Theory of Relativity – CEPI 0902

I. COURSE INFORMATION

Instructor: Scott Field (sfield@umd.edu)

Teaching Assistant: Mohsen Zayernouri (Mohsen_Zayernouri@brown.edu)

Dates: June 30 - July 11, 2014

Times: 12:45 pm - 3:35 pm

Location: Barus & Holley 153

Office Hours: Tuesday and Wednesday 3:45 pm - 4:45 pm in Barus & Holley lobby (or all other times with advance notice)

Website: http://www.dam.brown.edu/people/sfield/RelativitySummer2014/

Books: Albert Einstein, *Relativity: The Special and the General Theory.*
Richard Feynman, *Six Not-So-Easy Pieces: Einstein's Relativity, Symmetry and Space-Time*
George Gamow, *Mr. Tompkins in paperback*

II. COURSE DESCRIPTION

Einstein's theories of special and general relativity are two of the pillars of modern physics. It is deeply counter-intuitive, yet beautiful and ingenious. What does relativity tell us about the Universe? What are space and time? What would the world look like if the speed of light were 100 mph? What is a black hole and if you fall into one, what's the best survival plan? Special relativity reformulates how space and time are viewed and introduces the famous equation $E = mc^2$, suggesting a conversion between energy and mass. General relativity is a geometrical theory of gravitation: Gravitation is not due to a force, but is a "bending" of space and time.

This course is aimed to give an introduction to both special and general relativity. Special relativity will be discussed in some mathematical detail. Discussion of general relativity will be mostly based on geometrical intuition. As time permits we will consider a variety of special topics including black holes, twin paradox, time travel, dark matter, dark energy, super-luminal neutrinos, gravitational waves, and alternative theories to general relativity (e.g. String Theory and Brane World Cosmology).

This course will include lectures, discussions, labs, demonstrations, homework and reading assignments, and a final project to be chosen by the student. Course material will also draw from online resources.

Algebra and trigonometry will be assumed. Some familiarity with units of measurement, displacement, speed, and Newton's equations (e.g. $F = ma$) might be helpful and will be reviewed at the beginning of the course. No physics knowledge is assumed, and necessary skills will be developed.

III. SYLLABUS (SUBJECT TO CHANGE!)

Week 1

- Monday: Individual introductions, course introduction, metaphysics and model building, how to solve problems in physics, units of measurement, coordinate systems, velocity, questionnaire.
- Tuesday: Topics will depend on questionnaires and may include mechanics of Newton, acceleration, mass vs weight, energy, momentum, and Galilean Relativity. Electromagnetism, addition of velocities and the speed of light paradox. Frictionless cart (demo).
- Wednesday: Review of pre-1905 physics. Aether and the Michelson–Morley experiment, length contraction and time dilation, postulates of special relativity, worldlines, light cones and causality, simultaneity, the twin paradox, relativistic addition of velocities. Experimental verifications of special relativity. Muon detector cloud chamber (demo).

- Thursday: Spacetime intervals and sphere's of light. Relativistic energy and momentum, energy-momentum conservation, $E = mc^2$, mass at rest and in motion, accelerated motion. Build a cloud chamber (lab).
- Friday: No class. Happy fourth of July!

Week 2

- Monday: Review of special relativity and applications including GPS systems, atomic bombs, the Sun, and particle physics. Gravity of Newton. Motivation and postulates of general relativity. Equivalence of gravity and acceleration, curved spacetime. Leon's triangles (demo). Curved spacetime (demo).
- Tuesday: Implications and experimental verification of general relativity. Black holes. Cosmology and dark matter. "Final exam" review.
- Wednesday: "Final Exam". Physics of time travel. Relativity at the movies (Thor, Inception, Star Trek, Twelve Monkeys, Event Horizon, Back to the Future, etc.).
- Thursday: Professor James Van Cleve discusses philosophical implications of time travel. "Final exam" solutions. Relativity and beyond – gravitational waves, dark matter, dark energy, string theory, other dimensions, brane world cosmology, quantum gravity, creating black holes on Earth, shape of space, superluminal neutrinos. Expanding universe (demo).
- Friday: Final project presentations, final comments.

IV. HOMEWORK AND CLASS EXERCISES

There will be readings and problems assigned in class. Solutions will be discussed in class and posted to the course website. Additionally, there will be group problem solving during class as well as short quizzes.

V. FINAL PROJECT

Each student will propose a short project to be presented on the last day. Although you will work on and present your own project, you are encouraged to engage in discussions with me and fellow students about your project. More information on the final project will be provided.

VI. GRADING

The following will determine how you will be assessed in your successful completion of the course:

- Homework, quizzes, classroom assignments (35 %)
- "Final exam" (35 %)
- Final Project (20 %)
- Labs (10 %)

While the course is graded on a pass/fail basis (using the grading scheme given above) I am required to fill out a "Course Performance Report" which "provides valuable feedback to students, parents, and on occasion to college admission offices." This is where qualitative details like classroom participation may show up.

VII. COMMENTS

I will post details about each lecture online, but these will be far from complete. You should take notes in class, especially when we solve problems. Please no distracting items (phones, ipods, etc) in class. 3 hours is a long time to be in class! There will be short breaks, and feel free to bring drinks or snacks to class if you are hungry or thirsty.