Course Hand Out, PHY657 : 2024-2025, 2nd Semester

Instructor : Tapobrata Sarkar (tapo@iitk.ac.in).

Objectives : The objective of this course is to prepare the student for professional level physics skills in advanced General Relativity. The course will be useful only for those students who want to pursue research in GR and related theoretical areas in the future. The course will be highly mathematical in nature.

The prerequisite for this course is PHY407 (Special and General Relativity). Anyone who has not completed PHY407 will not be accepted.

Syllabus : The syllabus is as follows :

Module 1 : Tensors and their derivatives : covariant differentiation and Lie derivatives, Killing vectors. Geodesics and geodesic deviation. Locally flat metrics and Fermi normal coordinates. Elementary applications including radial and circular trajectories in a Schwarzschild background. .

Module 2 : Energy conditions and their relevance. Geodesic congruences for timelike and null geodesics and Frobenius theorem. Derivation of the Raychaudhuri equation. Illustrations for simple cases including cosmological significance.

Module 3 : Hypersurfaces and the induced metric. Integration on hypersurfaces and the Gauss theorem. Intrinsic curvature and the Gauss Codazzi equations. Junction conditions and thin shells. Oppenheimer Snyder collapse and the formation of black holes.

Module 4 : Lagrangian and Hamiltonian formulations of General Relativity. 3 + 1 decomposition. ADM formalism. Definitions of mass and angular momentum.

Module 5 : Basic properties of Schwarzschild, Reissner-Nordstrom and Kerr black holes. Event horizon, apparent horizon and Killing horizon. Penrose diagrams. Introduction to the laws of black hole thermodynamics.

There will be roughly 7-8 lectures per module.

Books : Eric Poisson, "A relativist's toolkit : the mathematics of black hole mechanics"

Some parts of Mathias Blau's online notes will also be followed.

Attendance : You are strongly encouraged to attend all classes.

You are **very strongly** encouraged to ask as many questions as possible in class.

Evaluation : Evaluation will be exam based. You might wish to take up a project but this **will not count** for evaluation. There will be 2 hr Mid Sem 40 marks, 3 hr End sem 60 marks with uniform weightage. No quiz. Pass cut off is strictly 30 percent. There is no separate weightage for home works.

Unfair means : We follow a zero tolerance policy for unfair means and anyone found doing this in exams will be immediately de-registered from the course.

Important :

Electronic devices such as cell phones, tablets, laptops etc. are to be strictly kept in the off mode throughout the duration of all lectures unless specifically asked by the instructor.

Please note that texting/messaging or engaging in any type of social media activity during class/tutorial/exam is considered a serious offence.