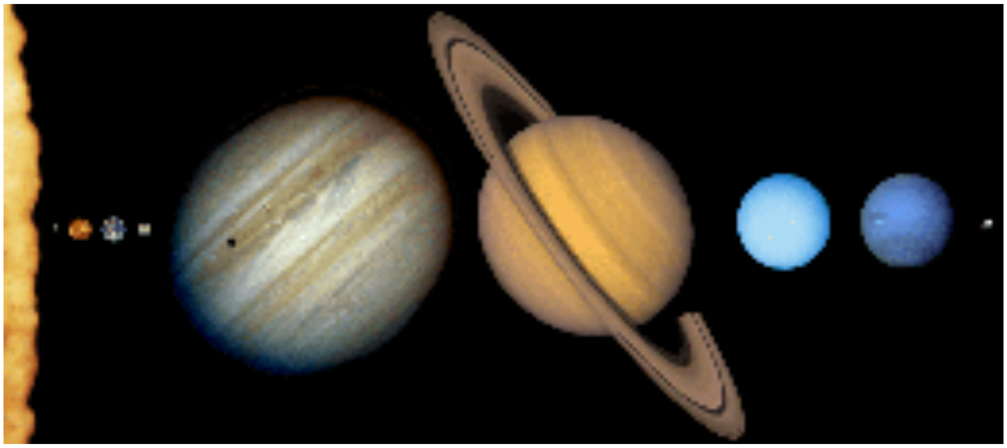
ASTR630:
Planetary Science, Spring 2023



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Textbook: Planetary Sciences by I. de Pater and J.J. Lissauer
Webpage: *http://www.astro.umd.edu/~hamilton/ASTR630*

This course will survey our Solar System with an emphasis on physical processes that help us understand its origin and connection to other planetary systems. According to the authors of our award-winning textbook "Planetary Sciences," the amount of material in the book "is difficult to cover in a one-year graduate-level course," so we will choose chapters selectively and cover them in greater depth. Topics to be explored in the first two months of the course include orbital dynamics, the physics of planetary atmospheres, and planetary interiors (chapters 1-4 and 6). We will emphasize techniques of problem solving and will focus a number of topics including the three-body problem, orbital resonances, hydrostatic equilibrium, equations of state, and the structure of a planet from the core to the exosphere.

During the final month of the course we will discuss three additional chapters from the textbook: Meteorites (Ch. 8), Rings (Ch. 11), and Planet Formation (Ch. 13). Since we will be covering a lot of material in a short amount of time, you will get the most out of class lectures if you read and think critically about the relevant book chapters before we go over them in class. All of the reading listed on the lecture schedule is fair game for tests.

We will have one or two quizzes, one in-class midterm, a final exam, and six homework assignments, largely but not exclusively drawn from the text. There will also be a class research project, with an abstract due in the middle of the semester and an oral presentation at the end of the semester. The presentations will be made at the TERPS 2023 Conference, to which the entire department is invited. Giving a talk to a friendly local audience is the best way for you to prepare to give a talk on your own scientific research at a professional meeting.

Grading Policy:

The grading for the class will be according to the following table.

Assignment	ASTR630
Homework	250
Quizzes	50
Midterm #1	100
Final	200
Research Project	150
Total	750

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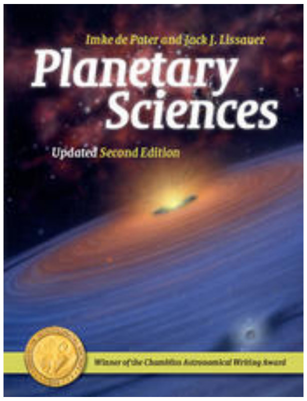
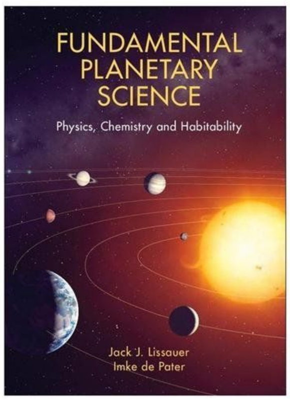
ASTR630 Textbooks



Required:

Planetary Sciences (I. de Pater and J.J. Lissauer), Updated 2nd Edition (2016, ISBN: 978-1-107-09161-0), $80.
A thorough quantitative treatment of the physics of the planets. A good choice if you want to go into more detail in a given area. Errata for the 2010, 2011, and 2016 printings.



Recommended:

Fundamental Planetary Sciences: Physics, Chemistry, and Habitability (J.J. Lissauer and I. dePater), 1st Edition (2013, ISBN 978-0-521-61855-7), about $50.
An excellent introduction to the physics of the planets. Covers the same material as the required text at a more accessible level.

Good General Solar System Information:

- The Nine Planets.
- NASA Photo Gallery.

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ASTR630 LECTURE SCHEDULE

Lecture Date	Lecture Topic	Reading
Thu. Jan. 26	Introduction to Planetary Science	Read Chap. 1
Tue. Jan. 31	Central Forces	Read Chap. 2
Thu. Feb. 2	Orbital Elements	
Tue. Feb. 7	The 2- and 3-Body Problems	
Thu. Feb. 9	Circular Restricted 3-Body Problem	
Tue. Feb. 14	Precession and Tides	
Thu. Feb. 16	Tides and Resonances	**HW #1 due**
Tue. Feb. 21	Non-Gravitational Forces	
Thu. Feb. 23	Planetary Atmospheres	Read Chap. 4.1, 4.2, 4.4;
Tue. Feb. 28	Adiabatic Lapse Rate	
Thu. Mar. 2	Cloud Formation & Hadley Cells	**HW #2 due**
Tue. Mar. 7	Hurricanes & Lightening	
Thu. Mar. 9	**QUIZ**	**TERPS Abstracts due**
Tue. Mar. 14	Planetary Interiors	Read Chap. 6
Thu. Mar. 16	Planetary Interiors	**HW #3 due**
Tue. Mar. 21	**SPRING BREAK**	
Thu. Mar. 23	**SPRING BREAK**	
Tue. Mar. 28	Planetary Interiors	

Thu. Mar. 30	**MIDTERM**	
Tue. Apr. 4	Planetary Interiors	
Thu. Apr. 6	Meteorites: Finds, Falls, and Sources	Read Chap. 8; **HW #4 due**
Tue. Apr. 11	Meteorites: Composition and Classification	
Thu. Apr. 13	Meteorites: Radioactive Decay	
Tue. Apr. 18	Planetary Rings	Read Chap. 11
Thu. Apr. 20	Planetary Rings	**HW #5 due**
Tue. Apr. 25	Planetary Rings	
Thu. Apr. 27	**QUIZ?**	
Tue. May 2	Planet Formation	Read Chap. 13
Thu. May 4	Planet Formation	**HW #6 due**
Tue. May 9	Planet Formation	**TERPS Summaries due**
Thu. May 11	Planet Formation	**TERPS Presentations due; TERPS Conference (Open to the Department)**
Tue. May 17	**FINAL EXAM** (10:30am-12:30pm)	

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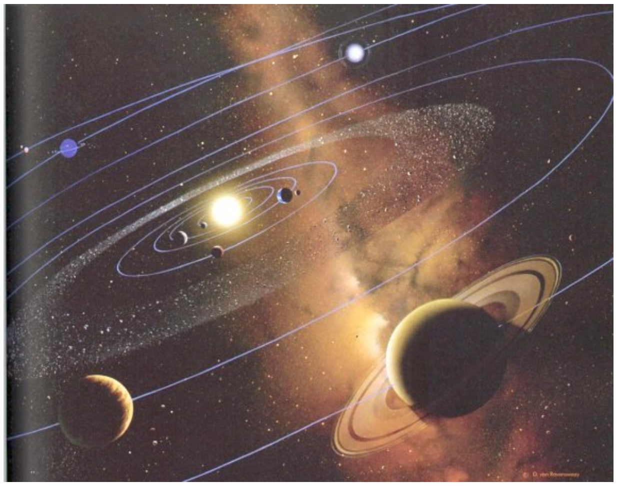
ASTR630 Assignments

Homework: Read and reread these Problem Solving Hints!



ASSIGNMENT	Due Date	Status
HW#1	Feb. 16	
HW#2	Mar. 2	
HW#3	Mar. 16	
HW#4	Apr. 6	
HW#5	Apr. 20	
HW#6	May 4	

TERPS 2023 Class Project

You are all invited (required!) to attend The Exciting Results in Planetary Science *(TERPS)* Conference to be held May 11 in the Astronomy Department at the University of Maryland, College Park. The Abstract Deadline is March 9; turn abstracts in here. The conference will be attended by top scientists from around the department (professors, researchers, graduate students) and you will be presenting invited 10-minute oral presentations on your recent research results. Start thinking about a Planetary topic that you would like to investigate further and report on to your peers! Your main resource should be a solid *Icarus* paper on your topic (Icarus is the most prestigious scientific journal in Planetary Sciences), and you should consult additional papers and the text for backup material. In addition. you will be doing a mini-research project of your own by re-deriving some of your chosen paper's results and then pushing them further. For example, you might replot some figures, derive some equations, run some simulations, or analyze some observational data. You can search for scientific research papers by subject or author with the ADS Astronomy and Astrophysics Abstract Service. Limit your search to Icarus papers by typing "Icar." in the box under " **Select References From:**". Your abstract should consist of the reference for your source paper, and a 1-page summary of both its content and how you intend to extend its results. This summary should differ from a standard abstract by providing more context. Describe in your own words the problem that the authors solve, why it is important, and how you will extend it.

Your presentation will be strictly limited to 6 minutes with 4 minutes for questions, so prepare accordingly. Typically you will have time to show 5-6 slides. Pitch your talk to the level others in the class who have not read your paper. Cole Miller's Ten Commandments of Oral Presentations and Further Hints on Giving Talks provide excellent advice! Conference munchies will be provided!

Besides the abstract due in March, a PDF copy of your talk and a ~2 page description of your extension to the project are due near the end of the semester. This description need not repeat material in your abstract and PDF talk, but should rather should supplement those writeups. Its purpose is to help me evaluate the scope of your research projects and achievements. I will grade your projects 1/3 on the quality and quantity of the research that you performed, 1/3 on the design of your PDF slides and 1/3 on your actual oral presentation. For some examples of interesting projects that students have chosen in the past, check out TERPS 2010, TERPS 2012, TERPS 2014, TERPS 2016, and TERPS 2018.

Do not panic - I am not expecting another second year project! Reading and research for this class project should take the equivalent amount of time as roughly 2 HW sets. So read a paper of interest and extend it a little bit, where a little bit is defined by the "2 HW sets" time limit.

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Problem Solving Hints

This page is meant to give you advice to help you improve your problem solving skills and your homework writeups. I expect you to follow these points for ASTR630 homeworks, and encourage you to employ them in your other science classes as well.

- **Write up Neat Homeworks.** Take pride in your homework writeups and do the best job that you can on them. Take the time to solve the homework problems roughly on scratch paper, and then copy them over neatly, filling in additional details on your final copy.

- **Show Your Work.** Give written descriptions of what you are doing, and why you are doing it. This is often especially useful at the beginning of a problem where it will force you to think about the problem physically and formulate your approach mathematically. Descriptions will also maximize the chances that I can follow what you have done in a derivation (especially if you go off on a wild tangent!) and will help me to give you constructive comments on your work. Give enough detail, and show enough mathematical steps, that students less advanced than you could understand your derivation!

- **Check Units.** Any equation that you write must be dimensionally correct. Check your equations occasionally as you go through a derivation. It takes just a second to do so, and you can quickly catch many common errors. Remember this general rule: in all physically valid solutions, the argument of all functions (e.g. trigonometric functions, exponentials, logs, hyperbolic functions, etc.) must be dimensionless. Taking the cosine of something with units of mass or length makes no physical sense.

- **Check Limits.** Check all of your final answers and important intermediate results to see if they behave correctly in as many different limits as you can think of. Sometimes you will know how a general expression should behave if a particular variable is set to zero, infinity, or some other value. Make sure that your general expression actually displays the expected behavior!

- **Take Advantage of Symmetries.** Symmetries are fundamental in physics (and astronomy!). Problems can have symmetry about a point (spherical symmetry), a line (cylindrical or axial symmetry), or a plane (mirror symmetry). You can use symmetries in two ways: 1) to check your final answer to a problem or, with a little more effort, 2) to simplify the derivation of that final answer. As an example, time-independent central forces (like gravity) have spherical symmetry because the force depends only on the distance from the origin. In this case, spherical symmetry means that once we find one solution (e.g. a particular ellipse for gravity), all other possible orientations of this solution in space are also solutions.

- **Use Common Sense.** Usually you will have some physical insight into how the solution to a problem should look. Compare your derived solution to a problem to what you expect from physical insight. Trust your instincts! If a derived equation or numerical value looks funny, go back through the derivation and look for an error. If you can't find an error, make a note of your concerns near your final solution and I will comment on them.

- **Get Help from Others.** Work on the homework problems on your own first and get as far as you can on them. This is the best way to improve your problem solving skill and prepare for in class tests. But by all means get help from other people (other students, or me) when you are stuck! By trying the problems first, you will be able to ask more intelligent questions and better understand the ideas of other students and/or the hints that I might give.

- **Go over Homework Solution Sets.** When you get homeworks back from me, go over the solution sets and your corrected homework together. Use the solution set to see how to get past points where you were stuck, and make sure that you could easily do a similar problem if given the chance, say on a midterm. Even if you get a particular problem correct, there is always much to learn by following through someone else's solution. I spend a lot of time writing up solution sets so that you can all improve you problem solving abilities. Take advantage of the opportunity!

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Dimensional Analysis

Step 1: Define the problem. First identify the result that you are looking for (call this A for answer). Then identify a set of variables v_i that fully constrain the problem. Specifically, be sure that if you know the values of all of these variables, then the answer that you are looking for is fully determined. Next, make sure that your variables are all independent of each other.

Step 2: From your list of variables v_i, form a quantity with the same units as A, the result that you seek. Call this Q.

Step 3: Form as many dimensionless quantities from your list of variables as you can. For instance, if your variables include a height and a length, then their ratio is a dimensionless number. If your list includes a height, width, and length, then you have two independent dimensionless quantities. Call these quantities ϕ_i.

Step 4: Multiply the quantity from Step 2 times the most general undetermined function f of your set of ϕ_i: $A = Qf(\phi_i)$. In the case where no dimensionless quantities can be formed from your variables (Step 3), then f is simply an undetermined constant. Finally, note that although dimensional analysis is a useful technique, it always gives less information that actually solving the problem.

EXAMPLE:

What is the horizontal distance D covered by a baseball thrown at a speed v at an angle θ from the horizontal?

Step 1: We are looking for a distance, D. The answer depends on v and θ, the initial conditions of the baseball on its release. The answer also depends on the strength of gravity. Since the baseball is thrown, we can assume that it doesn't go very high or far, and we can ignore things like the variation of gravity with height and the curvature of the Earth. So the answer also depends on g, the assumed constant acceleration due to gravity. The complete set of independent variables is v, θ, g, and we are looking for $D(v, \theta, g)$.

Step 2: Distance is measured in m, speed in m/s, θ in *radians* which are dimensionless, and acceleration in m/s^2. To make meters from the latter three quantities, simply divide v^2 by g. So $Q = v^2/g$.

Step 3: The only dimensionless quantity that can be formed from the variables v, θ, g is θ itself.

Step 4: The full solution to this problem must take the form $D = v^2/gf(\theta)$. The dimensional analysis is done, but does the result make sense? Check limits. If v is increased, the baseball goes farther, and if g is increased it goes less far. This seems reasonable. Convince yourself that $f(\theta) \to 0$ if either $\theta \to 0$ or $\theta \to \pi/2$.