Physics 370: Relativity, Spacetime, and Gravity   Fall 2010

Prof. Ted Allen
Eaton 108
781-3623 (Office)

`http://people.hws.edu/tjallen`
`tjallen@hws.edu`

	Room	Time
Lecture	Eaton 111	11:15-12:10 MWF

Texts

- James Hartle, *Gravity: An Introduction to Einstein's General Relativity* (Addison Wesley)
- Edwin Taylor and John Wheeler, *Spacetime Physics* (Freeman)

Recommended Text

- T. M. Helliwell, *Special Relativity* (University Science Books)

More advanced reading

- Charles Misner, Kip Thorne, and John Wheeler, *Gravitation* (Freeman)

Course Objectives
This course is an introduction to Albert Einstein's special and general theories of relativity. After completion of the course, students will be able to solve problems in relativity.

About Physics 370
It has been somewhat more than a hundred years since Einstein published his paper *"On the Electrodynamics of Moving Bodies."* In this paper he reconciled Maxwell's theory of electrodynamics with the Galilean relativity principle of Newtonian mechanics by replacing Newton's universal time and absolute space with a space and time that depend on an observer's state of motion and replacing the Galilean relativity transformations with the Lorentz transformations. We will understand how Einstein came to his conclusions, how space and time are unified into spacetime, and some of the consequences of Special Relativity. We will also understand why it is necessary to replace Newton's theory of Universal Gravitation by Einstein's General Theory of Relativity. We will explore the physics of a few of the exact solutions of General Relativity, including the gravitional field of a massive object, black holes, general relativistic effects in the solar system, and cosmology. If time permits, we will examine the field equations of General Relativity, which describe how matter curves spacetime much as Maxwell's equations describe how electric charges create the electromagnetic field.

Course Requirements
Regular Homework Problems
2 Exams
Final Exam

Grading
Grades in this class will be based on the following elements.

- **Participation** I expect each student to do the assigned readings and problems and to bring questions and comments to class and to participate in class discussions. Implicit in this is the expectation that all students will attend all classes. The grade for participation will be assigned at my discretion at the end of the semester.

- **Homework** Homework will be assigned on a regular basis and collected. I reserve the right not to give credit for late homework assignments, based on the belief that keeping up is an essential ingredient for success in the course. You may work together on the homework. Indeed, I encourage you to work together to understand the problems. However, you must each separately write up solutions in your own words (and equations) and may not turn in something you do not understand. (That is, you may not simply paraphrase someone else's solution as your own.) Paraphrasing without understanding, or outright copying, will be considered plagiarism.

- **Exams** There will be two hour exams and a final exam. The final exam will be comprehensive. Dates for the hour exams will be announced in lecture. The hour exams are likely to be take-home exams. The final exam will be in the period set by the Registrar, which should be Tuesday, December 14 8:30AM.

- **Quizzes** There may be quizzes in class, mostly for your own diagnostic use. Any quizzes will be announced in advance and will count towards your participation grade.

The relative weights of each element of the grade for the course is as follows.

Element	Weight
participation	10%
homework	30%
hour exams	30%
final exam	30%

Office Hours
Initially office hours will be Monday at 3:00 pm, Friday at 1:30 pm, and by appointment. If these hours are inconvenient for you, please let me know and I'll try to find some more convenient times. In addition, you may stop by any time to see if I am free to discuss physics, life, the universe, or anything else. If my door is closed, I am likely to be busy.

Tentative Outline

This syllabus is ambitious. I suspect that we will probably get through much of this material, though perhaps not at the depth covered by some of the text.

Newtonian Physics and Galilean Invariance
Inertial Frames. Universal time & absolute space. Galilean transformations. Invariance of Newton's second law.

Maxwell's Equations break Galilean Invariance
Transformations of fields. Wave equation is not Galilean invariant. Maxwell & Newton only consistent in a universal rest frame.

Einstein fixes the discrepancy without an Æther
Postulates of special relativity. Time dilation. Lorentz contraction. Lorentz transformations. Simultaneity is relative. Seeming paradoxes. Minkowski geometry & spacetime diagrams. Special relativistic mechanics.

Gravity & Geometry
Problems with Newtonian gravity. Can SR incorporate gravity? Gravitational & inertial mass. The Equivalence Principle: gravity as a fictitious force. Newtonian gravity in spacetime terms.

Describing curved spacetime
Coordinates. Metric tensor. Geometric quantities for diagonal metrics. Vectors in curved spacetime.

Geodesics
Variational principle. Geodesic equation.

Geometry outside a spherical star
Schwarzschild metric. Gravitational redshift. Precession of perihelion. Deflection of light. Solar system tests. Parametrized Post-Newtonian Parameters.

Miscellaneous Issues
Gravitational lensing. Accretion disks. Binary pulsars.

Black holes
Collapse to a black hole. Kruskal-Szekeres coordinates. Astrophysical black holes. Hawking radiation.

Rotating solutions
Frame dragging. Geodetic precession. Kerr geometry. Horizon of a rotating black hole. The Ergosphere.

Gravitational waves
Linearized gravitational wave. Detecting gravitational waves. Polarization. Gravitational wave interferometers.

Cosmology
Homogeneous, isotropic spacetimes. Cosmological redshift. Friedman-Robertson-Walker models.

Einstein field equations
Covariant derivatives. Tidal gravitational forces. Geodesic deviation. Riemann curvature. Einstein equation in vacuum. Stress-energy tensor.