EP 710
Nuclear Reactor Dynamics and Control
Fall/Winter 2021/22
Course Outline

CALENDAR/COURSE DESCRIPTION

This course will present advanced material on reactor kinetics and reactor control that blends nuclear engineering and classical control engineering methods. The objective of the course is to provide graduate students and practicing engineers with the knowledge and techniques that allow them to analyse and solve real-world problems in the area.

The course will cover the following topics:

- Nuclear reactor kinetics – the time dependent neutron transport equations; prompt and delayed neutrons.
- Approximations to the neutron transport equations; point kinetics; space-time kinetics – the generalized modal model and the Improved Quasi Static (IQS) method.
- The critical reactor, delayed super-criticality, prompt criticality, the sub-critical reactor.
- Analytical approximations for the point kinetics model. Reactivity feedback mechanisms- Doppler, coolant and power feedback; Xenon poisoning and reactor dynamics.
- Transfer function representation of a reactor; the inhour equation; the reactor transfer function with feedback. Xenon stability and Xenon oscillations.
- Reactor control mechanisms and devices, bulk power control; spatial power control, load following.
- Control system for CANDU and LWR reactors.

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

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

Office Hours:
Monday to Thursday – 11:00 am to 4:30 pm
Or by appointment

TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

N/A

COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

McMaster email or
http://avenue.mcmaster.ca/

COURSE OBJECTIVES

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

- Understand analytic approximations for reactor dynamics, including:
  - The point reactor kinetics model
  - The modal spatial reactor kinetics model
- Understand the role of delayed neutrons and photoneutrons in reactor power transients
- Understand and apply the prompt jump approximation for point reactor kinetics
- Apply these approximation models to real-world reactor kinetics problems
- Analyse reactor power excursions and the challenges they pose to potential fuel damage
- Analyse reactor response to linear ramp increases in reactivity
- Develop low power and high power transfer functions for a nuclear reactor
- Develop transfer functions for reactors with external feedback control
- Assess the stability of feedback control of reactors using Routh-Hurwitz criteria, Bode and Nyquist plots and root-locus diagrams
- Evaluate the response of reactors to spatial perturbations of reactivity and determine the limits of controllability for space-time kinetics of power reactor

MATERIALS AND FEES

Recommended Texts:
K.O Ott and R.J. Neuhold, "Introductory Nuclear Reactor Dynamics", American Nuclear Society, 1985.
Available at ANS Bookstore http://www.ans.org/store/item-350011/ Price US$70.00 (US$63.00 for ANS members)
Calculator:
Any calculator.
Other Materials:
Course notes and lecture overheads available on Avenue to Learn course website

COURSE OVERVIEW

Date/Week	Topic	Readings
1	Introduction to Reactor Dynamics: CANDU vs PWR	
2	Reactor point kinetics, delayed neutrons and photoneutrons	
3	The subcritical reactor, step changes in reactivity and approach to criticality	
4	The zero power reactor and the inhour equation	
5	The high power reactor and inherent reactivity feedback mechanisms	

6	Analysis of reactor power excursions driven by reactivity transients
7	Modal space-time kinetics: a generalized point kinetics model
8	Reactor transfer functions and feedback control systems
9	Analysis methods to evaluate stability of reactor feedback control systems
10	Bode and Nyquist methods
11	The Root-Locus method
12	Spatial control of large reactors
13	Case studies and review of course material

ASSESSMENT

Component	Weight
Attendance	5%
Assignments	60%
Final Exam (take-home 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 derive low-order approximation models for nuclear reactor kinetics	
Ability to solve nuclear reactor responses to reactivity perturbation	
Ability to design nuclear reactor feedback control systems	

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 Academic Accommodation of Students with Disabilities.

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

1. The McMaster Student Absence Form 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: http://www.eng.mcmaster.ca/current/documents.html

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 http://www.mcmaster.ca/policy/faculty/Conduct/ResearchEthicsPolicy.pdf.