EP 4NE3 / 6NE3
Advanced Nuclear Engineering

Undergraduate Studies
Winter 2021
Course Outline

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 (**4NE3**) and graduate students (**6NE3**) with the knowledge and techniques that allow them to analyse and solve real-world problems in nuclear engineering. The course content is the same for the two versions of the course, however the 6NE3 version will include a small design project which the graduate students will present to all registered students at the end of the course.

The course will cover the following topics:

- 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 with in fuel elements, bundles, assemblies and structural materials, decay heat from fission.
- Heat transfer from fuels to coolant; heat transport from reactor to steam generators; steam generator designs and performance; steam cycles (e.g. Rankine cycle and direct cycles).
- 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 due to stress, temperature and chemical effects (e.g. stress corrosion cracking, embrittlement); 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): Registration in the final level of an Engineering program
Antirequisite(s): None

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. John Luxat
JHE A326
luxatj@mcmaster.ca
ext. 24670

Office Hours:
Monday – 10:30 am
Tuesday – 10:30 am
Or by appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

None

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

http://avenue.mcmaster.ca/

Detailed course notes and summaries of notes will be posted on Avenue to Learn. It is expected that students will read these notes prior to tutorial and discussion sessions which will occur three times a week at the scheduled lecture times via interactive Zoom meetings.

COURSE INTENDED LEARNING OUTCOMES

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

Required Texts:
None – the detailed course notes provide the required material
Recommended Additional Texts:
None
Calculator:
No restriction.
Other Materials:
Supplementary material will be provided as appendices to the chapters of the course notes.
No lab kits are required

COURSE FORMAT AND EXPECTATIONS

The course is organized as follows:

- 3 classroom-based virtual tutorials/discussion sessions conducted via Zoom meetings
- 4 assignments

- 1 take-home final exam

COURSE SCHEDULE

Date/Week	Topic	Readings
1	Elements of Nuclear Engineering	Course Notes
2	Reactor types (I): PWR, BWR, HWR/CANDU	Course Notes
3	Reactor types (II): Gen IV Advanced Reactors, Small Modular Reactors (SMR)	Course Notes
4	Energy Generation and distribution in a nuclear reactor	Course Notes
5	Heat transfer and transport from reactor core to steam generators	Course Notes
6	Thermal behaviour of nuclear fuel	Course Notes
7	Nuclear power plant thermodynamics; Carnot Cycle and Rankine Cycle, feedwater systems	Course Notes
8	Nuclear materials production processes	Course Notes
9	Operating performance of nuclear materials (I): irradiation effects, material degradation mechanisms	Course Notes
10	Operating performance of nuclear materials (II): material degradation mechanisms due temperature, pressure and chemical embrittlement	Course Notes
11	Nuclear fuel cycles: mining, ore refining, fissile enrichment, oxide pellet production	Course Notes
12	Nuclear fuel cycles: spent fuel reprocessing, spent fuel management	Course Notes
13	Case studies on uranium, mixed oxide and thorium fuel cycles	Course Notes

ASSESSMENT

Component	Due Date	Weight
Attendance at Zoom meetings		10%
Assignments		60%
Final Exam take home, open book)		30%
Total		100%

This is a 400/600 Level course, graduate students will be required to prepare an additional critical review paper on two assigned topics, and more in-depth analysis of course material in the assignments..

ACCREDITATION LEARNING OUTCOMES

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.	

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 grade in the course.

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

EQUITY, DIVERSITY, AND INCLUSION

Every registered student belongs in this course. Diversity of backgrounds and experiences is expected and welcome. You can expect your Instructor to be respectful of this diversity in all aspects of the course, and the same is expected of you.

The Department of Engineering Physics is committed to creating an environment in which students of all genders, cultures, ethnicities, races, sexual orientations, abilities, and socioeconomic backgrounds have equal access to education and are welcomed and treated fairly. If you have any concerns regarding inclusion in our Department, in particular if you or one of your peers is experiencing harassment or discrimination, you are encouraged to contact the Chair, Associate Undergraduate Chair, Academic Advisor or to contact the Equity and Inclusion Office.

PHYSICAL AND MENTAL HEALTH

For a list of McMaster University's resources, please refer to the Student Wellness Centre.

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. **It is your responsibility to understand what constitutes academic dishonesty.**

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. For information on the various types of academic dishonesty please refer to the *Academic Integrity Policy*, located at https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/

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.

COURSES WITH AN ON-LINE ELEMENT

McMaster is committed to an inclusive and respectful community. These principles and expectations extend to online activities including electronic chat groups, video calls and other learning platforms.

Some courses may use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.). Students should be aware that, when they access the electronic components of a course using these elements, 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 a course that uses on-line elements will be deemed consent to this

disclosure. If you have any questions or concerns about such disclosure, please discuss this with the course instructor.

CONDUCT EXPECTATIONS

As a McMaster student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the *Code of Student Rights & Responsibilities* (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's *Academic Accommodation of Students with Disabilities* policy.

COURSE POLICY ON MISSED WORK, EXTENSIONS, AND LATE PENALTIES

1. It is the students' responsibility to regularly check the course webpage on. Avenue to Learn for updates and announcements.
2. Students should contact the instructor if they have missed submitting assignments and the instructor will discuss options for make-up work
3. Students should contact the instructor prior to the due date for an assignment if they require an extension of the due date. Extensions are not automatically granted and require the student to provide justification.

SUBMISSION OF REQUEST FOR RELIEF FOR MISSED ACADEMIC WORK

In the event of an absence for medical or other reasons, students should review and follow the Academic Regulation in the Undergraduate Calendar "Requests for Relief for Missed Academic Term Work".

1. **Relief for missed academic work worth less than 25% of the final grade resulting from medical or personal situations lasting up to three calendar days:**

    - Use the McMaster Student Absence Form (MSAF) on-line self-reporting tool. No further documentation is required.
    - Students may submit requests for relief using the MSAF once per term.
    - An automated email will be sent to the course instructor, who will determine the appropriate relief. Students must immediately follow up with their instructors. Failure to do so may negate the opportunity for relief.
    - The MSAF cannot be used to meet a religious obligation or to celebrate an important religious holiday.
    - The MSAF cannot be used for academic work that has already been completed attempted.
    - An MSAF applies only to work that is due within the period for which the MSAF applies, i.e. the 3-day period that is specified in the MSAF; however, all work due in that period can be covered by one MSAF.
    - The MSAF cannot be used to apply for relief for any final examination or its equivalent. See *Petitions for Special Consideration* above.

2. **For medical or personal situations lasting more than three calendar days, and/or for missed academic work worth 25% or more of the final grade, and/or for any request for relief in a term where the MSAF has been used previously in that term:**

    - Students must report to their Faculty Office to discuss their situation and will be required to provide appropriate **supporting documentation**.
    - If warranted, the Faculty Office will approve the absence, and the instructor will determine appropriate relief.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.