SFSU Physics 712: Physics of Plasmas

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Lectures & Office Hours

Lectures: TTh 15:35–16:50 in Thornton Hall 326
Help Session: TBD.
Office Hours: TTh 12:00–15:00 in Thornton Hall 308.

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.

Required Learning Resources

(2) Scientific calculator,
(3) Access to computer and mathematical software such as MATLAB, Mathematica, or IDL (for graphing and numerically solving differential equations).
Important Websites

(1) www.physics.sfsu.edu – Department of Physics & Astronomy
(2) ilearn.sfsu.edu (note: no www in web address) – 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.
(3) http://www.astro.wisc.edu/~dolan/constants/calc.html – Astro-physical calculator: an online calculator with buttons for fundamental constants and astronomical data
(5) http://mathworld.wolfram.com/ – Wolfram Mathworld

Recommended Preparation

(1) Physics 330 (Analytic Mechanics)
(2) Physics 360 & 460 (Electromagnetism I & II)
(3) Physics 370 (Thermodynamics & Statistical Mechanics)
(4) Physics 385 & 485/785 (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:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Homework</td>
<td>50.0%</td>
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<tr>
<td>In-class Midterm Exam</td>
<td>12.5%</td>
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<tr>
<td>In-class Oral presentation</td>
<td>12.5%</td>
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<tr>
<td>In-class Final Exam</td>
<td>25.0%</td>
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</tbody>
</table>

Letter grades will assigned according to the following scheme:

- A: 90.0% – 100.0%  A-: 85.0% – 89.9%
- B+: 80.0% – 84.9%  B: 75.0% – 79.9%  B-: 70.0% – 74.9%
- C+: 65.0% – 69.9%  C: 60.0% – 64.9%  C-: 55.0% – 59.9%
- D+: 50.0% – 54.9%  D: 45.0% – 49.9%  D-: 40.0% – 44.9%
- F: 00.0% – 39.9%

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 different 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 per week. 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, or Mathematica.
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. Cheating via any method on exams will result in a grade of zero on that exam and being reported to the department chair and college dean for possible discipline. Please see the official academic integrity policy for the Department of Physics & Astronomy at: www.physics.sfsu.edu/policy/plagiarism.pdf.

Drop, Withdrawal & Repeat Policy

The “Drop” deadline is Friday, February 4. You can drop yourself online without any penalty and without any record, for any reason. After February 4, students must petition for an official “withdrawal.” Documents must be provided to support the petition to withdraw. If the petition is approved, the designation “W” will appear on the transcript. Students are only allowed to repeat a class once at SFSU. Note that designations of W, WU, NC count toward this limit.

Expected Code of Conduct

Classroom discussion and participation are strongly encouraged. However, please refrain from unrelated chatter. Also, please remember to place cell phones and other electronic communication devices on silent or vibration mode so as not to distract your fellow classmates. If you must arrive late or leave early, please sit toward the back of the room near the doors so as to minimize disruption.

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 San Francisco State University 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.
Preliminary Schedule (Subject to Change!!)

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Chapter(s)</th>
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<tbody>
<tr>
<td>Jan. 25/27</td>
<td>Motion of charged particles</td>
<td>Ch. 3</td>
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<tr>
<td>Feb. 01/03</td>
<td>Motion of charged particles</td>
<td>Ch. 3</td>
</tr>
<tr>
<td>Feb. 08/10</td>
<td>Plasma concepts and parameters</td>
<td>Ch. 1</td>
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<tr>
<td>Feb. 15/17</td>
<td>Plasma concepts and parameters</td>
<td>Ch. 1</td>
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<tr>
<td>Feb. 22/24</td>
<td>Intro to equations of plasma dynamics</td>
<td>Ch. 2</td>
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<tr>
<td>Mar. 01/03</td>
<td>Intro to equations of plasma dynamics</td>
<td>Ch. 2</td>
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<tr>
<td>Mar. 08/10</td>
<td>Waves in plasmas</td>
<td>Ch. 4</td>
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<tr>
<td>Mar. 15/17</td>
<td>Waves in plasmas</td>
<td>Ch. 6</td>
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<td>Mar. 22/24</td>
<td>Review, Midterm exam</td>
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<td>Mar. 29/31</td>
<td>Spring Break</td>
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<tr>
<td>Apr. 05/07</td>
<td>Streaming instabilities, Landau damping</td>
<td>Ch. 5</td>
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<tr>
<td>Apr. 12/14</td>
<td>Magnetohydrodynamics</td>
<td>Ch. 9</td>
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<td>Apr. 19/21</td>
<td>Magnetohydrodynamics</td>
<td>Ch. 10</td>
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<td>Apr. 26/28</td>
<td>Magnetohydrodynamics</td>
<td>Ch. 11, 12</td>
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<td>May 03/05</td>
<td>Oral Presentations</td>
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<td>May 10/12</td>
<td>Oral Presentations</td>
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<tr>
<td>May 19</td>
<td>Final Exam, 13:30 – 16:00</td>
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Suggested Topics for Oral Presentation

- The plasma physics of plasma displays and televisions
- Rocket propulsion and ion thrusters
- Industrial applications: reactive ion etching, sputtering, surface cleaning, plasma enhanced chemical vapor deposition
- Lightning, sprites, elves, jets
- Polar aurorae
- Io-Jupiter flux tube
- Sunspots and the Solar Cycle
- Solar corona and solar wind
- Planetary magnetospheres: geodynamos
- Planetary magnetospheres: 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 astrophysics
- Cosmic rays
- Fusion research and experiments