in a program of seminars by internal and external speakers on current research topics. All MASc students will be required to give a seminar on their thesis research during the second year of their program.
- **Delivery Mode and Teaching Method:** Mandatory attendance in a series of seminars by internal and external speakers. There are no academic credits given for this course.
- **Student Evaluation:** Pass/Fail
- **Textbook requirements:** None
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:
  Outcome 1: comply with the social, professional, and ethical requirements involved in advanced education and research.
  Outcome 2: examine and reflect on contemporary issues and professional and ethical responsibilities which impact engineering and science, as well as and their specific area of interest.
  Outcome 3: appreciate the need, and have the knowledge and skills required, to further their education through lifelong learning.
  Outcome 4: prepare and present a research seminar on a significant topic, to an audience of peers and experts.
  Outcome 5: receive and respond to questions, critique and other feedback from peers and experts.
- **Information About Course Designer/Developer:**
  Course designed by G. Bereznai, PhD, School of Energy Systems and Nuclear Science
- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  N/A
- **Faculty qualifications required to teach/supervise the course:**
  N/A

Course Title: NUCL 5004G – Directed Studies

- **Course Description and Content Outline:** Faculty permission may be given for supervised research and development projects, individual study, or directed readings. Students wishing to pursue a course of directed studies must, with a faculty member who is willing to supervise such a course, formulate a proposal that accurately describes the course content, the learning goals, the intended method and extent of supervision, and the method by which the student's work will be evaluated. This course may only be taken once.
- **Delivery Mode and Teaching Method:** Dependent on the Topic
- **Student Evaluation:** Dependent on the Topic
- **Textbook requirements:** Dependent on the Topic
- **Learning Outcomes:** Dependent on the Topic
- **Information About Course Designer/Developer:**
  Course designed by G. Bereznai, PhD, School of Energy Systems and Nuclear Science
- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  All Faculty Members
- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering and relevant experience in teaching and research.

Course Title: NUCL 5005G – Special Topics

- **Course Description and Content Outline:** The course covers material in an emerging area or is a subject not covered in regular offerings. May be taken more than once, provided the subject matter is substantially different.
- **Delivery Mode and Teaching Method:** Dependent on the Topic
- **Student Evaluation:** Dependent on the Topic
- **Resources to be purchased by students:** Dependent on the Topic
- **Textbook requirements:** Dependent on the Topic
- **Learning Outcomes:** Dependent on the Topic
- **Information About Course Designer/Developer:**
- Course designed by G. Bereznai, PhD, School of Energy Systems and Nuclear Science
- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  All Faculty Members, Adjunct Professors and Sessional Lecturers.
- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering and relevant experience in teaching and research.

Course Title: NUCL 5006G – Industrial Research Project

- **Course Description and Content Outline:** Students enrolled part-time in a course based MEng program may designate a period of approximately four months in an industrial laboratory carrying out an industry-oriented project under the supervision of a suitably qualified staff engineer or scientist, as well as a university co-supervisor. The School will work with the candidate and consult the candidate's employer to arrange a suitable industrial project. A satisfactory project topic and appropriate arrangements are required for the project to be approved by the School and it is possible that in some cases this may not be feasible. Upon completion, the candidate will submit a substantial report on the project and make a presentation on it at the university. The industrial research project can only be undertaken after at least half the required courses have been taken.
- **Delivery Mode and Teaching Method:** N/A; this Project is equivalent to a 6 credit course.
- **Student Evaluation:** Students are required to write a report and give a presentation on their completed project. Upon completion, the student must defend the project in front of an examination committee.
- **Textbook requirements: None**
- **Learning Outcomes: Students who successfully complete the MEng project have reliably demonstrated the ability to:**

  Outcome 1: understand and explain the essential facts, concepts, principles, and theories relating to their research topic.
  Outcome 2: identify problems and opportunities for system analysis, design, development, and optimization.
  Outcome 3: understand, explain, and solve problems using quantitative and qualitative methods.
  Outcome 4. organize and complete a significant project in a timely manner.
  Outcome 5: synthesize significant information from the project and prepare well organized and complete technical reports.
  Outcome 6: prepare and present, orally and in writing, to peers and experts, a final report on a significant project.

- **Information About Course Designer/Developer:**
  Course designed by G. Bereznai, PhD, School of Energy Systems and Nuclear Science

- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  All Faculty Members in conjunction with approved industrial professionals

- **Faculty qualifications required to teach/supervise the course:**
  At least one of the industrial and university co-supervisors must have a PhD degree in engineering or science, and relevant experience in teaching and research.

Course Title: NUCL 5009G – Graduate Research Project

- **Course Description and Content Outline:** The MEng Project provides students with the opportunity, under the supervision of a faculty member, to integrate and synthesize knowledge gained throughout their program of study. The chosen topic will be dependent on the area of specialization of the student, using the resources normally available on Campus.
- **Delivery Mode and Teaching Method:** N/A; this Project is equivalent to a 9 credit course.
- **Student Evaluation:** Students are required to write a report and give a presentation on their completed project.
- **Textbook requirements: None**
- **Learning Outcomes: Students who successfully complete the MEng project have reliably demonstrated the ability to:**

  Outcome 1: understand and explain the essential facts, concepts, principles, and theories relating to their research topic.

  Outcome 2: identify problems and opportunities for system analysis, design, development, and optimization.

  Outcome 3: understand, explain, and solve problems using quantitative and qualitative methods.

  Outcome 4. organize and complete a significant project in a timely manner.

  Outcome 5: synthesize significant information from the project and prepare well organized and complete technical reports.

  Outcome 6: prepare and present, orally and in writing, to peers and experts, a final report on a significant project.

- **Information About Course Designer/Developer:**
  Course designed by G. Bereznai, PhD, School of Energy Systems and Nuclear Science

- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  All Faculty Members

- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering or science, and relevant experience in teaching and research.

Course Title: NUCL 5010G – Project Management for Nuclear Engineers

Prerequisite(s): none

- **Course Description and Content Outline:** This course in Project Management will prepare nuclear engineers and scientists in the application of this discipline in their work. It is an intensive investigation into the major principles of Project Management slanted towards, but not exclusively about, the management of nuclear engineering projects. The course uses the Project Management Institute's PMBOK (Project Management Body of Knowledge) as a skeleton and expands that coverage with relevant examples from nuclear, software and general engineering. Special emphasis will be placed on Risk Management, particularly in the area of safety-critical projects. The graduates will be well-positioned both to apply the knowledge in their area of engineering and to sit the PMI's PMP examination. The course will be taught using many case studies from industry and engineering.
- **Topics include:**
  - The Engineering Project Management Context
  - Project Management Processes
  - Project Integration Management
  - Project Scope Management
  - Project Cost Management
  - Project Time Management
  - Project Quality Management
  - Project Human Resource Management
  - Project Communications Management
  - Project Risk Management
  - Project Procurement Management
- **Length in Contact Hours: 3 hours/week, 3 credits**
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be given to students:** MS Project, course notes
- **Representative Texts:** H. Kerzner, Project Management, 8th Edition, John Wiley & Sons, ISBN 0-471-39342-8, and excerpts from PMBOK
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:
  - Develop Plans of various types used in the Nuclear Industry, such as Work Plans, Project Execution Plans
  - Develop project schedules for small, medium, and large size projects.
  - Schedule inputs of manpower, materials, and other costs.
  - Discuss the role of software in executing plans.
  - Use Cost Performance Index and Schedule Performance Index
  - Use Project Reporting Methods
  - Interface with other Engineering Groups
  - Use the Concepts of Critical Path

Information about Course Designer/Developer:
Course designed by M. Bennett PhD, PEng, PMP, Faculty of Engineering and Applied Science.

Identify faculty to teach the course and/or statement "faculty to be hired": M. Bennett, PhD, PEng, PMP, Faculty of Engineering and Applied Science.
Faculty qualifications required to teach/supervise the course: PhD and PEng holding the PMP certification.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: NA

Course Title: NUCL 5020G – Mathematical Methods in Nuclear Applications

Prerequisite(s):

- **Course Description and Content Outline:** Numerical analysis is the study of computer algorithms developed to solve the problems of continuous mathematics. Students taking this course gain a foundation in approximation theory, functional analysis, and numerical linear algebra from which the practical algorithms of scientific computing are derived. A major goal of this course is to develop skills in analysing numerical algorithms in terms of their accuracy, stability, and computational complexity. Topics include best approximations, least squares problems (continuous, discrete, and weighted), eigenvalue problems, and iterative methods for systems of linear and nonlinear equations. Demonstrations and programming assignments are used to encourage the use of available software tools for the solution of modelling problems that arise in physical, biological, economic, or engineering applications.
- **Topics include:**
  - Mathematical preliminaries
    - Normed linear spaces & inner product spaces
    - Triangle & Cauchy-Schwarz inequalities
    - Orthogonality & projection operators
  - Approximation theory
    - Best approximations
    - Chebyschev approximation
    - Least squares problems (weighted, continuous, discrete)
    - Orthogonal functions and orthogonal polynomials
  - Eigenvalue problems
    - Schur & Jordan canonical form
    - Power method and inverse power method
    - Householder method
    - QR method and Gram-Schmidt factorisation
    - Singular value decomposition
  - Classical stationary iterative methods for linear systems
    - Jacobi, Gauss-Seidel, SOR
  - Krylov subspace methods for linear systems
    - Invariant subspaces, Krylov subspaces
    - Arnoldi decomposition and Lanczos algorithm
    - Method of conjugate gradients
  - Variants of Newton's method for systems of nonlinear equations
    - Fixed point iteration for nonlinear systems
    - Newton's method for systems
    - Quasi-Newton methods
    - Inexact Newton methods and Newton-Krylov methods
    - Homotopy & continuation methods
- **Length in Contact Hours: 3 hours/week, 3 credits**
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects

- **Literature:**
  E. Anderson, Z. Bai, C. Bischoff, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorenson. LAPACK Users' Guide (3rd Ed). SIAM, 1999
  J. Demmel. Applied Numerical Linear Algebra. SIAM, 1997
  W. Gautschi. Numerical Analysis: an introduction. Birkhauser, 1997
  N. Higham. Accuracy and Stability of Numerical Algorithms (2nd Ed). SIAM, 2002
  D. Kincaid and W. Cheney. Numerical Analysis: Mathematics of Scientific Computing (3rd ed). Brooks/Cole, 2001
  G. W. Stewart. Afternotes goes to Graduate School. SIAM, 1997
  L.N. Trefethen and D. Bau. Numerical Linear Algebra. SIAM, 1997.
- **Proposed textbook requirements:** A. Quarteroni, R. Sacco, F. Saleri. Numerical Mathematics. Springer, 2000
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Formulate approximation problems in a suitable linear space, e.g., a continuous or discrete least squares problem with or without weights.
  - Implement the solution of a least squares problem with either the QR algorithm or the SVD for the solution of the normal equations using LAPACK or a problem-solving environment.
  - Formulate eigenvalue problems suitable for applied computation.
  - Implement the solution of an eigenvalue problem with the power method, the inverse power method, Householder's algorithm or the QR algorithm using LAPACK or a problem-solving environment.
  - Formulate and implement a matrix-free matrix-vector product for use with a Krylov-subspace iteration given a sparse system of linear equations using LAPACK or a problem-solving environment.
  - Implement the iterative solution of a system of linear equations with classical stationary iterative methods or Krylov subspace methods using LAPACK or a problem-solving environment.
  - Formulate and implement a routine for the computation of the nonlinear residual given a system of nonlinear equations using LAPACK or a problem-solving environment.
  - Implement the solution of a system of nonlinear equations with Newton's method using LAPACK or a problem-solving environment.

Information about Course Designer/Developer:
Dhavide Aruliah, Ph.D Computer Science, Faculty of Science, UOIT.

Identify faculty to teach the course and/or statement "faculty to be hired":
Dhavide Aruliah, Ph.D., Greg Lewis, Ph.D., William Smith, Ph.D.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
Ph.D. in Mathematics or Computer Science with experience in numerical analysis.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: NA

Course Title: NUCL 5030G – Transport Theory

Prerequisite(s): Linear algebra, differential equations, vector calculus.

- **Course Description and Content Outline:** This course is a general introduction to transport theory. Continuous-medium transport and discrete-particle transport are presented in a unified manner through the use of the probability distribution function. Various types of transport problems are presented together with analytic solutions for the simpler problems that allow them. Approximate and numerical methods are also covered. This course is cross-listed with MCSC 6160G – Transport Theory.
- **Topics include:**
  - Particle distribution functions
  - Generic form of transport equation
  - Particle streaming
  - One-speed transport theory
  - Linear collision operators
  - The Boltzmann collision term
  - Diffusion theory
  - Hydrodynamic equations
  - Eigenvalue problems
  - Boundary value problems
  - Perturbation and variational approximation methods
  - Deterministic numerical methods
  - Monte Carlo simulations
- **Length in Contact Hours: 3 hours/week, 3 credits**
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Transport Theory
  J.J. Duderstadt & W.R. Martin
  John Wiley & Sons, 1979, ISBN 0-471-04492-XJ.
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Identify the general terms of the transport equation for particle fields as well as for continuous media.
  - Express the Boltzman equation and the hydrodynamic equations for various systems.
  - Solve the Boltzman equation analytically for simple configurations.
  - Express specific forms of the transport equations for different types of particles.
  - Differentiate between fixed-source and eigenvalue transport problems.
  - Derive the diffusion equation as a first-order angular approximation to the transport equation.
  - Solve the diffusion equation analytically for simple configurations.
  - Apply perturbation and/or variational approximate methods to solve the transport equation.
  - Formulate discretized versions of the transport equation using different discretization ethods.
  - Decide which discretization method is appropriate for a specific transport problem.
  - Utilize Monte Carlo simulations for otherwise intractable transport problems.

Information about Course Designer/Developer: Course designed by: E Nichita, Ph.D., School of Energy Systems and Nuclear Science.
Identify faculty to teach the course and/or statement "faculty to be hired": E. Nichita, Ph.D., E. Waller, Ph.D., PEng.
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: Ph.D. in Science or Engineering, with experience in teaching transport theory and numerical methods. .
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: NA

Course Title: NUCL 5040G – Monte Carlo Methods

Prerequisite(s): Undergraduate theory of ordinary and partial differential equations and introductory statistics

- **Course Description and Content Outline:** This course provides an introduction to simulation of stochastic processes using Monte Carlo methods. The emphasis of the course will be Monte Carlo solution to the Boltzmann transport equation, specifically for radiation transport. Other applications of Monte Carlo analysis will be introduced to include, but not be limited to, molecular dynamics, statistical physics, biophysics, and queuing theory. Concepts presented will include pseudo-random number and random variate generation, direct simulation of physical processes, Monte Carlo integration and variance reduction, detector response and estimators, and Monte Carlo optimization. This course is cross-listed with MCSC 6165G – Monte Carlo Methods.

- **Topics include:**
  - Random number generation
  - Monte Carlo integration
  - Variance reduction techniques
  - Linear equations and Markov chains
  - Stochastic Optimization
  - Sensitivity analysis
  - Modelling of physical processes
  - Collision density and importance equations
  - Moment equations
  - Game playing
  - Applications
- **Length in Contact Hours: 3 hours/week, 3 credits**
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**

R. Rubinstein and B. Melamed, Modern Simulation and Modelling, Wiley, Toronto, 1998.

- **Representative Texts:**
  - R. Rubinstein, Simulation and the Monte Carlo Method, Wiley and Sons, Toronto, 1981.
  - R. Rubinstein, Monte Carlo Optimization, Simulation, and Sensitivity of Queueing Networks, Wiley and Sons, Toronto, 1986.
  - I. Lux and L. Koblinger, Monte Carlo Particle Transport Methods: Neutron and Photon Calculations, CRC Press, Boston, 1990.
  - E. Lewis and W. Miller, Computational Methods of Neutron Transport, ANS Publications, Illinois, 1993.
  - C. Cassandras and S. Lafortune, Introduction to Discrete Event Systems, Kluwer, Boston, 1999.
  - A. Gosavi, Simulation-Based Optimization: Parametric Optimization Techniques and Reinforcement Learning, Kluwer, Boston, 2003.
  - A. Law and W. Kelton, Simulation Modelling and Analysis (3rd ed.), McGraw-Hill, New York, 2000.

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Generate stochastic forms of physical equations, with emphasis on radiation transport theorems.
  - Apply various random sampling schemes to Monte Carlo problems.
  - Understand the application of the central limit theorem to Monte Carlo analysis.
  - Understand the limitations and applications of random number generators, with emphasis on congruential generators.
  - Apply statistical tests on pseudorandom numbers, such as Chi-square goodness of fit, Kolmogorov-Smirnov goodness of fit, Cramer von Mises goodness of fit, serial tests, run up/down tests, gap tests, and maximum tests.
  - Generate random variates using the inverse transform method, composition method, acceptance-rejection method, random vector simulation, continuous distributions and discrete distributions.
  - Applications of random sampling physical processes related to radiation transport, including photon energy selection from the Klein-Nishina formula, thermal neutron energy selection, Fission neutron energy selection and anisotropic scattering angle selection.
  - Apply Monte Carlo techniques to solution of differential and integral problems.
  - Apply variance reduction techniques to solution sampling and scoring.
  - Apply collision density and importance equations to Monte Carlo problems.
  - Understand principles of application of adjoint Monte Carlo
  - Generate moment equations in both non-multiplying and multiplying games.
  - Understand how special games can be applied to Monte Carlo analysis to improve solution convergence. Some examples include next-event estimation and perturbation analysis.

Information about Course Designer/Developer: Ed Waller, Ph.D., P.Eng. School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Ed Waller, Ph.D., P.Eng.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in Physics, Mathematics or Engineering with experience in Monte Carlo Simulation.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: See Classroom requirements; access to parallel computing facilities.

Course Title: NUCL 5050G – Applied Risk Analysis

Prerequisite(s): none

- **Course Description and Content Outline:** This course presents principles and methods for assessing and managing technological risks. The following subjects will be covered: probability theory; failure rates; availability; reliability; test frequencies; dormant and active systems; initiating events; fault trees and event trees; dual failures; defense in depth; principle of control, cool, contain; accident prevention, mitigation and accommodation; separation and independence; redundancy; common mode events; safety culture; safety analysis techniques; inherent safety features; plant safety systems; probability evaluation for simple systems; quantitative and probabilistic safety assessment; calculation of frequency and consequences of power plant accidents; risk-based decision making; and risk-based regulation. Applications include aerospace, energy, and nuclear systems safety analysis.
- **Topics include:**
  - Probability theory
  - Modeling of uncertainty
  - Parameter estimation
  - Reliability and availability
  - Fault tree and event tree analysis
  - Common Mode Failures
  - Probabilistic Safety Assessment
  - Risk-based decision making
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  H. Kumamoto and E. J. Henley, Probabilistic Risk Assessment and Management for Engineers and Scientists. New York: IEEE Press, 1996.
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Understand probabilistic risk assessment methodology
  - Apply fault tree and event tree for risk analysis
  - Understand risk-informed decision making
  - Apply risk-informed decision making for maintenance or design
  - Use related software to perform reliability and safety assessment
  - Calculate uncertainty in the calculated risk level
  - Simulate failure propagation

Information about Course Designer/Developer:

Course designed by: L. Lu, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement “faculty to be hired”:

Dr. L. Lu.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD in engineering, science or mathematics, with experience in applying safety analysis in nuclear power plants or related systems.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: none

Course Title: NUCL 5060G Nuclear Concepts for Engineers and Scientists

Prerequisite(s): differential equations, partial differential equations, vector calculus

- **Course Description and Content Outline:** The course is a fast introduction to atomic, nuclear and reactor physics for graduate students without an adequate background in these areas. Topics covered include nuclear structure, radioactivity, interaction of radiation with matter, neutron flux, neutron diffusion, nuclear reactors, reactor kinetics.
- **Topics include:**
  - Nuclear structure
  - Radioactivity
  - Nuclear reactions
  - Interaction of radiation with matter
  - Radiation detection
  - Radiation dose and protection.
  - Nuclear fission as used for power production
  - Nuclear reactors
  - Basic quantities and methods used to describe the behaviour of neutrons in a nuclear reactor.
  - Neutron diffusion equation
  - Methods of solution for the neutron diffusion equation.
  - Criticality
  - Reactor kinetics
  - Elementary solution methods for reactor kinetics.
  - Fission product poisoning
- **Length in Contact Hours: 3 hours/week, 3 credits**
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Introduction to Nuclear Engineering (third edition)
  J.R. Lamarsh & A.J. Baratta
  Prentice-Hall, 2001
  ISBN: 0-201-82498-1
- **Representative Texts:**
  Fundamentals of Nuclear Science and Engineering
  CRC; 1 edition (July 24, 2002)
  Language: English
  ISBN-10: 0824708342
  ISBN-13: 978-0824708344
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Understand the structure of the atom and the main components of the nucleus.
  - Find isotopes on the Table of Nuclei, and identify the nature of radioactive decay (if any) of a given isotope.
  - Describe the main differences between alpha, beta and gamma decay
  - Understand the concept of binding energy and how nuclei of different binding energies may undergo fission or fusion.
  - Compute the energy released in fission or fusion reactions.

- Describe the way different types of radiation interact with matter.
- Name the main radiation detector types and describe their functioning.
- Define radiation dose and the basic principles of radiation protection.
- Understand the concept of chain reaction and each component of the four (six)-factor formula.
- Formulate the neutron diffusion equation.
- Solve the static diffusion equation for simple geometries.
- Find the effective multiplication constant and flux shape in simple-geometry homogeneous reactors.
- Formulate the point kinetics equations.
- Solve approximately the point kinetics equations.
- Describe fission-product poisoning (Xe, Sm)

Information about Course Designer/Developer:
Course designed by: E. Nichita, Ph.D., School of Energy Systems and Nuclear Science.

Identify faculty to teach the course and/or statement "faculty to be hired":

Dr. E. Nichita, Dr. E. Waller.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:

Ph.D. in engineering or physics with experience in teaching nuclear physics.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: NA

Course Title: NUCL 5070G – Environmental Modeling

Prerequisite: undergraduate courses in physics, chemistry, differential equations, and statistics. A working knowledge of MS EXCEL is required.

- **Course Description and Content Outline:** The transport of pollutants through the total environment depends upon complex interactions between the atmosphere, geosphere and hydrosphere. Understanding the details of pollutant transport between source, environmental compartments and receptors allow for determination of potential dose, and thereby estimation of risk. This course explores the fundamental theory, equations and solutions to standard environmental transport models (with emphasis on radiolonuclide transport). In addition, this course introduces the student to the RESRAD codes for environmental modeling.
- **Topics include:**
  - Pollutants in the environment
  - The total environment
  - Concepts of environmental modeling
  - Processing and visualization of environmental data
  - Human-Environment interactions
  - Population Dynamics
  - Atmospheric dispersion models
  - Terrestrial transport models
  - Hydrological transport models
  - Biofeedback
  - Human receptor models
  - Non-human biota models
  - Dose construction and reconstruction
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week. Tutorial sessions (involving the RESRAD modeling code and/or Excel) will be conducted every second week.
- **Student Evaluation:** Assignments, Exams, Modeling Project
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**
  J. Hardisty, D. M. Taylor, S. E. Metcalfe, Computerised Environmental Modelling: A Practical Introduction Using Excel, Wiley, 1993
  or
  J. Wainwright and M. Mulligan, Environmental Modelling: Finding Simplicity in Complexity, Wiley, 2004.
  J.E. Lovelock, Gaia, Oxford Paperbacks, Oxford, 2000
  Custom Handouts
- **Literature:**
  - M. Eisenbud and T. Gesell, Environmental Radioactivity – From Natural, Industrial and Military Sources, 4th Edition, Academic Press, 1997
  - J. Cooper, K. Randle and R. Sokhi, Radioactive Releases in the Environment: Impact and Assessment, Wiley, 2003
  - D. Alstad, Basic Populus Models of Ecology, Prentice Hall, 2001
  - G.S. Campbell and J.M. Norman, An Introduction to Environmental Biophysics, Springer, 1998
  - R.J. Charbeneau, Groundwater Hydraulics and Pollutant Transport, Prentice Hall, 2000
  - D. Moeller, Environmental Health, Harvard, 1992
  - R.J. Chorley and P. Haggett (eds.), Models in Geography, Methuen, 1967

- M.J. Kirkby, P.S. Naden, T.P. Burt, and D.P. Butcher, Computer Simulation in Physical Geography, Second Edition, John Wiley, 1992
- N. Ostler (ed), Introduction to Environmental Technology, Prentice Hall, 1996

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:

Outcome 1: Analyze the sources of pollutants (esp. radionuclides) in the environment.
Outcome 2: Understand how various environmental compartments interact when transporting pollutants
Outcome 3: Analyse and utilize atmospheric, terrestrial and hydrological transport models
Outcome 4: Predict source-receptor relationships using environmental transport models
Outcome 5: Discuss population dynamics as related to environmental modeling
Outcome 6: Determine dose and risk to human and non-human biota
Outcome 7: Explain complex facets of the total environment to the public

Information About Course Designer/Developer:

Course designed by: E. Waller, PhD, PEng, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":

Dr. E. Waller.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:

PhD degree in Physics, Chemistry, Geography or Engineering

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: n/a

Course Title: NUCL 5080G – Advanced Topics in Environmental Degradation of Materials

Prerequisite(s): undergraduate course in corrosion

- **Course Description and Content Outline:** Predicting the corrosion performance-lifetime of components is an ongoing area of interest in maintaining nuclear power plants. Unexpected or premature degradation of components often occurs by localized corrosion processes such as pitting, crevice, or stress-assisted corrosion. In this course, we will examine current theories of various localized corrosion mechanisms, current practices for measuring and identifying corrosion processes, models and methodologies for predicting the occurrence of localized corrosion, and the application of this knowledge to specific aspects of the nuclear fuel cycle.

- **Topics include:**
  - Initiation, propagation, repassivation, and cessation of localized corrosion processes
  - Pitting and Crevice corrosion
  - Stress corrosion cracking
  - Hydrogen assisted cracking
  - Radiation and radiolysis effects on corrosion
  - Passivity
  - Effect of metal structure, composition, and treatment
  - Corrosion measurements at elevated temperature
  - Lifetime prediction models

- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** N/A

- **Representative Texts:**

"Electrochemical Techniques in Corrosion Science and Engineering", Robert G. Kelly, John R. Scully, David Shoesmith, and Rudolph G. Buchheit, 2002)

"Corrosion Mechanisms in Theory and Practice", Second Edition, Philippe Marcus (Ed)

"Pitting and Crevice Corrosion", Z. Szklarska-Smialowska

"Prediction of Long Term Corrosion Behavior in Nuclear Waste Systems" (EFC 36), D. Féron and Digby D. Macdonald (Eds)

"Control of Corrosion on the Secondary Side of Steam Generators", R. Staehle (Ed)

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - understand the basic processes for initiation, propagation, and cessation of localized corrosion processes and their damage consequences
  - predict the conditions for which localized corrosion could occur, could be accelerated, or could be stifled
  - determine reasonable chemistry control required for minimizing localized corrosion
  - determine methodologies for identifying corrosion processes and measuring their rate
  - use appropriate judgment for specifying material requirements

- use appropriate models to predict lifetime performance of components

Information about Course Designer/Developer:
Course designed by: B.M. Ikeda, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. B.M. Ikeda

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in engineering or science with experience in teaching and research in the corrosion of materials.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: none

Course Title: NUCL 5090G – Occupational Health and Safety

Prerequisite: N/A

- **Course Description and Content Outline:** This course explores the often neglected, although highly important, subject of occupational health and safety as it relates to industrial operations and complex processes. Concepts such as hazard avoidance, health and environmental control, machine guarding, electrical hazards and process safety will be discussed. In addition, management and institutional controls for workplace safety will be considered, such as communicating vital information, pre-task briefings and shift turnovers. Case studies and lessons learned from numerous industrial and manufacturing industry accidents will be used to highlight important information. Pre-requisites: Undergraduate courses in physics, differential equations, and statistics.
- **Topics include:**
  - Why Accidents Happen, or, The Nature of Industrial Failure
    - Analysis of Major Technological Disasters
    - Occupational Health and Safety Statistics
  - Common Accident Modes
  - Concepts of Hazard Avoidance
    - Enforcement
    - Psychological
    - Engineering
    - Analytical
  - Manufacturing and Industry Topics
    - Buildings & Facilities
    - Toxic Substances
    - Ventilation and Air Quality
    - Noise
    - Flammables and Explosives
    - Personal Protection
    - Fire Protection
    - Materials Handling & Storage
    - Transportation of Dangerous Goods
    - Machine Guarding
    - Welding
    - Electrical Hazards
    - Construction
    - Ionizing Radiation
    - Non-Ionizing Radiation
    - Temperature
    - Ergonomics
    - Management
  - Industrial process safety strategies
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Project
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**
  C. Ray Asfahl, Industrial Safety and Health Management, Prentice-Hall, 1999.
  Custom Handouts
- **Literature:**
  H.C. Howlett II, The Industrial Operator's Handbook, Techstar, 1995.
  R. Scott, Basic Concepts of Industrial Hygiene, Lewis, 1997.
  J. Looker, Disaster Canada, Lynx, 2000.
  J.G. Marone and E. J. Woodhouse, Averting Catastrophe, Uni of California, 1986
  Health and Safety Acts of Ontario and Canada.

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  Outcome 1: understand the nature of industrial failure
  Outcome 2: analyze occupational health and safety statistics
  Outcome 3: discuss common accident modes and relate to institutional failure
  Outcome 4: understand, analyze and design hazard avoidance strategies
  Outcome 5: understand the health and safety concepts of machine guarding, welding, electrical systems and construction
  Outcome 6: understand the health and safety concepts of toxic substances, materials handling and storage and transportation of dangerous goods
  Outcome 7: understand the health and safety concepts of ionizing and non-ionizing radiation
  Outcome 8: understand the health and safety concepts of building health, ventilation, air quality, noise control and temperature
  Outcome 9: understand the health and safety concepts of ergonomics and safety management
  Outcome 10: determine process strategies for industrial safety

Information About Course Designer/Developer:
Course designed by faculty eligible to teach this course: E. Waller, PhD, PEng, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. E. Waller, Dr. D. Gorman

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD degree in Physics or Engineering with experience in occupational health, safety, or industrial hygiene

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: n/a

Course Title: NUCL 5200G – Reactor Physics

Prerequisite(s): undergraduate courses in linear algebra, differential equations, vector calculus

- **Course Description and Content Outline:** The course is a graduate-level treatment of reactor physics, with emphasis on reactor statics. Topics covered include: static neutron balance equations, neutron slowing down, resonance absorption, multigroup transport and diffusion equations, homogenization methods and variational methods. Lattice and full-core numerical methods are also covered.
- **Topics include:**
  - Static Neutron Balance Equations
  - Fundamental Neutronic Problems (Fixed Source and Eigenvalue)
  - Space-Energy Separation of Variables
  - Multigroup Separation of Variables
  - Flux Shape in Homogeneous Reactors
  - One-Group Source Problems in Infinite Media
  - Neutron Slowing Down with Resonance Absorption
  - Neutron Transport
  - Multigroup Diffusion
  - Numerical Methods for Multigroup Diffusion
  - Homogenization Methods and Equivalence Theory
  - Lattice vs. Core Calculations
  - Variational and Modal Methods for Static Problems
  - Static Computer Codes
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Proposed textbook:**

Nuclear Reactor Analysis
James J. Duderstat & Louis J. Hamilton
ISBN: 0471223638

- **Representative Texts:**

Nuclear Reactor Physics
Weston M. Stacey
Wiley-Interscience, 2001
ISBN: 0-471-39127-1

Nuclear Reactor Analysis
J.J. Dudderstadt & L.J. Hamilton
John Wiley & Sons, 1976
ISBN: 0-471-22363-8

Introductory Nuclear Reactor Statics
Karl O. Ott & Winfred A. Bezella
American Nuclear Society, 1989
ISBN: 0-89448-033-2

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Write the Boltzmann equation and explain its main terms.
  - Differentiate between fixed-source and eigenvalue problems.
  - Solve the Boltzmann equation analytically for simple configurations.
  - Derive the diffusion equation as a first-order angular approximation to the transport equation.
  - Solve the diffusion equation analytically for simple configurations.
  - Understand neutron slowing down with and without resonance absorption.
  - Understand the application of the finite-difference, finite element and nodal methods to the solution of the multigroup diffusion equation.
  - Understand the use of the discrete-ordinate and collision-probability methods to the solution of the multigroup transport equation.
  - Apply equivalence theory to find multigroup homogenized cross sections.
  - Understand the basis of applying variational methods to reactor physics problems.

Information about Course Designer/Developer:
Course designed by: E. Nichita PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. E. Nichita, Dr. E. Waller

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics and experience in teaching reactor/radiation physics and numerical methods.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: not applicable

Course Title: NUCL 5210G – Advanced Reactor Physics

Prerequisite(s): NUCL 5200G – Reactor Physics

- **Course Description and Content Outline:** The course is a graduate-level treatment of reactor physics, with emphasis on reactor dynamics. Topics covered include: point kinetics, space-time kinetics, perturbation and generalized perturbation theory, fuel depletion, fission-product poisoning, elements of reactor control.
- **Topics include:**
  - Time-Dependent Phenomena in Nuclear Reactors
  - Prompt and Delayed Neutrons
  - Point Kinetics Equations
  - Perturbation Theory
  - Approximate Solutions of the Point Kinetics Equations
  - Measurement of Reactivity
  - Fission Product Poisoning – Xe Oscillations
  - Fuel Depletion
  - Space-Time Reactor Kinetics
  - Numerical Methods for Space-Time Reactor Kinetics
  - Elements of Reactor Control
  - Kinetics Codes
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Nuclear Reactor Analysis
  James J. Duderstat & Louis J. Hamilton
  ISBN: 0471223638
- **Representative Texts:**

Nuclear Reactor Physics
Weston M. Stacey
Wiley-Interscience, 2001
ISBN: 0-471-39127-1

Nuclear Reactor Analysis
J.J. Dudderstadt & L.J. Hamilton
John Wiley & Sons, 1976
ISBN: 0-471-22363-8

Introductory Nuclear Reactor Dynamics
Karl O. Ott & Robert A. Neuhold
American Nuclear Society
ISBN: 0-89448-029-4

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Write and solve the point kinetics equation and explain its main terms.
  - Solve approximately the point kinetics equations.
  - Use (generalized) perturbation theory to calculate reactivity.

- Describe static and dynamic reactivity measurement methods.
- Understand Space-Time Kinetics and Write the Space-Time Kinetics Equations in Diffusion or Transport Form
- Understand Solution Methods for Space-Time Kinetics in Diffusion
- Understand Fuel Depletion
- Understand Fission Product Poisoning and Xe Poisoning
- Write Xe Kinetics Equations and Solve Them for Simple Cases

Information about Course Designer/Developer:
Course designed by: E. Nichita PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. E. Nichita, Dr. E. Waller

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics and experience in teaching reactor/radiation physics and numerical methods.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: not applicable

Course Title: NUCL 5215G – Advanced Nuclear Engineering

Pre-requisites: Courses in linear algebra, differential equations, vector calculus.

- **Course Description and Content Outline:** The course is comprised of advanced topics in nuclear engineering, with emphasis on reactor physics. Topics covered include neutron slowing down, resonance absorption, multigroup transport and diffusion equations, reactor kinetics, and homogenization methods. Lattice and full-core numerical methods are also covered. This course is cross-listed with ENGR 5180 Advanced Nuclear Engineering
  - **Topics include:**
    - Neutronic Nuclear Reactions
    - Multigroup Neutron Diffusion
    - Numerical Methods for the Steady-State Multigroup Diffusion Equation
    - Neutron Transport Equation
    - Numerical Methods for the Steady-State Multigroup Transport Equation
    - Reactor Kinetics
    - Numerical Methods for the Space-Time-Dependent Multigroup Diffusion Equation
    - Generation of Multigroup Cross Sections
    - Homogenization (Equivalence Theory)
    - Perturbation Theory
    - Variational Methods
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**

  Stacey, W. M., 2001, *Nuclear Reactor Physics*, Wiley-Interscience.
- **Literature:**
  Stacey, W. M., 2001, *Nuclear Reactor Physics*, Wiley-Interscience.
  Duddwrstadt, J. J. and Hamilton, L. J., 1976, *Nuclear Reactor Analysis*, John Wiley & Sons.
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  Outcome 1: write the Boltzmann equation and explain its main terms.
  Outcome 2: solve the Boltzmann equation analytically for simple configurations.
  Outcome 3: differentiate between fixed-source and eigenvalue transport problems.
  Outcome 4: derive the diffusion equation as a first-order angular approximation to the transport equation.
  Outcome 5: solve the diffusion equation analytically for simple configurations.
  Outcome 6: understand the application of the finite-difference, finite element and nodal methods to the solution of the multigroup diffusion equation.
  Outcome 7: understand the use of the discrete-ordinate and collision-probability methods to the solution of the multigroup transport equation
  Outcome 8: apply equivalence theory to find multigroup homogenized cross sections.
  Outcome 9: derive the point-kinetics equations with six delayed neutron groups.
  Outcome 10: apply approximate solution methods to the point-kinetics equations.
  Outcome 11: understand the application of finite-difference and modal methods to the solution of space-time kinetics problems.
  Outcome 12: understand the basis of applying perturbation and/or variational methods to reactor physics problems.

Information About Course Designer/Developer: Course designed by faculty eligible to teach this course: E. Nichita, PhD, School of Energy Systems and Nuclear Science
Identify faculty to teach the course and/or statement "faculty to be hired": Dr. E. Nichita and Dr. E. Waller
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD in Science or Engineering, with experience in teaching reactor/radiation physics and numerical methods.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: None

Course Title: NUCL 5220G – Fuel Management in Nuclear Reactors

Prerequisite(s): knowledge of reactor physics at the undergraduate level is recommended

- **Course Description and Content Outline:** Nuclear fuel cycles are studied from mining to ultimate disposal of the spent fuel, including the enrichment processes and the reprocessing techniques, from a point of view of the decision-making processes and the evaluation of the operational and economical consequences of these decisions. For the steps within the fuel cycles, the method of determining the associated costs, in particular those relevant to the disposal of nuclear waste, and the overall fuel cycle costs are described. Burn-up calculations are performed for the swelling time of the fuel within the reactor core. The objectives and merits of in-core and out-of-core fuel management for CANDU Pressurized Heavy Water Reactors (PHWR) and Light Water Reactors (LWR) are analyzed in detail, for the refueling equilibrium as well as for the approach to refueling equilibrium. The course also covers fuel management for thorium-fuelled CANDU reactors and other advanced fuels such as MOX containing plutonium from discarded nuclear warheads, and DUPIC (Direct Use of PWR fuel in CANDU reactors). The fuel management problem is treated as an optimization problem, with objective functions or performance indexes identified, as well as decision variables and appropriate constraints (active and non-active). The course also includes a review of the major work done in this area along with the most important computer codes.
- **Topics include:**
  - Nuclear Fuel mining operations
  - Fuel processing
  - Fuel Enrichment
  - Fuel Transport
  - Fuel Design Concepts
  - Advanced Fuels: MOX Fuel, SEU Fuel, LVRF Fuel
  - Refuelling methods
  - Burnup Optimizarion
  - On-Site Storage of Used Fuel
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** Course Notes.
- **Representative Texts:** Literature Surveys (Journal Papers, Conference Proceedings)
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Explain the nuclear fuel cycle from source to final disposal.
  - Explain the various methods of enrichment
  - Demonstrate knowledge of design constraints on nuclear fuel
  - Discuss the relative merits of advanced fuels

Information about Course Designer/Developer:
Course designed by: G. Harvel, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Faculty to be hired.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD in nuclear engineering or physics with experience in reactor fuels.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: not applicable

Course Title: NUCL 5230G – Advanced Nuclear Thermalhydraulics

Prerequisite(s):undergraduate courses in fluid mechanics and heat transfer

- **Course Description and Content Outline:** This course expands on the importance of thermalhdyraulics in Nuclear Power Plant Design, Operation and Safety. Thermalhydraulic problems and solutions relevant to Nuclear Power Plants and Nuclear Research Reactors will be discussed. The course will discuss in detail Mass, Momentum, and Energy Equations and discuss various numerical techniques for solving these equations especially for applications to two-phase flow. Boiling, condensation, cavitation and waterhammer problems will be discussed. Special topics of recent interest such as Impact of Ageing Phenomena and Application of Electrohydrodynamic and Magnetohydrodynamic forces will be presented.
- **Topics include:**
    - Mass, Momentum, and Energy Equations for Thermalhydraulic Applications
    - Two-Phase Flow Phenomena: Flow regime, void fraction, phase velocity, Interfacial Area
    - Homogeneous, Separated flows, drift flux, and two-fluid models
    - Boiling, Condensation, Dryout Phenomena
    - Nuclear Fuel Heat Transfer
    - Heat Transport Systems
    - Cavitation, Waterhammer, and Unique Accidents
    - Engineered Safety Systems
    - Ageing Mechanisms
    - EHD and MHD Forces
- **Length in Contact Hours:** Lectures 3 hours/week, 4 Lab sessions (experimental and numerical) 3 credits
- **Delivery Mode and Teaching Method(s):** Lecture and Laboratory.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**

No specific textbook. Students will be required to perform literature searches in texts, handbooks, and journal papers.

- **Representative Texts:**

Not Required

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
    - identify the fundamental phenomena in multi-phase flow
    - build their own numerical models of thermalhydraulic systems
    - identify Nuclear Thermalhydrualic Systems and Designs
    - design Safety Systems for Thermalhydraulic Phenomena
    - identify ageing phenomena
    - understand how EHD and MHD forces affect two-phase flow
    - be knowledgeable of the current state of the art of Nuclear Thermalhydraulic Design

Information about Course Designer/Developer: Glenn Harvel, Ph.D., P.Eng., School of Energy Systems and Nuclear Science.

Identify faculty to teach the course and/or statement “faculty to be hired”:

Glenn Harvel, Ph.D., P. Eng.; Igor Pioro, Ph.D,

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: Ph.D. in Science or Engineering, with adequate background in thermalhydraulics, nuclear design, ageing phenomena, numerical modelling and multi-phase flow.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: Nuclear Design Laboratories, with some or all of the following equipment: 1. A two-phase thermalhydraulic loop for natural circulation experiments. 2. Access to FLUENT code for numerical modelling problems 3. A two-phase once through loop for force flow experiments. 4. Nuclear Industrial code such as CATHENA or TUF or ASSERT.

Course Title: NUCL 5240G – Heat Transfer in Nuclear Reactor Applications

Prerequisite(s): undergraduate course in heat transfer

- **Course Description and Content Outline:**

  This course will discuss advance heat transfer phenomena related to Nuclear Reactors in both current and future designs.

- **Topics include:**
  - Heat transfer phenomena (Conduction, convection, radiation)
  - Boiling and Condensation phenomena
  - Critical Heat Flux and Boiling Crisis
  - Supercritical fluids
  - Correlations for heat transfer at high pressure and high temperature
  - Advanced numerical methods
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Course notes.
- **Representative Texts:**

  Incropera, F.P. and DeWitt, D.P., 2004. Fundamentals of Heat and Mass Transfer", 5th edition, J. Wiley and Sons;

  Lahey, R.T., Jr. and Moody, F.J., 1993. The Thermal-Hydraulics of a Boiling Water Nuclear Reactor, 2nd Edition, American Nuclear Society, La Grange Park, IL, USA, 631 pages.

  Tong, L.S. and Weisman, J., 1996. Thermal Analysis of Pressurized Water Reactors, 3rd Edition, American Nuclear Society, La Grange Park, IL, USA, 748 pages.

  Collier, J.G. and Thome, J.R., 1996. Convective Boiling and Condensation, 3rd Edition, Clarendon Press, Oxford, UK, 631 pages.

  Levy, S., 1999. Two-Phase Flow in Complex Systems, J. Wiley & Sons, New York, NY, USA, 425 pages.

  Tong, L.S. and Tang, Y.S., 1997. Boiling Heat Transfer and Two-Phase Flow, 2nd Edition, Taylor & Francis, Washington, D.C., USA, 542 pages.

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Model the heat transfer of Nuclear Fuel and Nuclear heat Exchangers
  - Knowledge of supercritical reactor designs

Information about Course Designer/Developer:
Course designed by: I. Pioro, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. I. Pioro, Dr. G. Harvel.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course: PhD in nuclear engineering or physics with experience in teaching reactor heat transfer.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: none

Course Title: NUCL 5250G – Power Plant Thermodynamics

Prerequisite(s): undergraduate course in thermodynamics

- **Course Description and Content Outline:** This course presents the theoretical and practical analysis of the following with particular reference to CANDU plants.
  - Thermodynamic Cycles: Nuclear versus conventional steam cycles, regenerative feedwater heating, moisture separation and reheating, turbine expansion lines, heat balance diagrams, available energy, cycle efficiency and exergy analysis.
  - Nuclear Heat Removal: Heat conduction and convection in fuel rods and heat exchanger tubes, heat transfer in boilers and condensers, boiler influence on heat transport system, boiler swelling and shrinking, boiler level control, condenser performance.
  - Steam Turbine Operation: Turbine configuration, impulse and reaction blading, blade velocity diagrams, turbine seals and sealing systems, moisture in turbines, part load operation, back pressure effects, thermal effects and turbine governing.
- **Topics include:**
  - Balance of Plant Systems such as Main Steam Supply
  - High and Low Pressure Turbines
  - Condensers, Reheaters, Moisture Separators, and Feedwater Systems
  - Wet Steam and Gas Turbines
  - Turbine efficiency and design
  - Design optimization of Balance of Plant
  - Balance of Plant matching to Nuclear Steam Supply
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Course notes
- **Representative Texts:**
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Explain the detailed workings of a Balance of Plant Cycle.
  - Understand the design, operation, and ageing issues of a steam or gas turbine.
  - Perform conceptual design of Balance of Plant systems that support a steam or gas turbine.

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
I. Pioro, PhD., G. Harvel, PhD.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course: PhD in nuclear engineering or physics with experience in reactor thermalhydraulics
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: none

Course Title: NUCL 5260G – Reactor Containment Systems

Prerequisite(s): undergraduate course in thermodynamics

- Course Description and Content Outline: This course covers the design and main operating features of nuclear reactor containment systems, considering both normal and accident conditions. The course includes definition and purpose of containment, design requirements and considerations, a survey of containment designs in actual use and the use of simulation for safety analysis and design.

- **Topics include:**
  - hydrogen, radionuclides and severe accidents
  - overview of negative pressure containment
  - reactor building and dousing system
  - ventilation, cooling and vapour recovery
  - efads and connections between containment volumes
  - operational perspective
  - thermodynamics of air-vapour mixtures
  - closed vessel model
  - perfect gas in a closed vessel
  - steam thermodynamics
  - steam and air
  - modelling containment:
    - air coolers and heat sources
    - walls and structures
    - flow modelling
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be provided to the students:** course notes
- **Representative Texts:** course notes
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Define the objectives of containment
  - Specify the requirements for containment design
  - Use methods by which containment designs achieve these objectives
  - Describe the main components of a containment system
  - Allow for the influence of hydrogen, radionuclides and core meltdown on containment design
  - Approximate magnitudes of containment parameters
  - Describes trends in containment design
  - Perform specific containment designs
  - Implement a detailed realization of the CANDU containment design
  - Model the behaviour of thermodynamics of steam-air mixtures
  - Use mathematical techniques for modelling containment system features

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired": Faculty to be hired.
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD in engineering or physics with experience in the design of reactor containment systems.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: none

Course Title: NUCL 5270G – Control, Instrumentation and Electrical Systems in CANDU based Nuclear Power Plants

Prerequisite(s): undergraduate course in

- **Course Description and Content Outline:** This course covers the basic control, instrumentation and electrical systems commonly found in CANDU based nuclear power plants. The course starts with an overall view of the dynamics associated with different parts of the plant, i.e. reactor, heat transport systems, moderator, steam generator, turbine, and electrical generator. Based on such knowledge, the control and regulation functions in the above systems are then defined. Different instrumentation and measurement techniques are examined, along with control strategies. The time and frequency domain performance characterizations of control loops are introduced with consideration of actuator and sensor limitations. Different controller design and tuning methods and instrumentation calibration procedures are discussed. Two modes of operation of CANDU plants will be analyzed, i.e. normal mode and alternate mode. Advanced control technologies, such as distributed control systems, field bus communication protocols are introduced in view of their potential applications in the existing and newly constructed CANDU power plants. The electric systems in the CANDU plant will be examined. The modeling of the dynamics and control devices for the generator will be covered in detail. The dynamic interaction between the power plants and the rest of the electric power grid with other generating facilities and various types of loads will be studied.
- **Topics include:**
    - Review of Basic Concepts of Feedback Control and Regulation
    - Modeling of Major Dynamic Processes in a Nuclear Power Plant
    - Control/Regulation of Dynamic Processes
    - Control System Synthesis, Controller Tuning, and Simulation
    - Electrical Systems in a Nuclear Power Plant
    - Modern Control Systems with Potential Applications
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students: none**
- **Representative Texts:** handouts will be provided

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng. SESNS

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. L. Lu, Dr. G. Bereznai

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in CANDU electrical. Instrumentation and control systems.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: none

Course Title: NUCL 5280G – Advanced Reactor Control

Prerequisite(s): undergraduate course in control theory

- **Course Description and Content Outline:** This course presents the state-variable approach and the application of various state-space techniques to reactor dynamics and control. Topics include: state variables and the concept of the system state; stability in the state space; various definitions of stability; the second method of Liapunov; stability of nuclear systems; centralized versus distributed control; analogue and digital control; hardware and software; licensing requirements; computers in shutdown systems; and applying the principles of separation, diversity, redundancy.
- **Topics include:**
  - State-space representation of a system
  - Stability analysis in the state space
  - Liapunov stability of nuclear systems
  - Distributed control
  - Digital control
  - Safety protection systems
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  L. E. Weaver, Reactor Dynamics and Control, American Elseviewer Publishing Company, Inc., New York, 1968.
- **Representative Texts:** as above
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Understand modern control theory
  - Apply modern control theory to reactor control analysis
  - Understand advanced control techniques
  - Design advanced control systems for nuclear power plants
  - Understand stability
  - Apply stability analysis techniques to reactor control

Information about Course Designer/Developer:
Course designed by: L. Lu, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
L. Lu, Ph.D.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in engineering, science or mathematics, with experience in modern control systems

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access. **Equipment requirements:** none

Course Title: NUCL 5290G – Advances in Nuclear Power Plant Systems

Prerequisite: undergraduate course in nuclear power plant systems

- **Course Description and Content Outline:** A combination of lectures, self-paced interactive CD-ROM study and the use of power plant simulators imparts to students the advances in the key design and operating features of the main nuclear power plan types, including reactors using pressure vessels and pressure tubes, pressurized water, boiling water and gas cooled reactors; the use of natural versus enriched fuel, converters and breeders; overall plant control systems, load following capabilities, islanding operations; safety systems, responses to abnormal and emergency events. Nuclear plant simulators will be used throughout the course.
- **Content Outline by Topics**
  - Introduction to the key design & operating features of the main nuclear power plan types
  - Advances in the design features of reactors using pressure vessels and pressure tubes
  - Operating characteristics of pressurized water, boiling water and gas cooled reactors
  - Use of natural versus enriched fuel – design and operating aspects
  - Design of reactors that are fuel converters or breeders
  - Overall plant control systems and load following capabilities of the various reactor types
  - Frequency and voltage control under islanding operations
  - Evolution of safety system design
  - Simulated responses to abnormal and emergency events in real time
- **Delivery Mode and Teaching Method:** 3 hours of class lectures per week
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects.
- **Textbook requirements:** Course pack available from International Atomic Energy Agency.
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: specify the desired operating characteristics of a nuclear-electric generating unit to meet electric power system requirements.

  Outcome 2: define the key design parameters for pressurized or boiling water reactors, and the criteria for selecting light or heavy water as coolant and/or moderator.

  Outcome 3: demonstrate, using real time simulators, the normal operation of nuclear-electric power plants using various types of reactors.

  Outcome 4: explain the responses of various reactor types to malfunction conditions.

  Outcome 5: identify the conditions under which fast breeder reactors would be cost effective to construct and operate, and define the key reactor design parameters.

  Outcome 6: explain the improvements in the reliability of reactor safety systems, emphasizing the key characteristics of passive systems.

  Outcome 7: demonstrate, using real time simulators, the responses of nuclear-electric power plants using various types of reactors to design-basis emergency events.
- **Information About Course Designer/Developer:**
  Course designed by G. T. Bereznai, Ph.D., School of Energy Systems and Nuclear Science
- **Identify faculty to teach the course:**
  Dr. G. Bereznai.
- **Faculty qualifications required to teach/supervise the course:**
  Ph.D. degree in engineering or science, and relevant experience in teaching and research.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: each student must have access to an IBM compatible personal computer to execute reactor plant simulations.

Course Title: NUCL 5300G – Advanced Topics in Radioactive Waste Management

Prerequisite(s): undergraduate course in radioactive waste management

- **Course Description and Content Outline:** This course will examine the various international approaches used for the development of publicly acceptable radioactive waste disposal facilities. Particular emphasis will be placed on the technical aspects of geologic disposal systems, used/recycled fuel disposal, and the assessment of radioisotope release. The influence of public acceptance on the selection and implementation of technical solutions will also be considered.

Topics include:

- Performance factors and requirements for engineered barrier systems
- Environmental modelling of waste release
- Geologic barrier systems
- Used fuel behaviour

- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** N/A
- **Representative Texts:**

The geological disposal of nuclear waste : N. A. Chapman and I. G. McKinley. J. Wiley & Sons Limited, 1987

- **Literature**

B.W. Goodwin et al., “The Disposal of Canada’s Nuclear Fuel Waste: Postclosure Assessment of a Reference System”, AECL-10717, 1994.

L.H. Johnson et al., “The Disposal of Canada’s Nuclear Fuel Waste: The Vault Model for Postclosure Assessment”, AECL-10714, 1994.

C.C. Davison et al., “The Disposal of Canada’s Nuclear Fuel Waste: The Geosphere Model for Postclosure Assessment”, AECL-10719, 1994.

“Model summary report for the safety assessment SR-Can”, SKB TR-06-26, 2006

“Project Opalinus Clay: FEP Management for Safety Assessment –Demonstration of disposal feasibility for spent fuel, vitrified high-level waste and long-lived intermediate-level waste”, NTB 02-23, 2002.

Barbara Pastina, and Pirjo Hellä, (eds), “Expected Evolution of a Spent Nuclear Fuel Repository at Olkiluoto”, POSIVA 2006-05, 2006.

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - understand the strength and weakness of environmental modelling
  - understand the limitations and advantages of geologic systems for retarding waste release
  - understand the interrelationship between the various barrier systems, the geologic media, and the required dose release criteria

  perform estimates of local site performance based on international data.

Information about Course Designer/Developer:
Course designed by: B.M. Ikeda, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired": Dr. B.M. Ikeda
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD in engineering or science with experience in teaching and research in the managing or disposal of nuclear fuel waste.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: none

Course Title: NUCL 5400G – Advanced Radiation Science

Prerequisite: undergraduate course in radiation science

- **Course Description and Content Outline:** This course introduces advanced concepts in radiation engineering, with an emphasis on how ionizing radiation interactions with matter may be modelled. The course reviews fundamental particle interaction mechanics, measurement and detection of radiation, evaluation of nuclear cross sections and various solutions to the Boltzmann transport equation. Pre-requisites: Undergraduate courses in nuclear physics, differential equations, and statistics. This course is cross-listed with ENGR 5181G Advanced Radiation Engineering.
  - **Topics include:**
    - Charged and neutral particle interaction mechanics
    - Elastic scattering kinematics
    - Laboratory and Centre-of Mass co-ordinate system considerations
    - Wave function operators and the Schrödinger equation
    - Expectation values and the Hamiltonian
    - Nuclear shell, optical and compound nucleus models for cross sections
    - Asymptotic approximation to nuclear scattering cross sections
    - Energy averaged cross sections and cross section libraries
    - Boltzmann transport equation
    - Spherical harmonics approximations to solve the transport equation
    - Generation of the diffusion equation
    - Discrete ordinates method to solve the transport equation
    - Monte Carlo methods to solve the transport equation
    - Basic nuclear radiation detection principles
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**
  Lewis, E. and Miller, W., 1993, *Computational Methods of Neutron Transport*, ANS Publications: Illinois.
  Custom Handouts
- **Literature:**
  Lux, I. and Koblinger, L., 1990, *Monte Carlo Particle Transport Methods: Neutron and Photon Calculations*, CRC Press: Boston.
  Lewis, E. and Miller, W., 1993, *Computational Methods of Neutron Transport*, ANS Publications: Illinois.
  Duderstadt, J. and Martin, W., 1979, *Transport Theory*, Wiley-Interscience: New York.
  Schaeffer, N., 1974, *Reactor Shielding for Nuclear Engineers*, USAEC: Virginia.
  Knoll, G., 1989, *Radiation Detection and Measurement – 3rd Edition*, Wiley: Toronto.
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  Outcome 1: understand how charged and neutral particles interact with materials.
  Outcome 2: understand how radiation may be used to determine material properties.
  Outcome 3: solve particle scattering problems in both the laboratory and centre-of-mass frames of reference.
  Outcome 4: derive cross sections from the Schroedinger equation.
  Outcome 5: understand the various models for nuclear cross sections.

Outcome 6: understand how continuous and multi-group cross sections and generated and used in particle transport computations. Outcome 7: solve the Boltzmann transport equation using: a. Spherical harmonics; b. Discrete ordinates; and c. Monte Carlo analysis Outcome 8: understand the basic concepts of ionizing radiation detection.
Information About Course Designer/Developer: Course designed by faculty eligible to teach this course: E. Waller, PhD, PEng, School of Energy Systems and Nuclear Science
Identify faculty to teach the course and/or statement "faculty to be hired": Dr. E. Waller, Dr. E. Nichita,
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD degree in Physics, Mathematics or Engineering with experience in Radiation Transport.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: None

Course Title: NUCL 5410G – Physics of Radiation Therapy

Prerequisite(s): Nuclear Concepts for Engineers and Scientists, or equivalent.

- **Course Description and Content Outline:** A study of the uses of various types of radiation for therapeutic applications, including X-rays, gamma radiation, electrons, neutrons, lasers, UV, visible, infrared, radio-frequency, and microwaves. Topics include: production of radiation for therapeutic purposes; external beam radiotherapy, brachytherapy, electron beam therapy, boron neutron capture therapy, heavy ion therapy and photodynamic therapy; therapeutic dose calculation and measurement; dose calculation algorithms, treatment planning, optimization and verification; equipment calibration; dose impact on patients and workers. This course is cross-listed with RADI 4320 Therapeutic Applications of Radiation Techniques.
- **Topics include:**
  - Clinical Radiation Generators
  - Interactions of Ionizing Radiation
  - Measurement of Ionizing Radiation
  - Quality of X-ray Beams
  - Measurement of Absorbed Dose
  - External Beam Radiation Therapy
  - Treatment Planning
  - Electron Beam Therapy
  - Brachytherapy
  - Radiation Protection
  - Quality Assurance
  - Total Body Irradiation
  - Three-Dirnensional Conformal Radiation Therapy
  - Intensity-modulated Radiation Therapy
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  The Physics of Radiation Therapy
  Faiz M Khan
  ISBN: 0781730651
- **Representative Texts:**
  The Physics of Radiation Therapy
  Faiz M Khan
  ISBN: 0781730651

  Radiation Oncology Physics: A Handbook for Teachers And Students
  Intl Atomic Energy Agency (2005)
  ISBN: 978-9201073044

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Describe the main component of a clinical LINAC and teletherapy machine.
  - Understand the main types of interactions of ionizing radiation with matter.
  - Understand the dose units and measuring protocols for water phantoms.

- Understand the principles of external beam radiation therapy and basic field combinations.
- Apply simple correction methods for tissue inhomogeneity, patient shape, etc.
- Understand clinical terms for treatment specification (CTV, PTV, etc.).
- Understand the methods and equipment for treatment planning and verification.
- Be familiar with ancillary devices such as wedges, blocks, boluses and compensators.
- Understand the clinical uses and dose calculation for electron beam therapy.
- Understand the clinical uses and dose calculation for brachytherapy.
- Know the rules of radiation protection for patient and personnel.
- Describe the advantages of conformal therapy and Intensity-Modulated Radiation Therapy.

Information about Course Designer/Developer:
Course designed by: E. Nichita, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. E. Nichita, Dr. E. Waller

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in teaching the medical/radiarion physics.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: not applicable

Course Title: NUCL 5420G – Aerosol Mechanics

Prerequisite: undergraduate course in physics, chemistry, differential equations, and statistics. A working knowledge of the MATLAB code is required.

- **Course Description and Content Outline:** Aerosols, or particles suspended in the air, are generated from numerous processes and used in numerous ways. Some examples of commonly encountered aerosols are smoke from power generation, cigarette, forest fire, atmospheric aerosols causing ozone depletion, reduced visibility, rain, snow, cloud, fog, and respiratory deposition or drug delivery through respiratory system. Some aerosols cause significant health and environmental problems while others improve the quality of life. To prevent the formation of undesired pollutants or to produce materials of desired properties, it is important to understand the mechanics of aerosols. This course explores the properties, behaviour and measurement of airborne particulate. Concepts related particle motion, particle size statistics, forces acting on particles, respiratory and mechanical filtration and physicochemical properties of particles will be discussed. Real-world examples of particle transport will be used to reinforce the issues being discussed.
- **Topics include:**
  - Properties of gases
  - Particle motion
    - Uniform
    - Straight line acceleration
    - Curvilinear
    - Brownian motion
    - Diffusion
  - Particle size statistics
  - Adhesion
  - Thermal forces
  - Radiometric forces
  - Particle sampling and concentration measurement
  - Filtration
  - Respiratory deposition
  - Coagulation
  - Condensation
  - Evaporation
  - Electrical properties
  - Optical properties
  - Atmospheric aerosols
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Modeling Project
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**
  W. C. Hinds, Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, 2nd Ed, John Wiley & Sons, 1999.
  Custom Handouts
- **Literature:**
  J. H. Seinfeld, Atmospheric Chemistry & Physics of Air Pollution, John Wiley and Sons, 1998
  R. C. Flagan and J. H. Seinfeld, Fundamentals of Air Pollution Engineering, Prentice Hall
  S. Friedlander, Smoke, Dust and Haze, John Wiley and Sons

K. Willeke and P. Baron, Aerosol Measurement: Principles, Techniques and Applications, John Wiley and Sons, 2001
Journals:
J. Aerosol Science
Aerosol Science & Technology
J. Air & Waste Management Assoc.

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:

Outcome 1: Explain and calculate the statistics of a given particle size distribution.
Outcome 2: Determine the movement of aerosols by a given transport mechanics (inertial movement, diffusion, electrical migration and thermophoresis) and analyze the important mechanisms for a given aerosol system.
Outcome 3: Calculate the optical properties of a given aerosol system
Outcome 4: Derive expressions for a given aerosol system involving multiple aerosol mechanisms (nucleation, condensation, coagulation, diffusion) and analyze the dynamics of the particle size distributions.
Outcome 5: Design a system to generate, to collect aerosols and to measure particle size distribution.
Outcome 6: Explain the multi-disciplinary aspects of aerosol science & technology.
Outcome 7: Explain aerosol science & technology to the professional society and general public.

Information About Course Designer/Developer:

Course designed by faculty eligible to teach this course: E. Waller, PhD, PEng, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":

Dr. E. Waller

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:

PhD degree in Physics or Engineering with experience in teaching aerosol mechanics.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: n/a

Course Title: NUCL 5430G – Advanced Dosimetry

Prerequisite: undergraduate course in dosimetry

- **Course Description and Content Outline:** This course covers advanced concepts in radiation dosimetry linking fundamental radiation physics with metrological theory and practice for therapeutic, external and internal dosimetry. The course reviews basic radiation and charged particle interaction processes and the underlying quantities and units used in dosimetry and radiation monitoring. Cavity theory and the application of ionization chamber methods of dosimetry for photon and electron beams will be covered and a review of passive integrating dosimeters such as radiochromic film, chemical dosimeters and biological dosimetry given. The properties and role of various pulse-mode detectors in dosimetry and monitoring will be discussed along with the metrological relationship between measured quantities and effective dose. Internal dosimetry and dose assessment will be studied in terms of in-vitro and in-vivo monitoring methods along with the standard codes and methods used for assessing dose from bioassay data. The course will conclude with a survey of dosimetry practice under special circumstances and environments such as that encountered in space and in accident scenarios.
- **Topics include:**
  - Description of ionizing radiation fields
  - Quantities for describing radiation interaction
  - Charged particles and charged particle interactions
  - Cavity theory and ionization chambers
  - Dosimetry and calibration of photon and electron beams
  - Passive dosimeters for photon and electron beams
  - Pulse-mode detectors and radiation monitoring
  - Neutron monitoring
  - Radioactive decay and absorbed dose in radioactive media
  - In-vitro and in-vivo bioassay methods
  - Internal dose assessment
  - Special case dosimetry and monitoring practice
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**
  F.H. Attix – *Introduction to Radiological Physics and Radiation Dosimetry*, Wiley, 1986
  Custom Handouts
- **Literature:**
  E.B. Podgorsak, *Radiation Physics for Medical Physicists*, Springer, 2006; F.M. Khan, *The Physics of Radiation Therapy*, Lippincott Williams and Wilkins, 2003; Miscellaneous ICRU and NCRP Reports
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: understand how radiation interacts with matter and the quantities used to describe this interaction.

  Outcome 2: understand how ionization chambers can be used to measure absorbed dose in photon, electron and neutron fields and how these instruments are calibrated against national standards for absorbed dose.

  Outcome 3: understand the principles and application of passive and biological dosimetry systems and their calibration.

Outcome 4: understand the operation and application of pulse-mode detectors in dosimetry and dose monitoring.

Outcome 5: understand radioactive decay and absorbed dose in radioactive media.

Outcome 6: understand the bioassay methods used to quantify an intake of radioactive material.

Outcome 7: understand and carry out dose assessments of internal dose using industry-standard procedures and codes.

Outcome 8: understand the application of dosimetric principles and methods to special exposure situations and pathways.

Information About Course Designer/Developer:

Course designed by faculty eligible to teach this course: A.J. Waker, PhD, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":

Dr. A.J. Waker, and Faculty to be Hired

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:

PhD degree in Physics or Engineering with experience in radiation science and dosimetry

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: None

Course Title: NUCL 5440G – Advanced Radiation Biophysics and Microdosimetry

Prerequisite: undergraduate course in biophysics and/or dosimetry

- **Course Description and Content Outline:** This course introduces advanced concepts in radiation biophysics with an emphasis on the stochastic nature of radiation interaction with biological systems and the microdosimetric analysis of radiation effects. The course reviews fundamental charged particle interaction processes and the measurement of radiation energy deposition on the microscopic and sub-microscopic scale and how this knowledge can be used to quantify radiation quality. Microdosimetric descriptions of radiation quality will also be discussed in terms of low-dose radiation protection, medical applications of low LET radiation and high LET radiation therapy as well as the special nature of radiation fields encountered in space. Pre-requisites: Undergraduate courses in nuclear physics; radiation detection and the interaction of radiation with matter; statistics.
- **Topics include:**
  - Charged and neutral particle interaction mechanics
  - Linear Energy Transfer
  - DNA strand breaks and chromosomal aberrations
  - Cell survival
  - Target and hit theory
  - Relative Biological Effectveness
  - Microdosimetric quantities and the compound Poisson process in radiation energy deposition
  - Measurement of microdosimetric quantities
  - Dual radiation action and compound dual radiation action
  - Microdosimetry and low-dose radiation protection science
  - Microdosimetry and low-energy X-rays used in medical diagnosis and therapy
  - Microdosimetry of high-LET radiation used in radiotherapy
  - Microdosimetry and space radiation protection science
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Resources to be purchased by students:** N/A;
- **Textbook requirements:**
  Radiobiology for the Radiologist, Hall and Giaccia, sixth edition, Lippincott Williams and Wilkins, 2006; *Radiation Biophysics*, Alpen, 1997, Academic Press
- **Literature:**
  The Dosimetry of Ionizing Radiation, Volume I, Ed. Kase, Bjarngard and Attix, Academic Press, 1985; *Design, Construction and Use of Tissue Equivalent Proportional Counters,* Ed. Schmitz, Waker, Kliauga and Zoetelief, Radiat. Prot. Dosim, 64, No 4, 1995; *Proceedings of Micodosimetry Symposia*, 1967-2006; *Radiation Detection and Measurement – 3rd Edition*, Knoll, G., 1989, Wiley: Toronto.
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: understand how charged and neutral particles interact with matter.
  Outcome 2: understand how radiation affects cellular and sub-cellular biological structures.
  Outcome 3: understand the concept and physical basis of Relative Biological Effectiveness.
  Outcome 4: understand the theoretical and experimental basis of microdosimetry and microdosimetric quantities.

Outcome 5: understand the application of microdosimetry in medical applications of high and low LET radiation Outcome 6: understand how microdosimetry can inform low-dose and space radiation protection.
Information About Course Designer/Developer: Course designed by faculty eligible to teach this course: A.J. Waker, PhD, School of Energy Systems and Nuclear Science
Identify faculty to teach the course and/or statement “faculty to be hired”: A.J. Waker, and Faculty to be Hired
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD degree in Physics, Mathematics or Engineering with experience in Radiation Biophysics.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: None

Course Title: NUCL 5450G – Non-Destructive Analysis

Prerequisite: N/A

- **Course Description and Content Outline:** This course introduces a wide variety of non-destructive analysis techniques for use in research, design, manufacturing and industrial service. The course instructs how each technique works, how it can be applied, when and where it can be used and each technique's capabilities and limitations. The course describes how to take an industrial non-destructive analysis problem and determine which technique is best suited for the job, how to apply a given technique and which information the technique will provide. Laboratories will provide hands-on experience with non-destructive analysis equipment. Pre-requisites: Undergraduate courses in physics, differential equations, and statistics.
  - **Topics include:**
    - Basic wave physics applied to non-destructive analysis
    - Ultrasonic Testing methods
    - Acoustic Emission techniques
    - Magnetic Flux Leakage methods
    - Eddy Current technique
    - Radiography (photon and neutron)
    - X-ray Fluorescence and Diffraction
    - Microwave methods
    - Thermography
    - Advanced techniques
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week. Laboratories will be held every second week.
- **Student Evaluation:** Assignments, Exams, Laboratories
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**
  D.E. Bray and R.K. Stanley, Nondestructive Evaluation, A Tool for Design, Manufacturing, and Service, McGraw-Hill, New York, 1989.
  Custom Handouts
- **Literature:**

- L. Cartz, Nondestructive Testing, ASM Int., Materials Park, OH, 1995
- D.E. Bray and D. McBride, Nondestructive Testing Techniques, John Wiley & Sons, New York, 1992
- R.V. Williams, Acoustic Emission, Adam Hilger, Bristol, 1980
- J.R. Matthews, Ed., Acoustic Emission, Gordon and Breach, 1983
- J. Krautkramer and H. Krautkramer, Ultrasonic Testing of Materials, Springer-Verlag, Berlin, 1983
- A.J. Bahr, Microwave Nondestructive Testing Methods, Gordon and Breach, New York, 1982
- H.L. Libby, Introduction to Electromagnetic Nondestructive Test Methods, Willey-Interscience, New York, 1971

ASNT, Non-Destructive Testing Handbook, second edition, in nine volumes
H.L. Libby, Introduction to Electromagnetic Nondestructive Test Methods, Wiley-Interscience, New York, 1971
M.G. Silk, et al., The Reliability of Non-destructive Inspection, Adam Hilger, Bristol, 1987
J.J. Burke, and V. Weiss, Eds., Nondestructive Evaluation of Materials, Plenum Press, New York, 1976
P. Holler, Ed., New Procedures in Nondestructive Testing, Springer-Verlag, 1983
H.S. Lew, Ed., Nondestructive Testing, American Concrete Institute, Detroit, 1988

R.C. McMaster, Ed., Nondestructive Testing Handbook, Ronald Press, New York, 1959

Journals:

Int. Advances in Nondestructive Testing, W. G. McGonnagle, Ed., Gordon and Breach, New York.
Materials Evaluation
British J. Nondestructive Testing.
Non-destructive Testing Int.
J. Testing and Evaluation
Non-Destructive Testing
Soviet J. Nondestructive Testing
Research Techniques in Nondestructive Testing; Academic, New York

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:

Outcome 1: understand the theory of energy waves and how they may be used to inspect and analyze materials
Outcome 2: understand how radiation may be used to determine material properties
Outcome 3: analyze and solve problems of significance to non-destructive analysis
Outcome 4: design simple non-destructive analysis systems
Outcome 5: understand the theory and operation of common non-destructive analysis instruments
Outcome 6: understand the types of materials flaws that may be detected, and the best technique to detect them with
Outcome 7: learn about complex failure attributed to material flaws
Outcome 8: explore how non-destructive analysis techniques are used to improve the reliability of complex systems

Information About Course Designer/Developer:
Course designed by faculty eligible to teach this course: E. Waller, PhD, PEng, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. E. Waller, Dr. A. Waker.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD degree in Physics or Engineering with experience in non-destructive analysis

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: Ultrasonic (A-scan), x-ray radiography set, Eddy current probe, Magnetic yoke, x-ray fluorescence analyzer

Course Title: NUCL 5460G – Industrial Radiography

Prerequisite(s): no prerequisites

- **Course Description and Content Outline:** The course will describe the fundamental physics of neutron, X-ray, Gamma Ray, and Infra-Red radiography. Traditional and modern techniques currently in practise will be discussed as well as discussing recent advances in the technology. Applications of radiography to industrial environments will be presented. Considerations for radiography system design will be discussed.
- **Topics include:**
  - X-ray Imaging and Radiography
  - Gamma-Ray Imaging and Radiography
  - Neutron Imaging and Radiography
  - Infra-Red Imaging and Radiography
  - Film Based Techniques
  - Digital Techniques
  - Image Processing and Image Enhancement
  - X-Ray and Gamma Ray Sources
  - Neutron Sources
  - Industrial Applications of Radiography
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  None.
- **Representative Texts:**
  No specific textbook. Students will be required to perform literature searches in texts, handbooks, and journal papers.
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:
  - Identify the mechanisms of neutron, X-ray, and Gamma-Ray interaction with materials for radiography applications.
  - Identify the mechanisms of Infra-Red and other electromagnetic wave interactions with materials for radiography applications.
  - Identify and explain neutron, X-ray, and Gamma-Ray sources.
  - Understand film and digital (electronic) techniques of radiography.
  - Will be able to apply basic image processing techniques for image enhancement and image analysis.
  - Identify Industrial applications of radiography and the known strengths and weaknesses.
  - Be knowledgeable of the current state of the art of Industrial Radiography.

Information about Course Designer/Developer:
Course designed by: G. Harvel, Ph.D., P. Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. G. Harvel

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
Ph.D. in Science or Engineering, with experience in radiography, neutron, X-Ray, or Gamma interaction with matter, and imaging technologies.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements:

For the laboratory, some or all of the following equipment is required:

1. Neutron source and neutron imaging equipment
2. Gamma Source, appropriate shielding
3. X-ray source with appropriate shielding
4. Film and Film Processing Equipment
5. Dynamic Imaging Systems for X-Rays and Gamma-Rays
6. Infrared Camera
7. Computers with image acquisition hardware and image processing software

Course Title: NUCL 5470G – Nuclear Forensic Analysis

Pre-requisites: Undergraduate courses in nuclear physics, radiation detection, chemistry (preferably organic chemistry), differential equations, and statistics.

- **Course Description and Content Outline:** There are many techniques available to forensic investigators to investigate suspect criminal activity. In addition, there are many times when forensic techniques are required to investigate nuclear-related events. This course will explore nuclear and chemical techniques related to the nuclear technology and forensics. Both radiation and analytical chemistry techniques will be introduced. Risks and hazards associated with nuclear forensic investigations will be reviewed, and mitigation strategies developed. Data integrity and communication of results will be emphasized.
- **Topics include:**
  - Threats
    - Radiological dispersal devices forensics
    - Improvised nuclear weapons forensics
    - Weapons of mass destruction forensics
    - Trans-Uranium Elements
    - Fission Products
    - Identification
    - Trauma Accidents (including mass casualty)
    - Violent crime (gunshot; abuse; human rights violations)
    - Non-violent crime (smuggling; theft; forgery)
  - Techniques
    - Rapid Screening Measurements
    - Non- Destructive Assay
    - Neutron Activation Analysis and radiography
    - Alpha, Beta and Gamma Spectrometry
    - Neutron Counting, Portal Counting, Liquid Scintillation Counting, Gas Flow Proportional Counting
    - X-ray radiography and radiology
    - TLD/OSL/ESR/NMR
    - Methods and strategies for separation chemistry
    - Introduction to chemical analytical techniques
  - Data integrity, risk assessment and communications
    - Reliability, data quality objectives and reporting
    - Sample integrity and contamination control
    - Risk and hazard assessment of field and laboratory work
    - Communication of results
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Resources to be purchased by students:** N/A
- **Textbook requirements:**

  K. Moody, I. Hutcheon and P. Grant, Nuclear Forensic Analysis, CRC Press, 2005.
  Custom Handouts

- **Literature:**

B. Brogdon, <u>Forensic Radiology</u>, CRC Press, 1998
R. Jensen, <u>Mass Fatality and Casualty Accidents: A Field Guide</u>, CRC Press, 1999

- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to:

Outcome 1: Discuss the various types of radiological threats that exist
Outcome 2: Discuss the applications of radiation-based techniques (primarily radiography, radiology and radioscopy) used in forensic investigations
Outcome 3: Determine appropriate forensic techniques for given scenarios of interest
Outcome 4: Understand the complexities involved in determining origin of radioactive material
Outcome 5: Understand basics of analytical chemical techniques used in forensics
Outcome 6: Understand the requirements for chain of custody, data quality objectives and reporting of results in nuclear forensics
Outcome 7: Analyze and mitigate potential hazards while performing nuclear forensic analysis
Outcome 8: Communicate concepts of nuclear forensics to the professional society and general public.

Information About Course Designer/Developer:

Course designed by faculty eligible to teach this course: E. Waller, PhD, PEng, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":

Dr. E. Waller, Dr. S. Forbes (Faculty of Science)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:

PhD degree in Physics, Chemistry or Engineering

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: n/a

ELECTIVE GRADUATE COURSES FROM THE FACULTY OF ENGINEERING AND APPLIED SCIENCE

Course Title: ENGR 5010G – Advanced Optimization
Year and Semester: N/A
• **Course Description and Content Outline:** The objective of this course is to understand the principles of optimization and its application to engineering problems. Topics covered include: the steepest descent and Newton methods for unconstrained optimization; golden section, quadratic, cubic and inexact line searches; conjugate and quasi-Newton methods; the Fletcher-Reeves algorithm; fundamentals of constrained optimization theory; simplex methods for linear programming; modern interior-point methods; active-set methods and primal-dual interior-point methods for quadratic and convex programming; semidefinite programming algorithms; sequential quadratic programming and interior-point methods for nonconvex optimization. In addition, implementation issues and current software packages/algorithms for optimization will be covered. Global optimization, including genetic algorithms and simulated annealing, will be introduced. • **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week. • **Student Evaluation:** The principal form of assessment will be two major research projects, one counting for 30% and the other counting for 50% of the course mark. Assignments will count for the remaining 20%. The exact weighting of the various components will be presented to the students in the first week of lectures. • **Resources to be purchased by students:** N/A • **Textbook requirements (sample):** Antoniou, A. and Lu, W.-S., (In-Press), *Optimization: Methods, Algorithms, and Applications*, Kluwer Academic. • **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to: Outcome 1: formulate and solve unconstrained and constrained optimization problems. Outcome 2: understand how the major unconstrained, constrained, and global optimization techniques work. Outcome 3: use optimization as a tool for solving engineering design problems.
Information About Course Designer/Developer: Course designed by faculty eligible to teach this course: S. Nokleby, PhD, PEng, Faculty of Engineering and Applied Science
Identify faculty to teach the course and/or statement "faculty to be hired": S. Nokleby and D. Zhang
Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD degree in engineering and relevant experience in teaching and research. Faculty members will normally be registered Professional Engineers.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: Software requirements include MATLAB with both the Optimization Toolbox and the Genetic Algorithm and Direct Search Toolbox.

Course Title: ENGR 5121G – Advanced Turbo Machinery

Year and Semester: N/A

- **Course Description and Content Outline:** Basic Thermodynamics and Fluid Mechanics equations and definitions of efficiencies in turbomachines. Two-dimensional cascades (cascade analysis, performance of cascades and cascade correlations). Axial flow turbines. Radial flow turbines. Axial flow compressors. Centrifugal compressors and fans. Applications of turbomachinery to engineering problems. Design, analysis and performance analyses of turbomachines. Transport phenomena aspects. Software use and tests.
  - **Content outline by topic:**
    - Basic Thermodynamics and Fluid Mechanics equations and definitions of efficiencies in turbomachines.
    - Two-dimensional cascades (cascade analysis, performance of cascades and cascade correlations).
    - Axial flow turbines.
    - Radial flow turbines.
    - Axial flow compressors.
    - Centrifugal compressors and fans.
    - Applications of turbomachinery to engineering problems.
    - Design, analysis and performance analyses of turbomachines.
    - Transport phenomena aspects.
    - Software use and tests.
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Mid-term exam (20%), project and presentation (25%), weekly homework assignments (15%), and final exam (40%).
- **Resources to be purchased by students:** None
- **Textbook requirements:**
  Wilson, G. and Korakianitis, T., 2002, *The Design of High-Efficiency Turbomachinery and Gas Turbines – 2nd Edition*, Pearson: New York, NY.

Learning Outcomes. It is aimed to teach students the principles used in analyzing/designing compressors and turbines. Students will be expected to design a gas turbine to meet specific mission requirements. Upon completion of the course, students will be able to understand the design systems and techniques used in the aeropropulsion and gas turbine industries.

Information About Course Designer/Developer:
Course designed by faculty eligible to teach this course: I. Dincer, PhD, Faculty of Engineering and Applied Science

Identify faculty to teach the course and/or statement "faculty to be hired":
M. Rosen

Are there any plans to teach all or portions of this course on-line? Course materials and details will be available on WebCT. Numerical and analytical methods will be used.

Faculty qualifications required to teach/supervise the course:

PhD degree in engineering and relevant experience in teaching and research. Faculty members will normally be registered Professional Engineers.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: Engineering Equation Solver (EES) and MATLAB will be provided to the students.

Course Title: ENGR 5122G – Computational Fluid Dynamics

Year and Semester: N/A

- **Course Description and Content Outline:** Introduction to CFD modelling and mesh generation software. Basic equations of fluid flow and commonly used approximations. Turbulence modelling (one and two equation models, and higher order models). Iterative solution methods and convergence criteria. Practical analysis of turbulent pipe flow / mixing elbow and turbomachinery blade problems. Software use and tests.
  - **Content outline by topic:**
    - Introduction to CFD modelling and mesh generation software.
    - Basic equations of fluid flow and commonly used approximations.
    - Turbulence modelling (one and two equation models, and higher order models).
    - Iterative solution methods and convergence criteria.
    - Practical analysis of turbulent pipe flow / mixing elbow and turbomachinery blade problems.
    - Software use and tests.
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Mid-term exam (20%), project and presentation (25%), weekly homework assignments (15%), and final exam (40%).
- **Resources to be purchased by students:** None
- **Textbook requirements:**
  Chung, T. J., 2002, *Computational Fluid Dynamics*, Cambridge University Press: Oxford, UK.
  Ferziger, J. H., and Peric, M., 2003, *Computational Methods for Fluid Dynamics*, Springer: New York, NY.

Learning Outcomes. The aim of this course is to develop practical skills in Computational Fluid Dynamics and the use of FLUENT, the most widely used commercial CFD code available. Students are expected to apply these skills to relevant Engineering applications and gain an appreciation of the limitations and advantages of CFD modelling. On completion of the course a successful student should be able to: (i) Set up a numerical model (including mesh generation) using FLUENT. (ii) Identify and define the correct boundary conditions and most appropriate turbulence model. (iii) Interpret the results and validate them using experimental and theoretical data.

Information About Course Designer/Developer:
Course designed by faculty eligible to teach this course: I. Dincer, PhD, Faculty of Engineering and Applied Science

Identify faculty to teach the course and/or statement "faculty to be hired":
G. Naterer

Are there any plans to teach all or portions of this course on-line? Course materials and details will be available on WebCT. Numerical and analytical methods will be used.

Faculty qualifications required to teach/supervise the course:

PhD degree in engineering and relevant experience in teaching and research. Faculty members will normally be registered Professional Engineers.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: Special CFD software (e.g., FLUENT) will be provided to the students.

Course Title: ENGR 5740G – User Interface Design

- **Course Description:** This course is an introduction to user interface design and implementation on a wide range of hardware platforms. It covers the basic techniques used in user interface design, how users behave, implementation tools and techniques and the evaluation of user interface designs. It covers both desktop and mobile environments, including the design of user interfaces for cell phones, PDAs and mobile games.
- **Course Outline by Topic:**
  - User behaviour: Basic cognitive psychology, Types of users, Usage patterns
  - Design methodologies
  - Prototyping
  - Design and implementation tools: Prototyping systems, Software libraries, GUI builders
  - Evaluation of user interface designs: Mathematical models, User studies, Experimental techniques
  - User interfaces for mobile and embedded devices: Design challenges with limited devices: Mobile devices: cell phones, PDAs, and mobile entertainment, Appliances and consumer devices
- **Delivery Mode and Teaching Method:** 3 hours of lectures per week.
- **Student Evaluation:** assignments: 30%, final project: 25% and final examination: 45%.
- **Textbook Requirements:** Alan Cooper and Robert Reimann, *About Face 2.0: The Essentials of Interaction Design*, Wiley, 2003, 0764526413.
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: apply in-depth knowledge of the important properties of users and how they impact user interface design.

  Outcome 2: design and implement user interfaces for desktop, mobile and embedded environments.

  Outcome 3: illustrate the importance of evaluating user interface designs both before and after they are implemented.

  Outcome 4: follow a formal user interface design and implementation methodology.

  Outcome 5: select the appropriate tools for the design and implementation of a user interface and be able to use them in a competent manner.

  Outcome 6: apply in-depth understanding of the important difference between user interfaces for a desktop environment and user interfaces for mobile and embedded environments.

Information About Course Designer/Developer:

Course designed by M. Green, PhD, Faculty of Science

Identify faculty to teach the course and/or statement "faculty to be hired":

M. Green and additional faculty will be hired.

Faculty qualifications required to teach/supervise the course:

PhD degree in Engineering or Computer Science with relevant experience in teaching and research. Faculty members may normally be registered Professional Engineers.

Course Title: ENGR 5750G – Software Quality Management

- **Course Description and Content Outline**: An intensive investigation into software quality engineering issues, including testing techniques, defect detection and prevention, reliability engineering, examination of maintenance issues and configuration management. Software evolution issues, including planning for evolution, round out the course. Students will do a major team project examining issues in defect reduction. The course will have a strong industrial flavour.
- **Content outline by topic:**
  - Introduction to software quality engineering
  - Software Quality Standards
  - Testing: concepts, issues and techniques
  - Life cycle testing
  - Coverage and usage testing
  - Software quality metrics
  - Defect reduction, defect classification
  - Software inspection
  - Developing a software quality plan
  - Safety and quality Issues
  - Software reliability engineering
  - Software evolution
  - Maintenance issues
- **Delivery Mode and Teaching Method:** 3 hours of lectures per week.
- **Student Evaluation:** Mid-term exam: 10%, research project and presentation: 20%, assignments: 30%, and final exam: 40%.
- **Textbook requirements:** J. Tien, *Software Quality Engineering,* John Wiley 2005
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:
  Outcome 1: apply in-depth understanding of the importance of good quality in software.
  Outcome 2: explain and use the basic Quality Life Cycle.
  Outcome 3: use the 7 basic tools of quality control.
  Outcome 4: write a software quality management plan.
  Outcome 5: use software quality metrics.
  Outcome 6: implement defect reduction programs.
  Outcome 7: manage safety-software issues.
  Outcome 8: plan for the evolution of software.
  Outcome 9: manage software maintenance.
  Outcome 10: analysis case studies in software quality.
- **Information About Course Designer/Developer:**
  Course designed by J.M. Bennett, PhD, Faculty of Engineering and Applied Science
- **Identify faculty to teach the course and/or statement “faculty to be hired”:**
  J.M. Bennett, R. Liscano, C. Martin
- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering/computer science & relevant experience in teaching & research. Faculty members may be registered Professional Engineers.

Course Title: ENGR 5910G – Embedded Real-Time Control Systems

- **Course Description and Content Outline:** This course focuses on the design and implementation techniques for embedded real-time control systems. It covers embedded system design, instruction sets for microprocessor architecture, I/O, interrupts, hardware and software of embedded systems, program design and analysis, practical issues, multi-tasking operating systems, scheduling and system design techniques.
- **Content outline by topic:**
  - Embedded system design process
  - Instruction sets for microprocessor architecture
  - Mechanisms for input, output, and interrupts
  - Basic hardware and software platforms and Embedded computing
  - Program design and analysis
  - Practical issues related to computer based control systems
  - Multi-tasking operating systems for embedded applications
  - Real-time programming in high-level languages
  - Priority scheduling and System design techniques
- **Delivery Mode and Teaching Method:** 3 hours of lectures per week.
- **Student Evaluation:** mid-term exam: 20%, research project and presentation: 25%, homework assignments: 15%, and final exam: 40%.
- **Textbook requirements:** Wittenmark, K.J. 2000, *Principles of Embedded Computing System Design,* Wayne Wolf, Morgan Kaufmann Publishers. ISBN 1-55860-541-X
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: articulate the characteristics of embedded and real-time systems in terms of functionality, time constraints, power consumption, cost and development environment.

  Outcome 2: become familiar with the design process in real-time applications; use UML modeling language to design real-time applications.

  Outcome 3: describe architecture features of ARM RISC processor and SHARC processor; understand the difference between the two processors; and use instruction sets of these processors to accomplish simple operations.

  Outcome 4: understand and illustrate major challenges in embedded computing system design.

  Outcome 5: apply knowledge of practical issues related to computer based control systems: PID tuning, anti-aliasing filters, integrator saturation and windup, switch de-bouncing, selection of sampling rates.

  Outcome 6: write simple programs with multi-tasking operating systems.

  Outcome 7: design, build and integrate hardware and software for simple real-time embedded applications.

  Outcome 8: use industry-grade tools & development environment for embedded applications.

Information About Course Designer/Developer: Course designed by J. Ren, PhD, Faculty of Engineering & Applied Science and L. Lu, PhD, School of Energy Systems & Nuclear Science and Faculty of Engineering & Applied Science

- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  J. Ren, L. Lu, R.
- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering and relevant experience in teaching and research. Faculty members will normally be registered Professional Engineers.

Course Title: ENGR 5920G – Analysis and Control of Nonlinear Systems

- **Course Description and Content Outline:** Introduction to nonlinear systems, phase plane analysis, stability determination by Lyapunov direct method, advanced stability theory, existence of Lyapunov functions, describing function analysis, nonlinear control system design by feedback linearization, sliding control, variable structure control, adaptive control of linear and nonlinear systems, control of multi-output systems, control of multi-input multi-output systems.
- **Content outline by topic:**
  - Introduction to nonlinear systems
  - Planar systems and their phase space
  - Lyapunov stability theory
  - Input-output stability
  - Absolute stability
  - Passivity
  - Perturbed systems
  - Feedback linearization
  - Sliding mode control
  - Back-stepping control
  - Lyapunov based adaptive control
  - Nonlinear observers
- **Delivery Mode and Teaching Method:** 3 hours of lectures per week.
- **Student Evaluation:** mid-term exam: 20%, research project and presentation: 25%, homework assignments: 15%, and final exam: 40%.
- **Textbook:** Khailil, H.K. *Nonlinear Systems – 3rd Edition*. Prentice Hall, 2002.
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: apply knowledge of the basic fundamentals of nonlinear phenomena: multiple equilibria, limit cycles, complex dynamics, bifurcations.

  Outcome 2: identify second order nonlinear systems: phase plane techniques, limit cycles- Poincare-Bendixson theory, index theory.

  Outcome 3: understand Input-output analysis and stability: small gain theorem, passivity, describing functions.

  Outcome 4: understand and apply Lyapunov stability theory: basic stability and instability theorems, LaSalle's theorem, indirect method of Lyapunov.

  Outcome 5: linearize a system by state feedback: input-output and full state linearization, zero dynamics, inversion, tracking, stabilization.

  Outcome 6: apply basic software tools to the analysis of nonlinear systems.
- **Information About Course Designer/Developer:**
  Course designed by L. Lu, PhD, School of Energy Systems and Nuclear Science and Faculty of Engineering and Applied Science
- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  L. Lu and E. Esmailzadeh
- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering and relevant experience in teaching and research. Faculty members will normally be registered Professional Engineers.

Course Title: ENGR 5930G – Adaptive Control

- **Course Description and Content Outline:** This is a course on the general principles of adaptive control and learning. This course will cover real-time parameter estimation, deterministic self-turning regulators, stochastic & predictive self-tuning regulators, model reference adaptive systems, gain-scheduling, properties of adaptive systems, robust adaptive control schemes, adaptive control of nonlinear systems, practical issues and implementation.
- **Content outline by topic:**
    - Real-time parameter estimation
    - Deterministic self-turning regulators
    - Stochastic & predictive self-tuning regulators
    - Model reference adaptive systems
    - Gain-scheduling
    - Properties of adaptive systems
    - Robust adaptive control schemes
    - Adaptive control of nonlinear systems
    - Practical issues and implementation
- **Delivery Mode and Teaching Method:** 3 hours of lectures per week.
- **Student Evaluation:** mid-term exam: 20%, research project and presentation: 25%, homework assignments: 15%, and final exam: 40%.
- **Textbook requirements:** K. J. Astrom and B. Wittenmark, *Adaptive Control*, 2nd , Addison-Wesley, 1995
- **Learning Outcomes.** Students who successfully complete the course have reliably demonstrated the ability to

  Outcome 1: utilize the fundamental concepts of adaptive control and learning.
  Outcome 2: understand and apply the concepts of convergence, stability, and robustness to analyze control systems.
  Outcome 3: estimate parameters and learn models from empirical data.
  Outcome 4: understand and analyze the behavior of adaptive control schemes such as model reference, adaptive control and self tuning regulators.
  Outcome 5: articulate perturbation and averaging theory.
  Outcome 6: use advanced stability theory to analyze adaptation schemes.
  Outcome 7: design of gain-scheduling controllers.
  Outcome 8: be familiar with practical issues in implementation of adaptive controllers.
- **Information About Course Designer/Developer:**
  Course designed by J. Ren, PhD, Faculty of Engineering & Applied Science
- **Identify faculty to teach the course and/or statement "faculty to be hired":**
  J. Ren, L. Lu
- **Faculty qualifications required to teach/supervise the course:**
  PhD degree in engineering and relevant experience in teaching and research.
  Faculty members will normally be registered Professional Engineers.

Course Title: ENGR 5940G – Intelligent Control Systems

- **Course Description and Content Outline:** With the advance of increasingly faster computing hardware and cheaper memory chips, computational intelligence, also known as a part of "soft computation", is becoming more and more important in control engineering. This course will equip the student with the essential knowledge and useful resources to solve some of the systems control problems not easily solved using conventional control methods. This course will cover: fundamentals of fuzzy set theory, structures of fuzzy logic controllers, structures of neural networks, learning algorithms, genetic algorithms.

- **Content outline by topic:**
  - General characteristics of intelligent control systems.
  - Fundamentals of fuzzy set theory.
  - Application of fuzzy logic in control.
  - Basic and complex structures of fuzzy logic controllers.
  - Automated design and self-organization of fuzzy controllers.
  - Basic structures of neural nets.
  - Static and dynamic neural nets.
  - Learning algorithms.
  - Application of neural nets in modeling, identification and control of systems.
  - Optimization by using genetic algorithms.
  - Examples of intelligent control systems in industry.
- **Delivery Mode and Teaching Method:** One-term 3 hours of lectures per week.
- **Student Evaluation:** mid-term exam: 20%, research project and presentation: 25%, homework assignments: 15%, and final exam: 40%.
- **Textbook requirements:** C.T.Lin, C.S.G.Lee (1996): *Neural Fuzzy systems - A Neuro-Fuzzy Synergysm to Intelligent Systems*, Prentice Hall, New York.
- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: understand fundamental concepts of fuzzy logic (FL), neural network (NN) and genetic algorithm (GA).

  Outcome 2: use NN/FL to model the complex static/dynamic systems.

  Outcome 3: use NN/FL as a tool to construct the complex nonlinear controller to better control the complex dynamics systems.

  Outcome 4: use GA to solve global optimization problem.

  Outcome 5. gain hands-on experience on MATLAB toolboxes for NN and FL to solve practical control design problems.

  Outcome 6: explore and utilize the Internet resources on computational intelligent related to control engineering.

Information About Course Designer/Developer:

Course designed by J. Ren, PhD, Faculty of Engineering & Applied Science

- **Identify faculty to teach the course and/or statement "faculty to be hired":**

  J. Ren

- **Faculty qualifications required to teach/supervise the course:**

  PhD degree in electrical engineering and relevant experience in teaching & research. Faculty members will normally be registered Professional Engineers.

Course Title: ENGR 5960G – Power System Operations, Analysis and Planning

- **Course Description and Content Outline:** Transmission lines. Steady state transmission capacity; network compensation; voltage management; load flow simulation; transient stability simulation; system security; system planning; symmetric operation of power systems.
- **Content Outline by Topics**
  - o Introduction to single-phase, three-phase systems and the per unit system
  - o Transmission line models and steady-state transmission capacity
  - o Concepts of network compensation: impedance, voltage, angle and power
  - o Voltage management and effect on transmission capacity
  - o Load flow simulation: admittance matrix, problem structure, numerical simulation by the Newton-Raphson method
  - o Transient stability simulation: deriving the swing equation, complex generator models, complex component control models, numerical simulation techniques
  - o Reliability and security: criteria, deterministic concepts, transfer limits, security limits, contingencies, limit determination
  - o Power system planning: operations versus planning; planning processes and criteria
  - o Asymmetric operation of transmission systems

- **Delivery Mode and Teaching Method:** 3 hours of class lectures per week.
- **Student Evaluation:** Homework assignments: 50%; final exam: 50%.
- **Textbook requirements:** Marceau, R.J., *Notes on Power System Operation, Analysis and Planning*

- **Learning Outcomes:** Students who successfully complete the course have reliably demonstrated the ability to:

  Outcome 1: determine steady-state transmission line capacity employing all the possible compensation strategies; choose an appropriate compensation strategy according to circumstances; explain the operation of the different compensation technologies.

  Outcome 2: derive the equations which describe steady-state network operation; explain how these equations can be solved. Develop load flow software; analyze the result of simulations describing different operating conditions; make recommendations concerning compensation strategies required to solve network operating problems.

  Outcome 3: explain how power systems react to unforeseen circumstances; derive the swing equation. Explain how transient conditions are represented and solved; develop appropriate software for transient stability simulation. Integrate complex generator models and network component control system models; determine whether a system is stable or unstable; determine a transient stability transfer limit.

  Outcome 4: explain the difference between reliability and security. explain such concepts as: i) operations and planning criteria; ii) transfer limit; iii) security limit; iv) steady-state security; v) dynamic security; determine a security limit; explain how security limits are employed in system operation.

  Outcome 5: plan a transmission corridor using traditional three-phase AC transmission concepts.

  Outcome 6: explain how asymmetric operation can increase: i) reliability, ii) security and iii) economics of power system operation and planning; plan a transmission corridor employing asymmetric operation and planning concepts.

- **Information About Course Designer/Developer:**
  Course designed by R. J. Marceau, PhD, Faculty of Engineering and Applied Science

• **Identify faculty to teach the course and/or statement "faculty to be hired":** R. J. Marceau.
• **Faculty qualifications required to teach/supervise the course:** PhD degree in Electrical Engineering and relevant experience in teaching and research. Faculty members will normally be registered Professional Engineers.

ELECTIVE GRADUATE COURSES FROM THE FACULTY OF SCIENCE

Course Title: MCSC 6010G – Mathematical Modelling

Course Description and Content Outline:

The Mathematical Modelling course is a core course and forms an essential part of the MSc program. The student will get familiar with the fundamental principles and techniques in mathematical modelling, showcased through the use of classical and advanced models in physics, biology and chemistry. Several analytical techniques will be introduced through the study of the mathematical models presented.

Topics include:

- **Procedures of modelling:**
  - stochastic vs deterministic models
  - discrete vs continuous models
  - conservation laws
  - compartmental models
  - symmetries and other structures
- **Simplification procedures:**
  - non-dimensionalization
  - reduced models
  - toy models.
- **Analytical methods:**
  - asymptotic approximations
  - regular and singular perturbation methods
  - multiple scales
  - Methods to find: traveling wave solutions, shock waves and solitons.
  - relaxation dynamics
  - Steady-state, Hopf and Turing bifurcation.
- **Applications**
  - Population models and epidemiology
  - Neuron and cell dynamics
  - Nonlinear waves in biological, chemical and physical systems
  - Fluid Dynamics
  - Pattern formation (in fluid experiments, animal coat patterns, chemical reactions, visual cortex)
  - Coupled systems (neurons, traffic flows, lattice systems)

Length in Contact Hours: 3 hours/week, 3 credits.

Delivery Mode and Teaching Method(s): Lecture

Student Evaluation: Assignments, Exams, Oral Presentations, Projects

Literature:

- C M Bender and J A Orszag, *Advanced mathematical methods for scientists and engineers* McGraw Hill, 1978
- F B Hildebrand, *Methods of Applied Mathematics*, Dover, 1992
- A B Tayler, *Mathematical Models in Applied Mechanics*, OUP, 1985
- A C Fowler, *Mathematical Models in The Applied Sciences* CUP, 1997
- J Kevorkian and J D Cole, *Perturbation Methods in Applied Mathematics*, Springer, 1981
- J Kevorkian and J D Cole, *Multiple Scale and Singular Perturbation Methods*, Springer, 1996
- E J Hinch, *Perturbation Methods*, CUP, 1991
- M H Holmes, *Introduction to Perturbation Methods*, Springer, 1998

- J. Murray. *Mathematical Biology, Springer,*
- J. Keener and J. Sneyd. *Mathematical Physiology, Springer, 2002*

Proposed textbook requirements: None

Learning Outcomes:

Students who successfully complete the course have reliably demonstrated the ability to:

1. Formulate a model of an observable phenomenon using the most suitable mathematical procedure subject to the desired level of accuracy of the model and the choice or availability of techniques of mathematical analysis.
2. Analyze scientific data and determine whether the data is better modeled using stochastic or deterministic modelling.
3. Determine whether an observable phenomena is better modeled using discrete time models of continuous time models.
4. Identify properties of observable phenomena which can be abstracted into modelling hypotheses for the mathematical model. For instance: symmetry, time-reversibility, conserved quantities, coupled system structure, compartmental structure, etc.
5. Use various procedures, such as nondimensionalisation or linearization, to simplfy the analysis of the mathematical model.
6. Formulate toy models which are more easily analyzable in order to model only some specific features of the observable phenomena. Be able to compare the results with the actual data in order to validate or not the toy model. Iterate the formulation or the analysis of the toy model in order to improve the accuracy of the mathematical modelling.
7. Use various analytical methods to perform the mathematical analysis of models: asymptotic approximations, regular and singular perturbation methods, multiple scales, traveling wave solutions, shock waves and solitons, relaxation dynamics, elementary bifurcation theory for ordinary and parabolic partial differential equations, and discrete mappings , Turing bifurcations in reaction-diffusion equations.
8. Formulate mathematical models of various degrees of complexity and accuracy for phenomena arising in biology, chemistry, physics, finance, engineering using the mathematical procedures acquired in the course to obtain models. Analyze the mathematical models using the techniques acquired in the course.
9. Analyze the results of the mathematical analysis of models of observable phenomena, compare the results to the known data, identify predictions that the mathematical model makes about the phenomenon and identify the positive and negative features of the model.

Information about Course Designer/ Developer: Pietro-Luciano Buono and Peter Berg, Ph.D Mathematics, Faculty of Science, UOIT.

List faculty eligible to teach the course and/or statement of “faculty to be hired":

Dhavide Aruliah, Ph.D Computer Science
Peter Berg, Ph.D. Mathematics
Pietro-Luciano Buono, Ph.D. Mathematics
Anatoli Chkrebtii, Ph.D Physics
Greg Lewis, Ph.D Mathematics
Fedor Naumkin, Ph.D Physics
Eleodor Nichita, Ph.D Engineering
William Smith, Ph.D Applied Mathematics
Ed Waller, Ph.D Engineering

Are there any plans to teach all or portions of this course on-line?

A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, etc.

Faculty Qualifications to teach/supervise the course:
PhD in Physical Science (Mathematics, Computer Science, Physics, Chemistry) or Engineering.

Classroom requirements: Technology-enhanced classroom with data projector, VCR and DVD and internet access.

Equipment requirements: See Classroom requirements

Course Title: MCSC 6030G – High-Performance Computing

Pre-requisite(s): MCSC 6020G Numerical Analysis or equivalent.

Course Description and Content Outline:

The goal of this course is to introduce students to the tools and methods of high-performance computing (HPC) using state-of-the-art technologies. The course includes an overview of high-performance scientific computing architectures (interconnection networks, processor arrays, multiprocessors, shared and distributed memory, etc.) and examples of applications that require HPC. The emphasis is on giving students practical skills needed to exploit distributed and parallel computing hardware for maximizing efficiency and performance. Building on MCSC 6020G, students will implement numerical algorithms that can be scaled up for large systems of linear or nonlinear equations.

Topics include:

- Survey of high-performance computer architectures: interconnection networks, processor arrays, multiprocessors, multicomputers, Flynn's taxonomy
- Basic efficiency guidelines for high-performance computing
- Parallel algorithm design
- Programming tools for high-performance computing
    - Message Passing Interface (MPI)
    - BLAS, LAPACK, PBLAS, ScaLAPACK, BLACS
- Timing, profiling, and benchmarking
- Optimisations: floating point operations, memory accesses
- Case studies: parallelel programs from some scientific computations

Length in Contact Hours: 3 hours/week, 3 credits.

Delivery Mode and Teaching Method(s): Lecture.

Student Evaluation: Assignments, Exams, Oral Presentations, Projects

Resources:

- E. Anderson, Z. Bai, C. Bischoff, S. Blackford, J. Demmel, J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorenson. LAPACK Users' Guide (3^{rd} Ed). SIAM, 1999
- R. Barrett, M. Berry, T.F. Chan, J. Demmel, J. Donato, J. Dongarra, V. Eijkhout, R. Pozo, C. Romine, and H. Van der Vorst. Templates for the Solution of Linear Systems. SIAM, 1994
- S. Goedecker and A. Hoisie. Performance Optimization of Numerically Intensive Codes. SIAM, 2001
- G.H. Golub and C. Van Loan. Matrix Computations (3^{rd} Ed). John Hopkins, 1996
- W. Gropp, E. Lusk, and A. Skjelluj. Using MPI. MIT Press, 1994
- M. Overton. Numerical Computing with IEEE Floating Point Arithmetic. SIAM, 2001

Proposed textbook requirements:
M.J. Quinn. Parallel Programming in C with MPI and OpenMP. McGraw-Hill, 2004

Learning Outcomes:
Students who successfully complete the course have reliably demonstrated the ability to:

1. Use Foster's design methodology to design parallel algorithms by analysing sequential algorithms for simple applications (e.g., summing data vectors, computing N-body interactions, solving two-point boundary-value problems, etc.)
2. Formulate and code a parallel implementation of a matrix-free matrix-vector product for matrices with block or band structure for use with an iterative Krylov-subspace solver for linear equations.
3. Formulate and code a parallel implementation of the Jacobi method for the iterative solution of a system of linear equations.
4. Formulate and code a parallel implementation of the conjugate gradient method for the iterative solution of a banded symmetric positive definite system of linear equations.

Information about Course Designer/ Developer: Dhavide Aruliah, Greg Lewis and William Smith.

List faculty eligible to teach the course and/or statement of “faculty to be hired":

Greg Lewis, Ph.D Mathematics
Dhavide Aruliah, Ph.D Computer Science
William Smith, Ph.D Applied Mathematics

Are there any plans to teach all or portions of this course online?
A course website will play an integral role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, etc.

Faculty Qualifications to teach/supervise the course:
PhD in Mathematics, Computer Science or Physics with experience in Numerical Methods and/or High Performance Computing.

Classroom requirements: Technology-enhanced classroom with data projector, VCR and DVD and internet access.

Equipment requirements:
See Classroom requirements

Course Title: MCSC 6120G – Numerical Methods for Ordinary Differential Equations

Pre-requisite(s): Numerical Analysis MCSC6020G or equivalent

Course Description and Content Outline:
Differential equations are an indispensable tool for the modelling of physical phenomena. However, most often in practice, analytical solutions to model equations cannot be found, and numerical approximations must be made. In this course, practical computational techniques for the numerical solution of ordinary differential equations will be covered, with an emphasis on their implementation and the fundamental concepts in their analysis.

Topics include:

- Review of ordinary differential equations
- Initial value problems
  - Forward Euler
  - Convergence, accuracy, consistency, and 0-stability
  - Absolute stability
  - Stiffness: Backward Euler
  - A-stability, stiff stability
  - Trapezoidal scheme
- One-step methods
  - Basic Runge-Kutta methods and general formulation
  - Convergence and order for Runge-Kutta methods
  - Error estimation and control
  - Implicit Runge-Kutta and collocation methods
  - Runge-Kutta software
- Linear multistep methods
  - Adams-Bashforth, Adams-Moulton, Backward Differentiation Formulae (BDF)
  - Order, 0-stability and convergence
  - Absolute stability and stiff decay
  - Implementation issues: error estimation, predictor-corrector techniques, step selection and modification, nonlinear systems solution
  - Multistep software
- Boundary Value Problems
  - Simple and multiple shooting
  - Difference schemes
    - Midpoint and Trapezoidal
    - Convergence, accuracy, consistency and stability
    - Solving linear problems: elimination for block matrices, stability
    - Solving nonlinear problems: Newton's method
    - Scalar, second order ODEs
    - Collocation and Runge-Kutta
    - Convergence acceleration techniques
    - BVP software

Length in Contact Hours:
3 hours/week, 3 credits.

Delivery Mode and Teaching Method(s): Lecture.

Student Evaluation:
The mark will be determined from 4 assignments, which will require the implementation of various numerical methods to a variety of problems, and a term project, which will provide the student with experience of the implementation of a numerical method to a more in-depth problem.

Literature:

- U.M. Ascher, R.M. Mattheij, and R.D. Russell. Numerical Solution of Boundary Value Problems for Ordinary Differential Equations. SIAM, 1995.
- K.E. Brenan, S.L. Campbell, and L.R. Petzold. Numerical Solution of Initial Value Problems in Differential-Algebraic Equations. North-Holland, 1989.
- E. Hairer, S.P. Norsett, and G. Wanner. Solving Ordinary Differential Equations I. Springer-Verlag, second edition, 1993.
- E. Hairer and G. Wanner. Solving Ordinary Differential Equations II. Springer-Verlag, 1991.
- J.D. Lambert. Numerical Methods for Ordinary Differential Systems. Wiley, 1991.
- L.F. Shampine. Numerical Solution of Ordinary Differential Equations. Chapman & Hall, 1994.

Proposed textbook requirements:
U.M. Ascher and L.R. Petzold. Computer Methods for Ordinary Differential Equations and Differential-Algebraic Equations SIAM, 1998

Learning Outcomes:
Students who successfully complete the course have reliably demonstrated the ability to:

1. choose and implement the appropriate numerical technique when presented with an ordinary differential equation requiring a numerical solution, and to understand the limitations of this approximation
2. state the advantages and disadvantages of implicit versus explicit methods, single step versus multi-step methods, high-order versus low-order methods
3. state definition of stability, accuracy, convergence
4. state definition of stiffness and recognize the numerical consequences
5. derive a multi-stage Runge-Kutta method
6. design and implement codes for the solution of ordinary differential equations using a variety of methods
7. be familiar with existing software packages and the issues involve in implementing them

Information about Course Designer/ Developer:
Greg Lewis, Ph.D Mathematics, Faculty of Science, UOIT.

List faculty eligible to teach the course and/or statement of “faculty to be hired": Greg Lewis, Ph.D Mathematics, Faculty of Science, UOIT, Dhavide Aruliah, Ph.D Mathematics, Faculty of Science, UOIT.

Are there any plans to teach all or portions of this course online?
A course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, etc.

Faculty Qualifications to teach/supervise the course:
Ph.D in Mathematics, Computer Science or related field, with background in Numerical Analysis and Scientific Computing, and research experience in the development and/or implementation of numerical methods for ODEs.

Classroom requirements: Technology-enhanced classroom with data projector, VCR and DVD and internet access.

Equipment requirements:
See Classroom requirements

Course Title: MCSC 6125G – Numerical Methods for Partial Differential Equations

Pre-requisite: Numerical Analysis MCSC 6020G, satisfaction of admission requirements for the MSc. Program.

Course Description and Content Outline:
This course is an introduction to the mathematical concepts needed to develop accurate, reliable, and efficient numerical methods for the approximate solution of partial differential equations (PDEs). Partial differential equations constitute a vital modelling tool in science and a rich field of applied mathematical research. Essential model problems of elliptic, parabolic, and hyperbolic type are examined with corresponding numerical approximation techniques. This course includes a study of various discretisation frameworks: finite-difference methods, finite-element methods, finite-volume methods, and spectral collocation methods. Approximation schemes are compared and contrasted with an emphasis on error estimation, consistency, stability, and convergence as well as availability and convenience of existing software. There will be discussion of elements of iterative methods used for solving linear algebraic and nonlinear systems that arise from discretisation of PDE problems.

Topics include:

- Classification and well-posedness of PDE problems
  - Elliptic, parabolic, and hyperbolic model problems
  - Initial-boundary and boundary-value problems
- Finite difference discretisation schemes
- Finite element discretisation schemes
- Finite volume discretisation schemes
- Spectral collocation discretisation schemes
- Von Neumann analysis
- Accuracy, stability, and convergence
- Time-stepping algorithms and the method of lines
- Dissipation and dispersion
- A priori and a posteriori error estimates
- Iterative methods for systems of linear and nonlinear equations
- Possible applications: electromagnetics, fluid mechanics, solid mechanics, gas dynamics, semiconductor drift-diffusion models, chemical engineering applications

Length in Contact Hours: 3 hours/week, 3 credits.

Delivery Mode and Teaching Method(s): Lecture.

Student Evaluation: Assignments, Oral Presentation, Project

References:

U. Ascher and L. Petzold. Computer Methods for Ordinary Differential Equations and Differential-Algebraic Equations. SIAM, Philadelphia. 1998

D. Kincaid and W. Cheney. Numerical Analysis: Mathematics of Scientific Computing. Brookes/Cole. 3rd ed. 2002

J. Demmel. Applied Numerical Linear Algebra. SIAM, Philadelphia. 1997

P.G. Ciarlet. The finite element method for elliptic problems. SIAM, Philadelphia. 2nd ed. 2002

M. Gockenbach. Partial Differential Equations: Analytical and Numerical Methods. SIAM, Philadelphia. 2002

C.A. Hall and T.A. Porsching. Numerical Analysis of Partial Differential Equations. Prentice-Hall. 1990

R. Mitchell and D. F. Griffiths. The Finite Difference Method in Partial Differential Equations. Wiley, New York. 1980

Quarteroni, R. Sacco, and F. Saleri. Numerical mathematics. Springer, New York. 2000

L.N. Trefethen. Spectral Methods in MATLAB. SIAM, Philadelphia. 2000

Proposed textbook requirements:
K.W. Morton and D.F. Mayers. Numerical Solution of Partial Differential Equations.Cambridge. 1996

Learning Outcomes:
Students who successfully complete the course have reliably demonstrated the ability to:

1. Derive the symbol of a linear differential operator from a linear or nonlinear PDE or system of PDEs to classify according to type (elliptic, parabolic, hyperbolic).
2. Derive finite-difference schemes and develop computer codes for the numerical solution of standard scalar model PDE problems (first-order wave equation, heat equation, Schrodinger equation) in one or two spatial dimensions on regular grids.
3. Derive the symbol of the linearisation of a nonlinear PDE (or PDE system) to classify it according to type (elliptic, parabolic, hyperbolic) for the purpose of selecting appropriate numerical solution approaches.
4. Apply von Neumann analysis to finite-difference schemes for standard model PDEs to determine the associated amplification factors.
5. Derive dispersion relations for standard model PDEs and corresponding finite-difference schemes.
6. Analyse finite-difference schemes for standard model PDEs to determine their constistency, stability, and CFL condition.
7. Derive and code finite-difference implementations of standard boundary conditions (Dirichlet, Neumann, Robin) for PDEs in one, two or more dimensions on regular grids.
8. Implement spectral collocation and Galerkin finite element schemes for the solution of second-order elliptic PDE problems in one spatial dimension.

Information about Course Designer/Developer:
Dhavide Aruliah, PhD Computer Science, Faculty of Science, UOIT

List faculty eligible to teach the course and/or statement of “faculty to be hired":
Dhavide Aruliah, PhD Computer Science
Peter Berg, PhD Mathematics
Greg Lewis, PhD Mathematics

Are there any plans to teach all or portions of this course online
A course website will play an integral role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, etc

Faculty Qualifications to teach/supervise the course:
PhD in Mathematics or Computer Science with experience with partial differential equations and numerical analysis.

Classroom requirements: Technology-enhanced classroom with data projector, VCR and DVD and internet access.

Equipment requirements: See Classroom requirements. Students should have access to programming environments such as Matlab for the purpose of completing assignments and projects.

UNDERGRADUATE NUCLEAR ENGINEERING COURSES AVAILABLE FOR GRADUATE CREDIT

COURSE TITLE: ENGR 4510U Nuclear Plant Chemistry

- **Course Outline:** Corrosion and crud formation; heavy water chemistry; heavy water production and up-keep; moderator and heat transport system chemistry; purification systems to remove particulates, contaminants and chemicals added to control reactivity; decontamination; steam generator, condenser and feedwater chemistry; pH and pD control in power plants; online and offline control of process chemistry; metallurgical problems in nuclear power plants; metallurgical techniques for irradiated materials.
- **Topics include:**
  - corrosion and crud formation
  - heavy water chemistry
  - heavy water production and up-keep
  - moderator and heat transport system chemistry
  - purification systems to remove particulates, contaminants and chemicals added to control reactivity
  - decontamination
  - steam generator, condenser and feedwater chemistry
  - pH and pD control in power plants
  - online and off-line control of process chemistry
  - metallurgical problems in nuclear power plants
  - metallurgical techniques for irradiated materials
  - chemistry laboratory operation and field analyzers
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** none
- **Representative Texts:** none

Information about Course Designer/Developer: M. Dymarski, Ph.D., Academic Associate (SESNS)

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. M. Dymarski.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in nuclear plant chemistry

Classroom requirements: Standard computer enabled UOIT classroom equipped with VRC, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: none

Course Title: ENGR 4520U Nuclear Plant Safety Design

Prerequisites: ENGR 4640U, ENGR 4660U, ENGR 4700U.

- **Course Description and Content Outline:**

This course describes the regulatory requirements and the principles guiding the protection of workers and the general public from being harmed as a result of nuclear plant operations. Topics include: worker and public safety requirements; codes and standards; sources of radioactive release; defence in depth; principle of control, cool, contain; accident prevention, mitigation and accommodation; separation and independence; redundancy; common mode events; inherent safety features; plant safety systems; safety culture, management of plant safety; design basis accident; accident analysis; quantitative and probabilistic risk assessment; examples of nuclear accidents; online and off-line computer codes for the design and safety analysis of nuclear plants.

- **Topics included:**
  - regulatory requirements and the principles guiding the protection of workers and the general public from being harmed as a result of nuclear plant operations
  - worker and public safety requirements
  - codes and standards
  - design options, safety design optimization
  - sources of radioactive release
  - defence in depth
  - principle of control, cool, contain
  - accident prevention, mitigation and accommodation
  - separation and independence, redundancy, common mode events
  - inherent safety features, plant safety systems, safety culture, management of plant safety
  - design basis accidents, accident analysis
  - quantitative and probabilistic risk assessment
  - examples of nuclear accidents, lessons learned from them
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 1 hour of tutorial per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Systems Engineering: An Approach to Information-Based Design, by George A. Hazelrigg, Prentice Hall, (1996)

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng. School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement “faculty to be hired”:
D. Meneley, Ph.D., P.Eng., Adjunct Professor (SESNS)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in nuclear plant safety.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VRC, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: not applicable

Course Title: ENGR 4610U Corrosion for Engineers

Prerequisite: CHEM 1020U or CHEM 1800U.

- **Course Description and Content Outline:** A study of types, causes, costs, measurement and prevention of corrosion. Topics include: effects of material choices and the environment; types of corrosion discussed: general or uniform, galvanic, crevice, pitting, intergranular, selective leaching, stress-corrosion, erosion-corrosion, hydrogen effects; corrosion testing; selection of materials; aqueous corrosion; high temperature corrosion; corrosion in nuclear and fossil plants and other industrial environments; electrochemical principles; thermodynamics; electrode kinetics; aqueous corrosion kinetics; practical applications.
- **Topics include:**
  - study of the types, causes, costs, measurement and prevention of corrosion
  - effects of material choices and environments on corrosion
  - types of corrosion discussed: general or uniform, galvanic, crevice, pitting, intergranular, selective leaching, stress-corrosion, erosion-corrosion, hydrogen effects
  - corrosion testing
  - selection of materials
  - aqueous corrosion
  - high temperature corrosion
  - corrosion in nuclear and fossil plants and other industrial environments
  - electrochemical principles
  - chemical thermodynamics
  - electrode kinetics and corrosion kinetics
  - practical applications
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  J.R. Davis, ASM International, 2000.
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: B. Ikeda PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. B. Ikeda.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or chemistry with experience in corrosion in industrial settings.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VRC, DVD, data projectors, and wired and wireless internet access.

Course Title: ENGR 4620U Radioactive Waste Management Design

Prerequisites: ENGR 3570U, ENGR 3930U, ENGR 3610U

- **Course Description and Content Outline:**

Students will study: nature of radioactive waste; origin of low, intermediate and high activity waste; characteristics, forms and quantity of radioactive waste; production of radioactive waste at each stage of the nuclear cycle: mining, fuel fabrication, reactor operation and maintenance, spent fuel, reactor structural components; medical and industrial waste; handling, transporting, storing and disposing technologies for each type of waste; on-site and offsite storage; spent fuel reprocessing and disposal methods; radioactive waste management plans and practices in various countries; public concerns and perception of radioactive waste management. Two field trips will be arranged..

- **Topics included:**
    - nature of radioactive waste
    - origin of low, intermediate and high activity waste
    - characteristics, forms and quantity of radioactive waste
    - production of radioactive waste at each stage of the nuclear cycle: mining, fuel fabrication, reactor operation and maintenance
    - spent fuel
    - reactor structural components
    - medical and industrial waste
    - handling, transporting, storing and disposing technologies for each type of waste
    - on-site and off-site storage
    - spent fuel reprocessing and disposal methods
    - radioactive waste management plans and practices in various countries
    - public concerns and perception of radioactive waste management.
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures plus one hour of tutorial per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students: none**
- **Representative Texts: none**

Information about Course Designer/Developer:
Course designed by: B. Ikeda, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired": Dr. B. Ikeda.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or chemistry with experience in Radioactive Waste Management

Classroom requirements: Standard computer enabled UOIT classroom equipped with VRC, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: not applicable

Course Title: ENGR 4640U Nuclear Plant Operation

Prerequisite: PHY 1020U.

- **Course Description and Content Outline:**

A combination of lectures and self-paced interactive CD-ROM study will introduce students to the principles of energy conversion, to the operating features of the main nuclear reactor types, the use of pressure vessels and pressure tubes, natural versus enriched fuel, moderators, reactor coolant systems, steam turbines and associated water systems, generators, transformers, electrical output and plant electrical systems, grid frequency and voltage control, reactor-following-turbine and turbine-following- reactor unit control systems, turbine-generator governing, power maneuvering capability, trips, steam dumping to the condenser, normal and abnormal operating events.

- **Topics included:**
  - principles of energy conversion
  - operating features of the main nuclear reactor types
  - use of pressure vessels and pressure tubes
  - natural versus enriched fuel
  - moderators
  - reactor coolant systems
  - steam turbines and associated water systems
  - generators, transformers, electrical output and plant electrical systems
  - grid frequency and voltage control
  - reactor-following-turbine and turbine-following-reactor unit control systems
  - turbine-generator governing, power maneuvering capability
  - reactor and turbine trips
  - steam dumping to the condenser
  - normal and abnormal operating events
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 1 hour of tutorial per week.
- **Student Evaluation:** Assignments and exams
- **Literature and Resources to be purchased by students:**
  Course pack by Dr. G. Bereznai
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. G. Bereznai, Dr. G. Harvel.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in nuclear plant design or operations.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: each student must have access to an IBM compatible personal computer

Course Title: ENGR 4660U Risk Analysis Methods

Prerequisite: STAT 2800U.

- **Course Description and Content Outline:**

Students will apply probability theory to discrete and continuous events. Topics include: random variables; decision theory, including Bayes' Theorem, the likelihood principle, prior posterior and predictive distributions, survival models. Students will also study chemical, physical, biological hazards; recognition, evaluation, prevention and control of hazards; industrial hygiene and occupational health; analysis, assessment, characterization and communication of risks.

- **Topics included:**
  - application of probability theory to discrete and continuous events
  - random variables
  - decision theory, including Bayes' Theorem, the likelihood principle, prior, posterior and predictive distributions, survival models
  - chemical, physical, biological hazards
  - recognition, evaluation, prevention and control of hazards
  - industrial hygiene and occupational health
  - design options, packaging complexity, uncertainties of forecasting, cost and benefit
  - analysis, assessment, characterization and communication of risks
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 1 hour of tutorial per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Systems Engineering: An Approach to Information-Based Design, by George A. Hazelrigg, Prentice Hall, (1996)
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng.,School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. D. Meneley, Ph.D., P.Eng., Adjunct Professor (SESNS)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in risk analysis methods.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access. **Equipment requirements:** none

Course Title: ENGR 4670U Shielding Design

Prerequisite: ENGR 2950U.

- **Course Description and Content Outline:**

Radiation sources; characteristics and utilization of various radiation detectors; statistics of radiation counting; radiation spectroscopy with scintillation detector; semi-conductor detectors; identification and measurement of source strength, spectrum and geometry; shielding requirements for various types of radiation; shielding materials for equipment and processes employing radiation; radiation heating; radiation damage; measuring the effectiveness of various shielding materials; shielding for the transportation of radioactive materials; calculation and design of shielding for industrial and power plant applications; shielding requirements for spent fuel storage. 3 cr, 3 lec, 2 lab.

- **Topics include:**
  - radiation sources
  - characteristics and utilization of various radiation detectors
  - statistics of radiation counting
  - radiation spectroscopy with scintillation detector
  - semi-conductor detectors
  - identification and measurement of source strength, spectrum and geometry
  - shielding requirements for various types of radiation
  - shielding materials for equipment and processes employing radiation
  - radiation heating
  - radiation damage
  - measuring the effectiveness of various shielding materials
  - shielding for the transportation of radioactive materials
  - calculation and design of shielding for industrial and power plant applications
  - shielding requirements for spent fuel storage
- **Length in Contact Hours:** 5 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 2 hours of labs per week.
- **Student Evaluation:** Assignments, Exams, Lab reports, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** MicroShield® 7.01 software with Microsoft Word® and Excel® export capability supplied to students at no charge.
- **Representative Texts: none**

Information about Course Designer/Developer:
Course designed by: A. Keshavarz, Ph.D., P.Eng., Academic Associate, School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement “faculty to be hired”:
Dr. Keshavarz.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.
Faculty qualifications required to teach/supervise the course: PhD in nuclear engineering or physics with experience in radiation shielding
Classroom requirements: Standard computer enabled UOIT classroom equipped with VRC, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: radioactive sources and shielding calculation software.

Course Title: ENGR 4680U Nuclear Materials

Prerequisites: ENGR 2950U, ENGR 2220U.

- **Course Description and Content Outline:**

Irradiation effects on material properties, including neutrons, charged particles and gamma radiation; activation products; selection of materials for nuclear applications; radiation induced damage in materials; neutronic, thermal and structural considerations; material properties of nuclear fuels and fuel cladding; pressure vessel and pressure tube material behaviour; moderator, coolant and steam generator material properties; materials suitable for reactivity control device and shielding; materials used for long term storage of radioactive waste and spent fuel; activation analysis of materials using a neutron source.

- **Topics included:**
  - irradiation effects on material properties, including neutrons, charged particles and gamma radiation
  - activation products
  - selection of materials for nuclear applications
  - radiation induced damage in materials
  - neutronic, thermal and structural considerations
  - material properties of nuclear fuels and fuel cladding
  - pressure vessel and pressure tube material behaviour
  - moderator, coolant and steam generator material properties
  - materials suitable for reactivity control device and shielding
  - materials used for long term storage of radioactive waste and spent fuel
  - activation analysis of materials using a neutron source
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** To be determined when course is offered for the first time
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. B. Ikeda and Faculty to be hired.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in materials used in nuclear applications

Equipment requirements: none

Course Title: ENGR 4700U Nuclear Plant Design and Simulation

Prerequisites: ENGR 2010U, ENGR 4780U, ENGR 4640U.

- **Course Description and Content Outline:**

Introduces the main design and operating features of nuclear power plants using pressurized and boiling light water, pressurized heavy water and gas cooled reactors; small, medium and large reactors; unit control schemes; shutdown and safety systems; reactor cooling, shutdown and emergency core cooling systems; steam generator design features, level and pressure control; turbine and generator design; feedwater systems; unit electrical, service water and air systems. Where appropriate, nuclear power plant simulators will be used to demonstrate key aspects of power plant design.

- **Topics included:**
  - the concept of design and the design process is discussed in detail.
  - comparison of general design approaches and specific requirements in the nuclear industry are discussed.
  - the concept of working in a regulatory environment and the use of nuclear codes and standards as design inputs.
  - main design and operating features of nuclear power plants using pressurized and boiling light water, pressurized heavy water and gas cooled reactors
  - small, medium and large reactors; unit control schemes; shutdown and safety systems
  - reactor cooling, shutdown and emergency core cooling systems
  - steam generator design features, level and pressure control
  - turbine and generator design; feedheating systems
  - unit electrical, service water and air systems
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 1 hour of lab per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** There is no prescribed text for this course. Lecture notes and current events are used to discuss the design process
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: G. Harvel, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
G. Harvel, Ph.D., P.Eng., Associate Professor (SESNS)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: nuclear power plant simulators are used to demonstrate key aspects of power plant design. Students will work with current information obtained from industry to understand the influences of society, operating experience, and current industry practices on nuclear power plant design.

Course Title: ENGR 4730U Reactor Control

Co-requisite: ENGR 3740

- **Course Description and Content Outline:**

Control theory and application to nuclear power plants; use of indicators and alarms; role of the operator, man-machine interface; use of computers in reactor control; in-core and out-of-core measurement of neutron flux, spatial flux control, start-up instrumentation, failed fuel detection and location; reactivity control methods, mechanisms and algorithms; reactor shutdown methods, mechanisms and systems; loss of reactor control; temperature, pressure and flow measurements; heat transport system pressure and inventory control.

- **Topics included:**
  - Control theory and application to nuclear power plants
  - Use of indicators and alarms
  - Role of the operator, man-machine interface
  - Use of computers in reactor control
  - In-core and out-of-core measurement of neutron flux, spatial flux control
  - Start-up instrumentation
  - Failed fuel detection and location
  - Reactivity control methods, mechanisms and algorithms
  - Reactor shutdown methods, mechanisms and systems
  - Loss of reactor control
  - Heat transport system pressure and inventory control
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Modern Instrumentation and Control for Nuclear Power Plants: A Guidebook by International Atomic Energy Agency, Vienna, 1999.
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. L. Lu, Ph.D., Assistant Professor (SESNS)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course: PhD in engineering with experience in reactor instrumentation and control.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: each student must have access to an IBM compatible personal computer to use Matlab/Simulink to perform Proportional Integral and Derivative (PID) control.

Course Title: ENGR 4780U Nuclear Reactor Design

Prerequisites: ENGR 2500U, ENGR 2860U, ENGR 3820U, ENGR 3930U

- **Course Description and Content Outline:**

An introduction to thermal and fast reactors and reactor cooling systems. Topics include: natural and enriched fuels; pressure vessels and pressure tubes; reactor structures; moderator materials and systems; reactor coolant materials and systems; shutdown and safety systems, heat generation and removal in the fuel; modes of heat transfer from fuel to coolant; boiling heat transfer; cooling by natural circulation; measurement of thermalhydraulic parameters; momentum, mass and energy transfer processes; requirements for main heat transport, shutdown cooling and emergency core cooling systems. Nuclear power plant simulators will be used to demonstrate key aspects of reactor design. 3 cr, 3 lec, 1 tut.

- **Topics include:**
  - introduction to thermal and fast reactors and reactor cooling systems
  - natural and enriched fuels
  - pressure vessels and pressure tubes
  - reactor structures
  - moderator materials and systems
  - reactor coolant materials and systems
  - shutdown and safety systems
  - heat generation and removal in the fuel
  - modes of heat transfer from fuel to coolant: boiling heat transfer, cooling by natural circulation
  - measurement of thermalhydraulic parameters
  - momentum, mass and energy transfer processes
  - requirements for main heat transport, shutdown cooling and emergency core cooling systems
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 1 hour of lab per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  - Course pack consisting of selected chapters from:
  - Introduction to Nuclear Engineering, J.R. Lamarsh & A.J. Baratta, Prentice-Hall, 2001ISBN: 0-201-82498-1
  - Nuclear Reactor Analysis, James J. Duderstadt & Louis J. Hamilton, ISBN: 0471223638
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: G. Harvel, Ph.D., P.Eng., E. Nichita, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement “faculty to be hired”:
Dr. G. Harvel, Dr. E. Nichita

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course: PhD in nuclear engineering or physics with experience in nuclear reactor design.
Classroom requirements: Standard computer enabled UOIT classroom equipped with VRC, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: Students are required to run the Lattice Transport code DRAGON as part of a class project in which they perform fuel analysis/design.

Course Title: ENGR 4810U Nuclear Fuel Cycles

Prerequisites: ENGR 3610U, ENGR 3780U.

- **Course Description and Content Outline:**

Students study the production of fissile and fertile nuclear fuel; isotope separation; enrichment of uranium; characteristics of fuel-element materials; metal and ceramic uranium fuel; design and fabrication of fuel-elements; fuelling strategies; fuel failure mechanisms and detection of failed fuel; properties of irradiated fuel; the role of plutonium; principles of spent fuel reprocessing; dissolution of spent fuel from nuclear reactors; plutonium separation; meeting safe-guards requirements; natural versus slightly enriched fuel cycles; recycling of PWR fuel in CANDU; use of plutonium from the weapons program; thermal breeders; fast breeders.

- **Topics included:**
  - production of fissile and fertile nuclear fuel
  - isotope separation, enrichment of uranium
  - characteristics of fuel-element materials, metal and ceramic uranium fuel
  - design and fabrication of fuel-elements
  - fuelling strategies
  - fuel failure mechanisms and detection of failed fuel
  - properties of irradiated fuel
  - the role of plutonium
  - principles of spent fuel reprocessing
  - dissolution of spent fuel from nuclear reactors
  - plutonium separation
  - meeting safe-guards requirements
  - natural versus slightly enriched fuel cycles
  - recycling of PWR fuel in CANDU
  - use of plutonium from the weapons program
  - thermal breeders; fast breeders
- **Length in Contact Hours:** 3 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** none
- **Representative Texts:**

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
R. Ghafouri, PhD, P.Eng., Academic Associate (SESNS)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in nuclear fuel cycles.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.
Equipment requirements: none

Course Title: ENGR 4880U Principles of Fusion Energy

Prerequisites: ENGR 2500U, ENGR 3930U.

- **Course Description and Content Outline:**

This course explores the nature and energy generating potential of fusion reactions. Topics include: matter-energy transformations; fusion reaction analysis; Coulomb repulsion; deuterium-tritium reactions; production, extraction and storage of tritium; energy efficiency; fusion fuels and wastes; fusion reactor blankets; burn cycles; characteristics and diagnostics of plasmas; magnetic and inertial confinement schemes for fusion; tokomak techniques; laser fusion techniques; damage to walls and other materials; fission-fusion reactions; ITER Project; global fusion research projects.

- **Topics included:**
  - nature and energy generating potential of fusion reactions
  - matter-energy transformations
  - fusion reaction analysis
  - Coulomb repulsion
  - deuterium-tritium reactions
  - production, extraction and storage of tritium
  - energy efficiency
  - fusion fuels and wastes
  - fusion reactor blankets
  - burn cycles
  - characteristics and diagnostics of plasmas
  - magnetic and inertial confinement schemes for fusion
  - tokomak techniques, laser fusion techniques
  - damage to walls and other materials
  - fission-fusion reactions
  - global fusion research projects, ITER Project

Information about Course Designer/Developer:
Course designed by: G. Bereznai, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Peter Schwanke, M.A.Sc., Academic Associate (SESNS)

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD or specialist graduate degree in engineering or physics in the area of nuclear fusion.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: not applicable

UNDERGRADUATE HEALTH PHYSICS AND RADIATION SCIENCE COURSES AVAILABLE FOR GRADUATE CREDIT

Course Title: RADI 4220U – Radiation Biophysics and Dosimetry

Prerequisite(s): BIOL 2840U, ENGR 2950U or (RADI 2100U, RADI 2110U)

- **Course Description and Content Outline:**

This course will concentrate on providing the biophysical basis for radiation effects and health risks and the implications for ionizing radiation dosimetry and radiation protection. The course will cover the following topics; the physics of the interaction of radiation with matter; radiation damage at the molecular, sub-cellular and cellular level; tissue damage and health effects in humans; radiation quality; regulatory requirements and radiation protection dosimetry. The primary goals are to teach students the fundamental mechanisms of radiation interactions at the molecular and cellular levels and the various biological end-points that can result. Current concerns and controversy concerning the effects of low-dose exposures will also be covered in this course.

- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week and two hour tutorials biwekly.
- **Student Evaluation:** Assignments, Exams, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
- **Representative Texts:**

Information about Course Designer/Developer:
Course designed by: A. Waker, PhD., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. A. Waker, Dr. B. Neil

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or science with experience in radiation detection and measurements.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: none

Course Title: RADI 4430U Industrial Applications of Radiation Techniques

Prerequisites: RADI 4550U, ENGR 3740U.

- **Course Description and Content Outline:**

An introduction to application of ionizing and non-ionizing radiation to industrial probing, gauging, imaging and monitoring. Topics include: monitors (smoke detectors, radon monitors), density gauging using alpha, beta and gamma radiation; thickness gauging using charged particles, photons and neutrons; fluid flow and void fraction measurements, element and content analysis using neutron activation analysis and fluoroscopic excitation, Mossbauer spectroscopy, industrial radiography and computed tomography using photons and neutrons; emission tomography, ultrasound and eddy current flaw detection. 3 cr., 1 lab, 1 tut.

- **Topics include:**
  - application of ionizing and non-ionizing radiation to industrial probing, gauging, imaging and monitoring
  - monitors (smoke detectors, radon monitors)
  - density gauging using alpha, beta and gamma radiation
  - thickness gauging using charged particles, photons and neutrons
  - fluid flow and void fraction measurements
  - element and content analysis using neutron activation analysis and fluoroscopic excitation
  - Mossbauer spectroscopy, industrial radiography and computed tomography using photons and neutrons
  - emission tomography
  - ultrasound and eddy current flaw detection
- **Length in Contact Hours:** 5 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 2 hours of labs per week.
- **Student Evaluation:** Assignments, Exams, Lab Reports, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** none
- **Representative Texts:** none

Information about Course Designer/Developer:
Course designed by: E, Waller, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement “faculty to be hired”:
Dr. E. Waller, PhD, PEng, Dr. A. Waker, PhD.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access.

Equipment requirements: X-ray fluorescence spectroscopy, eddy current gauging

Course Title: RADI 4440U Radioisotopes and Radiation Machines

Prerequisites: RADI 2100U or ENGR 2950U.

- **Course Description and Content Outline:**

This course describes the various methods by which radiation can be produced (isotopic and electronic), and explains the operating principles, design and construction of machines utilizing radiation sources. An introduction to radioisotope production methods is given, along with the fundamentals of enrichment schemes. Design of machines that produce gamma, neutron, electron-beam, ion-beam, photon, laser and ultra-violet radiation are discussed. Specific aspects of radiation machines studied include the detectors used for high-energy radiation, low and high vacuum technology, high voltage power supplies, electron and ion beam generation, electron lens system, and the mechanisms of particle acceleration. Included in the discussion will be safety aspects regarding these machines.

- **Topics include:**
    - methods by which radiation can be produced (isotopic and electronic)
    - operating principles, design and construction of machines utilizing radiation sources
    - radioisotope production methods
    - fundamentals of enrichment schemes
    - design of machines that produce gamma, neutron, electron-beam, ion-beam, photon, laser and ultra-violet radiation
    - detectors used for high-energy radiation
    - low and high vacuum technology
    - high voltage power supplies
    - electron and ion beam generation
    - electron lens system
    - mechanisms of particle acceleration
    - safety aspects of radiation machines
- **Length in Contact Hours:** 4 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures per week and two hours of labs on alternate weeks.
- **Student Evaluation:** Assignments, Exams, Lab Reports, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:** none
- **Representative Texts:** none

Information about Course Designer/Developer:
Course designed by: E. Waller, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. B. Neil, Dr. E. Waller

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or physics with experience in the design and applications of radiation machines.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access. **Equipment requirements:** none

Course Title: RADI 4550U Radiation Detection and Measurement

Prerequisites: ENGR 2500U, ENGR 2950U or (RADI 2100U, RADI 2110U)

- **Course Description and Content Outline:**

In this course students learn how to measure radiation. They study the meaning and significance of the units for measuring radiation, the equipment that can be used to detect radiation, and the mathematical techniques used to interpret various detector readings. Topics covered include the nature and safe handling of radiation sources; measurement of source strength; the statistics of radiation counting; characteristics and utilization of various radiation detectors; radiation spectroscopy with scintillation detectors; semiconductor detectors; in-core and out-of-core neutron detectors; spectroscopy of fast neutrons; the application of radiation detectors and instrumentation; use of dosimeters; characteristics and utilization of radiation detectors devices needed for various radiation measurements; principles of nuclear instrument operation; factors considered to select nuclear instruments.

- **Topics included:**
  - radiation types, sources and interactions of radiation with matter
  - exploitation of interactions with matter to qualitatively and quantitatively detect radiation
  - characteristics and utilization of various radiation detectors and their associated electronics
  - measurement of source strength
  - the statistics of radiation counting
  - radiation spectroscopy with scintillation detectors
  - radiation spectroscopy with semiconductor detectors
  - in-core and out-of-core neutron detectors
  - spectroscopy of fast neutrons
  - use of dosimeters
  - principles of nuclear instrument operation, the practical application and their limitations
  - factors considered to select appropriate nuclear instruments for various applications
- **Length in Contact Hours:** 5 hours/week, 3 credits
- **Delivery Mode and Teaching Method(s):** This one-term course will be delivered using 3 hours of lectures and 2 hours of labs per week.
- **Student Evaluation:** Assignments, Exams, Lab reports, Oral Presentations, Projects
- **Literature and Resources to be purchased by students:**
  Radiation Detection and Measurement (Third Edition). Glenn F. Knoll. Wiley, 2000
- **Representative Texts:** as above

Information about Course Designer/Developer:
Course designed by: E. Waller, PhD., P.Eng., School of Energy Systems and Nuclear Science

Identify faculty to teach the course and/or statement "faculty to be hired":
Dr. E. Waller, Dr. B. Neil.

Are there any plans to teach all or portions of this course on-line? A WebCT course website will play a role in the delivery of resources for this course: syllabus, schedule, assignments, solutions to homework and exams, handouts, supplementary notes, but no on-line instruction.

Faculty qualifications required to teach/supervise the course:
PhD in nuclear engineering or science with experience in dosimetry.

Classroom requirements: Standard computer enabled UOIT classroom equipped with VCR, DVD, data projectors, and wired and wireless internet access. **Equipment requirements:** none