Lahore University of Management Sciences

PHY 442 MATH 466 PHY 642 - General Relativity

(نظریۂ عمومی اضافیت)

Spring 2024

Instructor	Moeez Hassan
Room No.	9-111A
Office Hours	After every class + TBA; or by appointment
Email	syed_hassan@lums.edu.pk
TA	TBA
TA Office Hours	TBA
Course URL (if any)	LMS

Course Teaching Methodology
• Teaching Methodology: Lectures will be in-person on-campus. All Covid related SOPs are to be strictly followed in the classroom. Unless medically exempted, all students sitting in the class must be fully vaccinated (i.e., they must have received the final dose of their vaccine at least 14 days prior to the start of classes).

Course Basics				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	75 minutes
Recitation/Lab (per week)	Nbr of Lec(s) Per Week		Duration	
Tutorial (per week)	Nbr of Lec(s) Per Week		Duration	

Course Distribution	
Core	No
Elective	Yes
Open for Student Category	
Close for Student Category	None

COURSE DESCRIPTION
It is a mathematical introduction to general relativity (A knowledge of special relativity and tensors is assumed). The course also covers basic ideas of differential geometry, and provides a brief introduction to some applications like cosmology, gravitational waves and black holes.

COURSE PREREQUISITE(S)	
•	For PHY 442: PHY 404 – Relativistic Electrodynamics.
•	For MATH 466: PHY 404 – Relativistic Electrodynamics OR Instructor's Permission.
•	For PHY 642: PHY 504 – Relativistic Electrodynamics with a grade of B+ or above OR Instructor's Permission.
	A pre-requisite knowledge of *multivariable calculus, special relativity, tensors (and tensor algebra including the index notation), and some classical mechanics (including Newtonian Gravity, Kepler's Laws etc.)* will be assumed.

COURSE OBJECTIVES	
•	The aim of this course is to develop a mathematical and physical understanding of general relativity. Starting from special relativity and the equivalence principle; and leading up to a geometric formulation of gravity through Einstein's equations. This course will also provide an introduction to basic ideas in differential geometry along the way. The course then moves on to a discussion of some of the important applications of GR, namely black holes, gravitational waves and elementary cosmology.

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Course Learning Outcomes	
	Students should be able to: 1. Understand the physical principles behind the theory of relativity. 2. Solve problems related to curved geometry. 3. Appreciate the geometrical formulation of general relativity and apply it. 4. Understand some important applications of GR – part 1 – Black holes. 5. Understand some important applications of GR – part 2 – Cosmology, gravitational waves.

Grading Breakup and Policy

Component	Weightage	Description

Assignments	20%	• Approximately 1 each week.
		• There will be an N/2 policy (top half of your hws will count).
		• Late Submissions: Not allowed.
		• HW grading scheme (0, 1 or 2 points for each problem):
		  ○ 2 points: Problem solved completely and correctly with margin for a minor error.
		  ○ 1 point: Problem incomplete, multiple minor errors, or a major error.
		  ○ 0 points: Problem not attempted, multiple major errors, or an incoherent solution.

Project	30%	• A final project consisting of a **Presentation (15%)** and **Final Report (15%)**. • Deadline to decide the project: • Final report submission deadline: • Presentations will be held in the last two classes. Additional sessions may be scheduled depending on enrollment. Depending on the class size, the duration of presentations will be 10-20 minutes plus questions.
Final Exam	50%	• Comprehensive final exam. • Closed book, closed notes. • Currently scheduled for

- The instructor reserves the right to vary these grade assignments or add new instruments by upto 10%.
- Graduate students (enrolled in PHY 642) must demonstrate that they have worked extra (beyond the undergraduate level) through their project (report and presentation).
- In the event that the course has to be shifted online, this grading breakup (and the details) may be substantially revised.
- **University policy for cheating/unfair means will be applicable on <u>all</u> grading instruments. You must submit your own work. If any evidence of plagiarism is found, these cases will be forwarded straight to the School DC.**

<u>COURSE POLICIES (READ CAREFULLY):</u>

- All Covid related SOPs are to be strictly followed in the classroom. Unless medically exempted, all students sitting in the class must be fully vaccinated (i.e., they must have received the final dose of their vaccine at least 14 days prior to the start of classes).
- **All emails** sent to the instructor or TAs must have a **subject line** of the following format (examples):
  "PHY 442--subject line"
- **All emails** must be signed with name and **roll-number**.
- If you email me asking me a question that is already answered in the outline, I will not answer your email.
- All announcements will be posted on LMS (with an email notification). **It is your responsibility** to regularly check the LMS site for this course.
- Please come on time. No talking/disturbance during class. No cell-phones, laptops etc. during class.
- **An approved petition from the OSA will be required for any missed components.**

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Examination Detail	
Midterm Exam	Yes/No: **No** Combine Separate: Duration: Preferred Date: Exam Specifications:
Final Exam	Yes/No: **Yes** Combine Separate: Duration: 3 hours Exam Specifications: **Closed book/notes**

COURSE OVERVIEW

Lecture	Topics	Recommended Readings	Objectives/ Application
1-3	Accelerated Motion in special relativity and equivalence principle	**Class notes; Schutz Ch 5**	**CLO 1**
4-9	Manifolds, Curvature	**Carroll Ch 3; Schutz Ch 5, 6**	**CLO 2**
10-12	Einstein's equations and their weak field (Newtonian) limit	**Carroll Ch 4; Schutz Ch 7, 8**	**CLO 2, 3**
13-16	Black holes, experimental tests	**Blau Ch 25 - 26; Carroll Ch 5**	**CLO 3, 4**
17-18	Mids week		
19-22	Cosmology	**Blau Ch 33 – 37 (Selected sections); Carroll Ch 8**	**CLO 3, 5**
23-26	Gravitational waves	**Blau Ch 23; Carroll Ch 7**	**CLO 5**
27-28	Presentations		

Textbook(s)/Supplementary Readings

An Introduction to General Relativity by Sean Carroll [Primary]
Lecture Notes on General Relativity by Matthias Blau (Available at: http://www.blau.itp.unibe.ch/GRLecturenotes.html) [Secondary]

Supplementary:
A First Course in General Relativity by Bernard Schutz
Gravity: An Introduction to Einstein's general relativity by James Hartle
General Relativity by Robert Wald [Advanced]

Academic Honesty

The principles of truth and honesty are recognized as fundamental to a community of teachers and students. This means that all academic work will be done by the student to whom it is assigned without unauthorized aid of any kind. Plagiarism, cheating and other forms of academic dishonesty are prohibited. Any instances of academic dishonesty in this course (intentional or unintentional) will be dealt with swiftly and severely. Potential penalties include receiving a failing grade on the assignment in question or in the course overall. For further information, students should make themselves familiar with the relevant section of the LUMS student handbook.

Harassment Policy

SSE, LUMS and particularly this class, is a harassment free zone. There is absolutely zero tolerance for any behaviour that is intended, or has the expected result of making anyone uncomfortable and negatively impacts the class environment, or any individual's ability to work to the best of their potential.

In case a differently-abled student requires accommodations for fully participating in the course, students are advised to contact the instructor so that they can be facilitated accordingly.

If you think that you may be a victim of harassment, or if you have observed any harassment occurring in the purview of this class, please reach out and speak to me. If you are a victim, I strongly encourage you to reach out to the Office of Accessibility and Inclusion at oai@lums.edu.pk or the sexual harassment inquiry committee at harassment@lums.edu.pk for any queries, clarifications, or advice. You may choose to file an informal or a formal complaint to put an end of offending behavior. You can find more details regarding the LUMS sexual harassment policy here.

To file a complaint, please write to harassment@lums.edu.pk.

SSE Council on Equity and Belonging

In addition to LUMS resources, SSE's **Council on Belonging and Equity** is committed to devising ways to provide a safe, inclusive and respectful learning environment for students, faculty and staff. To seek counsel related to any issues, please feel free to approach either a member of the council or email at cbe.sse@lums.edu.pk

Rights and Code of Conduct for Online Teaching

A misuse of online modes of communication is unacceptable. TAs and Faculty will seek consent before the recording of live online lectures or tutorials. Please ensure if you do not wish to be recorded during a session to inform the faculty member. Please also ensure that you prioritize formal means of communication (email, lms) over informal means to communicate with course staff.