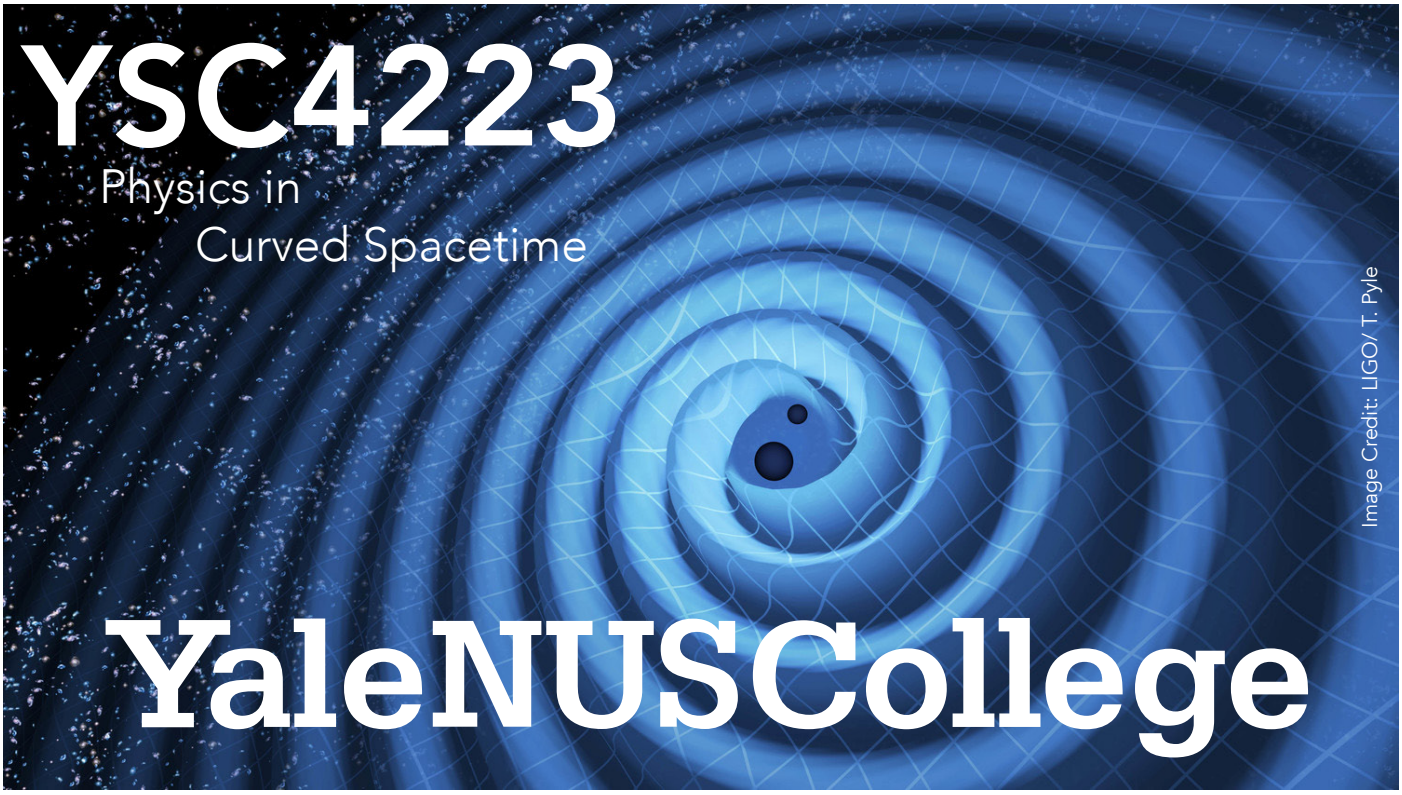


Semester 1, 2019/2020
9:00-10:20 Tue in Classroom 21
9:00-9:50 Thu in Classroom 21
16:00-17:20 Fri in Classroom 19

Instructor: Asst. Prof. Ben Andrew Olsen
Email: ben.olsen@yale-nus.edu.sg
Office: RC1-02-06A (Saga, 2nd floor)

Course Description

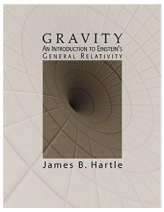
What is spacetime? How do objects move through spacetime? How do objects *change* spacetime? In this course, we will build conceptual and computational skills to understand the foundations of general relativity. Building from intuition and computational tools in flat spacetime, we will develop geometrical understanding in curved spacetime. Using these geometrical tools, we will explore gravitation, black holes, gravitational waves, and basics of cosmology.

Intended Learning Outcomes

- Explain relativistic phenomena like time dilation, length contraction, and geodesics
- Draw spacetime diagrams and use them to infer causality and calculate relativistic parameters
- Describe gravity using a Newtonian framework, and explain how it relates to the relativistic framework
- Explain the equivalence principle and its consequences
- Use the metric to calculate the motion of particles through flat and curved spacetime
- Calculate the effects of gravity on physics near the surface of the Earth, the sun, and a black hole
- Calculate physical properties using tensors and index notation

Required and supplementary texts

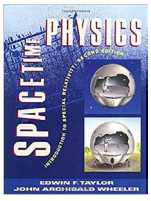
Required:



Gravity: An Introduction to Einstein's General Relativity
(James B. Hartle)
ISBN: 978-0805386622

See errata/resources at
http://web.physics.ucsb.edu/~gravitybook/

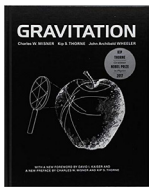
Supplementary/optional:



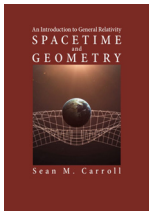
Special Relativity
Spacetime Physics
(Taylor & Wheeler)
ISBN: 978-0716723271
To help brush up on conceptual

physics in flat spacetime

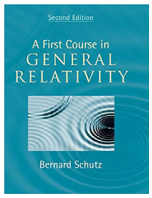
General Relativity (Advanced)
Gravitation
(Misner, Thorne & Wheeler)
ISBN: 978-0691177793
Graduate-level text with good diagrams and heavy emphasis on geometric reasoning



Spacetime and Geometry
(Sean M. Carroll)
ISBN: 978-1108488396
Graduate-level text with emphasis on differential geometry and calculations



A First Course in General Relativity
(Bernard Schutz)
ISBN: 978-0521887052
An alternative approach with more emphasis on tensor calculations



Assessment & Grading

Problem Sets	60%
Midterm Exam	15%
Infographic	10%
Final Exam	15%

(no curve)

A+	100% to 95%
A	< 95% to 90%
A-	< 90% to 85%
B+	< 85% to 80%
B	< 80% to 75%
B-	< 75% to 70%
C+	< 70% to 65%
C	< 65% to 60%
D+	< 60% to 55%
D	< 55% to 50%
F	< 50% to 0%

Problem Sets

There will be a problem set assigned on Friday each regular week of class. Problem sets are due at 9:00 the following Friday at the beginning of class. Solutions will be marked for correctness; show your reasoning. Students are encouraged to work together after attempting problems on their own, and **each student must submit their own work**. The lowest problem set score will be dropped.

Problem sets may be resubmitted up until the beginning of the next exam to earn up to half of the original missed points.

Midterm Exam

The midterm exam will be composed of a combination of theoretical, computational, and writing problems. Students will be provided with an equation sheet based on the midterm review session. The problems will be very similar to problem sets, so it will be beneficial to review those solutions and be able to reproduce them without notes.

Infographic

Due Thursday, Nov 14 in class; each student will present their graphic. Using one regular A4 sheet of paper (or its electronic equivalent), explain a topic from general relativity for a non-specialist audience. The graphic must convey a concise, interesting message and explain it with the appropriate level of technical detail. Milestones for the infographic (choice of topic, draft of message, etc.) will be in cluded in various problem sets.

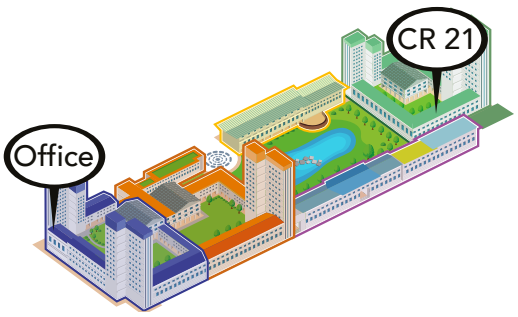
Final Exam

The final exam will be composed of a combination of theoretical, computational, and writing problems from the entire semester. Students will be provided with an equation sheet based on the final review session. The problems will be very similar to problem sets, so it will be beneficial to review those solutions and be able to reproduce them without notes.

Schedule of Topics

Week 1 Tue, Aug 13 Thu, Aug 15 Fri, Aug 17	Review of Gravity (Ch 1) Geometry (Ch 2) Newtonian Physics (Ch 3)	*Week 8* Tue, Oct 8 Thu, Oct 10 Fri, Oct 11	Gravitational Lensing (Ch 11)
Week 2 Tue, Aug 20 Thu, Aug 22 Fri, Aug 23	Special Relativity (Ch 4)	*Week 9* Tue, Oct 15 Thu, Oct 17 Fri, Oct 18	Black Holes (Chs 12-13)
Week 3 Tue, Aug 27 Thu, Aug 29 Fri, Aug 30	Special Relativistic Mechanics (Ch 5)	*Week 10* Tue, Oct 22 Thu, Oct 24 Fri, Oct 25	Mathematical Tools (Ch 20)
Week 4 Tue, Sep 3 Thu, Sep 5 Fri, Sep 6	Gravity & Geometry (Ch 6) *No Class* *No Class*	*Week 11* Tue, Oct 29 Thu, Oct 31 Fri, Nov 1	The Einstein Equation (Ch 21) Curving Spacetime (Ch 22)
Week 5 Tue, Sep 10 Thu, Sep 12 Fri, Sep 13	Curved Spacetime (Ch 7) Geodesics (Ch 8)	*Week 12* Tue, Nov 5 Thu, Nov 7 Fri, Nov 8	Gravitational Waves (Chs 16, 23)
Week 6 Tue, Sep 17 Thu, Sep 19 Fri, Sep 20	Geodesics, continued *Midterm Review* **Midterm Exam**	*Week 13* Tue, Nov 12 Thu, Nov 14 Fri, Nov 15	Cosmology (Ch 17) *Final Review*
Week 7 Tue, Oct 1 Thu, Oct 3 Fri, Oct 4	Spherical Stars (Ch 9) Tests of General Relativity (Ch 10)	Tue, Nov 26	**Final Exam**

- Chapters in parentheses are from Hartle
- Thursday sessions will generally be devoted to problem-solving practice
- Office hours: Physical Sciences Lounge, Tuesdays 17:30-19:00 in Classroom 2, Thursdays 17:30-19:00 in Classroom 3



Late Assignment Policy

Assignments will be considered late if they miss the deadline without an AD note or Medical Certificate from a Doctor. Late assignments will be penalized 10 % per day late. Students should request an extension at least one day in advance if they anticipate a scheduling conflict.

Attendance Policy

Students are expected to attend all classes. Students should notify the instructor as far in advance as possible of planned and unplanned absences.

Academic Integrity Policy

Yale-NUS College expects its students to abide by the highest standards of academic integrity as a matter of personal honesty and communal responsibility. Acting with academic integrity requires that

- students do their own work,
- students not interfere with the work of others,
- students accurately and honestly represent the content of their work, and
- students properly attribute others' work.

Violations of the College's academic integrity standards undermine both the community and the individual growth of students. Accordingly, they will be addressed with the utmost seriousness and sanctions ranging from grade penalties to expulsion. Examples of violations of academic integrity include plaigarism, copying or sharing homework answers, referencing solutions online or from previous versions of this course, submitting work completed for one course as "new" work for another course, or fabricating or falsifying research data. For more information, please visit the Student Services website, Policies and Procedures section: https://studentlife.yale-nus.edu.sg/policies/academic-integrity/

The Yale-NUS Library provides resources on citations and plaigarism here: http://library.yale-nus.edu.sg/plagiarism/

Learning Accommodations

Students who require academic accommodations must make arrangements through the Center for Teaching and Learning at https://teaching.yale-nus.edu.sg/student-support/learning-accommodation/. However, even if there are issues that are not officially recognized by the college, adjustments to the course may be possible that will benefit all students. You are encouraged to discuss ways to improve your learning with your instructor.

Nondiscriminatory Language and Conduct

This course encourages non-discriminatory language and conduct. Students should not use racist, sexist or other discriminatory language in class discussions or written work.

Course Modifications

During the course, it may make sense to modify the outlined schedule. The instructor reserves the right to modify elements of the course and will notify students accordingly (in class and posted to the course website).

Use of Online Elements

This course will use Canvas, and potentially Turnitin. Students should be aware that, when they access the electronic components of this course, private information such as first and last names, e-mail accounts, etc. may be apparent to the other students. Work evaluated with Turnitin will be added to a database for comparison. Continuation in this course will be deemed consent to these policies. Please direct questions or concerns to the instructor.