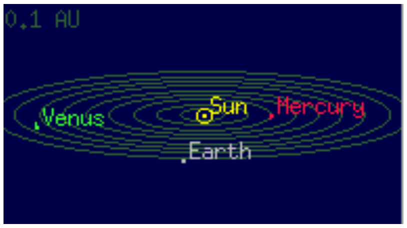
ASTR450
Orbital Dynamics, Spring 2024



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Office Hours: Anytime :)
Textbook: Danby (Celestial Mechanics)

ASTR450 Course Description

The solar system is a very dynamic place. The planets orbit the Sun along elliptical orbits but, on longer timescales, their orbits oscillate and precess -- some chaotically -- due to mutual gravitational perturbations. Asteroids are perturbed by resonant forces onto orbits that cross Earth's orbit; occasionally these objects strike our planet with deadly consequences. Jupiter tosses some comets into the Sun and ejects others from the solar system. Planets can also capture comets as temporary moons; some escape again while others are less lucky (like Shoemaker-Levy 9 which crashed into Jupiter in 1994). Ocean tides raised by the Moon are increasing the Earth-Moon distance by 3.7cm/year, thereby causing the length of our day to slowly increase. The same effect has driven the moons of Jupiter into resonance with one another, generating enough heat to power Io's volcanos. In Orbital Dynamics (ASTR450), we will study these and other important orbital phenomena. The course will emphasize analytical calculations, numerical simulations, and computer programming techniques. The prerequisites for ASTR450 are: (ASTR121 or ASTR 200) and (PHYS 273 or PHY 263).

Some Topics that we will cover in this class:

- Gravitational and Non-Gravitational Forces
- Two-body Problem (Energy + Angular Momentum)
- Three-body Problem (Roche Lobes, Zero Velocity Curves)
- Many-body Problem
- Orbital Elements + Orbital Perturbation Theory
- Tidal Forces and the Evolution of the Moon's orbit
- Orbital Resonances and the ``Capture'' of Pluto
- Resonant Sculpting of the Asteroid Belt
- Future of the Solar System - Chaos!

Web Site:

http://www.astro.umd.edu/~hamilton/ASTR450/

Grading Policy:

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

Assignment	ASTR450
Homework	275
Mini-Midterms	50
Midterm	100
Final	250
Participation	75
Total	750

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ASTR450 LECTURE SCHEDULE

Lecture Date	Lecture Topic	Reading
Thu. Jan. 25	Introduction to Orbital Dynamics	
Tue. Jan. 30	Spherical Trigonometry	Read Chap. 1,2
Thu. Feb. 1	Review of Vector Mechanics	Read Chap. 3
Tue. Feb. 6	Central Force Motion: Energy and Angular Momentum	Read Chap. 4
Thu. Feb. 8	Central Force Motion: Stability of Circular Orbits	HW 1 due
Tue. Feb. 13	Central Force Motion: Gravity	Read Chap. 6 and Appendix A (you can skip 6.9-6.13)
Thu. Feb. 15	Central Force Motion: General Relativity	HW 2 due
Tue. Feb. 20	The Two-Body Problem: Orbital Elements	
Thu. Feb. 22	The Three Dimensional Orbit	HW 3 due
Tue. Feb. 27	The Orbit in Time	
Thu. Feb. 29	Additional Problems in 2-Body Motion	HW 4 due
Tue. Mar. 5	The 3-Body Problem: Jacobi's Integral, Tisserand's Criterion	Skim Chap. 9; Read Chap. 8
Thu. Mar. 7	The 3-Body Problem: Zero Velocity Curves, Capture and Escape	HW 5 due
Tue. Mar. 12	The 3-Body Problem: Lagrangian Points, Horseshoe and Tadpole Orbits	
Thu. Mar. 14	**MIDTERM**	
Tue. Mar. 19	**SPRING BREAK**	
Thu. Mar. 21	**SPRING BREAK**	
Tue. Mar. 26	Rotating and Inertial Reference Frames	

Thu. Mar. 28	The Lagrange Equilibrium Points: Existence and Stability	HW 6 due
Tue. Apr. 2	Additional Problems in 3-Body Motion	
Thu. Apr. 4	The Perturbation Equations of Celestial Mechanics	HW 7 due
Tue. Apr. 9	The Perturbation Equations of Celestial Mechanics	Further reading will be primarily from Handouts. The material will parallel Danby's Chap. 11.
Thu. Apr. 11	Drag Forces; Tidal Evolution	HW 8 due
Tue. Apr. 16	Planetary Oblateness	
Thu. Apr. 18	Other Perturbations	HW 9 due
Tue. Apr. 23	Planet-Planet Interactions: The Disturbing Function	
Thu. Apr. 25	Planetary Perturbations: Resonances	HW 10 due
Tue. Apr. 30	Planetary Perturbations: Secular Effects	
Thu. May 2	**TBD**	HW 11 due
Tue. May 7	**TBD**	
Thu. May 9	**TBD**	HW 12 due
Fri. May 17	**FINAL EXAM** (10:30am-12:30pm)	

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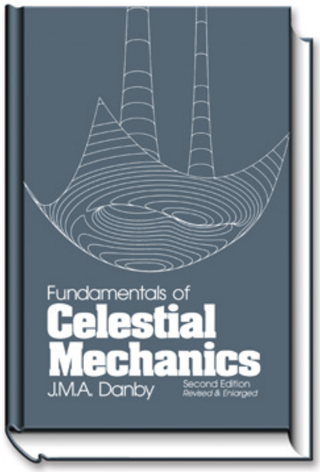
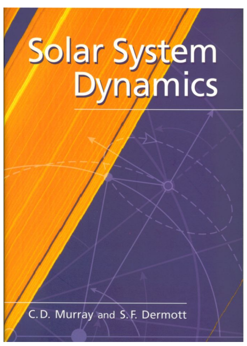
ASTR450 Textbooks



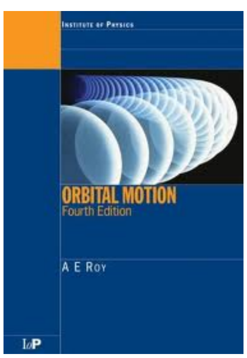
Required:

Fundamentals of Celestial Mechanics (J.M.A. Danby). About $30. Second edition last printed in 1992. Errata.



Other Good Orbital Dynamics Texts:

Solar System Dynamics (C.D. Murray and S.F. Dermott). About $80. Published in 1999. Excellent introduction to planetary dynamics written in a modern style at a graduate student level.



Orbital Motion (A.E. Roy). Fourth edition published in 2005.

Good General Solar System Information:

- The Nine Planets.
- NASA Photo Gallery.

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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 ASTR450 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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