

# Carleton University Physics Department

## PHYS 4804/5804 - Introduction to General Relativity

### Winter 2024 Course Outline

**Instructor:** Prof. Daniel Stolarski (he/him)

**Email:** stolar@physics.carleton.ca

**Office:** HP3320

**Schedule:** Monday & Wednesday, 10:05 A.M. - 11:25 A.M.

**Course delivery:** The course will consist of synchronous meetings that will follow an in person model where we will gather in our classroom. I will lead a discussion of the course material in a lecture style following the chalk-and-talk. Students are encouraged to ask questions and engage with the material during the lecture. These sessions are intended to be the primary method of course delivery and it is highly recommended that you attend these sessions except in the case of an emergency.

**Calendar Description:** Special relativity using tensor analysis. Curved spacetime with physics applications which may include the solar system, stars, black holes, and gravitational waves. Introduction to differential geometry and Einstein's field equations.

**Prerequisites:** PHYS 3802 (Advanced Dynamics), PHYS 3308 (Electromagnetism), and PHYS 3807 (Mathematical Physics), or permission of the Department.

**Course webpage:** See Brightspace

**Student Hours:** Student hours will be determined during the first week of the semester.

**Required Textbook:** James B. Hartle, "Gravity: An Introduction to Einstein's General Relativity," Addison Wesley, 2003.

**Inclusive teaching statement:**

Science is for everyone. I am committed to fostering an environment for learning that is inclusive for everyone regardless of gender identity, gender expression, sex, sexual orientation, race, ethnicity, ability, age, class, etc. All students in the class, the instructor, and any guests should be treated with respect during all interactions. It is my hope that our class will support diversity of experience, thought, and perspective. I will continually strive to create inclusive learning environments and would therefore appreciate your support and feedback. I welcome emails or in-person communications to let me know your preferred name or pronoun. Please see the Faculty of Science Equity, Diversity, and Inclusion (EDI) statement.

# Assignments and Grading

For undergraduates (PHYS 4804) the grades will be assigned as:

- Assignments - 50%
- Midterm - 20%
- Final - 30%.

For graduate students (PHYS 5804) the grades will be assigned as:

- Assignments - 40%
- Midterm - 15%
- Final - 25%
- Lecture Presentation - 20%.

Details for each of the components are given here.

## Assignments:

Assignments will be posted and submitted on Brightspace. Students can hand write their solutions and scan or photograph them to upload to the website. **Please upload a single pdf file.** In the first part of the course, assignments will be assigned weekly, and in the second part, they will be given every other week.

Working through problems is an essential part of developing a deep understanding of the subject as this material is heavily math based. **Students are permitted to discuss concepts and strategies related to solving the homework assignments; however, the work handed in must be their own.** Solutions showing significant overlap may have the mark divided by the number of people who provide that solution.

Viewing or searching for solutions in any form before your assignment is submitted is forbidden and will be considered an academic offence. This includes solution manuals, worked problems on the internet, AI generated solutions, solutions written by other students, and solutions provided by course instructors in previous years.

Late assignments will not be accepted without a legitimate reason, such as illness.

Students that are having significant difficulties with the material are encouraged to come see me during student hours. If the provided student hours do not work, accommodation can be made. Let me know as soon as possible, though, as I will not be able to accommodate last minute requests.

## Midterm Exam:

There will be an 80-minute, in-class midterm on February 14. The midterm will be open book and open notes.

In the case of an exam deferral for legitimate reasons, please inform me within 24 hours of the regularly scheduled midterm to arrange a time to write the deferred exam.

## **Final Exam:**

The final exam will be held during the final exam period in December, and will be 3 hours long. As with the midterm, it will be on brightspace and will be open book and open notes, but you may not use the internet (outside of the course web page) or consult with any other person. The final exam will focus on the material from the second half of the course.

In the event that a deferred exam is necessary, that exam will replace only the final exam component of the course mark, and will only be granted if adequate term work has been completed.

As noted above, the final may use remote Proctoring.

## **Lecture Presentation (5804 only):**

Graduate students will give a presentation on a topic from General Relativity not covered in class. Slides (such as powerpoint) are encouraged but not required. The presentations will be during the last week of classes, and will be 20 minutes long (subject to change depending on enrolment).

Possible topics include (but are not limited to):

- Solar system tests of GR
- Astrophysical black holes
- Numerical relativity
- de Sitter and anti-de Sitter spacetimes

Please email me your choice of topic by February 26. Topics will be given out on a first come first serve basis if multiple students try to choose the same topic. I am happy to provide references on any of the above topics.

## Course Outline

Below is a rough outline of the course, but it may change to fit the pace needed.

<b>Week</b>	<b>Textbook Chapters</b>	<b>Topic Description</b>
Jan 8	Chapters 1, 2	Geometry as Physics.
Jan 15	Chapters 3	Review of Newtonian Physics
Jan 22	Chapters 4,5	Review of special relativity.
Jan 29	Chapter 6	Gravity as Geometry
Feb 5	Chapter 7	Description of Curved Spacetime
Feb 12	Chapter 8	Geodesics
Feb 14		<b>Midterm</b>
Feb 19	Winter Break	No classes.
Feb 26	Chapter 9	Geometry Outside a Spherical Star
Mar 4	Chapter 12	Gravitational collapse and black holes
Mar 11	Chapter 16	Gravitational waves
Mar 18	Chapter 20	A little more math
Mar 25	Chapter 21	Curvature and Einstein's Equation
Apr 1	Chapter 21 (cont)	Curvature and Einstein's Equation
Apr 8	Eclipse!	No Class

### **Mental Health:**

Taking classes at university can be difficult and stressful. If you are struggling with your mental health, please do not hesitate to reach out. I can direct you to resources that might help. Remember that Carleton also offers an array of mental health and well-being resources, which can be found here.

## **Grade Definition:**

In accordance with the Carleton University Undergraduate Calendar Regulations, the letter grades assigned in this course will have the following percentage equivalents:

A+ = 90-100	A = 85-89	A- = 80-84
B+ = 77-79	B = 73-76	B- = 70-72
C+ = 67-69	C = 63-66	C- = 60-62
D+ = 57-59	D = 53-56	D- = 50-52
F < 50	WDN = Withdrawn from the course	

## **Academic Accommodations, Regulations, Plagiarism, Etc.**

Carleton University is committed to providing access to the educational experience in order to promote academic accessibility for all individuals. Academic accommodation refers to educational practices, systems and support mechanisms designed to accommodate diversity and difference. The purpose of accommodation is to enable students to perform the essential requirements of their academic programs. At no time does academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University. More information can be found [here](#).

University rules regarding registration, withdrawal, appealing marks, and most anything else you might need to know can be found on the university's website, [here](#).

## **Academic Accommodations for Students with Disabilities**

If you have a documented disability requiring academic accommodations in this course, please contact the Paul Menton Centre for Students with Disabilities (PMC) at 613-520-6608 or [pmc@carleton.ca](mailto:pmc@carleton.ca) for a formal evaluation or contact your PMC coordinator to send your instructor your Letter of Accommodation at the beginning of the term. You must also contact the PMC no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with your instructor as soon as possible to ensure accommodation arrangements are made. For more details, visit the Paul Menton Centre website.

## **Addressing Human Rights Concerns**

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at [equity@carleton.ca](mailto:equity@carleton.ca).

## **Religious Obligations**

Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation.

## **Survivors of Sexual Violence**

As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: <https://carleton.ca/sexual-violence-support/>.

## **Accommodations for Missed Work**

Carleton recognizes that these are unprecedented times during the COVID-19 pandemic, and that students may be experiencing greater stress and other life factors that are not in their control. As a result, Carleton has put into place a protocol for students to apply for accommodations using a self-declaration form in the event of missed work. The form can be found at: <https://carleton.ca/registrar/wp-content/uploads/self-declaration.pdf>.

## **For Pregnancy**

Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, please review the Student Guide to Academic Accommodation.

## **Accommodation for Student Activities**

Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see the Senate Policy on Accommodation for Student Activities.

## **Academic Integrity**

Academic misconduct undermines the values of honesty, trust, respect, fairness, and responsibility that we expect in this class. Carleton University provides supports such as academic integrity workshops to ensure, as far as possible, that all students understand the norms and standards of academic integrity that we expect you to uphold. Your teaching team has a responsibility to ensure that their application of the Academic Integrity Policy upholds the university's collective commitments to fairness, equity, and integrity. (adapted from Carleton University's Academic Integrity Policy, 2021). Examples of actions that do not adhere to Carleton's Academic Integrity Policy include:

- Plagiarism
- Accessing unauthorized sites for assignments or tests
- Unauthorized collaboration on assignment and exams

Students are expected to familiarize themselves with and follow the Carleton University Student Academic Integrity Policy. The Policy is strictly enforced and is binding on all students. For more information, please see Carleton's academic integrity page.

## **Course Copyright**

Classroom teaching and learning activities, including lectures, discussions, presentations, etc., by both instructors and students, are copyright protected and remain the intellectual property of their respective author(s). All course materials, including PowerPoint presentations, outlines, and other materials, are also protected by copyright and remain the intellectual property of their respective author(s). Students registered in the course may take notes and make copies of course materials for their own educational use only. Students are not permitted to reproduce or distribute lecture notes and course materials publicly for commercial or non-commercial purposes without express written consent from the copyright holder(s).

## **Assistance for Students**

Academic and Career Development Services  
Writing Services  
Peer Assisted Study Sessions (PASS)  
Science Student Success Centre

## **Important Dates:**

<https://calendar.carleton.ca/academicyear/>  
<https://carleton.ca/registrar/registration/dates/academic-dates/>