Introduction to Plasma Physics
Planetary Sciences 414/514 (PTYS/ASTR/PHYS 414/514)
Kuiper 312, TTh 14:00-15:15

Instructor:
Dr. Kristopher G. Klein, Kuiper Space Sciences 431; kgklein@arizona.edu
Office Hours: Tuesday: 3:30-5pm; Wednesday: 1 - 2pm (or by arrangement)
This class is scheduled to be taught in the in person modality.

This course will use a D2L website for assignments, lecture notes, and communications. Email communications with Prof. Klein should include **PTYS 414/514** and the student's name in the subject line and be from your UA email address; we will endeavor to respond to emails within one business day.

As this is a three credit course, there is an expectation of 90 hours of reading, homework, and other studies to be done by the student outside of lecture.

Course and Learning Objectives

A one-semester survey of the study of plasmas.
The purpose of this course is to present an introduction to the physics of plasmas. Topics include fundamental plasma scales and interactions, single particle motion, magnetohydrodynamic and fluid models, linear waves, kinetic theory, plasma stability, magnetic reconnection, and non-linear processes. The role of these processes are considered in a variety of systems, including the Sun and stars, their extended atmospheres, planetary magnetospheres, and laboratory devices. The emphasis throughout will be on basic physical processes and the various approximations used in their application to realistic and relevant problems. The graduate course is identical to ASTR/ATMO/PHYS 514, with PTYS as the home department.

During the course, students will learn about:
- *Fundamental Plasma Temporal and Spatial Scales*, through an introduction to the basic behavior of the most common state of baryonic matter,
- *Self-consistent Models for Plasma*, a derivation of the most commonly used self-consistent descriptions for plasma dynamics, and
- *Fundamental Processes*, spanning a plethora of specific processes, e.g. waves, instabilities, and magnetic reconnection.
- **514 Level:** An advanced topic of the student's choice beyond the scope of the course's one-semester duration.

Learning Outcomes:
Upon the completion of this course, students will be able to:
- Solve using appropriate mathematical tools problems relevant to plasma systems.
- Describe the various approximations used in modeling plasmas, and identify under what conditions such approximations are appropriate.
- Apply plasma physics concepts to areas of students' research.
- **514 Level:** Clearly communicate plasma physics concepts, articulating open research questions.

Texts and Course Materials

The course will trace the trajectory Gurnett & Bhattacharjee's *Introduction to Plasma Physics*, with supplemental material from other plasma physics and astrophysics texts as well as research papers from the literature.

Homework

There will be approx. weekly homework assignments throughout the semester, except for the weeks for which there is an exam or project due. Assignments will be posted in advance on the D2L website. Each homework will have at least one week for completion from posting, then they will be graded and returned to you within a week. You may discuss the homework with other students, but be sure the final work is yours. Do not let others copy your homework; it could result in your getting flagged for plagiarism, and **you receiving a zero for the assignment.**

Late Homework

No late homework will be accepted (except in very exceptional cases). For scheduled absences like religious holidays and university travel, the homework can be downloaded from D2L in advance so that it can be turned in early, and there is no reason for a due-date extension. In cases of a sudden family or medical emergency, late homework may be accepted, but only before the graded homework is returned and solutions posted.

Exams

There will be a midterm and a final exam, covering all aspects of the course including lectures, readings, in-class discussion, and homework. The dates of the exams are listed below; please check to see if you have an approved conflict.

Exhibiting suspicious behavior during an exam may result in confiscation of your exam and/or a zero grade. No cellphones, laptops, or notes are allowed during the examination.

You will have the option of taking either of the examinations in an oral or written format. Your selection of which format you intend to take the exam in must be conveyed to Prof. Klein at least one week in advance of the exam date.

Missed Exams

If you need to miss an exam for a University-approved reason, contact Dr. Klein as soon as possible. If you know that you will need to be absent or will miss course deadlines, you are expected to make every effort to inform us before it occurs so that we can make arrangements in advance. Note that illness will require documentation as described in the Absence and Class Participation Policy below. Skipping the exam without a University-approved excuse or proper documentation of your absence will result in a zero grade.

Final Project (Graduate Level Offering)

This graduate level offering of this course will have a final project that will involve selecting a fundamental plasma process not covered in the class, researching this topic, and then preparing a set of lecture notes.

There will be due dates throughout the semester for selecting and proposing a topic, turning in a draft for feedback and the opportunity to revise and resubmit, and final submission of the lecture notes. Details on this project are posted on D2L.

Lectures and Class Participation

Most lectures will be presented by Dr. Klein, although occasionally a guest lecturer may lead the class. The lecture notes and associated readings will be placed on D2L before the class. Lectures will be interactive, including participation in the form of questions and class discussion.

Grading Scale & Policies

The 414 (Undergraduate Level) offering of the course will have the following weights:

Midterm Exam: 20%	Final Exam: 30%	Homework: 50%

The 514 (Graduate Level) offering of the course will have the following weights:

Midterm Exam: 15%	Final Exam: 25%	Homework: 45%	Project: 15%

Final Letter Grades will be assigned as follows, and will be calculated to the nearest 0.1%. A curve may be considered, depending on the observed distribution of scores at the end of the semester.

A: $\geq 90\%$	B: $\geq 80\%$	C: $\geq 70\%$	D: $\geq 60\%$	E: $< 60\%$

University policy regarding grades and grading systems is available here. Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available here and here respectively.

Makeup Policy for Late Registering Students

Students who register by the end of the second week of class may be given an opportunity to make up missed assignments within a reasonable amount of time, to be mutually agreed upon by the student and instructor.

Regrades

All your work will be graded by Dr. Klein. Although I will make every effort to evaluate your work thoroughly and fairly, I am only human. If you think there is an error in grading your homework, please contact Dr. Klein; I will look at your work again and return it to you with a response, usually within a week. **You must report any grading errors within a week of the return of your assignment/exam to receive a regrade.**

Questions & Concerns

It is very important that you let the instructor know about any concerns about any aspect of the class as soon as they arise. There are many ways to contact us about questions or concerns about the course material and your grade. Weekly office hours are the best place to ask questions and get

help. You are also welcome to talk to me after class, or you can make an appointment to meet with me outside of office hours if that works better.

Classroom Attendance

If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel. Notify your instructor if you will be missing a course meeting or an assignment deadline. Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments. Please communicate and coordinate any request directly with your instructor. If you must miss the equivalent of more than one week of class, you should contact the Dean of Students Office (`DOS-deanofstudents@email.arizona.edu`) to share documentation about the challenges you are facing.

Academic Advising

If you have questions about your academic progress this semester, please reach out to your academic advisor (`https://advising.arizona.edu/advisors/major`). Contact the Advising Resource Center (`https://advising.arizona.edu/`) for all general advising questions and referral assistance. Call 520-626-8667 or email to `advising@.arizona.edu`

Life Challenges

If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at (520) 621-2057 or `DOS-deanofstudents@email.arizona.edu`.

Physical and mental-health challenges

If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520) 621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

Classroom Behavior Policy

We all have a shared responsibility to create a positive learning environment free from distractions. If you arrive late to class or need to leave early, please choose a seat on the aisle and enter/exit quietly. Please silence your phone during class. If you need to accept an emergency phone call, exit the lecture hall fully before talking on the phone. Behaviors that could be disruptive to other students are not acceptable and disruptive students will be asked to leave. Examples of potentially disruptive behaviors making phone calls, web surfing, watching videos, or reading a newspaper.

Department policy *forbids any outside food or drink, except water, in the lecture hall.*

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself.

UA Academic policies and procedures are available here. Student Assistance and Advocacy information is available here.

Accessibility & Accommodations

Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please contact Dr. Klein and the Disability Resource Center (520-621-3268) so that reasonable accommodations can be arranged. Additional information on reasonable accommodations can be found at the Disability Resource Center.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work and exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog.

Student who plagiarize will get a zero for the assignment.

If you have questions about how to cite sources or plagiarism, please talk to the instructor. The UA libraries also provide references on the distinction between citation and plagiarism.

UA Nondiscrimination and Anti-Harassment Policy

The University is committed to creating and maintaining an environment free of discrimination. The classroom is a place all are encouraged to ask questions and express well-formed opinions and their reasons for those opinions. We want to create a tolerant and open environment where comments and questions can be expressed without resorting to bullying or discrimination of others.

Confidentiality of Student Records

Student records, including grades, will be handled according to FERPA guidelines.
Please contact Dr. Klein yourself if you have questions about grades.

Subject to Change Statement

All information presented in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

University-Wide Policies

Policies established by UA regarding *Absence and Class Participation*, *Threatening Behavior*, *Accessibility and Accommodations*, *Code of Academic Integrity*, and *Nondiscrimination and Anti-Harassment* can be found at the Academic Affairs website.

COVID-19

Please consult the University's COVID-19 website for the latest information. Any changes to this course's schedule, modality, or meeting location will be communicated through D2L.

Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus and the COVID-19 vaccine is available for all students at Campus Health.

0.1 Class Recordings

For lecture recordings, which may be used at the discretion of the instructor, students must access content in D2L only. Students may not modify content or re-use content for any purpose other than personal educational reasons. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner inconsistent with UArizona values and educational policies (Code of Academic Integrity and the Student Code of Conduct) are also subject to civil action.

Approx. Course Schedule & Due Dates

Week	Date	Topic 1	Topic 2	Due
Part One: What is a Plasma?				
1	01/12/2022	Introduction	Fundamental Scales	—
2	01/17/2022	Characteristic Parameters	Single Particle Motion: Constant Field	HW#1
3	01/24/2022	Curvature and ∇B Drift	Magnetic Mirror & Time Varying Fields	HW#2
4	01/31/2022	Polarization Drift & Ponderamotive Force	Adiabatic Invariants	HW#3
Part Two: Self-Consistent Models				
5	02/07/2022	Cold Plasma Waves: Preliminaries	Unmagnetized Waves	HW#4
6	02/14/2022	Magnetized Waves	—	HW #5
7	02/21/2022	Ray Tracing	**Midterm Exam**	—
8	02/29/2022	Kinetic Theory	Moment Equations	HW#6
9	03/14/2022	Pressure Waves	Intro to MHD	HW#7
10	03/21/2022	Magnetic Pressure and Diffusion	MHD Conserved Quantities	HW#8
11	03/28/2022	MHD Waves	—	HW#9
Part Three: Plasma Processes				
12	04/04/2022	Magnetostatic Equilibria	Interchange Instabilities	HW#10
13	04/11/2022	Linear Force Operator	Rayleigh-Taylor Instability	HW#11
14	04/18/2022	MRI Instability	Drift Waves	HW#12
15	04/25/2022	Resistive Instabilities	Magnetic Reconnection	—
16	05/02/2022	Numerical Methods	**Final Exam** (date assigned by registrar)	—