Instructor: Dave Stevenson, x6534, djs@gps.caltech.edu

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Class Meeting Times: MWF 10, 162 S Mudd; we will schedule one additional hour as back-up.

**Rationale:** The idea is to provide you with an understanding of the basic ideas and techniques in planetary structure and evolution. This includes exoplanets. The course will *not* give you all the tools to do research in this area; those tools often come from basic science (e.g. material covered in Ph 136, Ae/Ge 160, etc.) But you will get bits of these tools, an awareness of why they are useful, and see how the observations tie into the basic science.

**What you will need (or need to catch up on):**

(a) Thermodynamics, an elementary understanding of the link between thermodynamics and statistical physics, elementary quantum mechanics and specifically its link to statistical mechanics (at least to the extent of knowing what is meant by Fermi and Bose statistics).

(b) Some E&M (~ the level of Ph 106), and the math tools commonly used in physics (i.e., applied math at the level of ACM 95/100).

(c) You will not be assumed to know any fluid dynamics, but you will need to pick up some aspects of this quickly.

**Background Material and References:** There is no good textbook that covers all aspects of the course, and there are parts of the course for which there is no good textbook at all.

Lecture notes are provided. These are fairly comprehensive and are evolving into a textbook.

The following books will be on reserve in the geology library:
Anderson, D. L. *Theory of the Earth* [also available for free on the web]
Canup and Righter (Eds) *Origin of the Earth and Moon*
Hubbard, W. B. *Planetary Interiors*
Jackson, I. (Editor) *The Earth’s Mantle*
Lodders, K. and Fegley, B. *The Planetary Scientist’s Companion*
Merrill, R. T., McElhinney, M. W. and McFadden, P. *Magnetic field of the Earth*
Newsom, H. and Jones, J. (Eds) *Origin of the Earth*
Poirier, J-P. *Introduction to the Physics of the Earth’s Interior*
Ringwood, A. E. *Origin of the Earth and Moon*
Schubert & Turcotte *Geodynamics*
Schubert, Turcotte and Olson *Mantle Convection in the Earth & Planets*
Stacey, F. D. *Physics of the Earth*
Taylor, S. R. *Solar System Evolution*
Zharkov, V. N. and Trubitsyn, V. P. *Physics of Planetary Interiors*

Anderson and Stacey contain some of thermodynamics background that we use. Hubbard is closest to the intent of this course but out of date or sparse in many aspects. Poirier has some of the condensed matter physics. Zharkov and Trubitsyn is occasionally useful. Taylor, Newsom and Jones, and Ringwood, deal mainly with cosmochemical and origins issues (a small part of the course). Schubert & Turcotte books emphasize earth and continuum mechanics (not including low viscosity fluid dynamics). Lodders and Fegley is a recent, all purpose compilation of lots of neat stuff. Jackson is also recent but Earth-specific.

Although not on reserve, there are several books in the University of Arizona Space Science series (mostly with blue covers, typically 1000 pages, and typically but not always titled with the name of a planet). Examples: *Mercury, Venus, Venus II, Mars, Jupiter, Saturn, Uranus, Neptune, Origin and Evolution of Planetary and Satellite Atmospheres, Protostars and Planets I, II, III, IV, V, Origin of the Earth and Moon*; etc. There is a new *Jupiter* (Cambridge University Press, 2006, ed. Fran Bagenal). There is also a conference proceedings *Origin of the Moon* that dates back to mid-1980’s and still has some merit.

Books that are useful for the background physics include: anything by Landau and Lifshitz (e.g. *Statistical Physics, Fluid Mechanics, Elasticity*), Ashcroft and Mermin’s *Solid State Physics*, Chandrasekhar’s *Stellar Structure*, Parker’s *Cosmic Magnetic fields*, etc.
There are also some useful review papers (though not as many as you might hope!) Where appropriate, I’ll make those available as PDFs. This will be especially necessary for exoplanet material.

**Structure of the Course:**
1. Two thirds of each lecture will be devoted to an overview of the material that you have already read and the other third will be spent on discussion of that material. *This means you must read the relevant lecture notes before coming to class.* Participation will be enforced through questions that you ask or I ask! Class participation counts for 15% of the grade in the course.

2. The class notes are provided in advance (on the web site). These notes are in the form of chapters that approximate lectures but do not, however, necessarily coincide with individual lectures. There will be homework, roughly once a week, at least for about the first two thirds of the quarter. Homework counts for 35% of the final grade.

3. The main part of the grade (50%) is a term project that you will need to choose soon; you will give a preliminary oral report (midway through the quarter) to the class to explain the problem. A final oral report and written report will be due at the end of the quarter. They are both important to the grade. The term project is on a research problem (i.e. could in principle turn into publishable research).

**Outline of the Course:** The number of lectures listed is only approximate and based on one hour lectures (three or four per week):

1. The basic ideas of planetary structure (1 lecture)

2. Solar system formation and the materials from which planets are formed (*a brief cosmochemical background*). 1 lecture

3. The condensed matter physics of planet-forming materials (*thermodynamics and transport properties*). 4 lectures

4. “Static” models of planets. (*Generic considerations rather than details of specific planets*). 1-2 lectures

5. The observations that constrain planetary structure and evolution. (*Gravity, rotational and tidal behavior, magnetism, seismology, heat flow, surface structure*). 3 lectures
6. Heat transport and fluid dynamics of planets. (General principles of planetary differentiation including magma oceans, core formation, crust formation, subsolidus convection, giant planet cooling, origins of oceans and atmospheres, life, etc.) 3 lectures

7. How planets generate magnetic fields. (Core convection, introductory dynamo theory). 3 lectures

8. A survey of what we know and don’t know about each planet: includes satellites & exoplanets. Some of this material is sprinkled about in earlier lectures but there will also be an attempt to summarize.

9. Student project reports. ~15/20 minutes per student. Last week of the quarter. Seniors do this earlier than rest of the class.