Theory of Relativity – CEPI 0902

I. COURSE INFORMATION

Instructor: Scott Field

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Teaching Assistant: Paul Huwe

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Dates: Jun 27 - Jul 08, 2011

Times: 12:45 pm - 3:35 pm

Location: Barus and Holley room 141

Office Hours: Barus and Holley lobby from 5pm - 6pm. You are welcome to drop by my office, Room 004 in 182 George St, any time but you might want to email first in case I'm not in my office.

Website: http://www.dam.brown.edu/people/sfield/RelativitySummer2011/CourseHome.html

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

II. COURSE DESCRIPTION

Einstein's theories of special and general relativity are two of the pillars of modern physics. It is deeply counterintuitive, 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. Special topics will include black holes, gravitational waves, cosmology, and alternative theories to general relativity (e.g. string theory and brane world cosmology).

No mathematics knowledge other than basic algebra is required. Necessary mathematical skills will be developed. Course will include lectures, discussions, a few demonstrations, class exercises, homework and reading assignments, and a final project to be chosen by the student. Course material will also draw from online references and resources.

III. SYLLABUS (SUBJECT TO CHANGE!)

Week 1

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

- Thursday: Relativistic energy and momentum, energy-momentum conservation, $E = mc^2$, mass at rest and in motion, accelerated motion. Build a cloud chamber (lab).
- Friday: Extended discussion on special relativity and its uses including GPS systems, atomic bombs, the Sun, and particle physics. Motivation for general relativity. Postulates of general relativity, equivalence of gravity and acceleration, curved spacetime. Leon's triangles (demo). Curved spacetime (demo). Equivalence Principle (demo and/or lab).

Week 2

- Monday: No class. Happy fourth of July!
- Tuesday: Discussion and implications of general relativity. Experimental verification of general relativity. Black holes, wormholes, and time travel. In class video. Relativity at the movies (Thor, Inception, Event Horizon, Star Trek, Twelve Monkeys).
- Wednesday: Cosmology and the shape of space. Creating black holes on Earth. Current research in gravitational waves and lenses. Expanding universe (demo). Gravitational lens (demo). Guest lecture by professor James Van Cleve on the nature of time travel.
- Thursday: "Final Exam". Beyond relativity – dark matter, dark energy, string theory, other dimensions, brane world cosmology and quantum gravity. Start of final project presentations.
- Friday: Final project presentations, final comments and final exam solutions.

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. Presentations should be roughly 5 minutes followed by a few minutes of class discussion. A suitable project can be anything which relates to the topics of the class and may contain significant math or no math at all. Many suggestions will be given in class. 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 (35 %)
- Classroom exercises and tests (35 %)
- Final Project (20 %)
- Labs (10 %)

VII. COMMENTS

I will post details about each lecture online, but these will be far from complete. You should definitely take notes in class, especially when we solve problems. Please no distracting items (phones, ipods, etc) in class, laptops only for note taking. 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.