

# Carleton University Physics Department

## PHYS 4804/5804 - Introduction to General Relativity

### Winter 2022 Course Outline

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

**Email:** [stolar@physics.carleton.ca](mailto:stolar@physics.carleton.ca)

**Schedule:** Monday & Wednesday, 8:35 A.M. - 9:55 A.M., Tory 342

The COVID-19 situation is rapidly evolving and thus the format of this course is subject to change throughout the semester. The plan as of January 7, 2022 is to have the course be fully online for the first three weeks, Jan 10 - 26, and then to transition to a HyFlex system where there are in person lectures which will be simulcast live via zoom. In both phases, this course will have **synchronous components**. This means students need to be prepared to meet some of the time online on zoom at the scheduled days and times. This course requires 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.

In the online phase of the course, there will be a mixture of synchronous meetings and asynchronous activities. The specific dates will be communicated on the course web page. 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.

Web conferencing sessions in this course will be recorded and made available only to those within the class. 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.**

Please note that tests and examinations in this course may use a remote proctoring service provided by Scheduling and Examination Services. You can find more information at [carleton.ca/ses/e-proctoring](http://carleton.ca/ses/e-proctoring).

The minimum computing requirements for this service are as follows:

- Hardware: Desktop, or Laptop
- OS: Windows 10, Mac OS 10.14, Linux Ubuntu 18.04
- Internet Browser: Google Chrome, Mozilla Firefox, Apple Safari, or Microsoft Edge
- Internet Connection (High-Speed Internet Connection Recommended)
- Webcam (HD resolution recommended)

Note: Tablets, Chromebooks and Smartphones are not supported at this time. Windows-based tablets are not supported at this time.

**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

**Teaching Assistant:** Carlos de Lima (he/him) CarlosHenriquedeLima@cmail.carleton.ca

**Student Hours**<sup>1</sup>: Carlos will have virtual office hours with the schedule to be determined. Prof. Stolarski's office hours are by email appointment. You can ask either Carlos or Prof. Stolarski questions about the material or assignment problems, but for questions about assignment marking, please contact Carlos.

**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 - 5%
- Assignments - 40%
- Midterm - 25%
- Final - 30%.

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

- Lecture questions - 5%
- Assignments - 35%
- Midterm - 20%
- Final - 25%
- Lecture Presentation - 15%.

Details for each of the components are given here.

### Lecture Questions:

Each week you are required to ask (at least) one question based on the lectures, and submit that question on brightspace. The questions are due **Fridays at 4 PM**. The questions should be from things that arise in lecture, and not based on the assignments. I will answer the questions during

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<sup>1</sup>Formerly called office hours, likely no longer in an office.

the Monday lectures.

## **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, 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.

## **Midterm Exam:**

There will be an 80-minute midterm during the class time on **Feb 16**. 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 the course web page) 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.

As noted above, the midterm may use remote Proctoring.

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

Please email me your choice of topic by March 7. 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.

| Week    | Textbook Chapters | Topic Description                      |
|---------|-------------------|--|
| Jan 10* | Chapters 1, 2     | Geometry as Physics.                   |
| Jan 17* | Chapters 3        | Review of Newtonian Physics            |
| Jan 24* | Chapters 4,5      | Review of special relativity.          |
| Jan 31  | Chapter 6         | Gravity as Geometry                    |
| Feb 7   | Chapter 7         | Description of Curved Spacetime        |
| Feb 14  | Chapter 8         | Geodesics                              |
| Feb 16  |                   | <b>Midterm</b>                         |
| Feb 21  | Winter Break      | No classes.                            |
| Feb 28  | Chapter 9         | Geometry Outside a Spherical Star      |
| Mar 7   | Chapter 12        | Gravitational collapse and black holes |
| Mar 14  | Chapter 16        | Gravitational waves                    |
| Mar 21  | Chapter 20        | A little more math                     |
| Mar 28  | Chapter 21        | Curvature and Einstein's Equation      |
| Apr 4   | Chapter 21 (cont) | Curvature and Einstein's Equation      |
| Apr 11  | Final class       | Review                                 |

\* Scheduled to be online.

### **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.

### **COVID-19 and the Classroom**

All members of the Carleton community are required to follow COVID-19 prevention measures and all mandatory public health requirements (e.g. wearing a mask, physical distancing, hand hygiene, respiratory and cough etiquette) and mandatory self-screening prior to coming to campus daily.

If you feel ill or exhibit COVID-19 symptoms while on campus or in class, please leave campus immediately, self-isolate, and complete the mandatory symptom reporting tool. For purposes of contact tracing, attendance will be taken in all classes and labs. Participants can check in using posted QR codes through the cuScreen platform where provided. Students who do not have a smartphone will be required to complete a paper process as indicated on the COVID-19 website.

All members of the Carleton community are required to follow guidelines regarding safe movement and seating on campus (e.g. directional arrows, designated entrances and exits, designated seats that maintain physical distancing). In order to avoid congestion, allow all previous occupants to fully vacate a classroom before entering. No food or drinks are permitted in any classrooms or labs.

For the most recent information about Carleton's COVID-19 response and required measures, please see the University's COVID-19 webpage and review the Frequently Asked Questions (FAQs). Should you have additional questions after reviewing, please contact [covidinfo@carleton.ca](mailto:covidinfo@carleton.ca)

Please note that failure to comply with University policies and mandatory public health requirements, and endangering the safety of others are considered misconduct under the Student Rights and Responsibilities Policy. Failure to comply with Carleton's COVID-19 procedures may lead to supplementary action involving Campus Safety and/or Student Affairs.

**Note about COVID-19 and Mental Health:** The global pandemic has led to extra stress and uncertainty for everyone, and while we may all be experiencing the same storm, this does not mean that we are all in the same boat! If you are struggling, 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 |            |
| ABS = Student absent from final exam | DEF = Deferred                  |            |

## **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)

Math Tutorial Centre

Science Student Success Centre

### **Important Dates:**

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

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