

Physics 171. General Relativity. Professor Michael Dine

Fall, 2009. Syllabus

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Office hours: Tues 2:00-4:00 (subject to change) or by appointment.

Course website: go to department website and click on Dine; follow link to Physics 171 or go to <http://scipp.ucsc.edu/~dine>

Homework and solutions and handouts will be posted here.

Course Description:

Einstein's theory of gravity, general relativity, is one of the great triumphs of twentieth century physics. As we enter the twenty first century, it is at the forefront of research in physics and astrophysics at extremely large distances (black holes and the big bang, especially) and at the shortest distances. General relativity has a reputation as an obscure topic. But while it is challenging, it is accessible to students with a knowledge of special relativity, advanced calculus, and the basics of mechanics and electricity and magnetism. In ten weeks, we will encounter the basic notions of space-time geometry, and apply them to black holes and the structure of the universe.

This will be a challenging course – for you and for me. It is important to devote a lot of time to it. You will need to keep up with the reading. The reading has to be done in a very active way, with pen and lots of scrap paper ready. Similarly for review of class notes. The problem sets are challenging.

Note on the text: Hartle's text is the first truly thorough and accessible text on the subject aimed at undergraduates. His coverage is thorough, and he does not condescend to his audience. He is also remarkably up to date. It is impossible to cover all of the material in the text in ten weeks, so we will have to be selective, both in our choice of subjects and in how we treat the material in those chapters we cover. I will often deviate from Hartle's presentations, sometimes because of my own preferences, and sometimes from the constraints of time. You will need to combine both the material in class and in the text. I expect to revise this syllabus continually through the course, and will try to give you a clear idea of sections which you should study closely and those which you can skip or skim.

Note on Einstein: Unlike any other physicist than Newton, Einstein's personality looms over this subject. I have put two biographies on reserve, and suggest you might want to consider purchasing one or both. I am not a historian, but I think it is useful – and interesting – to discuss the processes by which Einstein seems to have come to aspects of the General theory, and I may occasionally provide handouts on his life and work. It is also interesting to understand how other scientists, experimentalists and theorists, have approached this subject.

Books on Reserve:

1. S. Weinberg, *Gravitation and Cosmology*. This is a classic text. It treats the subject in a very straightforward way, developing the basic equations and working through their consequences. Some of the material on cosmology is dated, but the general treatment remains valuable.
2. S. Carroll, *General Relativity*. A modern graduate level course. You should find most of this material accessible by the end of the quarter.

3. A. Pais, *Subtle is the Lord*. A scientific biography, with a good deal of description of Einstein's actual work.
4. W. Isaacson, *Einstein*. This is a relatively new biography. It's treatment of the science is accurate and shows a good deal of understanding, though it is not as detailed as Pais's. On the other hand, the book is very readable, with more detailed description of Einstein's personal life and experiences.
5. J. Gleick, *Newton*. A very enjoyable little book, part of my "summer reading". While aimed at a popular audience, gives a great deal of insight, and also an appreciation for Einstein's significance – 250 years later.

I will put other books on reserve from time to time as seems appropriate.

Homework, exams,etc: There will be a problem set about once per 1.5 weeks. There will be an in class mid term and final, and occasional quizzes. The date for the midterm will be announced in a few weeks.

Very tentative Schedule; will be updated as quarter progresses

It is important to do the indicated reading.

1. Week 1 (Sept. 28, Sept. 30). Chapter 1,2. Introduction: what impelled Einstein to general relativity? Invariant notions in geometry.
2. Week 2 (Oct. 5, 7). Chapter 3,4. Newtonian mechanics. Inertial Frames, Galilean relativity, symmetries. Review of special relativity with a view to General.
3. Week 3 (Oct. 12,14). Chapter 5. Relativistic Mechanics. Chapter 6. Connections of gravity and geometry.
4. Week 4 (Oct. 19,21). Chapter 6, 7. Gravity and geometry; description of curved space-time (the metric, a central actor in the mathematics of GR).
5. Week 5 (Oct. 26,28). Chapter 8. The Geodesic Equation (motion of "particles" in gravitational fields).
6. Week 6 (Nov. 2, Nov. 4). Chapter 9. The Schwarzschild Geometry – this is the geometry which describes spherically symmetric systems (like the solar system, approximately). Important for tests of general relativity and for black holes.
7. Week 7 (Nov. 9,12). Chapter 10. Solar system tests of general relativity. Chapter 12: Gravitational Collapse and Black Holes.
8. Week 8 (Nov. 16,18). Chapter 13 (quickly): Astrophysical Black Holes. Chapters 20 and 21: Here, finally, we encounter the full mathematical machinery of the theory, and write down Einstein's equations for gravity.

9. Week 9 (Nov. 23,25) Continued study of the field equations. Cosmology. Chapter 17, 18: cosmological models and observations. Some of chapter 19.
10. Week 10 (Nov. 30, Dec., 2) Cosmology (continued), including some of chapter 19. Beyond General Relativity (String Theory?)