NE 500 Advanced Energy Conversion in Nuclear Reactors

COURSE INFORMATION

1. ***Instructor:*** Dr. Mihai A. Diaconeasa
   1110D Burlington Engineering Labs (BU), 919-515-3768
   E-mail (typical response within 12 hours): madiacon@ncsu.edu
   Office hours: Monday 1:00pm – 3:00pm
   or by appointment (use e-mail to request a time)
   https://ncsu.zoom.us/j/8292985327
2. ***Teaching Assistants:***
   Nolan Ritchie (ndritchi@ncsu.edu)
   Zoom Office hours: Monday 3:00pm – 5pm or by appointment.
   https://ncsu.zoom.us/j/8292985327
   Noah Etter (naetter@ncsu.edu)
   Zoom Office hours: Thursday 10am – 12pm or by appointment.
   https://ncsu.zoom.us/j/8292985327
3. ***Schedule:***
   a. Class: Monday and Wednesday 11:45am – 1:00pm.
   Location: 327 Daniels Hall (111 Lampe Drive)
   b. Laboratories only for ABM: will be arranged by the TAs (students will be polled to avoid schedule conflicts)
   Locations: 327 Daniels Hall, BU 3148, PULSTAR control room.
   c. Captured lectures will be available after each session under NE 500 at: https://ncsu.hosted.panopto.com/Panopto/Pages/Sessions/List.aspx#folderID=%22ef9571bf-ed85-43e4-8acf-b244018b1cf5%22.
   d. Possible make-up classes: Friday 11:45am – 1:00pm. Location: 327 Daniels Hall.
   e. Online **class evaluations** will be available for students to complete during the last 2 weeks of the semester then become unavailable at 8am on the first day of finals:
   8am April 10th through 8am April 24th
   Students will receive an email message 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 assigned.
   Evaluation website: http://go.ncsu.edu/cesurvey
4. ***Description***: A course which introduces 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. Design principles are emphasized in homework and in-class problems. Course project is required.
5. ***Prerequisites***:
   a. MAE 201 "Engineering Thermodynamics I"
   b. and a "**C-**" or better in NE 301 "Fundamentals of Nuclear Engineering"
6. ***Objectives:***
   The students completing this course will be able to:
   - **Define** and **apply** the concepts and principles of heat generation and removal in nuclear reactor systems
   - **Explain** and **evaluate** thermodynamic cycles
   - **Explain** and **evaluate** nuclear reactor heat sources
   - **Explain** and **evaluate** heat conduction in nuclear reactor elements
   - **Explain** and **evaluate** convective heat transfer in nuclear reactor systems

- **Explain** and **evaluate** the performance of heat exchangers
- **Explain** and **develop** numerical solutions to the heat conduction equation

7. ***Test Schedule***

Exam:	Date/Time/Location:
Test #1	Tuesday, February 18: 7:00am – 23:59pm (take-home)
Test #2	Tuesday, April 8: 7:00am – 23:59pm (take-home)
Final	Wednesday, April 30: 7:00am – 23:59pm (take-home)

https://studentservices.ncsu.edu/calendars/exam/#spring

8. ***Homework***: Homework will be assigned periodically throughout the semester. The last homework assignment may be due during the last week of classes. The submissions should be submitted as .pdf documents on Moodle. **Moodle** is used to post lecture notes, homework, and other materials:

   https://moodle-courses2425.wolfware.ncsu.edu/course/view.php?id=7828

   Late Assignments: Unless stated otherwise on Moodle, 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 unless exemption granted. To allow for unforeseen circumstances, students are granted a one-time 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, family emergencies, or other unforeseen circumstances.

9. ***Makeup Work Policy*****:** 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 as early as possible to create a plan.

10. ***Attendance*****:** Required; Active class participation is strongly encouraged. University policy on definition of excused absences:

    https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/

    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.

    Providing feedback to us: We encourage your feedback at any time throughout the semester about things that are helping you learn, or things that aren't helping. Please let us know if there are ways that we can improve the course to better support your learning.

11. ***Text and Selected References***

    Required text:

    1) N. E. Todreas and M. S. Kazimi, *Nuclear Systems I*: *Thermal Hydraulic Fundamentals, Third edition, 2021*.

    - Hardcover (Hill Reserves https://catalog.lib.ncsu.edu/catalog/NCSU5292745)
    - eBook (https://catalog.lib.ncsu.edu/catalog/NCSU4826761)

    Recommended text:

    2) El-Wakil, *Nuclear Heat Transport*

    Other References:

    3) Holman, *Heat Transfer*
    4) Hornbeck, *Numerical Methods*
    5) Carnahan, Luther and Wilkes; *Applied Numerical Methods*

6) Tong and Weisman, *Thermal Analysis of Pressurized Water Reactors*, 2nd Ed.
7) Lahey and Moody, *The Thermal-Hydraulics of a Boiling Water Nuclear Reactor*
8) Rust, *Nuclear Power Plant Engineering*
9) Lamarsh and Baratta, Introduction to Nuclear Engineering
10) Modest, Radiative Heat Transfer
11) Collier and Thome, Convective Boiling and Condensation
12) Knief, Nuclear Engineering: Theory and Technology of Commercial Nuclear Power

12. ***Grading:***

NE 500		NE400/500 ABM	
Classwork	3%	Classwork	3%
Tests (2)	30%	Tests (2)	24%
Homework	22%	Homework	18%
Project	25%	Lab	20%
Final	20%	Project	15%
		Final	20%

A+ ≥ 96%*	A 92 – 95%	A- 89 – 91%
B+ 86 – 88%	B 82 – 85%	B- 79 – 81%
C+ 76 – 78%	C 72 – 75%	C- 69 – 71%
D+ 65 – 68%	D 61 – 64%	D- 56 – 60%
	F < 56%	

*Must be top 5% student in the class as well to earn the “A+”.

13. **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 https://policies.ncsu.edu/regulation/reg-02-20-15/.
14. **Auditors (AU):** Information about and requirements for auditing a course can be found at https://policies.ncsu.edu/regulation/reg-02-20-04/.
15. ***Academic Integrity***:
    a. University policy on academic integrity: **Code of Student Conduct Policy** https://policies.ncsu.edu/policy/pol-11-35-01/
    b. 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.*"
    c. Absolutely no collaboration is permitted during the tests. All the tests are open notes and textbook. No other resources are allowed unless otherwise specified.
    d. Collaboration on homework assignments is encouraged, 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 offence. Second offense will be reported to the *Office of Student Conduct.*
    e. Alternatives to Academic Dishonesty:
        i. Seek out help – connect with your instructor and teaching assistant, ask if there is special tutoring available.
        ii. Ask for an extension – if you explain your situation to your instructor, an extended deadline may be granted.

iii. See a counselor at the Counseling Center, and/or your school, college or department – NC State has many resources for students who are feeling the stresses of academic and personal pressures.
iv. Drop the course – can you take it next semester it is offered when you might feel more prepared and less pressured?

16. ***Wellness Support:*** 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. The full list of resources available to you are found at: https://wellness.ncsu.edu/resources/.
17. ***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, I would encourage you to report this behavior by making a referral on the **NC State Cares** website: https://prevention.dasa.ncsu.edu/nc-state-cares/about/. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.
18. ***Accommodations for 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 **Academic Accommodations for Students with Disabilities Regulation** (https://policies.ncsu.edu/regulation/reg-02-20-01/).
19. ***Digital Course Components*****:** 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. All Moodle deliverables will have their originality automatically evaluated with the Turnitin software. You are not allowed to share any course materials with anyone or upload to any websites without instructor's written approval.
20. ***Use of electronic devices in class***: Communication devices are to be turned on silent prior to entering the classroom. Use of electronic devices during class for purposes other than taking notes is prohibited unless otherwise instructed. Tablets may be used in the lay-flat position on the desk for following the posted lecture materials or taking electronic notes only.
21. **Use of AI Tools:** In this course, students are encouraged to explore and utilize generative AI tools, such as chatbots, text generators, paraphrasers, etc., as part of their learning and coursework. These tools can be valuable for brainstorming, drafting, and enhancing your understanding of the material. However, it is important to critically assess and cite any AI-generated content used in your assignments and projects. Students are expected to demonstrate their own understanding and critical thinking in their final submissions. Proper attribution and transparency about your usage of an AI tool are expected. If you have any questions about what constitutes ethical and responsible use of AI tools, please consult with the instructor before submitting your work. We may also integrate AI Tools into some of our assignments. Here are some examples of ethical and responsible generative AI use.

a. Use AI tools only for tasks that are appropriate for your level of learning and understanding. Do not use AI tools to replace your own thinking or analysis, or to avoid engaging with the course content.
b. Cite any AI tools you use properly, following the citation style specified by the instructor. APA Example: OpenAI. (2025). ChatGPT (Jan 6 version) [Large language model]. https://chat.openai.com/chat
c. Provide evidence of how you used the AI tool and how it contributed to your assignment. Explain what you learned from the AI tool, how you verified its accuracy and reliability, how you integrated its output with your own work, and how you acknowledged its limitations and biases.
d. Take full responsibility for any mistakes or errors made by the AI tool. Do not rely on the AI tool to produce flawless or correct results. Always check and edit the output before submitting your work. If you discover any inaccuracies or inconsistencies in the output after submission, notify the instructor immediately and correct them as soon as possible.
e. If you are working on a group assignment, discuss the use of AI tools with your group members and agree on how you plan to use them and how you will be transparent with the instructor regarding their use.

22. **Health and Well-Being Resources:** These are difficult times, and academic and personal stress are natural results. Everyone is encouraged to take care of themselves and their peers. If you need additional support, there are many resources on campus to help you:
    a. Counseling Center (NCSU Counseling Center)
    b. Student Health Services (Health Services | Student)
    c. If the personal behavior of a classmate concerns or worries you, either for the classmate's well-being or yours, we encourage you to report this behavior to the NC State CARES team: (Share a Concern).
    d. If you or someone you know are experiencing food, housing, or financial insecurity, please see the Pack Essentials Program (Pack Essentials).
23. **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 https://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.
24. ***Free Parking:*** For those with cars but without parking permits, NC State provides Park & Ride commuter lots, all served by Wolfline buses: https://transportation.ncsu.edu/park-ride/. Claiming a **FREE** permit for the "Park & Ride" lots will allow the transportation office to contact you about any closures or other events that may have an impact on the lot.
25. ***Pack Proficiencies:*** Critical and creative thinking skills are essential to the success of all NC State graduates, and that's why they are part of our "Pack Proficiencies." To support the goals of this program, all students in this course are asked to complete an assessment of critical and creative thinking. You do not need to study for the assessment. Data collected during the assessment will help us improve our programs and guide future decisions regarding the education of NC State students. Your performance on the assessment itself will not impact your grade in this course; however, please do your best work! Additional information about the assessment is available online from go.ncsu.edu/senior-assessment. If you are registered

with the Disability Resource Office and require accommodation please contact Madalene Adams in DASA Assessment at mtadams2@ncsu.edu.

COURSE TOPICS

1. **Thermodynamic Cycles (8 lectures)**
   - 1.1 Carnot cycle (L1)
   - 1.2 Rankine cycle (L2)
     - 1.2.1 Reheat cycle (L3)
     - 1.2.2 Regenerative cycle (L4)
     - 1.2.3. Actual vs. Ideal Cycles (L5)
     - 1.2.4. Advanced examples (L6)
   - 1.3 Brayton Cycle (L7)
     - 1.3.1. Modified Brayton Cycle (L8)
   - 1.4. Reactor systems examples (L8)

2. **Heat Conduction in Reactor Elements (4 lectures)**
   - 2.1 Fundamentals of conduction (L1)
   - 2.2 Heat conduction equations (L1)
   - 2.3 One-dimensional steady-state conduction (L2)
   - 2.4 Temperature distributions in fuel elements (L3)
     - 2.4.1. Effects of gap and variable conductivity (L4)

3. **Convective Heat Transfer in Reactor Systems (3 lectures)**
   - 3.1 Reactor coolant characteristics (L1)
   - 3.2 Axial fluid temperature profiles (L1)
   - 3.3 Forced convective heat transfer correlations (L2)
     - 3.3.1 Pipe and tube flow
     - 3.3.2 Non-circular passages
     - 3.3.3 Flow across tube banks
     - 3.3.4 Flow parallel to rod bundles
   - 3.4. Natural Convection (L3)
   - 3.5. Boiling heat transfer (L3)

4. **Heat Exchangers (3 lectures)**
   - 4.1 Overall heat transfer coefficient (L1)
   - 4.2 Log-Mean Temperature Difference (L2)
   - 4.3 Heat exchangers in reactor systems (L3)

5. **Reactor Heat Sources (7 lectures)**
   - 5.1 Heat generation in reactor fuel elements (L1)
   - 5.2 Heat generation in power reactors (L2)
   - 5.3 Reactor shutdown heat generation (L3,5)
   - 5.4. Heat generation in reactor structure (L4)
   - 5.5 Heat generation by radioisotopes (L4,5)
   - 5.6 Temperature distributions in fuel elements – Non-Uniform heat generation (L6)
   - 5.7 Temperature distributions in thermal shields and pressure vessels (L6)
   - 5.8 Lumped Parameter Models (L7)

6. **Numerical Solutions to the Heat Conduction Equation (3 lectures)**
   - 6.1 Steady-state, multi-dimensional problems (L1)
   - 6.2 Heat balance approach for method development (L2)
   - 6.3 Time Dependent Solutions (L3)

COURSE PROJECT

Project deliverables (mark your calendar, all **via Moodle Turnitin**):

1. Choose the project option, or propose a suitable alternative – due **February 24** (see project options in separate document available on Moodle)
2. Specific plan (2-5 pages) on executing the project, including theoretical framework report (proposed equations to be used) and possible issues with the project formulation – due **March 17**.
3. Proposal on specific set of values to be used with the numerical code and justification – due **March 31**. The final report shall include at least 5 *parametric studies* (in the form of tables, plots, and analytical description)

demonstrating how the chosen parameters influence the design specifications. Include any progress made so far in this report.

4. Working code demonstration for specific set of parameters accompanied by analytical proof (when possible) that the results are trustworthy – due **April 14**.
5. Final report, which includes the electronic version of the code, and the detailed results section and conclusions on what is the best design choice based on the performed parametric studies – due **April 30**.

COURSE LABS*

Lab schedule and workflow:

Each lab (except lab #1) consists of:

a. Before the lab: Students will bring pre-lab homework (answers to several questions posted on Moodle along with the lab handout) and submit them at the beginning of their lab session.
b. Experimental part performed in groups of 4-5 students under the supervision of the lab TA and/or course instructor.
c. Data analysis report which is due to the lab TA according to the schedule below.
d. The report will be graded and returned by the TA according to the schedule below.
e. Final lab report is due according to the schedule.
f. The graded final lab report will be returned to students within a month of lab day (or before the final exam for the last lab).

Lab Title	Lab Date(s)	Data Analysis Due*	Final Lab Report Due
1. Propagation of errors	1/17	1/24	N/A
2. Heat Balance on the PULSTAR**	2/7	2/14	2/27
3. Heat Conduction	2/28	3/9	3/20
4. Forced Heat Convection	3/21	3/28	4/3
5. Condensation Heat Transfer	4/4	4/11	4/17

*These will be returned within 5 days after they have been received.
**PULSTAR lab day: all NE 400 and NE 500 ABM students must show up at 8 AM outside the PULSTAR control room entrance on the 2nd floor of BU (next to the NE library) unless otherwise specified.

- Lab #1 is conducted at our regular location 327 Daniels Hall (111 Lampe Drive).
- Lab #2 is conducted in the PULSTAR control room. Please bring a valid photo ID.
- Labs #3, #4, and #5 are conducted at BU 3148 (TH laboratory on the 3rd floor of BU).

*Course laboratories are required only for NE 400 and NE 500 ABM students.

- Each lab requires data analysis report (30% of total lab grade) and final report (70% of total lab grade).
- Absence of the pre-lab homework at the beginning of the lab session results in 10% penalty of the lab grade.
- Student absence (w/o prior arrangement) from the assigned lab session results in 50% penalty for the particular lab grade.

Please keep this syllabus easily accessible so that you can refer to it throughout the semester. Contact us with any clarifying questions in advance of the semester or within the first week. We look forward to supporting your learning in this course.