Indian Institute of Technology, Kanpur

Proposal for a New Course

1. Course No: A **600 level elective** number requested**.**

2. Course Title: **Advanced General Relativity**

3. No. of Lectures per week: 3 (L), Tutorial: 0 (T), Laboratory: 0 (P), Additional Hours[0-2]: 0 (A),

   Credits (3*L+2*T+P+A): 09 Duration of Course: Full Semester

4. Proposing Department/IDP : PHY.

   Other Departments/IDPs which may be interested in the proposed course: SPASE.

   Other faculty members interested in teaching the course: G. Sengupta, K. Bhattacharya, N. Kundu, D. Das.

5. Proposing Instructor: T. Sarkar (PHY)

6. Course Description:

   A) Objectives: The objective of this course is to familiarise the student with advanced aspects of General Relativity relevant to current research in the topic. The concepts taught in the course will be useful not only for theoretical research in gravitational physics but also for those who wish to specialise in astrophysical phenomena in the strong gravity regime. The large amount of observational data expected in the near future should boost research on strong gravity and this course will provide the basic framework to address this exciting area.

   B) Contents:

S. No.	Broad Title	Topics	No. of Lectures
	Introduction and fundamentals	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.	**8**

	Geodesic congruence and the Raychaudhuri equation	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.	**6**
	Gravitational Collapse	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.	**8**
	Lagrangian and Hamiltonian formulation	Lagrangian and Hamiltonian formulations of General Relativity. 3 + 1 decomposition. ADM formalism. Definitions of mass and angular momentum.	**10**
	Black Holes	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.	**8**
		Total number of lectures:	**40**

C) Pre-requisites: PHY407.

D) Short summary for including in the Courses of Study Booklet: Tensors and their derivatives, geodesics and Fermi normal coordinates, energy conditions, Raychaudhuri equations, hypersurfaces and Gauss theorem, Gauss-Codazzi equations, junction conditions and thin shells, gravitational collapse, Lagrangian and Hamiltonian formulations of General Relativity, black holes, with charge and rotation, Penrose diagrams, black hole thermodynamics.

7. Recommended books:

I. A relativist's toolkit : the mathematics of black hole mechanics by Eric Poisson, Cambridge, 2007.
II. General Relativity by Robert Wald, University of Chicago Press, 1984.
III. Gravitation by C. W. Misner, K. S. Thorne, J. A. Wheeler; W. H. Freeman and co., 1973.
IV. Lecture notes by Mathias Blau (available online).

Dated: 7 March, 2024. Proposer: T. Sarkar. T. Sar...

Dated: ______8/3/24______ DPGC Convener (PHY):____________________

The course is approved / not approved

____

Chairman, SPGC

Dated:______________________________