**UNIVERSITY OF MISSISSIPPI**
Department of Physics and Astronomy
General Relativity (Phys. 735) — Prof. Leo C. Stein — Fall 2024

**General Relativity Syllabus**

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| Class schedule: | MWF 1500–1550, Lewis 109 |
| Office hours: | W 1600–1700, Lewis 205 |
| Course website: | `https://duetosymmetry.com/teaching` |
| Professor: | Leo C. Stein (he/him; you can call me "Leo" or "Dr. Stein") |
| Email: | ⟨lcstein@go.olemiss.edu⟩ |
| Office: | 205 Lewis Hall |

Accessing homeworks/exams will be through Blackboard. If you are in this course and do not have access to the virtual classroom, email Leo ASAP!

## Course goals and learning outcome

This is a one-semester course on general relativity (GR). There's enough "textbook" material in GR to spread out into 3 semesters, so only the most important topics are included.

Key concepts (time permitting): • differential geometry, • tensor calculus, • geodesics, • curvature, • the Einstein field equations (EFEs), • Lagrangian formulation GR, • gravitational waves, • cosmology, • compact objects, • black holes, • overview of methods of solving EFEs.

Goals: Understand and apply the geometric viewpoint; introduce tools of differential geometry; strengthen tools of vector/tensor calculus; understand and apply the formulation of GR to physical systems; familiarity with key concepts of GR. These goals are to enhance students' mathematical reasoning, critical thinking, and analytical reasoning.

## Texts

The one required textbook is a pretty good introduction to GR at the graduate level,

- Carroll, *Spacetime and Geometry: An Introduction to General Relativity.*

No book is perfect or covers all the topics you want at the depth you want. There are a large number of other GR textbooks that I think are nice for a variety of other reasons.

- Misner, Thorne, and Wheeler (MTW), *Gravitation.* Though it's from 1973, it's still pretty encyclopedic in its scope, which is reflected in how heavy it is. Some people don't like the Wheelerian writing style, but it does a great job of introducing the geometric viewpoint to physicists, and it has lots of good exercises.
- Wald, *General Relativity.* More mathematically terse and precise, less pedagogical.
- Schutz, *A First Course in General Relativity.* More introductory than Carroll's text (aimed at advanced undergrads).

If you want to become a researcher (or just practitioner) in GR, I can give more recommendations! Just ask.

## Evaluation

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| Grade type: | Letter grade A–F |
| Grade ranges: | (subject to change)<br>• A: 88% and up<br>• B: 75–87%<br>• C: 65–74%<br>• D: 55–64%<br>• F: <55% |
| Grade breakdown: | (subject to change)<br>• 100% Homework |

## Homework, tests, and final exam

Homework assignments will be announced via the course web site, and they must be turned in by midnight on the due date. Late homework will be penalized 20% per day (exceptions and extensions permitted with good cause). Homeworks and exams may be physically handed in, or submitted as PDFs or JPGs via the course web site. Homework must be easy to read: please clearly write down your name and the problem set number, do not use a red pen.

## Attendance

There is no strict attendance requirement, but you are strongly advised to attend class. Attendance has a strong correlation with performance. I recommend that you read the book sections in advance and come ready to participate. If you miss an exam or cannot turn in homework, please inform me beforehand and get a doctor's note if applicable. Absences from tests count as zeros, unless they are justified. If you must be absent during a test for a University sponsored event, you must discuss this with me before the test date.

## Disability Access and Inclusion

The University of Mississippi is committed to the creation of inclusive learning environments for all students. If there are aspects of the instruction or design of this course that result in barriers to your full inclusion and participation, or to accurate assessment of your achievement, please contact the course instructor as soon as possible. Barriers may include, but are not necessarily limited to, timed exams and in-class assignments, difficulty with the acquisition of lecture content, inaccessible web content, and the use of non-captioned or non-transcribed video and audio files. If you are approved through SDS, you must log in to your Rebel Access portal at `https://sds.olemiss.edu` to request approved accommodations. If you are NOT approved through SDS, you must contact Student Disability Services at 662-915-7128 so the office can: 1) determine your eligibility for accommodations, 2) disseminate to your instructors a Faculty Notification Letter, 3) facilitate the removal of barriers, and 4) ensure you have equal access to the same opportunities for success that are available to all students.

## Academic Integrity

Violations of the University's policy of academic integrity will result in a failing grade and other disciplinary actions. A student with a documented case of plagiarism or cheating in this course will receive a failing grade for the course and may face disciplinary action by the University, including expulsion.

In particular, do not turn in problem set solutions copied from online or a solutions manual. Copying solutions does nothing to enhance your learning. If I see this then you will get an automatic 0 for the problem set. It if happens more than once I will report it to the chair of the department.

## Use of Generative Artificial Intelligence

Generative AI refers to technologies like ChatGPT or similar tools, that can draw on a large corpus of training data to create new written, visual, or audio content. The point of education is not just to correctly answer problems, but to deeply understand a topic for yourself. If you feel that generative AI helps you think for yourself and more deeply understand the material we are learning, I am not going to stop you from using it. Copying output from generative AI still constitutes plagiarism, and there is no guarantee that the tool is responding correctly (it is just like autocompletion). I therefore discourage you from using tools like OpenAI's ChatGPT, Google's Gemini, Microsoft's Copilot, Anthropic's Claude, etc.

## Other

If a change in the syllabus becomes necessary during the semester, it will be discussed in class and then posted on the course website. The course website will also contain up-to-date information on the class schedule, homework assignments, and complementary material.

## Schedule (subject to change)

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| M | Aug | 26 | Lecture 01: | Introduction and the Geometric Viewpoint on Physics |
| W | Aug | 28 | Lecture 02: | The Geometric Viewpoint on Physics continued |
| F | Aug | 30 | Lecture 03: | Introduction to Tensors |
| M | Sep | 02 | | Labor Day – Holiday |
| W | Sep | 04 | Lecture 04: | Tensors continued |
| F | Sep | 06 | Lecture 05: | Tensors continued |
| M | Sep | 09 | Lecture 06: | Volumes and Volume Elements; Conservation Laws |
| W | Sep | 11 | Lecture 07: | Conservation Laws continued |
| F | Sep | 13 | Lecture 08: | The Stress Energy Tensor |
| M | Sep | 16 | Lecture 09: | Christoffel Symbol |
| W | Sep | 18 | Lecture 10: | The Principle of Equivalence |
| F | Sep | 20 | Lecture 11: | The Principle of Equivalence continued |
| M | Sep | 23 | Lecture 12: | Parallel Transport |
| W | Sep | 25 | Lecture 13: | Lie Transport, Killing Vectors, Tensor Densities |
| F | Sep | 27 | Lecture 14: | Geodesics |
| M | Sep | 30 | Lecture 15: | Geodesics continued |
| W | Oct | 02 | Lecture 16: | Spacetime Curvature |
| F | Oct | 04 | Lecture 17: | Spacetime Curvature continued |
| M | Oct | 07 | Lecture 18: | Spacetime Curvature continued |
| W | Oct | 09 | Lecture 19: | The Einstein Field Equation |
| F | Oct | 11 | Lecture 20: | The Einstein Field Equation from the Action Principle |
| M | Oct | 14 | Lecture 21: | Linearized Gravity |
| W | Oct | 16 | Lecture 22: | Linearized Gravity continued |
| F | Oct | 18 | Lecture 23: | Linearized Gravity continued |
| M | Oct | 21 | Lecture 24: | Gravitational Radiation |
| W | Oct | 23 | Lecture 25: | Gravitational Radiation continued |
| F | Oct | 25 | Lecture 26: | Gravitational Radiation continued |
| M | Oct | 28 | Lecture 27: | Maximally Symmetric Spaces; Cosmology |
| W | Oct | 30 | Lecture 28: | Cosmology continued |
| F | Nov | 01 | Lecture 29: | Cosmology continued |
| M | Nov | 04 | Lecture 30: | Spherical Compact Sources |
| W | Nov | 06 | Lecture 31: | Spherical Compact Sources continued |
| F | Nov | 08 | Lecture 32: | Spherical Compact Sources continued |
| M | Nov | 11 | Lecture 33: | Black Holes |
| W | Nov | 13 | Lecture 34: | Black Holes continued |
| F | Nov | 15 | Lecture 35: | Black Holes continued |
| M | Nov | 18 | Lecture 36: | Overview of post-Newtonian theory |
| W | Nov | 20 | Lecture 37: | Overview of post-Newtonian theory continued |
| F | Nov | 22 | Lecture 38: | Overview of black hole perturbation theory |
| | | | | Nov 23–Dec 01 Thanksgiving Holidays |
| M | Dec | 02 | Lecture 39: | Overview of black hole perturbation theory continued |
| W | Dec | 04 | Lecture 40: | Overview of numerical relativity |
| F | Dec | 06 | Lecture 41: | Overview of numerical relativity continued |
| | | | | Dec 09–13 Final exams |

*=Leo has another responsibility (e.g. travel). So far, this schedule is just a suggested order. Please let me know about any holidays that I should be aware of (e.g. Eid, Yom Kippur, etc.).