

NE 405/505 Reactor Systems

Spring 2025, 3 Credit Hours

1 Course Information

- **Schedule**

- *Time:* Tuesdays and Thursdays, 1:30 pm - 2:45 pm
- *Location:* Room 331, 111 Lampe Drive
- *Course website:* **Moodle** will be used to post lecture slides, project assignments, exams and other materials.
<https://moodle-courses2425.wolfware.ncsu.edu/course/view.php?id=8303>
- *Lecture recordings:* **Panopto** will be used to host the lecture recordings.
<https://ncsu.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderID=%2828e167d1f-04d4-4464-99c5-b244018b20f1%22>

- **Instructor:**

- *Course Instructor:* Dr. Xu Wu, Assistant Professor of Nuclear Engineering
- *Office:* Burlington Laboratory 2110
- *Office Hour:* Tuesdays, 3:00 pm - 5:00 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
- *Office:* Burlington Laboratory 2151
- *Email:* fralsafa@ncsu.edu
- *Office Hours:* Thursdays 9:30 am - 11:30 am

- **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 (NSSS)**

- 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 Course Schedule

- Detailed course schedule will be available in a separate document, including dates for each section/topic, homework/project assignment dates and deadlines, exam dates, etc.

6 Assignments and Grading Policy

(1) There will be no homework assignments.

(2) **Exams (60%)**, see Table 1.

- We will use Moodle online exams for all the three exams in this class.

Table 1: Exams and quizzes

Exams	Format	Weights of total	Dates (tentative)
Midterm Exam 1	Moodle, open book	20%	02/27
Midterm Exam 2	Moodle, open book	20%	04/10
Final Exam	Moodle, open book	20%	TBD

(3) **Project (40%)**, see Table 2.

- We will use the International Atomic Energy Agency (IAEA) Nuclear Reactor Simulators for Education and Training (<https://www.iaea.org/topics/nuclear-power-reactors/nuclear-reactor-simulators-for-education-and-training>) for the computational project.
- There will be 2 projects. For graduate students taking NE 505, each project will include more tasks in the project assignment.
- The project report should include introduction, scenarios to be analyzed, model description, simulation results and conclusions. More details instructions will be posted along with the project assignment in Moodle.

Table 2: Projects

Project	Weights of total	Assignment dates	Due dates
Project 1	15%	02/18	03/18
Project 2	25%	03/18	04/22

(4) **Grading**

- The course will be graded on the letter grading scale listed in Table 3 and will count toward your GPA. More information can be found at <https://studentservices.ncsu.edu/your-grades/general-info/>.
- Requirements for Credit-Only (S/U) Grading:* In order to receive a grade of S, students are required to take all exams and quizzes, complete all assignments, and earn a grade of C- or better. Conversion from letter grading to credit only (S/U) grading is subject to university deadlines. Refer to the Registration and Records calendar for deadlines related to grading. For more details refer to <http://policies.ncsu.edu/regulation/reg-02-20-15>.

- *Requirements for Auditors (AU)*: Information about and requirements for auditing a course can be found at <http://policies.ncsu.edu/regulation/reg-02-20-04>.
- *Policies on Incomplete Grades*: If an extended deadline is not authorized by the instructor or department, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at <http://policies.ncsu.edu/regulation/reg-02-50-3>.

Table 3: Letter grades.

Low	Grade	High
97 ≤	A+	≤ 100
93 ≤	A	< 97
90 ≤	A-	< 93
87 ≤	B+	< 90
83 ≤	B	< 87
80 ≤	B-	< 83
77 ≤	C+	< 80
73 ≤	C	< 77
70 ≤	C-	< 73
67 ≤	D+	< 70
63 ≤	D	< 67
60 ≤	D-	< 63
0 ≤	F	< 60

7 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.
 - Updated Final Safety Analysis Reports (UFSAR) for Brunswick BWR and McGuire PWR.

8 Others

(1) Late Assignments Policy

- Unless stated otherwise, assignments are due by the end of day 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, each student will be granted a **one-time exemption**. The student should contact the course instructor **at least three days** before the original deadline and explain the situation in order to get an extension. The assignment must be turned in by the end of the new designated due date.

(2) Course Attendance/Absence Policy

- Active class participation is strongly encouraged.
- Attendance does not count towards the final grade.
- 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.
- *Absences Policy: Personal Problems:* We understand that sometimes life makes it difficult to focus on schoolwork. If you are having a personal problem that affects your participation in this course, please talk to us to create a plan. Please do not wait until the end of the semester to share any challenges that have negatively impacted your engagement and academic performance. The sooner we connect, the more options we will have available to us to support your overall academic success. If you are not comfortable speaking with us directly, please utilize the other student resources provided below in order to understand how to best approach success in this course given your personal needs as soon as possible.

(3) Transportation

- This course will not require students to provide their own transportation. Non-scheduled class time for field trips or out-of-class activities is NOT required for this class.

(4) Safety & Risk Assumptions

- N/A

(5) Digital Course Components

- 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.
- 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.

- Students may be required to disclose personally identifiable information to other students in the course, via digital tools, such as email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

(6) Academic Integrity

- Students are required to comply with the university policy on academic integrity found in the Code of Student Conduct found at <https://policies.ncsu.edu/policy/pol-11-35-01/>
- Absolutely no collaboration is permitted during closed-book tests. All the tests are closed book unless otherwise specified.
- 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.
- Violations of academic integrity will be handled in accordance with the Student Discipline Procedures (NCSU REG 11.35.02) at <https://policies.ncsu.edu/regulation/reg-11-35-02/>. 11.35.02)

(7) 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 Policy <https://policies.ncsu.edu/policy/pol-11-35-01/>

(8) 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.

(9) Accommodations for 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/>.

(10) Non-Discrimination Policy

- NC State provides equal opportunity and affirmative action efforts, and prohibits all forms of unlawful discrimination, harassment, and retaliation (“Prohibited Conduct”) that are based upon a person’s race, color, religion, sex (including pregnancy), national origin, age (40 or older), disability, gender identity, genetic information, sexual orientation, or veteran status (individually and collectively, “Protected Status”).
- Additional information as to each Protected Status is included in NCSU REG 04.25.02 (Discrimination, Harassment and Retaliation Complaint Procedure). NC State’s policies and regulations covering discrimination, harassment, and retaliation may be accessed at <http://policies.ncsu.edu/policy/pol-04-25-05> or <https://oied.ncsu.edu/divweb/>.
- Any person who feels that he or she has been the subject of prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 919-515-3148.

(11) **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.