# 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:***
   **Mostafa Hamza** (mmhamza@ncsu.edu)
   *Zoom Office hours*: Tuesday 9am – 11am or by appointment.
   https://ncsu.zoom.us/j/8292985327
   **Egemen Aras** (emaras@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=%22dc05515f-52bb-4d6b-af0f-b0d50176bbf5%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 11th through 8am April 25th
   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 20: 7:00am – 23:59pm (take-home) |
| Test #2 | Tuesday, April 9: 7:00am – 23:59pm (take-home) |
| Final | Friday, April 26: 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-courses2324.wolfware.ncsu.edu/course/view.php?id=7948

   ***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. ***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.

10. ***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*

11. ***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+".

12. ***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?
13. ***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/.
14. ***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.

15. ***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 **Academic Accommodations for Students with Disabilities Regulation** (https://policies.ncsu.edu/regulation/reg-02-20-01/).
16. ***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.
17. ***Health and Participation in Class****:* We are most concerned about your health and the health of your classmates and instructors. The course is delivered in a studio classroom; thus, the students can actively participate online as well when needed and the recordings will be available after each lecture.
    a. If you test positive for COVID-19 or are told by a healthcare provider that you are presumed positive for the virus, please work with your instructor on health accommodations and follow other university guidelines, including self-reporting: https://healthypack.dasa.ncsu.edu/coronavirus/. Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
    b. If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to class.
    c. If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to discuss the situation and make alternative plans, as necessary.
    d. If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor for the appropriate process to make a COVID-19 request.
18. ***Course Delivery Changes Related to COVID-19*****:** Please be aware that the situation regarding COVID-19 is frequently changing, and the delivery mode of this course may need to change accordingly, including from in-person to online. Regardless of the delivery method, we will strive to provide a high-quality learning experience.
19. ***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.

## 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 26** (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 18**.
3. Proposal on specific set of values to be used with the numerical code and justification – due **April 1**. 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 15**.
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 **May 1**.

# 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 | 1/19 | 1/26 | N/A |
| 2. Heat Balance on the PULSTAR** | 2/9 | 2/16 | 2/29 |
| 3. Heat Conduction | 3/1 | 3/8 | 3/21 |
| 4. Forced Heat Convection | 3/22 | 3/29 | 4/4 |
| 5. Condensation Heat Transfer | 4/5 | 4/12 | 4/18 |

*These will be returned within 5 days after they have been received.
**PULSTAR lab day: all NE 400 and 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).
- 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.**

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