PHYS 561 General Relativity

Spring 2016 Syllabus

Instructor: Prof. Edison Liang, x3524
Office: Room 342, Herman Brown Hall

Time: Tuesday and Thursday – 10:50 AM – 12:05 PM

Place: Herman Brown Hall 254

Class Website: http://spacibm.rice.edu/~liang/phys561

Prerequisites: Special Relativity, Classical Mechanics, Classical Electrodynamics, Tensor Calculus, or Instructor consent

Main References: There is no required text book. Copies of old lecture notes are available in the Dessler Reading Room HBH 310. However, the following Main References are most useful for supplemental reading and home works. Copies of MTW and LPPT will be put on reserve in the Fondren Library. The first two books (HS and HEL) together cover almost all of our topics. They are very different in style, notation, and emphasis. Students who like one tend to dislike the other. In the Course Schedule below we list the corresponding chapters in HS and HEL.

Hans Stephani (HS): *Relativity: An Introduction to Special and General Relativity* (Cambridge Paperback, 2004)
Hobson, Efstathiou and Lasenby (HEL): *General Relativity* (Cambridge 2006)
Misner, Thorne & Wheeler (MTW): *Gravitation* (Freeman 1973)
Lightman, Press, Price & Teukolsky (LPPT): *Problem Book in Relativity & Gravitation* (Princeton 1975)

Other Useful References:
Landau & Lifshitz (LL): *Classical Theory of Fields* (Pergamon 1989)
Weinberg (W): *Gravitation & Cosmology* (Wiley 1972)
Hartle (H): *Gravity* (Addison-Wesley 2003)

Schutz (S): *First Course in General Relativity* (Cambridge 1985)
Rindler (R): *Essential Relativity* (Springer 1969)
Adler, Bazin & Schiffer (ABS): *General Relativity* (McGraw Hill 1965)
Einstein (E): The Meaning of Relativity (Princeton 2014)

Grades: 55% Homeworks
10-15% Quiz or Midterm Exam
30-35% Final Exam, Project or Term Paper

Rice Honor Code:
Students are expected to uphold the Rice Honor Code. Students are allowed to work together on problems, but the final submitted homeworks and term paper must be his/her own work.

Course Objectives:
This is a graduate course on General Relativity (GR), Einstein's theory of gravitation. Most modern topics of GR will be covered in depth, including curved space-time, Einstein equations and solutions, black holes, gravitational waves, tests of GR and cosmology. The goal is to provide students with a solid training in GR, so that they will be well prepared for research in astrophysics, cosmology and particle physics, which require a working knowledge of GR.

Learning Outcomes:
Students are expected to turn in one homework assignment every two weeks, which will be graded, and complete a midterm examination and a term paper. Through homeworks, student should become fluent in solving problems in General Relativity. The examination will consist of both conceptual questions and computational problems. The term paper will help students to develop skills in writing and literature search.

Disability:
Any student with a documented disability that requires accommodation should contact both the course instructor and Disability Support Services in the Allen Center.

Tentative Course Schedule

Lecture Module	Topic	Homeworks	HS/HEL Chapters
0	Introduction & Overview		
1	Review of Special Relativity	PS #1	1 – 9 / 1, 5, 6
2	Riemannian Geometry & Curved Space	PS #2	14 – 20 / 2, 3, 4
3	Physics in Curved Spacetimes	PS #3	12, 13, 21 / 7
4	General Relativity & Einstein Equations	PS #4	22, 33 / 8, 19
5	Black Holes, Neutron Stars & Gravitational Collapse	PS #5	23, 26, 35-39 / 9, 11-13
6	Tests of GR	PS #6	24, 25 / 10, 18
7	Gravitational Wave & Radiation	PS #7	27 – 29 / 17, 18
8	Gravitational Lens & Cosmology		40 – 42 / 14 - 16

Module No. **Tentative Topics**

1. Introduction & Review of Special Relativity: Inertial Frames; Galilean transformation & invariance; noninertial frames; Mach's Principle; Lorentz & Poincare Transformations; Newtonian mechanics in arbitrary coordinates; electrodynamics.

2. Reimannian geometry: space-time as curved manifold; coordinate transformations; Covariant derivatives & tensor calculus; tetrads & coordinate-free forms; parallel & Fermi-Walker transport; curvature tensor; Ricci & Weyl tensor; Bianchi Identities; Lie-derivatives; Killing vectors & symmetry; spatial slices & local inertial frames.

3. Physics in curved space times: particle trajectories; photon trajectories & geometric optics; null coordinates; covariant form of Maxwell & other field equations; hydrodynamics; thermodynamics & kinetic theory.

4. General Relativity: principles of equivalence; Einstein Field Equations; stress-energy tensor; variational principle; Lagrangian & Hamiltonian formulations; 3+1 decomposition; concepts of mass and energy; conservation laws; symmetries; asymptotic flatness.

5. Schwarzschild solution; Kruskal & Penrose diagrams; Resissner - Nordstrom solution; event horizon; black hole, white hole and wormhole; Hawking radiation; Kerr-Newman solutions; rotating hole & ergosphere; dragging of inertial frames; Lense-Thirring effect; no-hair theorems; singularities; photon & particle orbits; interior solutions; gravitational collapse.

6. Tests of General Relativity: weak fields & PPN formalism; solar system tests; binary pulsar & other tests; GPB.

7. Gravitational radiation: null frames & invariant characterization of asymptotic fields; linearzed waves; polarization; generation of g-waves; the quadruple formalism; test particle response to g-waves; g-wave detectors.

8. Gravitational lens; cosmology: Robertson-Walker metric and Friedmann models, particle horizon; Kasner metric; standard hot big bang, Λ – term.