ASTRONOMY 704, GENERAL RELATIVITY
WEST VIRGINIA UNIVERSITY
SPRING 2020

Instructor Information

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Office hours:	by appointment (email me with a few available times)

Course Information

Name:	General Relativity
Number:	ASTR 704
Location:	G04 White Hall or G51 White Hall (Astronomy Annex Conference Room)
Schedule:	MWF 11:30 – 12:20 (will discuss possibility of at least occasionally running 2 days/week, 11:00 – 12:20 or 11:30 – 12:45)
Prerequesites:	Formally none, a mastery of undergraduate physics and mathematics is assumed. Undergraduate general relativity will help, but is not assumed.
Text:	REQUIRED:
	Guidry, *Modern General Relativity: Black Holes, Gravitational Waves, and Cosmology*, Cambridge University Press, 2019
	OPTIONAL/RECOMMENDED:
	Hartle, *Gravity: An Introduction to Einstein's General Relativity*, Pearson, 2003
	Schutz, *A First Course in General Relativity*, Cambridge University Press; 2nd edition, 2009
	ALSO RECOMMENDED FOR GRAD RESEARCHERS:
	Misner, Thorne, and Wheeler, *Gravitation*, Mac Higher, 1973
	Wald, *General Relativity*, UCP, 1984

Grading breakdown

Final Exam	20 %
Midterm	20 %
Paper/Coding	20 %
Homework	40 %
Total	**100 %**

Course Elements

Exams

There will be one midterm exam and a cumulative final exam. The midterm exam will be held in class on TBD. The final exam will be held on May 1, THE LAST DAY OF CLASS (NB: NOT DURING EXAM WEEK). ***Important***: No make-up exams will be given, unless I am provided with documentation in advance of your participation in an authorized university activity. Make up exams for other reasons must be arranged in advance and are at the discretion of the instructor. Requests to reschedule after the fact due to an unforeseen emergency should be supported by documentation (e.g. a note from your doctor for a medical emergency).

Exams will be open book, and you may bring a single sheet of paper with notes and equations. If you feel that your exam was graded incorrectly, you may request a review of your exam grade by resubmitting it with a written explanation up to one week after graded exams have been made available. After this window, your exam grade will not be changed.

Paper/Coding

Given the necessity of developing scientific writing skills and some level of coding skill, you'll be asked to write a paper on a topic within the broader subject of General Relativity, or to solve a relevant computational problem. Some examples include the global positioning system; gravitational redshift; cosmological redshift; Gravity Probe B; GOCE/Grace follow-on; LISA/LISA Pathfinder; precession of Mercury's perihelion; Shapiro time delay; weak and strong gravitational lensing; accretion disks around compact objects and active galactic nuclei; binary pulsars; quantum gravity; expansion of the Universe and the FRW metric. Computational projects can be numerical, eg evolving geodesics in a nontrivial background, or analytical, eg computing exact quantities in a given metric with Mathematica. Any other GR-related

subjects are fine, as long as you discuss them with me.

Your final paper should be 3000-4000 words long, and must review the salient points of the topic, highlight some recent work and outline possible areas for future progress. The paper should be written in the style of a scientific review article and be mostly descriptive in style, with use of mathematical formulae when appropriate. The paper must be submitted both in print and in PDF format generated by compiling from LaTeX and BibTeX source code (which is the standard approach for scientific publications) unless there is some extenuating circumstance that makes this impossible, in which case you must discuss using another format with me. For a coding project, a brief synopsis along with complete functioning source code must be provided, and the level of difficulty must be commensurate with that expected in the paper. Papers can be submitted at any time throughout the semester, and will be returned, graded, approximately one week after submission. The latest acceptable submission date for the paper or the coding project is Apr. 8. No late papers will be accepted. To avoid last minute scrambling, you must submit a title and abstract for the paper or coding project no later than Feb. 10 (i.e. you must get my approval of your topic before then). The total grade on this assignment will depend on the quality and timeliness of the title/abstract and the final completed paper or project .

Homework

Homework assignments will be given approximately every 2 weeks and will be due at the beginning of class 1 weeks after they are assigned. Material will primarily be assigned from the required textbook. You should expect homework assignments to be challenging, and it is acceptable (even encouraged) that you will collaborate with your classmates. If you are collaborating effectively, you are seeking to make sense of a problem through dialog, comments, questions, and critiques; you are teaching each other. If, as a group, you are collectively stuck on a specific problem, you are strongly encouraged to come to office hours to discuss the problem with me as a group.

However, you are individually responsible for your own learning and your own understanding. You need to think through the concepts for yourself in order to understand the material and do well on the exams. For all assignments, the work that you turn in must be your own. Simply copying homework from one another or from the Internet is not collaborating, but

cheating, and it will be dealt with as such (see the *Academic Integrity Statement* below). Credit will be awarded based on a clear, concise, and complete explanation of the problem leading to a solution.

Course Policies

Cancellations

For weather-related cancellations, we will follow the closings for the Monongalia County school district. For other unscheduled cancellations, announcements will be sent by email through eCampus.

Etiquette

You are expected to be present in class, both literally and in the sense of being engaged. Please turn off cell phones before the beginning of class and place them out of sight (for example, in a backpack or purse) until class has concluded. No laptops, headphones, or any other potential distraction should be used during class. If you must enter class late, or must leave early or use the restroom, please do so quietly.

Academic Integrity Statement

I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code at http://studentlife.wvu.edu/studentconductcode.html. Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me *before* the assignment is due to discuss the matter.

Social Justice

West Virginia University is committed to social justice. I expect to maintain a positive learning environment based upon open communication, mutual respect, and non-discrimination. Our university does not discriminate on the basis of race, sex, age, disability, veteran's status, religion, sexual orientation, color or national origin. Any suggestions as to how to further such a positive and open environment in this class will be appreciated and given serious consideration. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me

and make appropriate arrangements with the Office of Disability Services (304-293-6700).

Topic sequence

We will tackle topics in the following order, taking however long it takes on each. Students should do the corresponding reading before we cover a given chapter. We will briefly review some key material in class, then move directly to working through problems from the end of the chapter.

READING	**TOPIC**
1	Introduction
2	Coordinates
3	Tensors
4	Lorentz Covariance
5	Lorentz-Invariant Dynamics
6	Equivalence Principle
7	Curvature and General Covariance
8	General Relativity
9	Schwarzschild Spacetime
10	Neutron Stars and Pulsars
11 + MTW	Spherical Black Holes (inc. charge)
13	Kerr Spacetime
15	Central Engines
16	Hubble Expansion
17	Energy and Matter in Cosmology
18	Friedmann Cosmologies
19	Evolution of the Universe
22	Gravitational Waves
23	Weak Sources
24 + MTW	Strong Sources and Detectors
14	Evidence for Black Holes
20	Big Bang
21	Beyond Classical Big Bang
25	Tests of General Relativity
26	Beyond Standard Models
12	Quantum Black Holes