# EP718
# Reactor Heat Transport System Simulation and Analysis
Graduate Studies
Fall/Winter 2023/24
Course Outline

## CALENDAR/COURSE DESCRIPTION

Reactor Heat Transport System Simulation and Analysis covers the thermal-hydraulics analysis of reactor heat transport systems. The course presents the underlying physics, fluid flow and heat transfer modelling and analysis of nuclear reactor primary heat transport system.

This course covers the topic of thermal-hydraulics analysis of nuclear power reactors. It includes an overview of two-phase flow theory and application. Basic mass, momentum and energy differential equations are provided and explained, and their evolution into computer code models described. Elements of R&D performed in support of computer code development are summarized, including phenomena identification and ranking. Computer code V&V process and regulatory requirements are provided. Deterministic safety analysis principles and methodology are described in the course.

The theory and methodology of the CAHENA code is covered in the course, including practical modeling of selected thermal-hydraulic components of the reactor cooling system.

The course will be taught by means of lectures and assignments.

***Attendance at the lectures is mandatory***.

## PRE-REQUISITES AND ANTI-REQUISITES

Prerequisite(s): None
Antirequisite(s): None

## INSTRUCTOR OFFICE HOURS AND CONTACT INFORMATION

Dr. Nik Popov
BSB B140
npopov@mcmaster.ca
416-566-8233

Lecture Hours:
Thursday – 14:30 – 20:00
Online Tutorials
Monday – 19:00 – 20:00

## TEACHING ASSISTANT OFFICE HOURS AND CONTACT INFORMATION

**None**

## COURSE WEBSITE/ALTERNATE METHODS OF COMMUNICATION

http://avenue.mcmaster.ca/
www.coursewebsite.mcmaster.ca

Dropbox folder that will be shared with the students.

## COURSE INTENDED LEARNING OUTCOMES

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

- Understand and apply methods for development of thermal-hydraulic models in reactor heat transport system analysis.
- Understand and critically review thermal-hydraulic computer codes and numerical solution techniques.
- Understand and use the latest developments in computer code models for analysis of thermal-hydraulics networks.
- Develop processes and procedures for computer code V&V support.
- Develop and use processes for computer code accuracy assessment and applicability assessment.
- Gain overall theory knowledge and practical experience with modelling and analysis using the CATHENA computer code.

## MATERIALS AND FEES

Required Texts:
"The Essential CANDU: A Textbook on the CANDU Nuclear Power Plant Technology", "Chapter 7: Thermal-hydraulic Analysis", UNENE/COG, 2017.

Recommended Additional Texts:
CATHENA Computer Code Manuals.

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

Other Materials:
Selected journal and conference papers in this area.
Selected website with appropriate information on the course topics.

## COURSE FORMAT AND EXPECTATIONS

The course is organized as follows:

- 1 classroom-based lectures per week
- 1 tutorial per week (1 hour)
- 2 assignments: (1) develop nodalization for selected TH networks, and (2) assessment of CATHENA models to CANDU TH applications.
- 1 project: Develop a CATHENA model of selected reactor coolant components and networks.
- 1 student presentation on the project.

1 in-class final exam

## COURSE SCHEDULE

| | |
|---|---|
| 11 Jan 2024<br>16:30–20:00 | 1a Course Outline<br>1b Introduction to TH computer codes |
| 18 Jan 2024<br>16:30–20:00 | 2 Two-Phase Flow |
| 25 Jan 2024<br>16:30–20:00 | 3 Basic equations for thermal-hydraulic system analysis |
| 1 Feb 2024 | 4a Equation of state |

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|---|---|
| 16:30–20:00 | 4b The Rate form of equation of state |
| 8 Feb 2024<br>16:30–20:00 | 5a Nodalization<br>5b Thermal-hydraulic network simulation |
| 15 Feb 2024<br>16:30–20:00 | 6 TH Network Code Models (CATHENA) |
| 29 Feb 2024<br>16:30–20:00 | 7 Code Technical Basis |
| 7 Mar 2024<br>16:30–20:00 | 8 R&D Support |
| 14 Mar 2024<br>16:30–20:00 | 9 Code Validation and Assessment |
| 21 Mar 2024<br>16:30–20:00 | 10 Deterministic Analysis Methodology (DSA) |
| 4 Apr 2024<br>16:30–20:00 | TH Network Code Models (CATHENA) |
| 18 Apr 2024<br>16:30–20:00 | Final Exam<br>Closed book |
| 25 Apr 2024<br>16:30–20:00 | Project – Student Presentations<br>Final date for submission of Projects and Assignments |

## ASSESSMENT

| Component | Due Date | Weight |
|---|---|---|
| Assignment 1 | April 18, 2022 | 15% |
| Assignment 2 | April 18, 2022 | 15% |
| Project | April 18, 2022 | 30% |
| Lecture and tutorial attendance | | 5% |
| Student activity | | 5% |
| Final Exam | April 18, 2022 | 30% |
| Total | | 100% |

## 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, religions, 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 Graduate Chair, Academic Advisor, or to contact the Equity and Inclusion Office.

These principles and expectations extend to online activities including electronic chat groups, video calls and other learning platforms.

## 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 common 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.

Note that allowing another student to copy one's work also falls under academic dishonesty and will be treated in the same way as copying another student's work.

## COURSES WITH AN ON-LINE ELEMENT

*Some courses may* use on-line elements (e.g. e-mail, Avenue to Learn (A2L), LearnLink, web pages, capa, Moodle, ThinkingCap, etc.), or be delivered fully online. 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 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 them 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.

Note that accommodations granted while in the undergraduate program do not transfer automatically to the graduate program.

## 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.