

EP4D04_6D04
Nuclear Reactor Analysis (Reactor Physics)
Fall 2023
Course Outline

CALENDAR/COURSE DESCRIPTION

This is a course on nuclear fission reactors. The course aims to:

- Explain the concepts, physical processes, and quantities important in the context of the fission chain reaction
- Formulate and explain the basic descriptive equations (neutron-transport and neutron-diffusion equations)
- Show how to solve the neutron-diffusion equation for specific simple reactors
- Show how to solve for the evolution of neutron flux and power in simple time-dependent situations
- Explain the importance and effects of saturating fission products (e.g., Xe-135)
- Cover other miscellaneous topics in reactor physics
- Perform labs involving the McMaster Nuclear Reactor to gain an understanding of the nuclear physics processes underlying its operation
- Have students learn material ahead of class and come prepared to discuss/explain in class.

PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): EP3D03. Registration in the final level of an Engineering Physics program.

Antirequisite(s):

INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Benjamin Rouben
NRB B121
roubenb@mcmaster.ca

Office Hours:
By appointment or any time by e-mail or Zoom

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

Colin Colterjohn
colterca@mcmaster.ca

Office Hours:
By appointment

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

On Avenue to Learn, <http://avenue.mcmaster.ca/>

COURSE OBJECTIVES

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

- Describe and use in problems the important quantities which relate to the fission chain reaction, e.g., neutron flux and current, absorption, fission and radiative- capture cross sections, reactor multiplication constant, reactivity, buckling, fuel irradiation and burnup.
- Explain the neutron-diffusion equation and the various terms in it.
- Solve time-independent problems in non-multiplying media but with external neutron sources, to find the neutron-flux and current distribution in space.
- Solve time-independent problems in multiplying media to find the neutron-flux distribution and its absolute value, the reactor multiplication constant, and/or the reactor dimensions, given sufficient reactor data.
- Use the equation for subcritical multiplication to derive the value of system reactivity and/or device reactivity in an approach to critical.
- Solve time-dependent problems to calculate the evolution of flux and power following insertion of reactivity in a reactor.
- Explain the $^{135}\text{Xe}/^{135}\text{I}$ kinetics and solve problems relating to the effects of xenon in steady state and in transients.
- Describe the CANDU design. Explain the functions of its reactivity devices.
- Describe the characteristics of CANDU lattice reactivity with fuel irradiation/burnup, such as plutonium peak, discharge burnup.

MATERIALS AND FEES

Required Texts:

Primary reference text: Nuclear Reactor Analysis, by James J. Duderstadt & Louis J. Hamilton, John Wiley & Sons, Inc., ISBN: 0-471-22363-8

Calculator:

Only the McMaster Standard Calculator will be permitted in tests and examinations. This is available at the Campus Store.

Other Materials:

Instructor's presentations ("Learning Modules").

There are also a large number of other books on reactor physics, for example:

- The Essential CANDU - a textbook about the CANDU nuclear reactor (chapters 4 and 5) (<http://www.nuceng.ca/candu/>)
- John R. Lamarsh & Anthony J. Baratta, Introduction to Nuclear Engineering, Prentice Hall, ISBN: 0-20182-498-1

COURSE FORMAT AND EXPECTATIONS

The material to be covered will tentatively follow as much as possible the schedule below. But note that some change between one week and another may be made, for best presentation of material. Notes:

- There are mandatory labs to be performed. A missed lab (and missed lab analysis and report) will receive a mark of zero.
- There may be assignments every week, some parts possibly not to be marked.

COURSE SCHEDULE

Week 1: Fission and Other Nuclear Reactions, CANDU Nuclear Reactor
 Week 2: Flux and Current, Neutron Cycle, Neutron Balance
 Week 3: Source-Sink Problems
 Week 4: The Finite Reactor in 1 Energy Group, Flux Shape in Various Reactor Geometries
 Week 5: Statics Problems
 Week 6: Diffusion in Two Energy Groups
 Week 7: Mid-Term Examination
 Week 8: Subcritical Multiplication, Approach to Critical
 Week 9: Irradiation, Burnup, Evolution of Lattice Properties
 Week 10: Delayed Neutrons, Fast Kinetics, Kinetics Problems
 Week 11: Xenon-Iodine Kinetics
 Week 12: Reactivity Coefficients, Course Review.

ASSESSMENT

Component	Weight
Labs	20%
Assignments	20%
Midterm Exam	20%
Final Exam	40%
Total	100%

Notes:

Any missed component will be entered as zero in the calculation of the grade.

A 50% mark on the final exam is a requirement for a passing mark in the course.

6D04 students (i.e., graduate students) will have an extra assignment (project), worth an additional 20 marks. The total mark, including the extra assignment, will then be renormalized to a maximum of 100 per cent.

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
Competence in Specialized Engineering Knowledge	1.4
Demonstrates an ability to identify reasonable assumptions (including identification of uncertainties and imprecise information) that could or should be made before a solution path is proposed.	2.1

Demonstrates an ability to identify a range of suitable engineering fundamentals (including mathematical techniques) that would be potentially useful for analyzing a technical problem.	2.2
An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	3
Selects appropriate model and methods and identifies assumptions and constraints.	3.2
An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.	4

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 student's responsibility to regularly check the course webpage (ex. Avenue to Learn) for assignments, updates and announcements.
2. Missed work will not be marked and will receive a mark of 0....

NOTIFICATION OF STUDENT ABSENCE AND 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.