

## SYLLABUS

### Course

This course covers special relativity in more detail than a Modern Physics course does, and gives an introduction to general relativity and differential geometry. These topics have a reputation for being mathematically intense, but we will cover the basics in an accessible way starting from junior high school concepts like map projections and the law of cosines. By the end of this course, you should be able to solve problems on topics in special and general relativity such as time dilation, redshifts, particle orbits, and gravitational waves, as well as basic entities in differential geometry such as proper volumes and geodesics.

Course materials can be found on Blackboard.

### The double standard

Although this course is listed as undergraduate, it is really a combination of graduate and undergraduate course material and both types of students are taking it. Grad students will have more reading and more problems to do. In class I will indicate what material is grad-oriented, generally chapter numbers in the 20s. Sometimes it will be whole lectures, sometimes a brief aside. Undergrads are expected to follow those lectures, but will not be assigned problems based on them. Grad-only problems will be clearly indicated.

### Instructor

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Office hours: Tu 12:30-1:30, Th 11:30-12:30, and by appointment

I do research on gravitational waves, particularly as probes of neutron stars. The textbooks are all out of date on this topic since it is developing fast, so I will give you an updated overview of it.

### Reading

The required textbook is *Gravity: An Introduction to Einstein's Relativity* by James B. Hartle, which is commonly used in both grad and undergrad courses. It does a great job of covering the basics starting from mathematically simple foundations. We will cover the early, crucial parts and selected topics from the advanced parts.

Other textbooks may help. A more mathematically advanced textbook (at the United Kingdom undergraduate level) is *A First Course in General Relativity* by Bernard F. Schutz, which is not required but may be fitting for math majors and double majors. Common graduate textbooks with a modern (set theory) version of differential geometry are by Sean Carroll and Robert Wald.

## Grading

Your grade comes entirely from homework, which is due at 11:59pm on Blackboard on the days indicated in the schedule below. I will grade it up to a week late for half credit. Last minute work is dangerous thanks to network hiccups, etc, not to mention the risk of not understanding the material and not having time for questions. You can scan or take a good photo of your handwritten solutions, or LaTeX them or otherwise make a PDF. You will be graded on your presentation as well as the correctness of your answers, just like in the outside world when you need to explain what you've done to your boss or other stakeholders.

The conversion from total percentage scores to letter grades is 80%/70%/60% for A/B/C.

You are welcome to discuss and work with your colleagues, but the final writeup needs to be your own. You are welcome to use Wolfram and similar tools to do integrals (note that in your writeup), but be careful of Wikipedia and random stuff on the internet. It can be useful with filtering, but can also be garbage. There is no such thing as artificial intelligence, and the large language models that are advertised as artificial intelligence are basically like random internet searches.

## Schedule

Here is the tentative schedule of lectures and readings. Any changes will be announced in class and this document will be updated on Blackboard.

I recommend skimming the reading before class, then hitting it more carefully after we have discussed it in class. In class I point you toward highlights and mention some things not covered in the book, but the book has some details we do not have time for in class. You need both to get a thorough idea of the subject.

Date	Section(s)	Topics
Aug. 28	Syllabus, Ch. 1, App. A	Overview, natural units
Sep. 2	2.1–2.5	Gravity as geometry, line element
Sep. 4	2.5–3.3	Line element, Newtonian gravity
Sep. 9	3.4–4.3	Lagrangians, velocity addition, spacetime HOMEWORK #1 DUE
Sep. 11	4.4–5.1	Time dilation, length contraction, 4-vectors
Sep. 16	5.1–5.5	4-vector mechanics, massless particles HOMEWORK #2 DUE
Sep. 18	5.4–6.3	Light
Sep. 23	6.4–6.6	(Post-)Newtonian gravity HOMEWORK #3 DUE
Sep. 25	7.1–7.4	Curved spacetime, metric
Sep. 30	7.5–7.6, 7.8–7.9	Light cones, volumes, vectors, surfaces HOMEWORK #4 DUE
Oct. 2	7.7, 8.1–8.4	Embedding diagrams, geodesics
Oct. 7	20.1, 20.2, 20.3	Vectors, dual vectors, tensors HOMEWORK #5 DUE
Oct. 9	20.4	Covariant (and other) derivatives

Oct. 14	21.1–21.3	Tides and curvature HOMEWORK #6 DUE
Oct. 16	21.4–21.5	Einstein equations in vacuum
Oct. 21	9.1, 9.2	Schwarzschild geometry HOMEWORK #7 DUE
Oct. 23	9.3	Orbits of massive particles
Oct. 28	9.4	Orbits of massless particles HOMEWORK #8 DUE
Oct. 30	11.1–11.3	Relativity in action
Nov. 4	12.1–12.3	Black hole basics HOMEWORK #9 DUE
Nov. 6	13.1–13.3	Real black holes
Nov. 11	14.1–14.6	Spins in general HOMEWORK #10 DUE
Nov. 13	15.1–15.4	Rotating black holes
Nov. 18	16.1–16.5	Gravitational wave theory HOMEWORK # 11 DUE
Nov. 20	—	Gravitational wave observations
Nov. 25	22.1–22.4	Einstein equations with matter HOMEWORK # 12 DUE
Nov. 27	NO CLASS	THANKSGIVING
Dec. 2	23.1–23.6	Linearized gravity, quadrupole formula
Dec. 4	24.2, —	Neutron stars
Dec. 9	18.1–18.5	Cosmology, quantum gravity HOMEWORK # 13 DUE
Dec. 16	—	NO CLASS (FINAL SLOT) HOMEWORK # 14 DUE

## Academic Integrity

Academic integrity is an important value at UMBC. By enrolling in this course, each student assumes the responsibilities of an active participant in UMBC's scholarly community in which everyone's academic work and behavior are held to the highest standards of honesty. Cheating, fabrication, plagiarism, and helping others to commit these acts are all forms of academic dishonesty, and they are wrong. Academic misconduct could result in disciplinary action that may include, but is not limited to, suspension or dismissal.

The purposes of higher education are the learning students and faculty undertake, the knowledge and thinking skills developed, and the enhancement of personal qualities that enable students to be strong contributing members of society. In a competitive world, it is essential that all members of the UMBC community uphold a standard that places integrity of each student's honestly earned achievements above higher grades or easier work dishonestly sought.

## **Accessibility and Disability Accommodations, Guidance and Resources**

Accommodations for students with disabilities are provided for all students with a qualified disability under the Americans with Disabilities Act (ADA & ADAAA) and Section 504 of the Rehabilitation Act who request and are eligible for accommodations. The Office of Student Disability Services (SDS) is the UMBC department designated to coordinate accommodations that creates equal access for students when barriers to participation exist in University courses, programs, or activities.

If you have a documented disability and need to request academic accommodations in your courses, please refer to the SDS website at [sds.umbc.edu](https://sds.umbc.edu) for registration information and office procedures.

SDS email: [disAbility@umbc.edu](mailto:disAbility@umbc.edu)

SDS phone: 410-455-2459

If you will be using SDS approved accommodations in this class, please contact the instructor to discuss implementation of the accommodations. During remote instruction requirements due to COVID, communication and flexibility will be essential for success.

## **Sexual Assault, Sexual Harassment, and Gender Based Violence and Discrimination**

UMBC Policy in addition to federal and state law (to include Title IX) prohibits discrimination and harassment on the basis of sex, sexual orientation, and gender identity in University programs and activities. Any student who is impacted by sexual harassment, sexual assault, domestic violence, dating violence, stalking, sexual exploitation, gender discrimination, pregnancy discrimination, gender-based harassment, or related retaliation should contact the University's Title IX Coordinator to make a report and/or access support and resources. The Title IX Coordinator can be reached at [titleixcoordinator@umbc.edu](mailto:titleixcoordinator@umbc.edu) or 410-455-1717.

You can access support and resources even if you do not want to take any further action. You will not be forced to file a formal complaint or police report. Please be aware that the University may take action on its own if essential to protect the safety of the community.

If you are interested in making a report, please use the Online Reporting/Referral Form. Please note that, if you report anonymously, the University's ability to respond will be limited.

## **Notice that Faculty and Teaching Assistants are Responsible Employees with Mandatory Reporting Obligations**

All faculty members and teaching assistants are considered Responsible Employees, per UMBC's Policy on Sexual Misconduct, Sexual Harassment, and Gender Discrimination. Faculty and teaching assistants therefore required to report all known information regarding alleged conduct that may be a violation of the Policy to the Title IX Coordinator, even if a student discloses an experience that occurred before attending UMBC and/or an incident that only involves people not affiliated with UMBC. Reports are required regardless of the

amount of detail provided and even in instances where support has already been offered or received.

While faculty members want to encourage you to share information related to your life experiences through discussion and written work, students should understand that faculty are required to report past and present sexual harassment, sexual assault, domestic and dating violence, stalking, and gender discrimination that is shared with them to the Title IX Coordinator so that the University can inform students of their rights, resources, and support. While you are encouraged to do so, you are not obligated to respond to outreach conducted as a result of a report to the Title IX Coordinator.

If you need to speak with someone in confidence, who does not have an obligation to report to the Title IX Coordinator, UMBC has a number of Confidential Resources available to support you:

Retriever Integrated Health (Main Campus): 410-455-2472; Monday – Friday 8:30 a.m. – 5 p.m.; For After-Hours Support, Call 988.

Center for Counseling and Well-Being (Shady Grove Campus): 301-738-6273; Monday-Thursday 10:00a.m. – 7:00 p.m. and Friday 10:00 a.m. – 2:00 p.m. (virtual) Online Appointment Request Form

Pastoral Counseling via The Gathering Space for Spiritual Well-Being: 410-455-6795; i3b@umbc.edu; Monday – Friday 8:00 a.m. – 10:00 p.m.

## **Other Resources**

Women’s Center (open to students of all genders): 410-455-2714; womenscenter@umbc.edu; Monday – Thursday 9:30 a.m. – 5:00 p.m. and Friday 10:00 a.m. – 4 p.m.

Shady Grove Student Resources, Maryland Resources, National Resources.

## **Child Abuse and Neglect**

Please note that Maryland law and UMBC policy require that faculty report all disclosures or suspicions of child abuse or neglect to the Department of Social Services and/or the police even if the person who experienced the abuse or neglect is now over 18.

## **Pregnant and Parenting Students**

UMBC’s Policy on Sexual Misconduct, Sexual Harassment and Gender Discrimination expressly prohibits all forms of discrimination and harassment on the basis of sex, including pregnancy. Resources for pregnant, parenting and breastfeeding students are available through the University’s Office of Equity and Civil Rights. Pregnant and parenting students are encouraged to contact the Title IX Coordinator to discuss plans and ensure ongoing access to their academic program with respect to a leave of absence – returning following leave, or any other accommodation that may be needed related to pregnancy, childbirth, adoption, breastfeeding, and/or the early months of parenting.

In addition, students who are pregnant and have an impairment related to their pregnancy that qualifies as disability under the ADA may be entitled to accommodations through the Office of Student Disability Services.

## **Religious Observances and Accommodations**

UMBC Policy provides that students should not be penalized because of observances of their religious beliefs, and that students shall be given an opportunity, whenever feasible, to make up within a reasonable time any academic assignment that is missed due to individual participation in religious observances. It is the responsibility of the student to inform the instructor of any intended absences or requested modifications for religious observances in advance, and as early as possible. For questions or guidance regarding religious observances and accommodations, please contact the Office of Equity and Civil Rights at [ecr@umbc.edu](mailto:ecr@umbc.edu).

## **Hate, Bias, Discrimination and Harassment**

UMBC values safety, cultural and ethnic diversity, social responsibility, lifelong learning, equity, and civic engagement.

Consistent with these principles, UMBC Policy prohibits discrimination and harassment in its educational programs and activities or with respect to employment terms and conditions based on race, creed, color, religion, sex, gender, pregnancy, ancestry, age, gender identity or expression, national origin, veterans status, marital status, sexual orientation, physical or mental disability, or genetic information.

Students (and faculty and staff) who experience discrimination, harassment, hate, or bias based upon a protected status or who have such matters reported to them should use the online reporting/referral form to report discrimination, hate, or bias incidents. You may report incidents that happen to you anonymously. Please note that, if you report anonymously, the University's ability to respond may be limited.