

NC STATE UNIVERSITY

NE 533 Course Syllabus

Nuclear Fuel Performance

Spring 2025

Instructor Information

Name	Office Phone	Mobile Phone	Email	Office Location
Benjamin Beeler	919.515.3737	270.589.1757	bwbeeler@ncsu.edu	BU 1110C



Office Hours

Wednesdays 10-11am, BU 1110C.

Preferred Method of Communication & Response Time

- **Preferred method of communication:** If you need to contact me directly, my preferred method of communication is email. You can expect to receive a response within two business days (i.e. not over the weekend). If I email you directly, please strive to respond within two business days. It is recommended that you check your NC State email at least once a day to stay on top of course communications.

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- **Asking questions about the course:** If you have a question about the course or its content, you can email me or post your question on the Student Help Forum in Moodle. You can expect to receive a response within two business days (i.e. not over the weekend).
- **Email guidelines:** Always include a descriptive, specific but concise subject. Include your course number and section in your email and provide adequate context for your question to ensure full understanding of your email. Be sure to use your NC State email account and sign in with your name and Student ID number.

Course Information

Course Website: [NC State WolfWare](#)

Meeting Time and Location: Tuesday/Thursday, 3:00-4:15, Classroom Lampe 331

Course Credit Hours: 3

Catalog Description

In this course, we will study the basic role of fuel in reactor operation and understand how the fuel impacts heat generation and transport to the coolant. The course will begin with an overview of different fuels and the fabrication processes required to construct nuclear fuel. This will include various fuel types and geometries, with a focus on light water reactor fuel and cladding. Thermal transport, mechanics, and thermomechanics affecting fuel behavior will be introduced, and methods to solve the governing equations numerically and analytically will be developed. Subsequently, changes in the fuel and cladding material that degrade the performance of the fuel will be examined. Finally, the knowledge gained throughout the course will be utilized to conduct fuel performance simulations with MOOSE.

Structure

The majority of this course is **synchronous**, delivered through real-time, face-to-face class sessions. Additional materials and activities are delivered through **Moodle**, a secure and easy-to-use online learning platform.

Learning activities in this course will include exams, PowerPoint presentations, reports, and individual projects.

This course consists of four modules. Modules contain 4-5 lectures, with an exam at the end of the module.

Module 1: Fuels, Systems, Heat Conduction Equation, and Numerical Discretization

Module 2: Mechanics, Thermomechanics, and Intro to MOOSE

Module 3: Fission Products, Swelling, and Pellet Cladding Interactions

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Module 4: Corrosion, Accidents, and Advanced Fuels

Meeting Time and Tool Used

Classes will be held in person at the stated time and location. This course will also have a hybrid option utilizing Zoom. Lectures will be recorded either via Zoom or Panopto for offline access.

Prerequisites/Corequisites

NE 409 or equivalent

Minimum Technical and Digital Information Literacy Skills

- Navigate and use Moodle, NC State's Learning Management System.
- Use Gmail, including attaching files to email messages
- Create and submit files in commonly used word processing program formats (MS Word, text editors, Google Docs).
- Download and install software as needed (see [section on required software](#))
- Download and upload attachments
- Use spreadsheets, presentations, graphics programs, and other applications in digital environments
- Use web conferencing tools including Zoom and Google Meet.
- Post to discussion boards and forums
- Perform online research using various search engines and library databases. Visit [Distance Learning Services](#) at NC State Libraries for more information.
- Use computer networks to locate and store files or data.
- Use online search tools for specific academic purposes, including the use of search criteria, keywords, and filters
- Analyze digital information for credibility, currency, and bias (e.g... disinformation, misinformation)
- Properly cite information sources
- Prepare a presentation on research findings

General Education Program (GEP) Information

N/A

Learning Outcomes

Upon completion of this course, students will be able to:

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1. Summarize the basics of fuel fabrication
2. Evaluate traditional and alternative nuclear fuel types and their application
3. Determine the rate at which heat is transported to the coolant from the fuel
4. Determine the stress state within both the fuel and the cladding
5. Describe the most important microstructural changes that take place in the fuel and cladding and how they impact fuel performance
6. Critically analyze existing literature in fuel performance modeling
7. Use an existing fuel performance code

Course Materials

Required textbook

None

Other required materials

None

Optional materials

Light Water Reactor Materials, Vol. 1 Fundamentals, D. Olander and A. Motta

Nuclear Fuel Elements, B. Frost

Fundamentals of Radiation Materials Science, G. Was

Comprehensive Nuclear Materials Science, R. Konings and R. Stoller

Technology Requirements

NC State University Libraries offers [Technology Lending](#), where many devices are available to borrow for a 7-day period. [Computer labs](#) are available in various locations around campus for student use.

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Computer

A computer is required for students taking this course. NC State's Office of Information Technology provides recommendations for [your computer at NC State.](#)

Other devices

The RDFMG cluster (<https://www.ne.ncsu.edu/rdfmg/rdfmg-guide/>) will be made available for the computer projects.

Software and digitally-hosted course components

The following software and tools will be used in this course. Some tools are a part of NC State's enterprise tools. See [information about their purpose, how to access them, accessibility information, and privacy policies](#). The same information for any other tools required in this course is provided in the list below.

- MOOSE (free) <https://mooseframework.inl.gov/>

Other Student Expenses

- None

Communication Guidelines

Respecting our learning community

The [NC State Code of Student Conduct](#) outlines expectations for behavior in the classroom (whether virtual or physical) and the consequences for students who violate these expectations. Any behavior that impacts other students' ability to learn and succeed will be addressed but expressing diverse viewpoints and interpretations of course content is welcome.

Community guidelines for this course include:

- Use a respectful tone in all forms of communication (email, written, oral, visual)
- Maintain professionalism (avoid slang, poor grammar, etc.) in your written communication.
- Respect regional dialects and culturally embedded ways of oral communication.

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- Stay home or in your dorm room if you are exhibiting symptoms of a contagious illness (fever, chills, etc.).
- Enter our virtual and/or physical classroom community respectfully by refraining from lewd or indecent speech or behavior, helping to maintain a safe physical environment, not using your cell phone for voice or text communication except when explicitly given leave to do so, and not attending class under the influence of any substance.
- Treat each community member with respect by not recording others without their consent or engaging in any form of hazing, harassment, intimidation, or abuse.
- Respect cultural differences that may influence communication styles and needs.

Plan for interaction between instructors and students

Students are encouraged to interact with the instructors for brief questions/issues directly after the end of the in-person courses. For more detailed questions or issues students are encouraged to attend office hours or schedule appointments with the instructors. For any change/update of the course schedule, or for approaching deadlines, the instructor will contact the students via email. A Slack channel will be made available for rapid communication outside of class.

Expectations for learner participation and interaction

Communication expectations including frequency and content are detailed in the information about each assignment or activity when it appears in the course.

Grading and Feedback

Grading criteria, details, and timing of feedback

Grading Components for NE 533

Percentage of grade	Component	Details and timing of feedback
64%	Exams	<ul style="list-style-type: none">• Four exams, each worth 16%.• Exams will be preceded by an in-class problem session.• You will receive a grade/feedback within one week of the date of the exam.
16%	Presentation	<ul style="list-style-type: none">• Presentation during class summarizing an assigned paper on nuclear fuel performance.

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		<ul style="list-style-type: none"> You will receive a grade/feedback within one week of the date of the presentation.
20%	MOOSE Project	<ul style="list-style-type: none"> Project conducted throughout the class utilizing a fuel performance software. The project will be conducted in 3 parts, worth 5%, 5%, and 10% of the total grade, respectively. You will receive a grade/feedback within one week of the due date for each part.

Modifications to the timing of grades/feedback, if required, will be announced via email.

Grading scale

This course uses the standard NCSU grading scale:

Low	Letter	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

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Requirements for earning a grade of “Satisfactory”

If you are taking this course for credit only (S/U), your grade will be reported as S (Satisfactory) when coursework is equivalent to a C- or better or U (Unsatisfactory) when coursework is equivalent to less than a C-. For more information, see the [Credit Only Courses regulation](#).

Requirements and procedures for auditing this course

Auditing this course is approved on a case-by-case basis. Please contact the course instructor to attain approval. Refer to the [Audit regulation](#) for more information and links to required forms.

Course Schedule

Please note: the course schedule is subject to change.

Week	Topic	Assignments
Week 1	Course Introduction, Fuel Types, Fuel Fabrication	
Week 2	Heat generation, Analytical Heat Conduction Equation	
Week 3	Thermal conductivity, Critical Heat Flux, Numerical Discretization, Problem Session	
Week 4	Exam 1, Intro to MOOSE	Exam 1
Week 5	Mechanics 1, Mechanics 2	
Week 6	Thermomechanics, Numerical Thermomechanics	MOOSE Part 1
Week 7	Mechanistic Modeling, Problem Session	
Week 8	Exam 2, Fuel Chemistry	Exam 2
Week 9	Paper Presentations	Presentations
Week 10	Fission gas release and swelling	MOOSE Part 2
Week 11	Zirconium cladding, pellet cladding interactions 1	
Week 12	Pellet cladding interactions 2, Problem Session	

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Week 13	Exam 3, Oxide Formation	Exam 3
Week 14	Hydride formation, Operational Limits	
Week 15	Water Chemistry, MOX, Advanced Reactors	
Week 16	Problem Session, Exam 4	Exam 4, MOOSE Part 3

Course Policies

Proctored exams

The exams are 75 minutes, closed book with a cheat sheet, and are administered in person during the class period. If necessary, arrangements will be made for a student to take an exam outside of class hours.

Late assignments

Extensions on assignments beyond the due date can be requested without penalty. A written justification needs to be provided at least 3 business days before the assignment is due. Otherwise, late assignments will be accepted with a 10% penalty for each business day the assignment is late, up to a maximum of 3 days, after which no assignments will be accepted and a zero will be awarded.

Incomplete grades, withdrawals

Information on incomplete grades can be found at [REG 02.50.03 – Grades and Grade Point Average](#). If you encounter a serious disruption to your work not caused by you and you would have otherwise successfully completed the course, contact your instructor as soon as you can to discuss the possibility of earning an incomplete in the course for the semester, including an agreement on when the remaining work must be done in order to change the grade to the appropriate letter grade.

If a student must withdraw from a course or from the University due to hardship beyond their control, see [Withdrawal Process and Timeline | Student Services Center](#) for information and instructions.

Attendance

Attendance for this course is highly recommended, but not required. Active class participation is strongly encouraged.

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Related NC State Policy: [REG 02.20.03 – Attendance Regulations](#)

University Policies

Academic integrity and honesty

Students are required to comply with the university policy on academic integrity found in the [Code of Student Conduct 11.35.01 sections 8 and 9](#). Therefore, students are required to uphold the Pack Pledge: “I have neither given nor received unauthorized aid on this test or assignment.” Violations of academic integrity will be handled in accordance with the [Student Discipline Procedures](#).

Please refer to the [Academic Integrity](#) web page for a detailed explanation of the University’s policies on academic integrity and some of the common understandings related to those policies.

Student privacy

Originality Checking Software

Software is not used in this course to detect the originality of student submissions.

Class recording statement:

In-class sessions are recorded in such a way that might also record students in this course. These recordings will NOT be used beyond the current semester or in any other setting outside of the course.

Class privacy statement:

This course requires online exchanges among students and the instructor, but NOT with persons outside the course. Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like 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.

Other Policies

Students are responsible for reviewing the NC State University PRR’s which pertain to their course rights and responsibilities:

- [Equal Opportunity and Non-Discrimination Policy Statement](#) and [additional references](#)

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- [Code of Student Conduct](#)
- [Grades and Grade Point Average](#)
- [Credit-Only Courses](#)
- [Audits](#)

Student Resources

Academic and Student Affairs maintains a website with links for student support on campus, including academic support, community support, health and wellness, financial hardship or insecurity, and more. [Find Help on Campus.](#)

Disability resources

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the [Disability Resource Office \(DRO\)](#). For more information on NC State's policy on working with students with disabilities, please see the [Policies, Rules and Regulations page maintained by the DRO](#) and [REG 02.20.01 Academic Accommodations for Students with Disabilities](#).

Safe at NC State

At NC State, we take the health and safety of students, faculty and staff seriously. The [Office for Institutional Equity and Diversity](#) supports the university community by providing services and resources to support and guide individuals in obtaining the help they need. See the [Safe at NC State webpage](#) for resources.

Supporting Fellow Students in Distress

[Example: 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 remain a healthy and safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you, either for the classmate's well-being or yours. If you feel this way, I would encourage you to report this behavior to the [NC State CARES website](#). Although you can report anonymously, it is preferred that you share your contact information so they can follow up with you personally.]

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Course Evaluations

ClassEval is the end-of-semester survey for students to evaluate the instruction of all university classes. The current survey is administered online and includes 12 closed-ended questions and 3 open-ended questions. Deans, department heads, and instructors may add a limited number of their own questions to these 15 common-core questions.

Each semester students' responses are compiled into a ClassEval report for every instructor and class. Instructors use the evaluations to improve instruction and include them in their promotion and tenure dossiers, while department heads use them in annual reviews. The reports are included in instructors' personnel files and are considered confidential.

Online class evaluations will be available for students to complete during the last two weeks of the semester for full-semester courses and the last week of shorter sessions. Students will receive an email directing them to a website to complete class evaluations. These become unavailable at 8 am on the first day of finals.

- Contact ClassEval Help Desk: classeval@ncsu.edu
- [ClassEval website](#)
- [More information about ClassEval](#)

Syllabus Modification Statement

Our syllabus represents a flexible agreement. It outlines the topics we will cover and the order in which we will cover them. Dates for assignments represent the earliest possible time they would be due. The pace of the class depends on student mastery and interests. Thus, minor changes in the syllabus can occur if we need to slow down or speed up the pace of instruction.