SH2374 General Relativity 7.5 credits - Period 4, Spring 2026, Academic Year 2025/2026

Examiner and course responsible

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Teachers

- Professor Tommy Ohlsson, lectures (14 x 2h.)
- Matthias Flór, exercises (10 x 2h.)

Literature

The course literature consists of the following books:

Guidry	Mike Guidry, *Modern General Relativity – Black Holes, Gravitational Waves, and Cosmology*, Cambridge (2019)
Blennow (MB)	Mattias Blennow, *Mathematical Methods for Physics and Engineering*, CRC Press (2018)
Blennow & Ohlsson (B&O)	Mattias Blennow and Tommy Ohlsson, *300 Problems in Special and General Relativity – With Complete Solutions*, Cambridge (2021)

Guidry will be used as the main course book. MB and B&O will be used for the exercises. Note that it is not necessary to have your own copy of MB.

Additional literature

Further recommended reading:

Carroll	Sean M. Carroll, *Spacetime and Geometry – An Introduction to General Relativity*, Cambridge (2019)
Cheng	Ta-Pei Cheng, *Relativity, Gravitation and Cosmology – A Basic Introduction*, 2nd ed., Oxford (2009)
Schutz	Bernard Schutz, *A First Course in General Relativity*, 3rd ed., Cambridge (2022)
Wald	Robert M. Wald, *General Relativity*, Chicago (1984)

Carroll, Cheng, Schutz, and Wald can be used as alternative books to Guidry or as complements.

Course contents

- Manifolds. Local coordinates on manifolds. Covariant and contravariant vectors and tensors. Transformation properties of tensors. Vector fields. (Pseudo-) Riemann metric.
- Covariant derivatives (Christoffel symbols and Levi-Civita connection). Parallel transport and geodesics. Curved spaces. Lie derivatives and Killing vector fields.
- Basic concepts and principles in general relativity. Rindler coordinates.
- The Schwarzschild solution. Eddington–Finkelstein coordinates. Kruskal–Szekeres coordinates.
- Experimental tests of general relativity.
- Einstein's field equations.
- The Einstein–Hilbert action. The energy-momentum tensor.
- The weak field approximation.
- Gravitational lensing. Gravitational waves.
- Introductory cosmology (including the Friedmann–Lemaître–Robertson–Walker metric), including inflation and dark energy.

About the lectures, the exercises, the quizzes, and the final exam

The material presented in the lectures is based on similar material that is covered in the books by Guidry, Carroll, Cheng, Schutz, and Wald. Lecture notes will be posted on Canvas after each lecture. Note that the material for the first five lectures is extensive, and the lecturer will not be able to present all material at these lectures, but it will be included in the lecture notes.

The exercises are based on problem solving. The teaching assistant will present the problems and their solutions to some of the listed problems during the exercises (about four problems at each exercise). All listed problems are also given as PDF files with problem statements and solutions on Canvas. For the listed problems that are not solved during the exercises, you are encouraged to solve them on your own. For some exercises, there are also listed some additional problems that are not posted as PDF files on Canvas.

The course will be examined through continuous examination. During the course, there will be four scheduled one-hour quizzes with six conceptual questions and/or smaller problems each. Each quiz can give up to 10 % of the total examination score, which means that all four quizzes can give up to 40 % of the total examination score. At the end of the course, there will be a final written exam consisting of six full computational problems (similar to the problems that are solved during the exercises). The final written exam can give up to 60 % of the total examination score. In order to pass the course (and the examination TEN1), you need to achieve at least 50 % of the total examination score. This means that the quizzes are not mandatory, i.e. you can pass the course without the quizzes. However, you cannot pass the course without the final written exam, i.e. the final written exam is a requirement. Please see *Examination* and *Grades*.

Examination

			Examination score
Q1	Quiz 1	6 conceptual questions and smaller problems	10 %
Q2	Quiz 2	6 conceptual questions and smaller problems	10 %
Q3	Quiz 3	6 conceptual questions and smaller problems	10 %
Q4	Quiz 4	6 conceptual questions and smaller problems	10 %
FE	Final written exam	6 full computational problems	60 %
			100 %

Each quiz is given at a specific occasion for one hour on Canvas (using *Safe Exam Browser*) in a particular room and only one time during the academic year. The results of the quizzes are valid during the whole academic year. The final written exam will be given twice during the academic year.

Grades

Grade	*Examination score*
A	≥ 90 %
B	≥ 80 %
C	≥ 70 %
D	≥ 60 %
E	≥ 50 %
F	< 50 %

If you do not have any results from the quizzes, then the highest grade that you can obtain in the course is D. Since the highest result on the quizzes corresponds to 40 %, you cannot pass the course without taking the final written exam.

Good luck with the course!

Lecture, exercise, quiz, and final exam plan

L = lecture, E = exercise, Q = quiz, FE = final exam

L1 [Mon. 16/3, 10–12; FB55] Manifolds. Local coordinates on manifolds. Covariant and contravariant vectors and tensors. Transformation properties of tensors. Vector fields. (Pseudo-) Riemann metric.
Recommended reading: Guidry Chapter 2, 3.1–3.12, 3.14; Carroll 1.4–1.7, 2.1–2.5; Cheng 5.2, 13.1.1; Schutz Chapter 5, 6.1–6.2; Wald Chapter 2, Appendix A, C.1

L2 [Wed. 18/3, 10–12; FB55] L1 (continued).

E1 [Fri. 20/3, 08–10; FD41] MB 1.50, 2.10, 2.20, 2.21, 2.29, 9.1, 9.4, 9.7, 9.9, 9.10 (10 problems)
Additional problems: MB 2.1, 2.12, 2.26, 9.2, 9.3, 9.5, 9.11

L3 [Mon. 23/3, 10–12; FB55] Covariant derivatives (Christoffel symbols and Levi-Civita connection). Parallel transport and geodesics.
Recommended reading: Guidry 3.13, 7.4; Carroll 3.2–3.5, 2.6–2.10; Cheng 13.1.2–13.1.3, 13.2; Schutz 6.3–6.4; Wald 3.1, 3.3, C.2

L4 [Wed. 25/3, 10–12; FB55] Curved spaces. Lie derivatives and Killing vector fields.
Recommended reading: Guidry 7.5–7.8, 8.4, 5.6; Carroll 3.6–3.10; Cheng 5.3, 13.3; Schutz 6.5–6.7, 7.4, 7.6; Wald 3.2, 3.4, C.3

E2 [Fri. 27/3, 10–12; FB55] B&O Some differential geometry 2.5, 2.9, 2.15, Christoffel symbols, … 2.33, 2.45 (5 problems)
Additional problems: MB 9.14, 9.15, 9.16, 9.17, 9.18, 9.19, 9.21, 9.24, 9.25, 9.26, 9.27, 9.29, 9.34, 9.35, 9.36; B&O 2.35, 2.39, 2.50

Q1 [Fri. 27/3, 13–14; FD41] Quiz 1 (based on lectures L1–L4 and exercises E1–E2)

L5 [Mon. 30/3, 10–12; FB55] Basic concepts and principles in general relativity. Rindler coordinates. The Schwarzschild solution.
Recommended reading: Guidry 7.1–7.2, 6.1–6.3, 9.1; Carroll 4.1, 4.7, 5.1–5.2; Cheng 6.1, 7.1; Schutz 7.1–7.3, 10.1; Wald 1.3–1.4, 4.1, 6.1

L6 [Tue. 31/3, 10–12; FB55] The Schwarzschild solution (continued). Eddington–Finkelstein coordinates. Kruskal–Szekeres coordinates.
Recommended reading: Guidry 9.3, 11.1–11.4; Carroll 5.3–5.4, 5.6–5.7, 6.1–6.3; Cheng 8.1–8.2, 14.1, 14.3, Schutz 10.2, 10.4–10.6, 11.2; Wald 6.2, 6.4, Chapter 9

E3 [Thu. 2/4, 10–12; FB51] B&O Killing vector fields 2.63, 2.65, Schwarzschild metric 2.72, 2.73 (4 problems)
Additional problem: B&O 2.69

L7 [Mon. 13/4, 10–12; FB55] Experimental tests of general relativity.
Recommended reading: Guidry 6.4–6.5, 9.2, 9.4–9.8; Carroll 5.5; Cheng 7.3.1, 8.3; Schutz 10.7, 11.1; Wald 6.3

E4 [Tue. 14/4, 09–11; FD41] B&O Frequency shifts 2.125, Metrics, … 2.97, 2.98, Schwarzschild metric 2.76 (4 problems)
Additional problems: B&O 2.108, 2.126

Q2 [Tue. 14/4, 11–12; FD41] Quiz 2 (based on lectures L5–L7 and exercises E3–E4)

L8 [Fri. 17/4, 10–12; FB55] Einstein's field equations. The Einstein–Hilbert action. The energy-momentum tensor.
Recommended reading: Guidry 8.5, 7.3; Carroll 4.2–4.6, 5.8; Cheng 14.2; Schutz 8.1–8.2, 10.3; Wald 4.3

E5 [Fri. 17/4, 13–15; FB55] B&O Some differential geometry 2.16, Christoffel symbols, … 2.41, Metrics, … 2.78, 2.93 (4 problems)
Additional problems: B&O 2.79, 2.80

L9 [Mon. 20/4, 10–12; FB55] The weak field approximation.
Recommended reading: Guidry 8.1–8.3, 8.6–8.8, 22.2; Carroll 7.1–7.3; Cheng 6.2–6.3, 15.1–15.2; Schutz 8.3–8.4; Wald 4.4

E6 [Mon. 20/4, 13–15; FB55] B&O Maxwell's equations … 2.53, 2.59, Weak field … 2.116, 2.118 (4 problems)
Additional problems: B&O 2.57, 2.58, 2.114

L10 [Wed. 22/4, 10–12; FB51] Gravitational lensing. Gravitational waves.
Recommended reading: Guidry 17.7, 9.9, 22.1, 22.3–22.6; Carroll 8.6, 7.4–7.7; Cheng 7.2, 7.3.2, 15.3–15.4; Schutz Chapters 9, 12; Wald 6.3, 4.4

E7 [Wed. 22/4, 13–15; FB51] B&O Gravitational lensing 2.119, Metrics, … 2.82, Gravitational waves 2.133 (3 problems)
Additional problem: B&O 2.135

Q3 [Fri. 24/4, 09–10; FD41] Quiz 3 (based on lectures L8–L10 and exercises E5–E7)

L11 [Mon. 27/4, 10–12; FA31] Introductory cosmology (including the Friedmann–Lemaître–Robertson–Walker metric), including inflation and dark energy.
Recommended reading: Guidry 16.1–16.2, 17.1–17.5, 17.11–17.13, Chapters 18, 19, 21.3; Carroll 8.1–8.5, 8.7–8.8; Cheng 9.1, 9.3–9.4, 10.1–10.3, 11.1–11.5, 14.4; Schutz Chapter 13; Wald Chapter 5

L12 [Tue. 28/4, 10–12; FB55] L11 (continued).

E8 [Wed. 29/4, 10–12; FB51] B&O Metrics, … 2.81, 2.103, Cosmology … 2.146 (3 problems)
Additional problems: B&O 2.131; Guidry 19.1, 19.2, 19.6

L13 [Mon. 4/5, 10–12; FB55] L12 (continued).

E9 [Mon. 4/5, 13–15; FB55] B&O Cosmology … 2.144, 2.147, 2.149 (3 problems)
Additional problems: B&O 2.148; Guidry 21.2, 21.5

Q4 [Mon. 4/5, 15–16; FB55] Quiz 4 (based on lectures L11–L13 and exercises E8–E9)

L14 [Wed. 6/5, 10–12; FB55] Extra

E10 [Wed. 6/5, 13–15; FB55] Additional problem solving

FE [Tue. 26/5, 08–13; FB55, FD41] Final written exam