ASTRONOMY 320
THEORETICAL ASTROPHYSICS
Spring 2023

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Lectures: T/Th 11:00 AM - 12:15 PM • Discussion: W 1:00 - 1:50 PM • Location: ATL 2428

Course Summary & Goals

Modern astronomy has its roots firmly grounded in the fundamental principles of physics (both classical and quantum). Furthermore, many branches of physics as we know them today trace their origins to the search for universal physical laws to explain natural phenomena discovered and analyzed by astronomers.

The goal of theoretical astrophysics is to provide physical and conceptual understanding of the diverse systems that represent our universe. Introductory astronomy courses are often organized by scale (planets, stars, galaxies and the universe as a whole) and observational astronomy courses are often organized by wavelength because of the different technologies. To emphasize the different approach needed for developing a theoretical framework, this course is organized into themes of governing physical principles. For each of the three main themes (I. gravity, II. gas physics, and III. radiation physics), we start with fundamental principles and then discuss applications in various astronomical contexts. We will also discuss systems in which several principles interact synergistically and demonstrate how astrophysical theories are developed by successive model refinements and confrontation with data. We will show how application of simple physical laws can explain the observed properties of an astounding range of astronomical objects!

It is expected that you have taken the astronomy and physics prerequisites (ASTR120, ASTR121, PHYS270, PHYS271, PHYS273) and are familiar with the basic astronomy and physics concepts taught in those courses. It will also be assumed that you are familiar with vectors, and integral, differential, and partial differential equations.

Text

Required:

- Principles of Astrophysics, Charles Keeton, Springer, 2014

Other useful texts (not required):

- An Introduction to Modern Astrophysics (2nd ed.), Bradley W. Carroll & Dale A. Ostlie, Addison Wesley (Pearson), 2007
- Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press, 2010
- Astrophysics in a Nutshell, Dan Maoz, Princeton University Press, 2007

Office hours

Kempton: Tuesday & Wednesday 3:00-4:00 PM, or by appointment
Savel: TBD

Course Structure

To ASTR 320 has two weekly lecture classes of 75 minutes each and one discussion section of 1 hour, each week. There will be homework assignments ("problem sets") assigned weekly, and there will be 3 midterm exams, each covering 1/3 of the course content. Reading assignments from the textbook are also provided to accompany each lecture. It is best to review the readings ***both*** before and after the class for which they are assigned, to first develop an initial understanding of the material for the day's lecture, and then to clarify any points of confusion and to supplement what you learned in class.

The lecture classes will combine chalkboard lecture, question/answer, and problem solving exercises. In each lecture period there will be approximately 1-2 exercises that I will ask you to solve in small groups. These exercises will typically involve short calculations, derivations, or problem solving / brainstorming sessions. The in-class exercises are meant to reinforce the lecture content and to provide an active learning component to the class in which you will directly grapple with what you have just learned and identify areas of confusion of weakness.

The discussion sections, which will be led by our TA, Arjun Savel, will give you additional opportunity to clarify points of confusion from the lecture and the reading, and to develop strategies for tackling challenging homework problems.

It is expected that you will attend lectures ***and*** discussions. A major part of the learning in this course is centered around in-class discussions and exercises; simply doing the reading and working on your homework in isolation will not allow you to be successful in this course. To further encourage attendance, there is a "class participation" component of your grade which will be based on participation in both lecture and discussion.

Final Grade Criteria

Class Participation 10%

While I can present material, I cannot make you learn, and without your help this class will not be a success. Because of this, I will be grading on participation. Students who receive an "A" in participation will do the following things:

- Attend class (both lecture and discussion)
- Ask questions (before, during, or after class)
- Answer questions (being correct is not important)
- Attempt in-class problems
- Work effectively, respectfully, and collegially with their fellow classmates

Homework Assignments 30%

Homeworks will be due weekly at the start of class on Thursdays, excepting weeks of midterm exams when there will not be a homework assignment. Well-motivated requests for homework extensions must be received by 48 hours prior to the homework submission deadline. Otherwise late homework will not be accepted. At the end of the semester, I will drop your lowest homework grade. Other homework policies will be clearly spelled out on the assignment itself. Read these *carefully*. Homework assignments are meant to challenge you and to build on the content presented in class and in the reading. It is important that you give yourself enough time to grapple with challenging homework problems. In general, ***it is best to start early*** and to assume that it will not be possible to complete a homework assignment in a single sitting.

Exams 60% (20% each)

There will be three in-class exams this semester on 3/7, 4/13, and 5/13. (The third "midterm" exam will cover material from the final third of the semester and will be given during the final exam time slot for ASTR 320.) The midterm exams will not be cumulative — i.e. they will not explicitly test you on material from a previous midterm. However, the nature of some of the material will be to build upon topics from earlier in the semester. Midterms #1, 2, and 3 will cover parts I (gravity), II (gas physics), and III (radiation physics) of the semester, respectively. On each exam you will be allowed a calculator and a 1-page note sheet, handwritten by you and turned in with your exam. *Any arrangements for taking an exam in an alternative time slot should be set up well in advance of the exam date.*

Collaboration Policy

I encourage you to collaborate ***in class*** and on ***homework assignments***. The course is graded on an absolute scale, so you won't reduce your grade by helping others on these assignments. It is very important that you do **NOT** collaborate with each other on ***midterm exams***.

On homework assignments: Your fellow classmates are an important resource to help you understand the course material in order to complete the homework. The best strategy is to first attempt to complete an assignment on your own, before consulting with your fellow students. If you are having trouble completing a homework problem, you may wish to consult with any of the following resources: *your textbook, your class notes, your professor, or your classmates*. Other resources are not allowed unless I specifically approve them. Copying of a classmate's work or making your own work available for direct copying are considered violations of the academic honesty policy, and are not collaboration. Similarly, seeking out homework solutions on the internet or using unapproved online resources to complete homework assignments are also not allowed. If you have any questions about appropriate use of outside resources, please confer with me directly. If you collaborate on a homework assignment, you must (1) state the names of the students with whom you collaborated, and (2) submit your own individual, original solutions, which you write without consulting someone else's solutions.

Any suspected violation of the collaboration policy will be forwarded to the Student Honor Council. (For more information, the UMD Code of Academic Integrity is outlined here: https://www.president.umd.edu/sites/president.umd.edu/files/documents/policies/III-100A.pdf)

Grading

The course will be graded on an absolute scale, with the following letter grade assignments. I reserve the right to revise the dividing line between letter grades downward. I will not revise them upward.

90-100%: A (+/-)
78-89%: B (+/-)
66-77%: C (+/-)
56-65%: D (+/-)
55% or less: F

UMD Course-Related Policies

Please see the following link for questions related to UMD course-related policies for undergraduate students:
https://www.ugst.umd.edu/courserelatedpolicies.html

Approximate Course Schedule

Date	Topic	Reading
1/26	Review of units & dimensional analysis	Syllabus & Ch 1
	Part I: Gravity	
1/30	Newtonian gravity	Ch 2
2/2	Kepler's laws I	Ch 3.1
2/7	Kepler's laws II	Ch 3.2 - 3.3
2/9	2-body dynamics I	Ch 4.1
2/14	2-body dynamics II	Ch 4.2 - 4.3 (*4.3.3 is extremely out of date!*)
2/16	Tides	Ch 5
2/21	Restricted 3-body problem & Lagrange points	Ch 6
2/23	N-body dynamics & the virial theorem	Ch 8.1 - 8.2
2/28	Strong gravity & gravitational lensing	Ch 9
	Part II: Gas Physics	
3/2	Kinetic theory of gases I – Boltzmann statistics	Ch 12.1
3/7	**Midterm #1**	
3/9	Kinetic theory of gases II – the ideal gas law	Ch 12.1 (cont'd)
3/14	Hydrostatic equilibrium	Ch 12.2 - 12.3
3/16	Degenerate gases	Ch 17.1
	**** Spring break ****	
3/28	Degenerate gas applications: white dwarfs and neutron stars	Ch 17.1 - 17.3
3/30	Stellar pulsations	Ch 18.1
4/4	Gravitational collapse	Ch 19.1 - 19.2
4/6	Radiation as a photon gas: radiation pressure	Ch 19.3
	Part III: Radiation Physics	
4/11	Blackbody radiation I	Ch 13.1
4/13	**Midterm #2**	
4/18	Blackbody radiation II	Ch 13.1 (cont'd)
4/20	Radiative transfer basics	Ch 13.2 - 13.3
4/25	Planetary temperatures & the greenhouse effect	Ch 13.5
4/27	Energy levels & ionization I	Ch 13.4
5/2	Energy levels & ionization II	Ch 14.1
5/4	Applications to stellar spectra	Ch 14.2

Date	Topic	Reading
5/9 5/11	Other forms of energy transport: conduction & convection Review / Catch up	Ch 16.1
5/13	**Midterm #3 (8:30 – 10:00 AM)**	