
SFSU Physics 712: Physics of Plasmas

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Lectures & Office Hours

Lectures: MW 2:00-3:15 PM
Office Hours: W 3:15-4:45 PM

Quick note on e-mail contact

So that I can identify and respond to e-mails from you expeditiously, please put [PHYS712] at the beginning of the subject line.

Course Overview & Objectives

Physics 712 is an introduction to the physics of plasmas, often called the “fourth state” of matter. A plasma is an ionized gas, a “soup” of positive and negative ions. Particles are accelerated by electric and magnetic fields; in turn, the motion of ions generates currents and magnetic fields. Because of the long-range nature of electromagnetic forces, plasmas exhibit “collective” effects. Topics include: basic plasma concepts, single-particle motion, plasmas as fluids (magnetohydrodynamics), waves in plasmas, diffusion & resistivity, equilibrium & stability, kinetic theory, and nonlinear effects in plasmas. Applications include both laboratory (fusion research, laser produced plasmas, propulsion systems) & geophysical/astrophysical plasmas (astro/geodynamo, solar wind/magnetosphere interactions, interstellar medium & star formation, pulsars, intergalactic medium).

Course objectives & student learning outcomes include:

- (1) To understand how the equations of electromagnetism (Maxwell’s equations) and the equations of fluid dynamics (Navier-Stokes equations) are coupled together to yield new linear and nonlinear phenomena in plasmas.
- (2) To develop and apply mathematical tools (vector calculus, linear algebra, differential equations, complex analysis, calculus of variations, numerical/computational methods) to solve problems in plasma physics.
- (3) To apply plasma concepts to real-world plasma systems such as: fusion research, laser produced plasmas, propulsion systems, astro/geodynamo, solar wind/magnetosphere interactions, interstellar medium & star formation, pulsars, intergalactic medium.

Course Format

This is a lecture course. During class time, instructor will present theory and outline applications. Student questions are strongly encouraged throughout class time. Occasionally, students will work on in-class activities in groups. Homework will explore theory and applications.

Required Learning Resources

- (1) “Introduction to Plasma Physics with Space, Laboratory and Astrophysical Applications” by Donald Gurnett & Amitava Bhattacharjee, 2nd edition, 2017, Cambridge University Press.
- (2) “Plasma Physics” by Richard Fitzpatrick (U. Texas, Austin), free online textbook:
<http://farside.ph.utexas.edu/teaching/plasma/Plasma/index.html>
- (3) Access to computer and mathematical software such as MATLAB, Mathematica, or Python for graphing and numerically solving differential equations.

Useful Websites

- (1) ilearn.sfsu.edu – Login to access course website. Please check frequently for new announcements, updates to the syllabus & schedule, tips & tricks on the homework, and links to additional learning resources.
- (2) <http://www.astro.wisc.edu/~dolan/constants/calc.html> – Astrophysical calculator: an online calculator with buttons for fundamental constants and astronomical data
- (3) <http://www.wolframalpha.com> – “Computational Knowledge Engine.” All SFSU students have free Pro accounts.

Recommended Preparation

- (1) Physics 330 (Analytic Mechanics)
- (2) Physics 360 & 460 (Electromagnetism I & II)
- (3) Physics 370 (Thermodynamics & Statistical Mechanics)
- (4) Physics 385 & 785 (Mathematical Methods for Physics)
- (5) Computer Science 309 (Intro Scientific Programming)

Please see me if you have any concerns about your preparation.

Assignment of Grades

Grades will be determined according to the following rubric:

| | |
|-------------------|-----|
| Homework | 75% |
| Oral presentation | 15% |
| Oral final exam | 10% |

Letter grades will assigned according to the following table:

| | |
|-------------------|-------------------|
| A: 90.0% – 100.0% | A-: 85.0% – 89.9% |
| B+: 80.0% – 84.9% | B: 75.0% – 79.9% |
| C+: 65.0% – 69.9% | C: 60.0% – 64.9% |
| D+: 50.0% – 54.9% | D: 45.0% – 49.9% |
| | D-: 40.0% – 44.9% |

Suggested Topics for Oral Presentation

- The physics of plasma displays and televisions
- Rocket propulsion and ion thrusters
- Industrial uses: plasma etching, surface cleaning, plasma enhanced chemical vapor deposition
- Lightning, sprites, elves, jets
- Polar aurorae
- Io-Jupiter flux tube
- Detecting exoplanets via radio synchrotron emission
- Sunspots and the Solar Cycle
- Solar corona and solar wind
- Planetary magnetospheres: geodynamo, interactions with solar wind
- Magnetic fields & star formation, ambipolar diffusion
- Magnetic reconnection
- Magnetorotational instability in accretion disks
- Pulsar atmospheres
- Magnetohydrodynamic turbulence
- Synchrotron emission in astrophysics (supernovae, galactic, etc)
- Bremsstrahlung emission in galaxy clusters
- Cosmic rays
- Fusion research and experiments

Homework _____

You cannot learn physics solely from lectures. You must work through many problems, seeing how the theoretical concepts discussed in lecture apply in various contexts. Homework is an integral part of the learning process; how serious you take the homework will ultimately determine how much you will understand physics and how well you will do in the course overall. There will be approximately one homework assignment due every two weeks. Most problems will require analytic solutions, however there will usually be one problem per assignment that will involve graphing and numerical solution with computer software such as Microsoft Excel, MATLAB, Mathematica, or Python.

Policy on Collaboration & Academic Integrity _____

You are strongly encouraged to discuss course material with your fellow classmates. When working on homework, first try to solve the problems on your own. Struggle. Struggle some more. If you get stuck, feel free to discuss overall methods and approaches with your classmates, but not the details! Your written solutions should be solely your own, and should be written-up in isolation from your fellow classmates. Copying is strictly prohibited. Using the internet to download solutions manuals is also considered cheating. Cheating via any method on exams will result in a grade of zero on that exam and being reported to the department chair and/or college dean for possible discipline. Please see the official plagiarism and academic ethics policies for the Department of Physics & Astronomy at: <http://www.physics.sfsu.edu/Academics/Policies.html>

Add/Drop, Withdrawal, CR/NC Policies _____

Friday, February 12, 2021, 11:59 PM: Add/Drop Deadline – This is the last date to enroll in the class. It is also the last day to drop the course without anything appearing on your transcript. You can drop yourself from the class online without any penalty and without any record, for any reason.

Monday, April 19, 2021, 11:59 PM: “Regular” Withdrawal Deadline – Because of COVID-19 and remote instruction, students will be allowed to withdraw without documentation during this “regular” withdrawal period. A “W” will appear on the transcript.

Friday, May 14, 2021, 5:00 PM: Change of Grading Option Deadline – This is the last date a student can change their grading option between letter grade to/from CR/NC. For graduate classes, CR indicates grades of B-minus or higher, NC indicates grades of C+ or lower.

Friday, May 14, 2021, 11:59 PM: “Late” Withdrawal Deadline – Withdrawals will only be approved for serious and extenuating circumstances. External documentation will be required. A “WM” will appear on the transcript.

Disability Access _____

Students with disabilities who need reasonable accommodations are encouraged to contact me early in the semester. The Disability Programs and Resource Center is available to facilitate the reasonable accommodations process. The DPRC, located in Student Services Building 110, can be reached by phone at 415-338-2472 (voice/TTY) or by e-mail at dprc@sfsu.edu.

Religious Holidays _____

The faculty of SFSU shall accommodate students wishing to observe religious holidays when such observances require students to be absent from class activities. It is the responsibility of the student to inform the instructor, in writing, about such holidays during the first two weeks of the class each semester. It is the responsibility of the instructor to make every reasonable effort to honor the student request without penalty, and of the student to make up the work missed.

Student Disclosures of Sexual Violence _____

SF State fosters a campus free of sexual violence including sexual harassment, domestic violence, dating violence, stalking, and/or any form of sex or gender discrimination. If you disclose a personal experience as an SF State student, the course instructor is required to notify the Dean of Students. To disclose any such violence confidentially, contact:

The SAFE Place - (415) 338-2208; http://www.sfsu.edu/~safe_plc/

Counseling and Psychological Services Center - (415) 338-2208; <http://psychservs.sfsu.edu/>

For more information on your rights and available resources - <http://titleix.sfsu.edu>

Recording of Lectures & Privacy _____

As the instructor of this course, I will be using Zoom to record our class sessions/lectures for the sole purpose of supporting student learning. To maintain privacy, I will post links to the recordings in our campus's learning management system iLearn to limit access to the members of this course only. It is expected that students also refrain from sharing these recordings outside the context of this course. Students who have privacy concerns may turn off their video and/or change their user name for the duration of the session.

At the beginning of each recorded Zoom session, you will be prompted to acknowledge that the session is being recorded and that you would like to continue in the session. These recordings will be retained for one semester beyond the end of this course, to support students who may have received an incomplete grade, and will then be deleted. As always, any student who has concerns about these recordings may speak with me at any time during the semester to discuss your concerns.

COVID-19 and Our Campus

Your health and safety are our paramount concerns at SF State. During the COVID-19 pandemic, every member of our Gator community is expected to do their part in keeping fellow students, faculty, and staff safe and well. Feeling well and safe will support you in focusing on your academic success. For the limited number of classes meeting face-to-face, in-person class attendance is an option, but not a requirement. Students will be allowed to take such classes virtually or be provided with other remote options for course completion. Please consult the campus plan website (<https://news.sfsu.edu/campus-plan>) for up-to-date information. For all students attending in-person, the following are required:

- Wear a face covering when around other people outside of those in your household.
- Stay at least 6 feet physically distant from people outside the members of your household.
- Stay home if you have one or more symptoms of COVID-19 (Please check in with the SF DPH website for the most up-to-date symptoms & testing: <https://www.sfcdc.org/wp-content/uploads/2020/04/GetTestedSF-Eng-052920.pdf>).
- If you would like to discuss reasonable accommodations based on disability related to COVID-19, please contact the Disability Programs & Resource Center: dprc@sfsu.edu.

Information is changing rapidly, as our health professionals, scholars, and researchers are learning more about COVID-19, and as such, we encourage you to frequently check your San Francisco State University email account and <https://news.sfsu.edu/campus-plan/students-families> for the most current information.

- You are encouraged to keep your emergency information updated on Campus Solutions in order to receive campus emergency alerts: <https://upd.sfsu.edu/ENSFAQ>.
- You are also encouraged to provide your contact information to receive city of SF emergency alerts, including COVID-19 updates and instructions for public safety: <https://sfdem.org/get-city-alerts>.
- If you have any questions regarding COVID-19 or your own health during this time, please reach out to Student Health Services: <https://health.sfsu.edu>.
- If you are feeling overwhelmed, you are encouraged to connect with our on-campus health professionals in Counseling & Psychological Services: <https://caps.sfsu.edu>.
- If you are looking for education on how to keep yourself and your loved ones healthy, then reach out to our Health Promotion & Wellness Team: <https://wellness.sfsu.edu>.