EP 4NE3 – 6NE3
Advanced Nuclear Engineering
Winter 2025
Course in-person delivery

CALENDAR / COURSE DESCRIPTION

This course presents advanced material on multidisciplinary areas of nuclear engineering covering the various reactor types; energy generation and deposition in the core of a nuclear reactor; heat transfer and transport of energy from the core and heat rejection to systems that result in the generation of electricity. Also covered are the production processes of nuclear materials, their behaviour under irradiation, the mechanisms that can cause material degradation under operating conditions, and nuclear fuel cycles.

The objective of the course is to provide senior undergraduate students and graduate students with the knowledge and techniques that allow them to analyse and solve real-world problems in nuclear engineering.

The course will cover the following topics:

- Operating reactor types: Light Water Reactors (PWR and BWR); Heavy Water Reactors (CANDU); Advanced Reactors (Liquid Sodium cooled fast reactors, High Temperature Gas reactors).
- Small Modular Reactors (SMR)
- Fission in nuclear fuel within the reactor core, energy deposition within fuel elements, fuel bundles, fuel assemblies and structural materials, decay heat from fission.
- Heat transfer from fuel to coolant; heat transport from reactor to steam generators; steam generator designs and performance; steam cycles (e.g. Rankine cycle and direct cycles), gas cycles (e.g. Brayton cycle).
- Nuclear reactor materials; production processes for uranium fuel elements (UO_2 pellets, fuel cladding); pressure retaining components (e.g. pressure tubes); control rod materials.
- Operating performance of nuclear reactor materials: irradiation damage mechanisms; damage due to stress, temperature and chemical effects (e.g. stress corrosion cracking, embrittlement, delayed hydride cracking); material fitness for service impacts.
- Fuel cycles: mining, ore processing and refining, oxide production, fissile material enrichment, spent fuel reprocessing, and spent fuel management. Case studies on uranium, mixed oxide and thorium fuel cycles.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): Either completion of EP 3D03, Principles of Nuclear Engineering or Approval of Instructor

Antirequisite(s): None

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Name: Dr. Nik Popov
Email: npopov@mcmaster.ca
Phone: 416-566-8233

Classroom: ABB 162

Lectures: Tuesday, 11:30 – 12:20
Thursday, 10:30 – 12:20

Delivery: In person

Office Hours:
Zoom Mon and Fri 18:00 pm to 19:00 pm
Or by appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Name: Peter Kriemadis
Email: kriemadp@mcmaster.ca

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

Dropbox: students will get invitation to join Dropbox folder where information will be posted and students will place their assignments and project

Avenue to Learn will not be used.

COURSE OBJECTIVES

By the end of this course, students should be able to:

- Understand the development of the major nuclear reactor types since the early 1960`s to the present day
- Understand the fission process, fission energy and energy deposition within a reactor, decay heat and heat deposition in structural material
- Understand and apply the basic steady state heat transfer and heat transport in the power cycle of a nuclear reactor (reactor to electrical generator)
- Understand the requirements that have led to the selection and development of materials for the various reactor types,
- Understand and apply the fissile isotope enrichment processes associated with different enrichment technology options.
- Understand and apply the fissile isotope separation processes associated with different separation technology options
- Understand and apply the means to assess the various mechanisms that can cause degradation of reactor materials during operation.
- Understand and apply the mathematics of characterizing the various processes in nuclear fuel cycles.

- Understand the requirements and limitations for nuclear fuel cycles based on specific fissile isotope mixtures (uranium, uranium+plutonium, thorium)

MATERIALS AND FEES

Recommended Texts:

1. John Luxat's Textbook, 2020 (posted on Dropbox – no cost)
2. Essential CANDU Textbook, UNENE, 2014 (available on web site – no cost)

Suggested Reference Texts:

1. B.J. Lewis, E.N. Onder, A.A. Prudil, Fundamentals of Nuclear Engineering, John Wiley & Sons, 2027 (Amazon: $195.00).
2. Kenneth D. Kok (Ed.), Nuclear Engineering Handbook (2nd Edition), CRC Press, 2017 (Amazon: $260.00).
3. John Lamarsh, Anthony Baratta, Introduction to Nuclear Engineering (4th Edition), Prentice Hall, 2017 (Amazon: $225.00).

Calculator: Any calculator.

Other Materials:
Detailed course notes, lecture overheads and other supplementary notes are available on Dropbox course website.

COURSE OVERVIEW

Week	Topic	Reading
1	Elements of Nuclear Engineering	
2	Reactor types (I): PWR, BWR, HWR/CANDU	
3	Reactor types (II): Gen IV Advanced Reactors, Small Modular Reactors (SMR)	
4	Energy Generation and distribution in a nuclear reactor	
5	Heat transfer and transport from reactor core to steam generators	
6	Thermal behaviour of nuclear fuel	
7	Nuclear power plant thermodynamics; Carnot Cycle, Rankine Cycle, feedwater systems, and Brayton gas cycle.	
8	Nuclear materials production processes	
9	Operating performance of nuclear materials (I): irradiation effects, material degradation mechanisms, steam generator corrosion mechanisms.	
10	Operating performance of nuclear materials (II): material degradation. Mechanisms due temperature, pressure and chemical embrittlement. Hydriding of Zircaloy components (fuel sheath, pressure tubes), delayed hydride cracking, hydride blister formation)	
11	Nuclear fuel cycles: mining, ore refining, fissile enrichment, oxide pellet production	

12	Nuclear fuel cycles: spent fuel reprocessing, spent fuel management	
13	Case studies on uranium, mixed oxide and thorium fuel cycles.	

ASSESSMENT

Component	Weight
Attendance	5%
Class activity (quizzes)	10%
Assignments (3)	30%
Midterm exam (4NE3)	20%
Project (6NE3)	20%
Final Exam (open book exam)	35%
Total	100%

ACCREDITATION LEARNING OUTCOMES

The Learning Outcomes defined in this section are measured for Accreditation purposes only, and will not be directly taken into consideration in determining a student's actual grade in the course.

Outcomes	Indicators
Ability to calculate approximate energy generation and distribution in a reactor core	
Ability to solve nuclear reactor heat transfer and transport under steady state operating conditions	
Ability to assess characteristics on various nuclear fuel cycles.	

For more information on Accreditation, please visit: https://www.engineerscanada.ca

ACADEMIC INTEGRITY

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity.

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various types of

academic dishonesty please refer to the Academic Integrity Policy, located at http://www.mcmaster.ca/academicintegrity

The following illustrates only three forms of academic dishonesty:

1. Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. Improper collaboration in group work.
3. Copying or using unauthorized aids in tests and examinations.

ACADEMIC ACCOMMODATIONS

Students who require academic accommodation must contact Student accessibility Services (SAS) to make arrangements with a Program Coordinator. Academic accommodations must be arranged for each term of study. Student Accessibility Services can be contact by phone at 905.525.9140 ext. 28652 or e-mail at sas@mcmaster.ca. For further information, consult McMaster University's Policy for Student Accessibility Services (SAS) | McMaster University.

NOTIFICATION OF STUDENT ABSENCE AND SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

1. The https://www.eng.mcmaster.ca/app/uploads/2023/11/MSAF-form-new-Fall-2023.pdf is a self-reporting tool for Undergraduate Students to report absences DUE TO MINOR MEDICAL SITUATIONS that last up to 3 days and provides the ability to request accommodation for any missed academic work. Please note this tool cannot be used during any final examination period.
2. You may submit a maximum of 1 Academic Work Missed request per term. It is YOUR responsibility to follow up with your Instructor immediately (NORMALLY WITHIN TWO WORKING DAYS) regarding the nature of the accommodation. Relief for missed academic work is not guaranteed.
3. If you are absent for reasons other than medical reasons, for more than 3 days, or exceed 1 request per term you MUST visit the Associate Dean's Office (JHE/A214). You may be required to provide supporting documentation.
4. This form must be submitted during the period of absence or the following day, and is only valid for academic work missed during this period of absence.
5. It is the prerogative of the instructor of the course to determine the appropriate relief for missed term work in his/her course.
6. You should expect to have academic commitments Monday through Saturday but not on Sunday or statutory holidays. If you require an accommodation to meet a religious obligation or to celebrate an important religious holiday, you may submit the Academic Accommodation for Religious, Indigenous and Spiritual Observances (RISO) Form to the Associate Dean's Office. You can find all paperwork needed here:
   https://www.eng.mcmaster.ca/app/uploads/2023/11/academic_accommodation_for_religous_indigenous_and_spiritual_observances_riso-final_examinations.pdf

NOTICE REGARDING POSSIBLE COURSE MODIFICATION

The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.

TURNITIN.COM STATEMENT

In this course we will be using a web-based service (Turnitin.com) to reveal plagiarism. Students will be expected to submit their work electronically to Turnitin.com and in hard copy so that it can be checked for academic dishonesty. Students who do not wish to submit their wok to Turnitin.com must still submit a copy to the instructor. No penalty will be assigned to a student who does not submit work to Turnitin.com. All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, etc.). To see the Turnitin.com Policy, please go to http://www.mcmaster.ca/academicintegrity/.

ON-LINE STATEMENT FOR COURSES REQUIRING ONLINE ACCESS OR WORK

In this course, we will be using e-mail and Avenue to Learn. Students should be aware that, when they access the electronic components of this course, private information such as first and last names, user names for the McMaster e-mail accounts, and program affiliation may become apparent to all other students in the same course. The available information is dependent on the technology used. Continuation in this course will be deemed consent to this disclosure. If you have any questions or concerns about such disclosure, please discuss this with the course instructor.

REFERENCE TO RESEARCH ETHICS

The two principles underlying integrity in research in a university setting are these: a researcher must be honest in proposing, seeking support for, conducting, and reporting research; a researcher must respect the rights of others in these activities. Any departure from these principles will diminish the integrity of the research enterprise. This policy applies to all those conducting research at or under the aegis of McMaster University. It is incumbent upon all members of the university community to practice and to promote ethical behaviour. To see the Policy on Research Ethics at McMaster University, please go to https://secretariat.mcmaster.ca/app/uploads/ResearchEthicsPolicy.pdf.