PHYS 3725 Introduction to General Relativity I: Fall/Spring 2025-2026

M- W-F 10:00 --10:50, 105 Allen Hall

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Office Hours: W-F, 4:15 pm to 5:00 pm in 208 Allen : if you cannot make these office hours call me or send me e-mail requesting an appt. (give me a few choices).

Program for first semester: Special Relativity, time dilation, length contraction and simultaneity. Lorentz transformations, intervals, world lines and geometry of SR, variational principle: Minkowski space-time, metric, space-time diagrams. Covariance of SR. Scalars, vectors and tensors. Applications of SR to astrophysics and particle physics: Doppler shifts (transverse and longitudinal), stellar aberration, beaming and gamma ray bursts, kinematical thresholds: an astrophysical puzzle: Ultrahigh energy cosmic rays and GZK. Energy in SR. Accelerated observers: an event horizon, comment: Unruh temperature and accelerated observers. General coordinate systems, geodesics and the variational method: Christoffel symbols.
Gravity at last: the equivalence of inertial and gravitational mass, the equivalence principle: gravitational redshift and light bending, tidal forces, gravity as geometry. GPS: SR + GR in action. Weak field limit. The geometry of space-time outside a non-rotating spherical star: the Schwarschild metric: consequences, Killing vectors and conservation laws, the gravitational redshift. Particle orbits: advance in the perihelion of Mercury, light bending, radar echo. PPN and solar system tests of GR. Gravitational lensing: thin lenses, microlensing and Machos, macrolensing and Dark Matter. Tidal forces and geodesic deviation, the geodetic effect, Lense-Thirring (frame dragging) and Gravity Probe B-experiment.
The march towards Einstein's field equations: geometry first, a taste of Riemannian geometry, absolute and covariant derivatives, curvature and the curvature tensor.

The second semester will include: energy momentum tensors, fluids: sound waves and eqn. of state. Einstein equations. A gravitating fluid and the Jeans instability: the origin of structure and galaxy formation. A *tour de force* on stellar evolution, relativistic stars and TOV: white dwarfs, neutron stars, pulsars, supernovaes (I and II) and Black Holes. Schwarzschild and Kerr black holes. Gravitational collapse, event horizons and ergospheres. Some quantum aspects of BH: Hawking radiation, evaporation, graybody factors, BH thermodynamics and the information paradox. Gravitational Waves: quadrupole formula and energy loss, Taylor Hulse pulsar, LIGO, perturbations: ringing and quasinormal modes of Black Holes. Pulsar timing arrays: correlations. Cosmology: homogeneous and isotropic Universe, FRW, standard Big Bang the CMB. The cosmological constant and Lambda CDM. Elements of Inflation, quantum fluctuations as seeds of CMB anisotropies and Galaxy formation, SVT decomposition of perturbations. Basics of Gravitational collapse in expanding cosmology: structure formation. Dark Matter, Dark Energy.

Books: I recommend the following outstanding books: I) Gravity an introduction to Einstein's General Relativity by J. Hartle; II) General Relativity, an Introduction for Physicists by M. P. Hobson, G. Efstathiou, A. N. Lasenby; III) S. Weinberg's Cosmology and Gravitation; IV) S. Carroll: An introduction to GR: spacetime and geometry. My class notes will be shared with students who enroll for credit in the class. I will send my notes via PDF two days prior to the class.

Format of the course: One homework problem set (4-5 problems) per week, one take home midterm and a take home final. The final grade is the average of HM+mid+final.