

Carleton University Physics Department  
PHYS 4804/5804 - Introduction to General Relativity  
Fall 2020 Course Outline

**Instructor:** Prof. Daniel Stolarski

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**Schedule:** Tuesdays & Thursdays, 10:05 A.M. - 11:25 A.M.

This course is an online course where there is a mixture of synchronous meetings and asynchronous activities. This means students need to be prepared to meet some of the time online via Big Blue Button at the scheduled days and times. The specific dates will be communicated on cuLearn. The tentative plan is to meet once per week, but this is subject to change. The asynchronous activities are intended to provide flexibility to students when the class is not meeting synchronously. Students are expected to remain up to date with the deadlines and due dates provided. These courses require reliable high-speed Internet access and a computer (ideally with a webcam), and a headset with a microphone. If there are issues with equipment, please email as soon as possible.

Web conferencing sessions in this course will be recorded and made available only to those within the class. Sessions are recorded to enable access to students with internet connectivity problems, who are based in different time zone, and/or who have conflicting commitments. If students wish not to be recorded, they need to leave the camera and microphone turned off. You will be notified at the start of the session when the recording will start. Please note that recordings are protected by copyright. The recordings are for your own educational use, but you are not permitted to publish to third party sites, such as social media sites and course materials sites. You may be expected to use the video and/or audio and/or chat during web conferencing sessions for participation and collaboration. **If you have concerns about being recorded, please email me.**

**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.

**Office Hours:** By email appointment.

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

**Course webpage:** See CULearn.

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

## Assignments and Grading

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

- Lecture questions - 10%
- Assignments - 30%
- Assignment Presentations - 20%
- Midterm - 15%
- Final - 25%.

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

- Lecture questions - 10%
- Assignments - 25%
- Assignment Presentations - 20%
- Midterm - 10%
- Final - 20%
- Lecture Presentation - 15%.

Details for each of the components are given here.

### Lecture Questions:

Each week there will be a series of lecture videos to watch. You will answer questions based on the videos. The questions are intended to be straightforward to answer if you watch the videos, or read the equivalent chapter of the textbook. One of the prompts will always be for you ask a question based on the lecture. This could be an aspect of the lecture you did not understand, or a follow up question of something you want explained further. Full credit will be given for any question related to the lecture videos or textbook sections.

The lecture questions will be done on cuLearn and must be completed one hour before the live lecture. The questions you ask will be answered during the synchronous lecture.

### Assignments:

Assignments will be posted and submitted on CULearn. Students can hand write their solutions and scan or photograph them to upload to cuLearn. **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, 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 schedule an appointment for virtual office hours. Please email me with sufficient notice as last minute requests will not be accommodated.

### **Assignment Presentation:**

Each student will present to the class two assignment solutions after they have completed the assignments. You will know when your presentations will be, but you may not be told which problem you will be asked to present. You will be marked based on the clarity of your solution as well as on how you answer questions from your peers.

### **Midterm Exam:**

There will be an 80-minute midterm during the class time on Oct 22. It will be administered the same way as the assignments, and after time is up you will have 20 minutes to scan and submit your solutions. If you have technical issues with submissions, please email me immediately.

The midterm will be open book and open notes, but you may not use the internet (outside of cuLearn) or consult with any other person.

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 cuLearn and will be open book and open notes, but you may not use the internet (outside of cuLearn) 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.

### **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
- Matter waves in a gravitational potential.

Please email me your choice of topic by November 3. 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>
Sept 10	Chapters 1, 2	Geometry as Physics.
Sept 15	Chapters 3	Review of Newtonian Physics
Sept 22	Chapters 4,5	Review of special relativity.
Sept 29	Chapter 6	Gravity as Geometry
Oct 6	Chapter 7	Description of Curved Spacetime
Oct 13	Chapter 8	Geodesics
Oct 20	Chapter 9	Geometry Outside a Spherical Star
Oct 22		Midterm
Oct 27	Fall Break	No classes.
Nov 3	Chapter 12	Gravitational collapse and black holes
Nov 10	Chapter 16	Gravitational waves
Nov 17	Chapter 20	A little more math
Nov 24	Chapter 21	Curvature and Einstein's Equation
Dec 1	Chapter 21 (cont)	Curvature and Einstein's Equation
Dec 8		Graduate Student Presentations
Dec 10	Final class	Review

## University policies

### 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	B+ = 77-79	C+ = 67-69	D+ = 57-59
A = 85-89	B = 73-76	C = 63-66	D = 53-56
A- = 80-84	B- = 70-72	C- = 60-62	D- = 50-52
F = <50			

WDN = Withdrawn from the course

ABS = Student absent from final exam

DEF = Deferred

Standing in a course is determined by the course instructor subject to the approval of the Faculty Dean. This means that grades submitted by the instructor may be subject to revision. No grades are final until they have been approved by the Dean.

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

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:

<http://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/>

### Academic Integrity

The University Senate defines plagiarism as “presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one’s own.” This can include:

- reproducing or paraphrasing portions of someone else’s published or unpublished material, regardless of the source, and presenting these as one’s own without proper citation or reference to the original source;
- submitting a take-home examination, essay, laboratory report or other assignment written, in whole or in part, by someone else;
- using ideas or direct, verbatim quotations, or paraphrased material, concepts, or ideas without appropriate acknowledgment in any academic assignment;
- using another’s data or research findings;
- failing to acknowledge sources through the use of proper citations when using another’s works and/or failing to use quotation marks;
- handing in “substantially the same piece of work for academic credit more than once without prior written permission of the course instructor in which the submission occurs.”

Plagiarism is a serious offence that cannot be resolved directly by the course’s instructor. The Associate Dean of the Faculty conducts a rigorous investigation, including an interview with the student, when an instructor suspects a piece of work has been plagiarized.

Penalties for plagiarism:

First offence: A grade of F in the course.

Second offence: A grade of F in the course and a one-term suspension from studies.

Third offence: Expulsion from the University.

Note: While these are the standard penalties, more severe penalties may be applied when warranted.

### **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).

### **Academic Accommodations**

Text from <https://students.carleton.ca/course-outline/>

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.

#### ***Pregnancy Obligation:***

Please contact your instructor 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, visit the Equity Services website

<https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf>

#### ***Religious Obligation:***

Please contact your instructor 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, visit the Equity Services website

<https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf>

#### ***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 <https://carleton.ca/pmc>

- The deadlines for contacting the Paul Menton Centre regarding accommodation for final exams for the Fall exam period is **November 13, 2020** and for the Winter exam period is **March 12, 2021**.

**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>

**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 your instructor 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 policy at <https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf>

**Assistance for Students:**

Career Services: <https://carleton.ca/career/>

Academic Advising: <https://carleton.ca/academicadvising/>

Co-operative Education: <https://carleton.ca/co-op/>

Centre for Student Academic Support: <https://carleton.ca/csas/>

Writing Services: <https://www.carleton.ca/csas/writing-services/>

Peer Assisted Study Sessions (PASS): <https://carleton.ca/csas/group-support/pass/>

Math Tutorial Centre: <https://carleton.ca/math/math-tutorial-centre/>

Science Student Success Centre: <https://sssc.carleton.ca/>

**Freedom of Information and Protection of Privacy:**

Carleton University is committed to protecting the privacy of those who study or work here (currently and formerly). To that end, Carleton's Privacy Office seeks to encourage the implementation of the privacy provisions of Ontario's *Freedom of Information and Protection of Privacy Act* (FIPPA) within the university.

In accordance with FIPPA, please ensure all email communication with staff/faculty is via your Carleton email account. To get your Carleton email you will need to activate your MyCarletonOne account through Carleton Central. Once you have activated your MyCarletonOne account, log into the MyCarleton Portal.

**Important Dates:**

<https://calendar.carleton.ca/academicyear/>

<https://carleton.ca/registrar/registration/dates-and-deadlines/>