NE 752: Thermal-Hydraulic Design Calculations
Fall 2024

Course Description

Graduate level course focused on thermal-hydraulic design calculations of nuclear reactors. The governing equations forming the basis for the three-dimensional thermal-hydraulic analysis methods commonly used in the nuclear industry will be derived and discussed; specific models used for closure will be presented.

3 credit hours

Instructors

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Class location

331 111 Lampe Drive

Meeting time

Mo We 10:15AM – 11:30AM

Prerequisites

Graduate standing. NE 724 or graduate level course on fluid dynamics and heat transfer.

Course Objectives

To provide nuclear engineering students with sufficient knowledge in thermal-hydraulic analysis of nuclear reactor cores with emphases on the application of conservation equations and closure relationships for single- and two-phase flow, and modeling of the reactor cores using three-dimensional and sub-channel analysis methods.

Student Learning Outcomes

By the end of this course, the student should be able to understand and apply the concepts and principles of:

- Thermal-hydraulic analysis of nuclear reactor cores.
- Application of conservation equations and closure relationships for single- and two-phase flow.
- Modeling of the reactor cores using three-dimensional and sub-channel analysis methods.

Course Requirements and Evaluation Methods

- Homework: Three assignments each valued at 10%. Homework assignments to be submitted via Moodle.
- Quizzes: Weekly quizzes worth 20% of total course grade. Quizzes will be conducted during class period.
- Exams: One mid-term exam worth 20% of total course grade.
- Project: Computational course project worth 30% of total course grade.
- Grading Scale: A+ (>100); A (92÷100); A- (90÷91); B+ (88÷89); B (82÷87); B- (80÷81); C+ (78÷79) C (72÷77); C- (70÷71); D+ (68÷69); D (62÷67); D- (60÷61); F (<60)

- Late Assignments: Unless stated otherwise, assignments are due at the beginning of class on the designated due date. Assignments turned in within 24 hours of this time are considered LATE and will be assessed 25% penalty. Assignments turned in after 24 hours will be marked and returned to the student, but no credit will be assigned. To allow for unforeseen circumstances, students are granted a onetime exemption if an assignment is turned in by 5:00 PM on the designated due date. Exceptions to this policy may be granted for documented medical or family emergencies.

Attendance and Absence policy

- Face-to-face attendance is highly recommended.
- Active class participation is strongly encouraged. University policy on definition of excused absences: http://policies.ncsu.edu/regulation/reg-02-20-03

Required Textbook

No required textbook. Class notes and reading material will be provided free of charge.

Additional (optional) References

N. Todreas and M. Kazimi, Nuclear Systems I: Thermal Hydraulic Fundamentals (Selected Sections)
N. Todreas and M. Kazimi, Nuclear Systems II: Elements of Thermal Hydraulic Design (Selected Sections)

Computer and Internet Requirements

Please review minimum computer specifications recommended by NC State University and Engineering Online.

Course Delivery

- Face-to-Face: On Campus
- Distance Education: DELTA.
- Captured Lectures: This on campus course will be captured and distributed via the Internet and/or electronic media as part of the Engineering Online (EOL) program for distance students. These video recordings may contain an image of you entering the classroom, asking questions or being a part of the studio class. Please notify EOL if you DO NOT want your image to be included in the lecture presentation. If we do not hear from you after the first week of the class, we will assume that you are in agreement with this procedure.

Academic Integrity

- University policy on academic integrity: Code of Student Conduct Policy (POL11.35.01) (http://policies.ncsu.edu/policy/pol-11-35-01). Violations of academic integrity will be handled in accordance with the Student Discipline Procedures (NCSU REG11.35.02). The unauthorized posting of any lecture notes, homework answers, exams, or any other course materials on third-party websites constitutes a violation of copyright as described in section 8.2 (f) of the Code of Student Conduct. Students posting such materials will be immediately referred to the Office of Student Conduct.

Supporting Fellow Students in Distress

As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you. When this is the case, you are encouraged to report this behavior to NC State CARES: https://prevention.dasa.ncsu.edu/nc-state-cares/about/

Students with Disabilities

Reasonable accommodation will be made for students with verifiable disabilities. In order to take advantage of available accommodation, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see REG 02.20.01 – Academic Accommodations for Students with Disabilities – Policies, Regulations & Rules (ncsu.edu)

Additional NC State Rules and Regulations

Students are responsible for reviewing the NC State University Policies, Rules, and Regulations (PRRs) which pertain to their course rights and responsibilities, including those referenced both below and above in this syllabus:

- Equal Opportunity and Non-Discrimination Policy Statement https://policies.ncsu.edu/policy/pol-04-25-05 with additional references at https://oied.ncsu.edu/divweb/policies/
- Code of Student Conduct https://policies.ncsu.edu/policy/pol-11-35-01.

List of topics

PART I: SUMMARY OF THERMAL-HYDRAULIC FUNDAMENTALS

- Introduction
  - Nuclear Power Reactors – Background
  - Heat Generation, Transfer and Removal in Reactor Cores – Review
- Single-Phase Flow in Rod Bundles
  - Approach to Simplified Flow Analysis
  - Single-Phase Pressure Drop
  - Single-Phase Heat Transfer
- Two-Phase Flow in Rod Bundles
  - Two-Phase Flow Models
  - Two-Phase Pressure Drop
  - Boiling Heat Transfer
- Thermal Analysis of Fuel Elements
  - Heat Conduction in Fuel Elements
  - Thermal Resistance between the Fuel and Coolant
- Thermal Design Principles and Application
  - Thermal Design Limits
  - Thermal Design Margins
  - Generalized Formulation of the Reactor Thermal-Hydraulic Design Problem

Part II: Computational Core Thermal-Hydraulics

- Modeling of Interacting Channels
  - Porous Media Approach for Interacting Channels
  - Sub-channel Approach for Interacting Channels
- Sub-channel Thermal-Hydraulic Codes
  - Problem Formulation
  - Input / Output Description
- Computational Models for Singe- and Two-Phase Flow
  - Conservation of Mass, Momentum, and Energy

Flow Regime Maps
Momentum, Heat, and Mass Transfer Modeling
Cross-Flow in Rod Bundles
Interfacial Heat and Mass Transfer Modeling
Wall Heat Transfer Modeling
Spacer Grid Effects in Rod Bundles

Models for Heated and Unheated Structures

Heat Generation and Conduction
Fuel Rod Modeling: Gap Conductance; Pellet-Cladding Contact Conductance; Fuel Rod Deformation; etc.

Additional Topics of Interest

Numerical Solution Methods in Thermal-Hydraulic Codes
Accuracy and Uncertainty Analysis in Modeling
Boron Tracking Models in Thermal-Hydraulic Codes
Thermal-Hydraulics to Core Neutron Kinetics Coupling and Treatment of the Feedback Effects