

NE 405/505 Reactor Systems

Spring 2023, 3 Credit Hours

1 Course Information

- **Schedule:**

- *Time:* Tuesdays and Thursdays, 10:15 am - 11:30 am
- *Location:* Room 327, 111 Lampe Drive
- *Course website:* **Moodle** will be used to post lecture slides, homework, projects and other materials.
<https://moodle-courses2223.wolfware.ncsu.edu/course/view.php?id=6474>
- *Lecture recordings:* **Panopto** will be used to host the lecture recordings.
<https://ncsu.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderID=%2283306dd9-1f74-4795-a5e1-af6c011a838b%22>
- *Zoom:* N/A.

- **Instructor:**

- *Course Instructor:* Dr. Xu Wu, Assistant Professor of Nuclear Engineering
- *Office:* Burlington Laboratory 2110
- *Office Hour:* Tuesdays, 1:00 pm - 3:00 pm, in-person or Zoom (by appointment). Office hour for **Distance Education students** is flexible, please email me to request a Zoom meeting.
- *Phone:* 919-515-6570
- *Email:* xwu27@ncsu.edu
- *Website:* <https://www.ne.ncsu.edu/people/xwu27>

- **Teaching Assistant:**

- *TAs:* Farah Alsafadi and Mahmoud Yaseen
- *Emails:* fralsafa@ncsu.edu, mqyaseen@ncsu.edu
- *Office Hours:* Wednesdays, 2:00 pm - 4:00 pm (please email in advance)

- **Course evaluations:**

- Online class evaluations will be available for students to complete during the last 2 weeks of the semester. It will become unavailable at 8am on the first day of finals.
- Students will receive an email directing them to a website where they can login using their Unity ID and complete evaluations.
- All evaluations are **confidential**; instructors will **not** know how any one student responded to any question, and students will not know the ratings for any instructors.
- Results of the evaluation is revealed to the instructor **after** the grades are posted.
- Evaluation website: <http://go.ncsu.edu/cesurvey>

2 Description and Objectives

- This course provides a detailed discussion over nuclear power plant (NPP) systems, including Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), advanced light water reactors (LWR), as well as advanced non-LWRs. Topics to be covered include the PWR/BWR core design, primary loops, auxiliary and emergency systems, containment, reactor control and protection systems, accident and transient behaviors.
- The students are expected to learn how to apply knowledge in engineering sciences to design and understand complex systems, and gain an understanding of NPP engineering utilizing specific analytical skills acquired in other courses.

3 Prerequisites

- NE 400/500 - Nuclear Reactor Energy Conversion (Prerequisite for NE 402/502)
 - Introduction to the concepts and principles of heat generation and removal in reactor systems. Power cycles, reactor heat sources, analytic and numerical solutions to conduction problems in reactor components and fuel elements, heat transfer in reactor fuel bundles and heat exchangers.
- NE 401/501 - Reactor Analysis and Design
 - Elements of nuclear reactor theory for reactor core design and operation. Includes one-group neutron transport and multigroup diffusion models, analytical and numerical criticality search, and flux distribution and calculations for homogeneous and heterogeneous reactors, slowing down models, introduction to perturbation theory.
- NE 402/502 - Reactor Engineering
 - A course in thermal-hydraulic design and analysis of nuclear systems. Single and two-phase flow, boiling heat transfer, modeling of fluid systems. Design constraints imposed by thermal-hydraulic considerations are discussed.

4 Outline of Topics

- Part 1: Introduction
 - Introduction
 - Overview of PWR Systems
 - Overview of BWR Systems
- Part 2: Core Design of LWRs
 - PWR Fuel Design, Nuclear Design, Thermal-Hydraulics Design
 - BWR Fuel Design, Nuclear Design, Thermal-Hydraulics Design
- Part 3: Nuclear Steam Supply Systems

- PWR NSSS - Primary and Secondary Systems
- PWR NSSS - Auxiliary Systems
- BWR NSSS - Reactor Coolant Systems
- BWR NSSS - Auxiliary Systems
- Part 4: Instrumentation and Control (I&C) Systems
 - PWR Instrumentation & Control Systems
 - BWR Instrumentation & Control Systems
- Part 5: Nuclear Power Plant Accidents and Safety Systems
 - PWR Engineered Safety Features Systems
 - PWR Reactor Protection System
 - PWR Emergency Core Cooling Systems
 - PWR Containment Systems
 - BWR Reactor Protection System
 - BWR Emergency Core Cooling Systems
 - BWR Containment Systems
- Part 6: Advanced LWR Systems and Passive Safety
 - Passive safety principles
 - GE Hitachi ABWR
 - GE Hitachi ESBWR
 - Westinghouse AP1000
 - EPR
- Part 7: Generation IV Reactor Systems
 - Very High Temperature Reactors (VHTRs)
 - Super-Critical Water-cooled Reactors (SCWRs)
 - Molten Salt Reactors (MSRs)
 - Gas-cooled Fast Reactor (GFRs)
 - Sodium-cooled Fast Reactors (SFRs)
 - Lead-cooled Fast Reactor (LFRs)
- Part 8: Small Modular Reactors (SMRs) and Micro-reactors Systems
 - NuScale SMR
 - GEH SMR BWRX-300
 - X-energy SMR Xe-100
 - Kairos Power SMR KP-FHR
 - Westinghouse Micro-reactor eVinci

5 Assignments and Grading Policy

(1) **Homework problems (25%)**, see Table 1.

- Homework will be assigned periodically throughout the semester. The last homework assignment may be due during the last week of classes.
- Homework will be **submitted via Moodle**.
- The instructor and TA will typically grade the homework within one week.
- *Late submission*: 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 a 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 one-time exemption. Exceptions to this policy may be granted for documented medical or family emergencies. But the students need to contact the course instructor before the deadline.

Table 1: Homework

Homework	Weights of total	Due dates (tentative)
Homework 1	5%	02/07
Homework 2	5%	02/21
Homework 3	5%	03/07
Homework 4	5%	03/21
Homework 5	5%	04/04

(2) **Exams (50%)**, see Table 2.

- For Distance Education students or those joining virtually, Engineering Online will be offering proctoring and homework services. Instructions on this will be offered before the exams.

Table 2: Exams and quizzes

Exams	Format	Weights of total	Dates (tentative)
Midterm Exam 1	in-class, closed book	15%	03/02, in class
Midterm Exam 2	in-class, closed book	15%	04/11, in class
Final Exam	open book	20%	05/02, 08:30 am - 11:00 am

(3) **Project (25%)**, see Table 3.

- The project will use a PWR simulator developed by Professor Doster. Access to the simulator will be provided when the project is assigned. Instructions on using the simulator will be provided.
- There will be only 1 project. For graduate students taking NE 505, there will be more requirements in the project assignment.
- The report should include introduction, scenarios to be analyzed, results and conclusions.

Table 3: Projects

Project	Weights of total	Due dates (tentative)
Project 1	25%	04/28

6 Texts and References

- (1) Lahey, R. T., & Moody, F. J. (1993). The Thermal-Hydraulics of a Boiling Water Nuclear Reactor. Second Edition. American Nuclear Society, La Grange Park, Illinois USA.
- (2) Tong, L. S., & Weisman, J. (1996). Thermal analysis of pressurized water reactors. Third Edition. American Nuclear Society, La Grange Park, Illinois USA.
- (3) Todreas, N. E., & Kazimi, M. S. (2021). Nuclear systems volume I: Thermal hydraulic fundamentals. Third Edition. CRC press.
- (4) Todreas, N. E., Kazimi, M. S., & Massoud, M. (2021). Nuclear Systems Volume II: Elements of Thermal Hydraulic Design. CRC Press.
- (5) Texts are not required. The references below will be posted in Moodle.
 - BWR/6: General Description of a BWR by GE Nuclear Energy.
 - The Westinghouse PWR Nuclear Power Plant by Westinghouse.
 - NE 400/500 and NE 402/502 class notes by Professor Doster.
 - Updated Final Safety Analysis Reports (UFSAR) for Brunswick BWR and McGuire PWR.

7 Others

(1) Course Attendance

- Required; Active class participation is strongly encouraged.
- NC State attendance policies can be found at: REG 02.20.03 – Attendance Regulations – Policies, Regulations & Rules (<https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/>). Please refer to the course’s attendance, absence, and deadline policies for additional details.

(2) 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 the distance students and to support COVID-19 measures on campus.
- These video recordings may contain an image of you entering the classroom, asking a question or being a part of the studio class.
- Please notify Dr. Linda Krute, Director of EOL, at ldkrute@ncsu.edu if you DO NOT want your image to be included in the lecture presentation. If EOL does not hear from you after the first week of the class, we will assume that you are in agreement with this procedure.

(3) Academic Integrity

- University policy on academic integrity: POL 11.35.01 – Code of Student Conduct <https://policies.ncsu.edu/policy/pol-11-35-01/>
- By signing your name on either test or homework for this course every student implies the following statement: “I have neither given nor received unauthorized aid on this test or assignment”.
- Absolutely no collaboration is permitted during closed-book tests.
- Collaboration on homework assignments is allowed, but the submitted work must be your own individual work. Homework assignments must not be treated as group assignments. Zero grade will be assigned for particular homework for the first offense. Second offense will be reported to the Office of Student Conduct.

(4) Use of Electronic Devices in Class

- Cell phones are to be turned OFF prior to entering the classroom/lab. No exceptions.
- Use of laptops/other electronic devices during class is permitted only for the purpose of following the posted lecture materials/taking electronic notes.

(5) Students with Disabilities

- Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, 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 the “REG 02.20.01 – Academic Accommodations for Students with Disabilities” at <https://policies.ncsu.edu/regulation/reg-02-20-01/>.

(6) Student Mental Health

- As a student you may experience a range of personal issues that can impede learning, such as strained relationships, increased anxiety, alcohol/drug concerns, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance and may impact your ability to participate in daily activities. It is very important that you have a support system and that you ask for help when you are struggling. The Counseling Center at NC State offers confidential mental health services for full time NC State students, including same-day emergency services. Please visit <https://counseling.dasa.ncsu.edu/> to get connected.