Introduction to Relativity (PHYS431000)
Outline of Lectures

Instructor: Professor Chong-Sun Chu, GB II.P519.
cschu@phys.nthu.edu.tw, http://www.phys.nthu.edu.tw/∼cschu/GR/index.html

Time and Location: 15:30 - 18:10 (with one 10 minutes break); Lecture room A, 4F, General Building III.

Office Hour: Appointment by email

TA: Jui-Lin Kuo, juilinkuo@gmail.com

Resources:

I. Books

- **Bernard Schutz, A First Course in General Relativity** (Cambridge University Press; 2 edition, 2009).
  Main textbook of the course. Pedagogical and accessible introduction to the subject. Good for a first reader.
- **Steven Weinberg, Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity** (John Wiley & Sons 1972).
  A great book with emphasis on physical perspectives. However non-geometrical and no blackhole.
- **Robert M. Wald, General Relativity** (U Chicago Press 1984).
  An advanced textbook. Clear and precise, but maybe too formal for a first learner. An authorative reference.
- **Sean Carroll, Spacetime an Geometry - An Introduction to General Relativity** (Addison Wesley, 1st Ed, 2003). An older online version of the book (different is available on the preprint server: http://arxiv.org/pdf/gr-qc/9712019.
  Covers some modern developments of the subject

II. Others

- Maple and GRTensor. Maple is a computation system which allows one to do algebraic computation as well as numerical analysis. The package GRTensor allows one to compute curvature tensors and other useful quantities which are useful in general relativity. It is a system actually used by researchers in research. GRTensor can be downloaded from http://grtensor.phy.queensu.ca/

Course Outline by Topical Areas: The course will be dealing with the following main areas:

- Theory of General Relativity.

  Special relativity. Tensor analysis. curvature. manifold. Physics in curved spacetime. Einstein field equation.

- Applications of General Relativity.

  A selection of the following topics: Gravitational radiation. classical tests. ADM mass. blackholes. cosmology. action principle. Hawking radiation. quantum gravity. inflation etc

The theory of general relativity is structurally very clear and beautiful. Mathematically it is demanding as you will need to learn about manifold and differential geometry.

But don't worry, you can do it! You need to work hard, but I promise you it will be fun and worthwhile!

Evaluation: Passing mark is 60 %.

- homeworks count 30 %, midterm counts 30 %, final exam counts 40 %.
- *I expect that you are taking this course because you are interested in the subject. You are expected to work hard and have fun in the process. If you feel that a written exam is not for you, you are encouraged to talk to me to discuss about alternative evaluation method (e.g. oral exam, take home exam, project, etc).*

Lectures :

- I will start the lecture each week with a brief review of previous materials. Overview will be given when appropriate.
- Occassionaly, I will go through some of the homework problems in class.
- You are expected to grasp the materials of each week lecture fairly well in order to progress and follow in the class. So if you get stuck or get loss at any point, please come to me or your TA to fix it immediately.

Homework problems :

- Homework will be collected in the begining of each leacture. Please put them in the folder in front as you enter the classroom.
- Homework will be marked and returned to you in class in the week after.

Week	Main topics	Homework
(11/9 & 9/18) (Overview) (Review of SR)	Overview of GR and advanced topics; Postulates of SR; inertial frames; Natural units; spacetime diagram and invariant interval; time dilation, length contraction, doppler effect Lorentz transformation; velocity composition	- 1.1 - 1.10 except 1.7 (1.14, 1.18, 1.19)
(25/9) (Vec. analysis in SR)	Definition of Lorentz 4-vector and tensor, basic manipulations of tensors 4-velocity, 4-momentum and 4-acceleration scalar products, photons	2.1, 2.2, 2.5, 2.9, 2.12, 2.14 2.15- 2.19, 2.21, 2.24 2.31, 2.32
(2/10) (Physics of SR in tensorial form)	Relativistic Newton's law, J^μ and $T^{\mu\nu}$ for a system of particles; spin.	-
(9/10)	National Holiday	
(16/10) (Physics of SR in tensorial form)	Fluid approx.; Properties of general fluid: $T^{\mu\nu}$, N^μ and 1st law of thermo. examples (perfect fluid and dust)	3.10, 3.20, 3.24, 3.25, 3.29, 4.10, 4.16, 4.17, 4.20, 4.21 4.23
(23/10) (Equivalence Principle and curved spacetime)	Equivalence Principle gravitational redshift and curved spacetime; gravity and geodesics Principle of General Covariance	5.3, 5.10, 5.11-13, 5.21, 5.22
(30/10) (Tensors; Manifolds) (Riem manifold)	Tensors, covariant derivatives covariant curl and divergences Manifold; Metric and Riemannian manifold Riem normal coord, parallel transport curvature tensor, geodesic deviation	 6.1, 6.3, 6.10, 6.25, 6.28 6.29, 6.31, 6.34, 6.35
(6/11) (Physics in curved spacetime)	Principle of covariance. Particle dynamics EM, slightly curved spacetime (weak field) conserved quantities	 -
(13/11)	**Mid Term Exam**	
(20/11) (Einstein eqn)	Derivation, Geometrized units comments on Einstein eqn, weak grav. field Einstein eqn in weak field, Newtonian grav. fields, far field approx	8.1, 8.5, 8.7, 8.8, 8.11 8.20 -
(27/11) (Grav wave)	Einstein eqn in weak field approx.; plane wave soln.; TT-gauge; helicity; effects of wave on particles; polarizations;	-
(4/12) (Grav wave)	Exact plane wave soln; quadrupole radiation simple harmonic oscillator as example; Energy flux of grav wave; Energy loss by grav rad. system;	9.14, 9.29, 9.33, 9.40, 9.44
(11/12) (Schw geom & BH)	Classical Tests of GR: bending of light, precession of perihelia, radar echo delay	10.9,10.10, 10.14
(18/12) (Cosmology)	Cosmological properties of universe: homogeneity, isotropy, Hubble's law; cosmological principle, Robertson-Walker metric;	 -
(25/12) (Cosmology)	Friedmann eqn; critical density and density parameters; evolution of the scale factor	 -
(8/1)	**Final Exam**	