2022/2023 Academic Year: Winter, 2023
MECH 4106A: Nuclear Power Plant Design
Department of Mechanical and Aerospace Engineering

COURSE OUTLINE

Nuclear power plant design encompasses the concept, composition and operation of all structures, systems and components (SSCs). In a nuclear power plant, the heat source comes from a fission process taken place within the fuel. The generated heat energy is transferred to coolant to turn water directly or indirectly into steam, which in turn drives turbine generators to produce electricity.

The design of a nuclear power plant must be developed, verified, implemented, validated, and controlled by an integrated and structured process, which needs to meet the highest standards. This process must consider the plant's capacity, performance and longevity and taking into account, most importantly, the protection of the public and the environment. International safeguards must also be fully integrated into the design process.

The design decision-making process ensures that the SSCs of a nuclear power plant have the **appropriate characteristics**, **material composition** and **technical, operational and maintenance specifications**, so that the plant can be built, commissioned, and operated safely and reliably throughout its lifetime.

The organizational programmes and procedures that are necessary to generate electricity in a **safe, reliable and economically viable manner** are also included. Safety considerations, including **regular safety assessments**, are of particular importance. Comprehensive and systematic assessments of a planned nuclear power plant's safety features are a critical element of the design process. In this view, **safety analyses** have been widely used in the design and safety assessment of nuclear power plants.

This course "**Nuclear Power Plant Design"** will explore with the perspective of the Defence in Depth approach in mind, which assumes the following:

1. Nuclear station design will have some flaws
2. Equipment will occasionally fail and
3. Operating Personnel will occasionally make mistakes

All the major reactor designs will be discussed but emphasis of in-depth design may be restricted to the **CANDU reactor**, the only operating commercial reactors in Canada. New and/or Novel (First of a Kind) designs will also be stressed with emphasis on the **GE Hitachi Design BWRX300**. This design will be the first new power plant that has been confirmed for construction in Canada in over 4 decades.

INSTRUCTOR: Dr. Sam Gyepi-Garbrah - sam.gyepigarbrah@carleton.ca
Office Hours: 5:05 pm to 5:45 pm Tuesdays in **ME 2186** (Except the reading week).
Note: I work full-time for the CNSC so I do not have full office on campus and I am not on campus on days when I'm not teaching, unless when very urgent and necessary. If your question can't be answered by email please arrange and/or plan to meet with me before class during the office hours.

TEACHING ASSISTANT: Cem Kalkan - CemKalkan3@cmail.carleton.ca
Office Hours: 10:00 am to 11:00 am Fridays in **ME 3236** (Except the reading week).

First day for office hours: 3rd week of Classes (Week of January 23rd, 2023
Last day for office hours: April 11, 2023 (Week of April 10th, 2023)

COURSE OBJECTIVE

The objective of the course is to:

1. Describe the basic design and technology of nuclear reactors
2. Describe the elements of nuclear reactor design
3. Describe how safety systems meet licensing requirements with reference to IAEA, CNSC and USNRC regulations on plant design
4. Describe the major systems in a nuclear plant, as well as the **important CANDU and BWRX-300 reactor** safety principles and systems.
5. Describe the important systems and components of the Balance of Plant (BoP)
6. Discuss some computer codes used in the safety assessments and design of nuclear power plants
7. Learning objectives are listed after course outline below

PREREQUISITES:

None

LECTURES AND SCHEDULE

January 10 to April 11, 2023. Lectures: Once week. 18:05 –20:55 Tuesdays in **UC 180**

All activities will be **in class model except some of the exams and final exams.** You will be informed as events change/evolve over the term.

SUGGESTED REFERENCES POSTED ON BRIGHTSPACE

1. "The Essential CANDU, A Textbook on the CANDU Nuclear Power Plant Technology", Editor-in-Chief Wm. J. Garland, Selected Chapters, University Network of Excellence in Nuclear Engineering (UNENE), ISBN 0-9730040. (Reference is a free textbook entitled "The Essential CANDU" published by the Canadian Nuclear Society which can be found at the following link: http://www.unene.ca/essentialcandu/
2. Advances in Small Modular Reactor Technology Developments A Supplement to: IAEA Advanced Reactors Information System (ARIS) 2020 Edition
3. IAEA-TECDOC-1792, Benefits and Challenges of Small Modular Fast Reactors Proceedings of a Technical Meeting, Vienna 2021
4. IAEA-Nuclear Energy Series, No. BR-T-1.18, Technology Roadmap for Small Modular Reactor Deployment, Vienna, 2021

SUGGESTED REFERENCES USED BUT NOT POSTED ON BRIGHTSPACE

1. IAEA-TECDOC-1791, Considerations on the Application of the IAEA Safety Requirements for the Design of Nuclear Power Plants
2. Nuclear Reactor Design, An advanced Course in Nuclear Engineering, Editor, Yoshiaki, Oka, Springer (2-14), ISBN 2195-7714 (electronic); ISBN 978-4-431-54898-0 (e-book) (selected topics)
3. Elements of Nuclear Reactor Design, Editor Joel Weisman, Publisher Elsevier Scientific Publishing Company (1977) (selected topics)
4. Design of Reactor Facilities: Nuclear Power Plants", Regulatory Document REGDOC2.5.2, Canadian Nuclear Safety Commission (CNSC), 2014.
5. Appendix A to Part 50—General Design Criteria for Nuclear Power Plants, USNRC
6. Implementation of Defence in Depth at Nuclear Power Plants, Lessons Learnt from the Fukushima Daiichi Accident, OECD 2016, NEA No. 748

OTHER RELATED TEXTBOOKS:

1. Introduction to Nuclear Engineering, J.R. Lamarsh and A.J. Baratta, 3rd Edition, Prentice Hall (2001), ISBN 0-201-82498-1
2. Nuclear Reactor Engineering, S. Gladstone and A. Sesonske, 3rd Edition (1981), Macmillan, ISBN 0-442-20057-9

QUIZZES

Three (3) one to two-hour quizzes will be scheduled in class during the course. Each will be 10% for a total of 30% of the final mark for the course. The dates are **January 31st, February 28th, and March 28th, 2022. All Quizzes may be online on Brightspace**

TERM EXAM

There will be **one Term exam on Brightspace** for a total of 20% of term mark on **March 14th, 2022**.

FINAL EXAM

The final exam (50% of grade) will be scheduled by the university during the final exam period. The final examinations will be comprised of multiple choice, hand-written essay and analytical (numerical) questions. **Details will be provided in the last few weeks of lectures.**

E-PROCTORING

Please note that mid-term and examinations in this course **may use** a remote proctoring service provided by Scheduling and Examination Services. You can find more information at https://carleton.ca/ses/e-proctoring

- *The minimum computing requirements for this service are as follows:*
  Hardware: Desktop, or Laptop
  OS: Windows 10, Mac OS 10.14, Linux Ubuntu 18.04
  Internet Browser: Google Chrome, Mozilla Firefox, Apple Safari, or Microsoft Edge
  Internet Connection (High-Speed Internet Connection Recommended)
  Webcam (HD resolution recommended)
  Note: Tablets, Chromebooks and Smartphones are not supported at this time. Windows-based tablets are not supported at this time.

MARKING SCHEME

The final course grade will be determined according to the following:

Component	**%**
Quizzes (3 x)	30
Term Exam	20
Final Exam	50
Total	100

EVALUATION

Standing in a course is determined by the course instructor subject to the approval of the Faculty Dean. This means that grades submitted by the instructor may be subject to revision. No grades are final until they have been approved by the Dean."

LEARNING OUTCOMES/OBJECTIVES:

Knowledge base

1. Knowledge of basic design and technology of nuclear reactors
2. Knowledge of the elements of nuclear reactor design
3. Knowledge of the Inputs from Regulatory Agencies on how safety systems of plant design meet licensing requirements (example, IAEA, CNSC and USNRC)
4. Knowledge of major systems in a nuclear plant, particularly the CANDU reactor safety principles and systems.
5. Knowledge of the Balance of Plant
6. Knowledge of some computer codes used in the safety assessments and design of nuclear power plants

Problem analysis

1. Utilize the knowledge learned to analyze reactor and plant design problems
2. Critically assess published material on nuclear design with knowledge and analysis skills learned in the course to make engineering design decisions

Investigation and Communication

1. Follow procedures and instructions to produce a feedback on an SMR design documentation concerning some aspects of reactor design and regulatory requirements.

A passing mark (50% and higher) is required on the final exam to pass the course. According to the policy of the Faculty of Engineering and Design, the final examination is for evaluation purposes only and the marked final examination papers will not be returned to the students.

PLAGIARISM

The University Academic Integrity Policy defines plagiarism as "*presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own."* This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source. Examples of sources from which the ideas, expressions of ideas or works of others may be drawn from include but are not limited to: books, articles, papers, literary compositions and phrases, performance compositions, chemical compounds, artworks, laboratory reports, research results, calculations and the results of calculations, diagrams, constructions, computer reports, computer code/software, material on the internet and/or conversations.

Examples of plagiarism include, but are not limited to:

- any submission prepared in whole or in part, by someone else;
- using ideas or direct, verbatim quotations, paraphrased material, algorithms, formulae, scientific or mathematical concepts, or ideas without appropriate acknowledgment in any academic assignment;
- using another's data or research findings without appropriate acknowledgement;
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own; and
- failing to acknowledge sources through the use of proper citations when using another's work and/or failing to use quotations marks.

Plagiarism is a serious offence that cannot be resolved directly by the course's instructor. The Associate Dean of the Faculty conducts a rigorous investigation, including an interview with the student, when an instructor suspects a piece of work has been plagiarized. Penalties are not trivial. They can include a final grade of "F" for the course.

COURSE OUTLINE

The current plan is for the following topics to be presented over 14 weeks by Dr. Sam Gyepi-Garbrah and there may be potentially guest appearances and other experts in nuclear technology. One guest is confirmed but others may be invited. Some of the potential guest lecturers will be likely from:

- Prof. Glenn McRae, MAAE, Carleton
- Dr. Thambiayah Nitheanandan (Director, Engineering Design and Assessment Division, CNSC)
- Mr. Tarek Tabikh, Acting Director, Advanced Reactor Assessment Division, CNSC)

Weeks	Date	Topics
1	January 10	Overview of the course • General Introduction Nuclear Reactor Design • Elements of Design
2	January 17	Prof. Glenn McRae, MAAE, Carleton • Guest Lectures - Pressure Tube Fabrication
3	January 24	Nuclear Reactor Design • Components of a Nuclear Reactor • Types of Nuclear Reactors
4	January 31	**Quiz 1 - Types of Nuclear Reactors and Nuclear Reactor Design** Lectures – Selected Small Modular Reactors (SMRs)
5	February 7	Balance of Plant (BoP) • Important Systems for BoP
6	February 14	Regulatory Requirements on Nuclear Reactor Design • IAEA Guides • USNRC Regulations • CNSC Regulations/Guides
7	February 21	**READING WEEK – NO CLASSES**
8	February 28	**Quiz 2 - Concepts, BoP and Regulatory Requirements on Reactor Design** Lecture – Regulatory Requirements on SMRs
9	March 7	Guest Lecture - CANDU Fuel Design **Dr. Thambiayah Nitheanandan**
10	March 14	**Term Exam (Lectures on SMRs, Jan 31 and Feb 28)**
11	March 21	Defence in Depth (DiD) in Nuclear Reactor Design • General Approach • CANDU Approach Practical DiD Lessons learned from Fukushima Accident
12	March 28	**Quiz 3 – DiD, CANDU Fuel Design** Lecture – Practical DiD Lessons learned from Fukushima Accident
13	April 4	Guest Lecture – Operational Experience and Fundamental Safety Functions in Design – **Mr. Tarek Tabikh** Computer Codes used in Nuclear Reactor Design and Safety Assessment • Use of computer codes used in the safety assessments and design
14	April 11	Make up class/Final Review
	April 14	Final Exams – **Tentative**, To be Arranged and Announced by University

ACADEMIC ACCOMMODATION

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

Pregnancy obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form (click here).

Religious obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details click here.

Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

Survivors of Sexual Violence
As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities
Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf

Special Information for Pandemic Measures

Carleton will continue to follow all public health guidelines as the COVID-19 pandemic continues. Instructors may find it helpful to review the guidelines for in-class teaching and labs. Both guideline documents are available on the COVID-19 website.

It is important to remember that COVID is still present in Ottawa. The situation can change at any time and the risks of new variants and outbreaks are very real. There are a number of actions you can take to lower your risk and the risk you pose to those around you including being vaccinated, wearing a mask, staying home when you're sick, washing your hands and maintaining proper respiratory and cough etiquette.

Feeling sick? Remaining vigilant and not attending work or school when sick or with symptoms is critically important. If you feel ill or exhibit COVID-19 symptoms do not come to class or campus. If you feel ill or exhibit symptoms while on campus or in class, please leave campus immediately. In all situations, you must follow Carleton's symptom reporting protocols.

Masks: Carleton has paused the COVID-19 Mask Policy, but continues to strongly recommend masking when indoors, particularly if physical distancing cannot be maintained. It may become necessary to quickly reinstate the mask requirement if pandemic circumstances were to change.

Vaccines: Further, while proof of vaccination is no longer required as of May 1 to attend campus or in-person activity, it may become necessary for the University to bring back proof of vaccination requirements on short notice if the situation and public health advice changes. Students are strongly encouraged to get a full course of vaccination, including booster doses as soon as they are eligible, and submit their booster dose information in cuScreen as soon as possible. Please note that Carleton cannot guarantee that it will be able to offer virtual or hybrid learning options for those who are unable to attend the campus.

All members of the Carleton community are required to follow requirements and guidelines regarding health and safety which may change from time to time. For the most recent information about Carleton's COVID-19 response and health and safety requirements please see the University's COVID-19 website and review the Frequently Asked Questions (FAQs). Should you have additional questions after reviewing, please contact covidinfo@carleton.ca.