

# NC STATE UNIVERSITY

## NE/PY 528 Course Syllabus

### Introduction to Plasma Physics and Fusion Energy

Fall 2024 Semester, 3 Credit Hours

#### Instructor Information

Name	Role	Office Phone	Email	Office Location
Dr. Florian M. Laggner	Instructor	(919) 51 33603	fmlaggner@ncsu.edu	Burlington Laboratories 3152
Arthur Mazzeo	Teaching Assistant	-	amazzeo@ncsu.edu	Burlington Laboratories



F. M. Laggner  
(Instructor)



A. Mazzeo  
(Teaching Assistant)

#### Office Hours

F. M. Laggner:

Mon, 10 AM - 11 AM, 3152 Burlington Laboratory

Wed, 3 PM - 4 PM, 3152 Burlington Laboratory

A. Mazzeo:

TBA

TBA

# NC STATE UNIVERSITY

## Preferred Method of Communication & Response Time

- **Preferred method of communication:** If you need to contact the instructor(s) directly, the preferred method of communication is email. Typical response time via email is within 24 h during the week. Do not expect any email communication on weekends. If an instructor emailed you directly, please strive to respond within 24 h. Highly recommended that you check your NC State email at least once a day to stay on top of course communications.
- **Asking questions about the course:** If you have a question about the course or its content, please post your question on the Student Help Forum in Moodle. You can expect to receive a response within 24 h during the week (i.e. not over the weekend). You also may send your question via email.
- **Email guidelines:** Always include a descriptive, specific but concise subject. Include your course number in your email, and provide adequate context for your question in order to ensure full understanding of your email. Be sure to use your NC State email account, and sign with your name and Student ID number.

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## Course Information

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**Course Website:** <https://moodle-courses2425.wolfware.ncsu.edu/course/view.php?id=190>

**Meeting Time and Location:** Monday and Wednesday, 1:30 PM – 2:45 PM, Room 331 111 Lampe Drive

**Course Calendar:** The Moodle calendar will be kept up to date and it can be exported to any desired platform; see [https://docs.moodle.org/402/en/Using\\_Calendar](https://docs.moodle.org/402/en/Using_Calendar). It is recommended to use 'Dynamic Link to Moodle Calendar'.

**Course Credit Hours:** 3

## Catalog Description

Concepts in plasma physics, basics of thermonuclear reactions; charged particle collisions, single particle motions and drifts, radiation from plasmas and plasma waves, fluid theory of plasmas, formation and heating of plasmas, plasma confinement, fusion devices and other plasma applications.

# NC STATE UNIVERSITY

## Structure

This course is delivered in a **hybrid** format, meaning it has asynchronous and synchronous components. Asynchronous components (homework assignments) are delivered through **Moodle**, a secure and easy-to-use online learning platform.

This course has 5 units, typically one of them is taught over two to three weeks.

Unit	Unit title	Course Content	Week
I	Introduction	Fusion in stars and in a fusion reactor Reaction rates Energy gain Fusion triple product Characteristics of plasmas Saha equation and ionization equilibrium Plasma frequency and collective behavior Debye length and plasma shielding	1-2
II	Single Particle Motion	Lorentz force equation Particle trajectories in uniform fields Behavior in non-uniform fields Particle drifts Adiabatic invariance	3-4
III	Plasma Fluid Theory	Introduction to the kinetic problem Moments of the Boltzmann equation Plasma fluid dynamics Diamagnetic drift Introduction to waves Perturbation analysis and plasma wave phenomena Transport processes Magnetohydrodynamic (MHD) theory Ideal MHD approximation 'Frozen-In' flux concept	5-10
IV	Plasma Instabilities	Stability criteria Electrostatic instabilities - Two stream instability MHD instabilities - Rayleigh-Taylor instability	11-12
V	Plasma Confinement And Fusion Technology	Confinement concepts Inertial confinement fusion (ICF) Magnetic confinement fusion (MCF) - Tokamaks MCF - Stellarators Plasma material interaction (PMI) Fuel cycle and breeding blankets	13-14

# NC STATE UNIVERSITY

## Prerequisites/Corequisites

MA 401 and PY 208

## Minimum Technical and Digital Information Literacy Skills

### Required technical 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 upload attachments
- Use spreadsheet, presentation, graphics programs and other applications in digital environments
- Use web conferencing tools including Zoom and Google Meet.
- Post to discussion boards and forums

### Required digital information literacy skills

- 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.b. disinformation, misinformation)
- Properly cite information sources

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## Learning Outcomes

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Understand concepts in plasma physics and basics of thermonuclear reactions.

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

1. Understand the fundamentals of fusion reactions, including reaction rates and energy gain.
2. Comprehend basic plasma physics principles and characteristics.
3. Analyze single particle motion in plasmas, including various particle drifts and adiabatic invariance.
4. Derive and interpret fluid equations for plasmas, including dispersion relations.
5. Examine various types of waves in plasmas, including cold plasma waves.
6. Classify and analyze different types of plasma instabilities.
7. Analyze magnetized plasma behavior using magnetohydrodynamic (MHD) theory

# NC STATE UNIVERSITY

8. Compare and contrast different plasma confinement approaches in fusion

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## Course Materials

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### Textbooks

Textbooks are optional (Free online access for NCSU students):

**[U]** 'Principles of Plasma Physics for Engineers and Scientists' U. S. Inan and M. Golkowski,

1st Edition, ISBN: 978-0-521-19372-6 <https://catalog.lib.ncsu.edu/catalog/NCSU4450335>

**[C]** 'Introduction to Plasma Physics and Controlled Fusion' F. Chen, 3rd Edition,

ISBN:978-3-319-22309-4 <https://catalog.lib.ncsu.edu/catalog/NCSU3556298>

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## Technology Requirements

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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.

### Computer

A laptop computer is recommended for students taking this course. NC State's Online and Distance Education provides [technology requirements and recommendations](#) for computer hardware, and NC State's Office of Information Technology provides recommendations for [your computer at NC State](#).

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## Other Student Expenses

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- None

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## Communication Guidelines

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### 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 success 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.

# NC STATE UNIVERSITY

- 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 or harassment or intimidation or abuse.
- Respect cultural differences that may influence communication styles and needs.

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## Grading and Feedback

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### Grading criteria, details, and timing of feedback

Percentage of grade	Component	Details and timing of feedback
50 %	Homework	<ul style="list-style-type: none"><li>● <b>Students will submit homework individually.</b></li><li>● <i>The homework problems will be typically made available on Monday and they are due Wednesday the following week 1:30 PM Eastern Time.</i></li><li>● <b>Requests for regrades</b> are only accepted when they <b>include a written justification</b> and must be submitted not later than 1 week after the homework was returned.*</li><li>● <i>The tentative assignment schedule can be found under 'Course Schedule'.</i></li></ul>
30 %	Midterm Exams (15 % each)	<ul style="list-style-type: none"><li>● <i>Midterm exams are closed book, in-class and timed.</i></li><li>● <i>You are allowed one double-sided 8.5x11 'cheat sheet' for each exam along with a scientific calculator.</i></li><li>● <i>You will receive a grade / feedback within two weeks of the due date.*</i></li></ul>
20 %	Final Exam	<ul style="list-style-type: none"><li>● <i>Exam is closed book, in-class and timed.</i></li><li>● <i>You are allowed one double-sided 8.5x11 'cheat sheet' along with a scientific calculator.</i></li><li>● <i>You will receive a grade / feedback within two weeks of the due date.*</i></li></ul>

\*modifications to the timing of grades/feedback, if required, will be announced via the Moodle Forum.

# NC STATE UNIVERSITY

## Extensions and 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**, which is Friday 1:30 PM Eastern Time of the week the problems were made available. Exceptions to this deadline can be made in extraordinary circumstances, e.g. unforeseen health conditions.

**Late or incomplete submissions** of homework assignments will be **graded a “zero” grade**.

## Grading scale

This course uses this grading scale:

Low	Letter	High
95 ≤	A+	≤ 100
90 ≤	A	< 95
85 ≤	A-	< 90
80 ≤	B+	< 85
76 ≤	B	< 80
72 ≤	B-	< 76
68 ≤	C+	< 72
64 ≤	C	< 68
60 ≤	C-	< 64
56 ≤	D+	< 59
52 ≤	D	< 56
48 ≤	D-	< 52
0 ≤	F	< 48

## Important Dates

Please refer to the NCSU Academic Calendar for important dates (<https://studentservices.ncsu.edu/calendars/academic/>).

Important dates include: Last day to add/drop a class, Last day to withdraw without a "W", Last day to change from credit to audit or audit to credit, etc.

For course-related important dates, see the course schedule section. The schedule is subject to change with fair notice. The schedule will be updated regularly and posted on Moodle.

# NC STATE UNIVERSITY

## Course Schedule

Please note that this schedule is tentative and subject to change with fair notice. The schedule is updated regularly and will be posted on Moodle.

Class	Dates	Class Detail	Reading (optional)	HW assigned	HW due	HW return
1	Mon, Aug-19	Introduction to Fusion	[C] 1.3, 10.1	1		
2	Wed, Aug-21	Reaction Rates, Triple Product	[C] 10.2.1			
3	Mon, Aug-26	Introduction to Plasmas	[U] 1, ([C] 1)	2		
4	Wed, Aug-28	Single Particle Motion I	[U] 2.1, ([C] 2.1)		1	
	<b>Mon, Sep-02</b>	<b>LABOR DAY – NO CLASS</b>		3		
5	Wed, Sep-04	Single Particle Motion II	[U] 2, ([C] 2.1)		2	1
6	Mon, Sep-09	Particle Drifts	[U] 2.2, 2.3 ([C] 2.3 - 2.7)	4		
7	Wed, Sep-11	Adiabatic Invariance	[U] 2.4 ([C] 2.8)		3	2
8	Mon, Sep-16	Introducing to Kinetic Problem	[U] 3.3-3.6	5		
9	Wed, Sep-18	Moments of Boltzmann Equ.	[U] 4.1-4.4, 5.2, 13.4		4	3
10	Mon, Sep-23	<b>MIDTERM EXAM 1</b>		-		
11	Wed, Sep-25	Diamagnetic Drift	[U] 5.3 ([C] 3.4)		5	4
12	Mon, Sep-30	Waves, Dispersion Relation	[U] 9.1, ([C] 4.1- 4.2)	6		
13	Wed, Oct-02	Electrostatic Waves	[U] 4.2, 10.1-10.2 [C] 4.3		-	5
14	Mon, Oct-07	Transport, Plasma Diffusion	[U] 8.1 - 8.3	7		
15	Wed, Oct-09	Magnetohydrodynamics	[U] 6.1, 6.2		6	-
	<b>Mon, Oct-14</b>	<b>FALL BREAK – NO CLASS</b>		-		
16	Wed, Oct-16	MHD Diffusion	[U] 8.3 ([C] 5.5, 5.10)		7	6
17	Mon, Oct-21	Frozen-in magnetic flux lines	[U] 6.4.1, 11.3	8		
18	Wed, Oct-23	MHD Force Balance	[U] 6.5, 6.6		-	7
19	Mon, Oct-28	<b>MIDTERM EXAM 2</b>		-		
20	Wed, Oct-30	Stability, Two Stream Instability	[C] 6.5, [U] 12.2.3		8	-
21	Mon, Nov-04	Rayleigh–Taylor Instability	[C] 6.7	9		
22	Wed, Nov-06	Bremsstrahlung			-	8
23	Mon, Nov-11	Fusion Concepts		10		
24	Wed, Nov-13	Inertial Confinement Fusion	[C] 10.4		9	-
25	Mon, Nov-18	MCF: Tokamaks	[C] 10.2.1.5	11		
26	Wed, Nov-20	MCF: Stellarators	[C] 10.2.1.4		10	9
27	Mon, Nov-25	Fusion Fuel Cycle & Blankets		-		
	<b>Wed, Nov-27</b>	<b>THANKSGIVING – NO CLASS</b>				10
28	Mon, Dec-02	Review		-		
	Wed, Dec-05	<b>READING DAY - NO CLASS</b>			11	
29	<b>Fri, Dec-08</b>	<b>FINAL EXAM</b>				11

Note on reading recommendations:

[U] 'Principles of Plasma Physics for Engineers and Scientists' U. Inan and M. Golkowski, 1st Edition

[C] 'Introduction to Plasma Physics and Controlled Fusion' F. Chen, 3rd Edition



# NC STATE UNIVERSITY

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## Course Policies

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### Course project assignments

The tentative assignment schedule is given in the syllabus. Students will submit their project report as a group. Students will present their project portion individually in class. Requests for regrades are only accepted when they include a written justification and must be submitted not later than 1 week after the report was returned.

### 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 you 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

- Students participation in class enhances the learning experience not only for the individual but for the class as a whole.
- **Students are expected to regularly attend lectures.**
  - Make-up work for missed classes include watching the full online recordings of the missed lectures.
- Students may be asked to provide documentation for multiple consecutive class absences or frequent single class absences.

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

# NC STATE UNIVERSITY

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## University Policies

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### 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 being used in this course to detect the originality of student submissions.
- Software is not used in this course to detect 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.
- In-class sessions are recorded in such a way that might also record students in this course. These recordings MAY be used beyond the current semester or in any other setting outside of the course. Contact your instructor if you have concerns.
- Students will not be able to be identified in any course recordings, or the course will not be recorded at all.

#### 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.
- Student information in this course may be accessible to persons beyond the instructor and students in the course. This course may involve electronic sharing or posting of personally identifiable student work or other information with persons not taking or administering the course. Students will be asked to sign a consent form allowing disclosure of their personally identifiable work. No student is required to sign the consent form as a condition of taking the course. If a student does not want to sign the consent form, he or she has the right to ask the instructor for an alternative, private means of completing the coursework.

# NC STATE UNIVERSITY

## Other policies

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

- [Equal Opportunity and Non-Discrimination Policy Statement](#) and [additional references](#)
- [Code of Student Conduct](#)
- [Grades and Grade Point Average](#)
- [Credit-Only Courses](#)
- [Audits](#)

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## 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 remains 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 instruction of all university classes. The current survey is administered online and includes 12 closed-ended questions and 3 open-ended

# NC STATE UNIVERSITY

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 8am on the first day of finals.

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

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## Syllabus Modification Statement

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Our syllabus represents a flexible agreement. It outlines the topics we will cover and the order we will cover them in. 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. Schedule changes will be announced via email with fair notice.