Physics 675: Introduction to relativity, gravitation and cosmology. Fall 2016

Professor: Jonathan C. McKinney
Lectures: Physics Building, **room 1402.** Tuesday and Thursday: 9:30am-10:45am.
Final exam: Thursday Dec 15th from 8:00AM to 10:00AM, Physics room 1402.
http://www.registrar.umd.edu/current/registration/exam%20tables%20fall.html
Office: PSC 3114
Office hours: by appointment
Email: jcm@umd.edu

Teaching Assistant: None

Topics to be covered (to be expanded, depending on the pace of the class):

Differential geometry as needed to study basic General Relativity (manifolds, Lie and covariant derivatives, parallel transport, geodesics, curvature tensors, gauge invariance).

The Einstein equations

Black hole solutions and analysis of their geometry.

Cosmology

Linearized theory, gravitational waves.

Exams: All exams (including final) are take-home exams, with 24 hours starting from the Tuesday 9:30am class time through 9:30am next Wednesday for normal exams. Given about every 4 weeks, currently scheduled for Oct 4, Nov 1, Nov 29, and final exam Dec 15. Final exam is take-home, and questions will be given Tuesday Dec 13 and solutions are due end of final exam time of 10am Thursday Dec 15. All take-home exams should be scanned and emailed to jcm@umd.edu by the deadline.

Homework: None

Talk: 8 minute talk given last class day on topic approved by Prof. McKinney. Talk will be graded on clarity (33%), teaching moments (33%), and difficulty (33%) of topic.

Topics can choose from include (max 2 people per topic):
Difficult (full 33% of difficulty credit):

1) Role of Relativity in Quantum Entanglement
2) Role of Relativity in Delayed Choice Quantum Eraser Double Slit Experiment
3) Black Hole Information Paradox and Firewall
4) Warp drive GR solutions and their feasibility

Moderate (25% of difficulty credit):

1) Spin energy extraction from rotating black hole
2) Location of gravitational energy in GR and energy conditions
3) Neutron star mass determination from equations of state and GR

Easy (17% of difficulty credit):

1) Where/how did Einstein get his ideas, standing on shoulders of giants.
2) Prove how Mercury's orbit gives evidence for GR
3) Describe evidence that exists for special and general relativity

Grading:
95% of the final grade will be based on exams. 5% is based upon talk.

Grades:
A: 90%-100%
B: 80%-89%
C: 60%-79%
D: 50%-59%.

Required textbook:
We will be following mostly *"FIRST COURSE IN GENERAL RELATIVITY"*, by Schutz. We will not have time to cover all of it, though, and I will also take some material or examples from other books or from myself, but Carroll's book is an excellent read so spend as much time on it as possible for further discussions of what we will cover during lecture time!.

Below is list of other important bibliographic resources.

Other books and bibliographic resources:

1. -*"Problem book in relativity and gravitation"*, by Lightman, Press, Price and Teukolsky. Edited by Princeton University Press, 1975. A very valuable list of problems with solutions. Highly recommended. If you have the time, do all of them!.

2. -"Semi-Riemannian geometry, with applications to relativity", by Barrett O'Neill. Mostly a book on the differential geometry aspect of GR. Very readable.

3. - *"Gravitation"*, by Misner, Thorne and Wheeler. Edited by W. H. Freeman, 1973. A classic among classics. Usually referred to as "MTW". If you are interested in GR, you should have a copy of this huge book for reference on so many topics. I would not recommend it as text to learn GR, but certainly a must have once you have learned GR.

4. -*"Spacetime and Geometry: An Introduction to General Relativity"*, by Sean Carroll (edited by Addison Wesley). An interesting book exploring the physics of GR with several detailed side calculations related to quantum mechanics and Langrangian formulations of GR and E&M.

5. -*"Gravity from the ground up"*, by Bernard Schutz (edited by Cambridge). It uses very little math and instead it focuses on "high level" discussions of many aspects related to gravity. A very good complementary read.

6. -*"General Relativity"*, by Robert M. Wald (edited by The University of Chicago Press). One of the best books, but rather terse. Carroll's book in fact can be seen as a "more legible, with more explanations" version of around half of the material in Wald's. Probably not a book to learn GR for the first time.

7. -*"The large scale structure of spacetime",* by Stephen Hawking and George Ellis, edited by Cambridge University Press (1975). Excellent book, with a focus on the singularity theorems, along with their proofs. Probably not the best place to start learning GR.

1. -*"Relativity"*, by Albert Einstein, with an introduction by Roger Penrose and Commentary by Robert Geroch. Edited by PI Press, 2005. This is a short book written by Einstein himself for the lay public, with modern comments and and an introduction by Geroch and Penrose, respectively.

2. -Living reviews in Relativity: a collection of online reviews written by experts in their fields and edited by the Max Planck Society. They are expected to be updated by the authors, so they present the state of the art of any topic related to GR at a high level. Excellent resource.

Reviews:

1. - Kerr black holes, Penrose extraction if time allows. Material: Carroll's book, chapter 6.

2. -Einstein and his initial disbelief on the “physical reality of the “Schwarzschild singularity”. Reference: “On a stationary system with spherical symmetry consisting of many gravitating masses”, Albert Einstein, Annals of Mathematics, Second Series, vol. 40, No 4, pp 922-936 (1939). Here is a a pdf copy of the article.

1. -Stability of the Schwarzschild solution. This involves gauge invariant, odd parity, vacuum perturbations of the Schwarzschild metric, the even parity sector formalism was developed by Zerilli in the 70’s. The original reference is a paper by Regge and Wheeler from 1957. A much modern and geometrical presentation is available here and here. A complete second order covariant and gauge invariant perturbation formalism was developed here.

1. - Precession of Mercury. Material: Carroll's book, Chapter 5, pages 212-218.

- Experimental tests of gravity: any topic of your choice from Cliff Will's Living Review "The confrontation between General Relativity and experiment".

1. - Critical phenomena in gravitational collapse. Living Review by Gundlach and Jose M. Martin-Garcia.

2. - "Analogue gravity": This focus on, in particular, black hole analogues in non-gravitational physics Living Review by Barcelo, Liberati, Visser.

3. -"The cosmological constant", Living review by Carroll.

4. -If anyone has a background on quantum field theory and is brave enough: Hawking effect. References: Carroll’s book has some of it (chapter 9) but I would recommend Wald’s book.

5. -The history of gravitational waves. There is an historical account here (the title refers to a saying by Eddington, who did not believe on the existence of gravitational waves). And a pdf from the author’s webpage (i.e. I assume it is legal) is here.

- “Resolution” of the big bang singularity by loop quantum cosmology. This is a nice review by Ashtekhar.

Attendance:
It is not required, except for exams.

Announcements

All announcements (new exams being posted, deadlines, etc) will be done by ELMS, even if they have also been done during lecture time. Check it regularly for exams, deadlines, and other.

Exam policy:

Exams and their deadlines will be sent by email and posted on this webpage.

- Please turn in the exam to McKinney by the specified deadline. You will usually have around four weeks between exams and have one 24-hour period to complete the exam.

- In grading the turned in exams, your work for reasoning, logic, completeness and clear explanations will be considered. Points will be deducted if your answer is hard to read or difficult to understand, or the logic not clearly explained, even if the final result is correct.

- Late exams will **only** be accepted under the exceptional circumstances stipulated by UMD (see below).

- You are encouraged to discuss the exams with others. However, the work you turn in should reflect your own formulation and understanding and writing and should not be copied from others work (verbal or written or etc.).

Effectiveness in class participation

In order to take advantage of lecture time and the array of topics to be covered, it is strongly encouraged that you try to read the material of each lecture ahead of time, even if you only have time for a "casual" read. We will usually proceed in an interactive manner. By the end of each class we will discuss what the next class topic will be.

Make-up exams policy

The course will adhere to the University policy for make-up exams, see http://www.testudo.umd.edu/soc/atedasse.html for a full description of it. A summary follows:

"In order to get a make up for a missed exam you need to provide in written the reason, which has to be one of allowed by the university. Namely, due to illness (of the student or a dependent), religious observance (where the nature of the observance prevents the student from being present during the class period), participation in University activities at the request of University authorities, or compelling circumstances beyond the student's control. Students claiming excused absence must apply in writing and furnish documentary support for their assertion that absence resulted from one of these causes. "

"Students who have a concern regarding religious observances should see their instructors at the start of the semester. Although the University attempts to accommodate the religious beliefs of all of its members, it functions within a secular environment and is limited in the extent to which it can interrupt its normal operations. The President shall determine when it is appropriate for the campus community to restrict rescheduling examinations or other significant assessments on the dates of religious observance.
At this time, examinations or other significant assessments may not be scheduled on Rosh Hoshanah, Yom Kippur, Good Friday, or the first two days of Passover."

It is the student's responsibility to inform me, by email, within the first two weeks of classes, of any intended absences or delays in handling exams, **for the whole semester**, due to religious observances.

Students with disabilities

Students with disabilities should contact me as soon as possible so that appropriate arrangements can be made to accommodate the student's needs.

Academic integrity

The University of Maryland, College Park has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.shc.umd.edu.
To further exhibit your commitment to academic integrity, remember to sign the Honor Pledge on all examinations and assignments: "I pledge on my honor that I have not given or received any unauthorized assistance on this examination (assignment)."