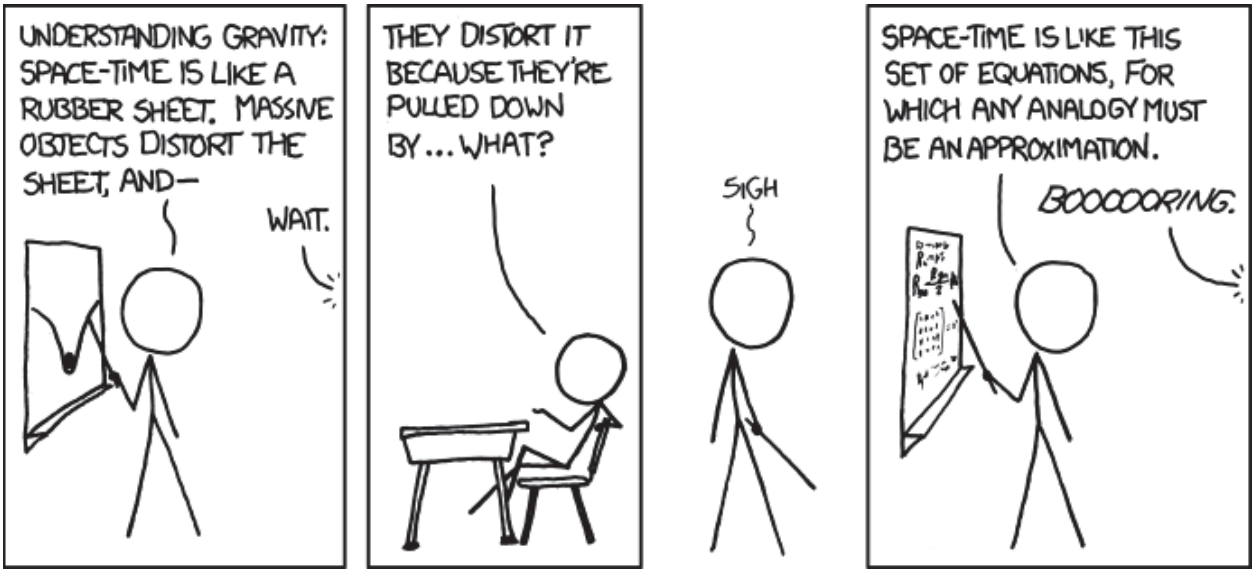
PHYS 597, 01E, 22949, GENERAL RELATIVITY

COURSE SYLLABUS: SPRING 2025



https://xkcd.com/895/

INSTRUCTOR INFORMATION

Instructor: Dr. William Newton
University Email Address: william.newton@tamuc.edu
Class hours: TR 9:30-10:45am
Office Location: STC 236
Office Hours: Wednesdays 9:30-11am and 12:30-2:30pm
Preferred Form of Communication**:** email/chat in person before/during/after class, in the hallway (if I'm not in a rush!) and during office hours
Communication Response Time: email: 24 hours

COURSE INFORMATION

Materials – Textbooks, Readings, Supplementary Readings

The *syllabus/schedule are subject to change.*

Textbook(s) Required: “Gravity” by James Hartle, Addison-Wesley, ISBN: 978-0805386622

Software Required: Python

Optional Texts: A Student’s Guide to General Relativity by Norman Gray, Cambridge University Press, ISBN 978-1-316-63479-0

The End of Everything (Astrophysically Speaking) by Katie Mack – a fun (if you like existential dread) take on Cosmology at a popular science level

Course Description

General Relativity is a theory of gravity. It is applicable not only in situations where Newton’s theory of gravity applies, but in situations where a lot of mass and energy are localized in a small amount of space and Newton’s theory breaks down. It doesn’t mean Newton’s theory is wrong – just that Newton’s theory is the low mass/energy limit of General Relativity.

General Relativity makes an astonishing claim about the nature of gravity – that it is caused by the very geometry of spacetime. Mass curves spacetime and spacetime tells matter how to move. This is a big conceptual leap – how to visualize a four-dimensional manifold that is non-Euclidean – and requires some sophisticated math to describe that manifold. However, in one sense the math is just math you already know recast in a streamlined notation so that it can be expanded upon in more complex ways. But it’s worth remembering that all the way through, you’re just doing algebra and calculus.

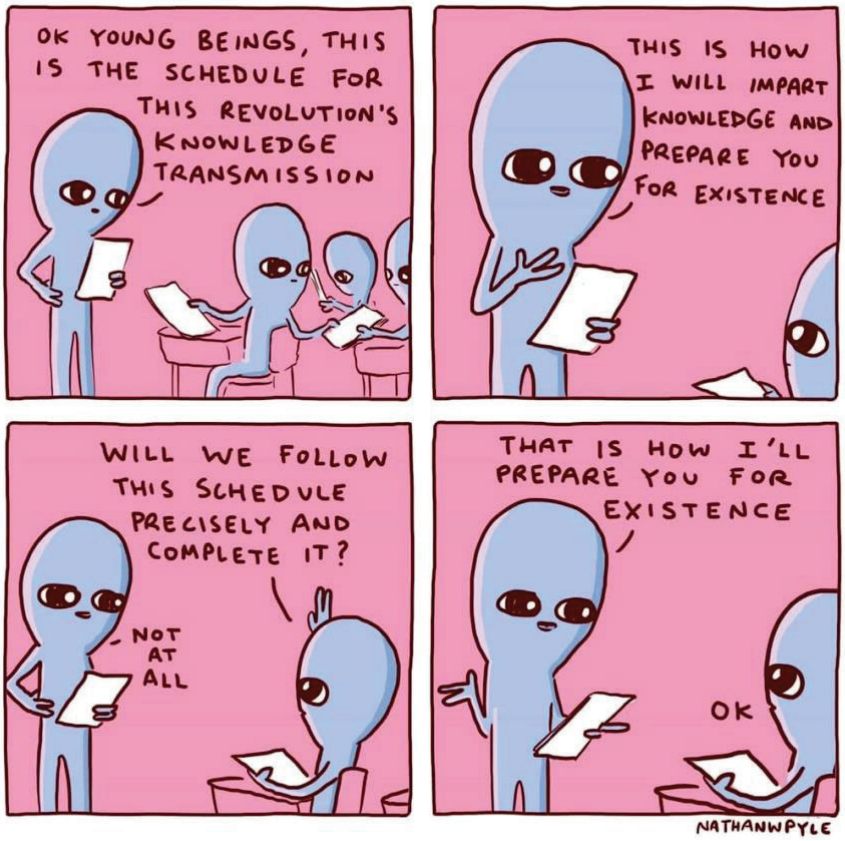
We’ll explore a number of applications of General Relativity, from the effect on the orbit of Mercury and GPS satellite timing, to the universe as a whole.

The study of the universe as its own complete object is called Cosmology, and in the last third of the semester we’ll use General Relativity as a jumping off point to explore it. We’ll learn the basic equations for the evolution of the universe and examine the evidence that the universe began in a Big Bang.

Student Learning Outcomes

1. Students will demonstrate understanding of how the equivalence principle leads to a geometric understanding of gravity.
2. Students will be able to apply geometrical methods to solve problems of Galilean and Special Relativity.
3. Students will be able to apply spacetime diagrams to understand qualitatively situations in flat and curved spacetime, including black holes and the universe as a whole.
4. Students will be able to use variational principles to derive the generalized form of Newton's first law of motion in curved space-time and use that law to analyze the trajectories of particles in free fall in different spacetimes.
5. Students will be able to derive experimentally and observationally testable consequences from various spacetime metrics.
6. Students will be able to describe the large-scale evolution of spacetime
7. Students will be able to demonstrate quantitatively the evidence for the Big Bang theory of Cosmology.

A TENTATIVE SCHEDULE



This is a rough guide only. Don't @ me (is that what the kids still say?)

Week	Topic
1	Motivation: how can you tell whether you're in a gravitational field?
2	Motivation: How can you tell a surface you're on is curved?
3	The equivalence principle and gravitational redshift; introduction to index notation
4	Special Relativity, the line element, proper time, and Minkowski spacetime
5	More fun in Minkowski space time; the metric tensor
6	The Schwarzchild metric as a first example of a curved space time; orbits and the precession of the perihelion of Mercury (a.k.a General Relativity works!)
7	Black holes and spacetime diagrams when spacetime is curved
8	Black holes and spacetime diagrams continued; the geodesic equation and Christoffel symbols

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9	The Einstein equations for the impatient
10	The linearized Einstein equations and gravitational waves
11	Applying GR to the whole universe! The FRW equations
12	A little differential geometry
13	The Einstein Equations for the little more patient
14	Rotating black holes, neutron stars
15	Applications

Minimal Technical Skills Needed

Most of the heavy lifting is done by tensor algebra and calculus. Tensor algebra is basically vector/matrix algebra – that is, linear algebra – in index notation. So knowing your way around vectors (representing them in both matrix and unit/basis vector forms), vector and matrix multiplication, determinants, types of matrix… is the main requirement. This will really kick in from the third week onwards, so if you need to brush up, the first two weeks are the time to do it. Of course, if you need any help, let me know. *Basic knowledge of (and access to) python will be assumed.*

Instructional Methods

My aim is to use 30-45 minutes of class time for lecturing and the rest for group work. You learn by doing, and for me to be most effective in helping you learn I need to see you in action! I will give you my lecture notes as we go along to supplement the textbook.

Student Responsibilities or Tips for Success in the Course

I set deadlines to keep you on task. There will be no penalties for turning work in late; you are responsible for your own learning. There will be times where you unavoidably turn things in late for life reasons, and there's no need to feel stressed about that. I will help you keep on track if you keep me informed about what's going on.

It is unfortunately unavoidable that turning in work late happens regularly, you will get out of sync with the class, you will become increasingly rushed and find it harder to find the time needed to truly understand the material, and therefore be less likely to be successful on future assignments. That's why it's important to let me know as soon as you are able if there is something that is getting in the way of the class work (you don't need to be specific about what it is if you don't want to). I can then help. Remember,

I've struggled through classes in the past, and I've done badly in my fair share of them, and have figured out a lot of stuff based on those experiences.

I will keep you updated on the sections of the book you need to be reading outside of class. This is not an afterthought – the lectures and their notes are just the skeleton, while the textbook contains the flesh that goes over them and holds it together. That (I guess) makes you the organs that power the General Relativity body (that analogy got gross and out of hand, apologies).

I urge you to practice *active reading* when it comes to the textbook. Don't just sit down and read a chapter from start to finish with no clear intention. Very, very little will go in. The SQ3R method is a very good place to start:

https://academicresourcecenter.harvard.edu/2024/03/27/sq3r/

Here's a great video that shows you a concrete example of active reading. It's in a different field to physics, but the philosophy is the same: you are actively thinking and figuring stuff out, and making notes and maybe drawing charts, diagrams, pictures or just writing down words in some some structure, *while* you are reading the book. And you are reading it WHILE pulling what you know already about physics to the front of your mind and combining it with the text. This example is actually quite similar to how I read texts.

https://www.youtube.com/watch?v=WRjsOU6mOp4

But you should experiment and find the way that feels right for you, if you haven't already. If you want tips I could happily talk about this sort of thing for hours!

GRADING

Assignments	8x5% = 40%
Progress assessments	5x9% = 45%
Culminating project	15%
TOTAL (can you guess?)	100% (correct!)

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Final grades in this course will be based on the following scale:

A = 90%-100%
B = 80%-89%
C = 70%-79%
D = 60%-69%
F = 59% or Below

Assessments

Assignments: These will consist of a mixture of traditional textbook questions, more conceptual problems, and the odd computational problem. They will be assigned every two weeks. The day they are assigned, you will have half an hour in class to make a start on them in collaboration with your group (and me). The following week there will also be half an hour devoted to continuing the assignment, during which I can assist in your making progress. This means it is in your best interest to get started early to make the most of those second in-class sessions.

Progress Assessments: These take the place of midterms. They will be shorter assessments done in class every three weeks or so. The purpose of them is so that I can check in on how your understanding is progressing and give you extra help in areas of difficulty.

To encourage constant improvement, for **both** the assignments and progress assessments I employ a reward system for streaks of scores that improve on each other. I do this by replacing the scores of all the assessments in the streak by the highest score in the streak for all of them. For example, if your scores on assessments are (out of 100)

56, 66, 85, 80, 90

They will be replaced at the end of the semester by

85, 85, 85, 90, 90

And similarly for assignments.

General Relativity is a challenging subject, both conceptually and in the mathematical formalism, and it can take a while to get a handle on things. This system is designed to give you time and space (ha!) to get your mind round the material without feeling the pressure of having to get high grades right away.

Culminating Project: This project will combine a take-home assessment and an in-class exam-style component, that are linked. More info ~~when I figure out just what that means~~ closer to the end of the semester.

TECHNOLOGY REQUIREMENTS

LMS

All course sections offered by Texas A&M University-Commerce have a corresponding course shell in the myLeo Online Learning Management System (LMS). Below are technical requirements

LMS Requirements:
https://community.brightspace.com/s/article/Brightspace-Platform-Requirements

LMS Browser Support:
https://documentation.brightspace.com/EN/brightspace/requirements/all/browser_support.htm

Zoom Video Conferencing Tool
https://inside.tamuc.edu/campuslife/CampusServices/CITESupportCenter/Zoom_Account.aspx?source=universalmenu

ACCESS AND NAVIGATION

You will need your campus-wide ID (CWID) and password to log into the course. If you do not know your CWID or have forgotten your password, contact the Center for IT Excellence (CITE) at 903.468.6000 or helpdesk@tamuc.edu**.**

Note: Personal computer and internet connection problems do not excuse the requirement to complete all course work in a timely and satisfactory manner. Each student needs to have a backup method to deal with these inevitable problems. These methods might include the availability of a backup PC at home or work, the temporary use of a computer at a friend's home, the local library, office service companies, Starbucks, a TAMUC campus open computer lab, etc.

COMMUNICATION AND SUPPORT

If you have any questions or are having difficulties with the course material, please contact your Instructor.

Technical Support

If you are having technical difficulty with any part of Brightspace, please contact Brightspace Technical Support at 1-877-325-7778. Other support options can be found here:

https://community.brightspace.com/support/s/contactsupport

Interaction with Instructor Statement

COURSE AND UNIVERSITY PROCEDURES/POLICIES

Course Specific Procedures/Policies

Syllabus Change Policy

The syllabus is a guide. Circumstances and events, such as student progress, may make it necessary for the instructor to modify the syllabus during the semester. Any changes made to the syllabus will be announced in advance.

University Specific Procedures

Student Conduct

All students enrolled at the University shall follow the tenets of common decency and acceptable behavior conducive to a positive learning environment. The Code of Student Conduct is described in detail in the Student Guidebook. https://inside.tamuc.edu/admissions/registrar/documents/studentGuidebook.pdf.

Students should also consult the Rules of Netiquette for more information regarding how to interact with students in an online forum: https://www.britannica.com/topic/netiquette

TAMUC Attendance

For more information about the attendance policy please visit the Attendance webpage and Procedures 13.99.99.R0.01 http://www.tamuc.edu/admissions/registrar/generalInformation/attendance.aspx

Academic Integrity

Students at Texas A&M University-Commerce are expected to maintain high standards of integrity and honesty in all of their scholastic work. For more details and the definition of academic dishonesty see the following procedures:

Undergraduate Academic Dishonesty 13.99.99.R0.03

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Undergraduate Student Academic Dishonesty Form

http://www.tamuc.edu/aboutUs/policiesProceduresStandardsStatements/rulesProcedures/documents/13.99.99.R0.03UndergraduateStudentAcademicDishonestyForm.pdf

Graduate Students Academic Integrity Policy and Form

Graduate Student Academic Dishonesty Form

https://inside.tamuc.edu/aboutus/policiesProceduresStandardsStatements/rulesProcedures/13students/graduate/13.99.99.R0.10.pdf

Students with Disabilities-- ADA Statement

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you have a disability requiring an accommodation, please contact:

Office of Student Disability Resources and Services
Texas A&M University-Commerce
Velma K. Waters Library Rm 162
Phone (903) 886-5150 or (903) 886-5835
Fax (903) 468-8148
Email: studentdisabilityservices@tamuc.edu

Website: Student Disability Services

https://www.tamuc.edu/student-disability-services/

Nondiscrimination Notice

Texas A&M University-Commerce will comply in the classroom, and in online courses, with all federal and state laws prohibiting discrimination and related retaliation on the basis of race, color, religion, sex, national origin, disability, age, genetic information or veteran status. Further, an environment free from discrimination on the basis of sexual orientation, gender identity, or gender expression will be maintained.

Campus Concealed Carry Statement

Texas Senate Bill - 11 (Government Code 411.2031, et al.) authorizes the carrying of a concealed handgun in Texas A&M University-Commerce buildings only by persons who have been issued and are in possession of a Texas License to Carry a Handgun. Qualified law enforcement officers or those who are otherwise authorized to carry a concealed handgun in the State of Texas are also permitted to do so. Pursuant to Penal Code (PC) 46.035 and A&M-Commerce Rule

34.06.02.R1, license holders may not carry a concealed handgun in restricted locations.

For a list of locations, please refer to the Carrying Concealed Handguns On Campus document and/or consult your event organizer.
Web url:
http://www.tamuc.edu/aboutUs/policiesProceduresStandardsStatements/rulesProcedures/34SafetyOfEmployeesAndStudents/34.06.02.R1.pdf

Pursuant to PC 46.035, the open carrying of handguns is prohibited on all A&M-Commerce campuses. Report violations to the University Police Department at 903-886-5868 or 9-1-1.

A&M-Commerce Supports Students' Mental Health

The Counseling Center at A&M-Commerce, located in the Halladay Building, Room 203, offers counseling services, educational programming, and connection to community resources for students. Students have 24/7 access to the Counseling Center's crisis assessment services by calling 903-886-5145. For more information regarding Counseling Center events and confidential services, please visit **www.tamuc.edu/counsel**

Mental Health and Well-Being
The university aims to provide students with essential knowledge and tools to understand and support mental health. As part of our commitment to your well-being, we offer access to Telus Health, a service available 24/7/365 via chat, phone, or webinar. Scan the QR code to download the app and explore the resources available to you for guidance and support whenever you need it.

http://telusproduction.com/app/5108.html

AI use policy [Draft 2, May 25, 2023]

Texas A&M University-Commerce acknowledges that there are legitimate uses of Artificial Intelligence, ChatBots, or other software that has the capacity to generate text, or suggest replacements for text beyond individual words, as determined by the instructor of the course.

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Any use of such software must be documented. Any undocumented use of such software constitutes an instance of academic dishonesty (plagiarism).

Individual instructors may disallow entirely the use of such software for individual assignments or for the entire course. Students should be aware of such requirements and follow their instructors ’guidelines. If no instructions are provided the student should assume that the use of such software is disallowed.

In any case, students are fully responsible for the content of any assignment they submit, regardless of whether they used an AI, in any way. This specifically includes cases in which the AI plagiarized another text or misrepresented sources.

13.99.99.R0.03 Undergraduate Academic Dishonesty
13.99.99.R0.10 Graduate Student Academic Dishonesty