RELATIVITY PHYS 570
Fall 2017
22852
COURSE INFORMATION

Class Days: MWF
Class Times: 12:00 to 12:50 PM
Class Location: P-149

Professor: Fridolin Weber
Contact Information: fweber@sdsu.edu
URL: fweber.sdsu.edu
Office Hours Days: MW
Office Hours Times: MW 1:00 PM to 1:45 PM
and by appointment
Office Hours Location: P-142

Course Overview

Course Content: Tensors and differential forms. Physical interpretation of the metric tensor. The Lorentz transformation. Covariant formulation of the laws of physics. Applications of special relativity. The geodesic equation. Einstein's field equations of general relativity. Solutions of Einstein's field equations. Tests of the general theory of relativity. Mercury's perihelion shift. Deflection of light. Physics of black holes. Physics of relativistic stars. Cosmology

Overview: We will study one of the most elegant theories of physics, Einstein's Theory of General Relativity. Part one of this course is a brief review of the concepts of space and time in Newtonian physics and of the essential elements of special relativity (invariance principle, space-time, time dilation, twin paradox, Lorentz boosts, four-vector notation, special relativistic kinematics and dynamics). Part two of this course concentrates on the curved space-times of general relativity and on Einstein's famous field equation. We will derive this equation in class and you will learn how to solve it for simple mass-energy distributions. We will use Einstein's theory to study the structure and stability of relativistic stars, the emission of gravitational waves from compact stellar systems, and to explore cosmological models of the Universe.

Learning outcome: The students shall master calculating with tensors and differential forms. They shall also be able to describe physical phenomena in different coordinate systems and to transform from one coordinate system to another. They shall be familiar with covariant derivatives and covariant Lagrangian dynamics and geodesic curves. They shall be able to calculate the components of the Riemann curvature tensor from a given line element. They shall also be able to write down the energy-momentum tensor for a perfect fluid and solve Einstein's field equations for static spherically symmetric problems and for isotropic and homogeneous universe models. They shall master calculating the relativistic time dilation for clocks moving in a gravitational field and be able to calculate the corresponding frequency shift for sources moving in a gravitational field. They shall also master to calculate the bending of light passing a spherical mass distribution and the precession of perihelion for a planet in the Solar system. The students shall also be able to give a mathematical description of relativistic star models and universe models.

Enrollment Information

Prerequisites: Physics 354 and 400A/B.
First day of classes: August 28, 2017.
Last day of classes: December 14, 2017.
Final examinations: December 15 – 21, 2017.
Last day for faculty to drop students from classes: September 7, 2017.
The last day to officially withdraw from the university: September 11, 2017.
No classes on September 4, November 10, November 22 – 24, 2017.

Course Materials

I will not follow any specific textbook very closely. However, most material covered in lecture (and more) can be found in any of these recommended resources:

- James B. Hartle, *Gravity: An Introduction to Einstein's General Relativity*, ISBN: 0805386629, Addison Wesley 2003 (required for homework assignments).
- Bernard F. Schutz, *A First Course in General Relativity*, Cambridge University Press, Cambridge, 1986.

Course Structure and Conduct

Problem sets are an essential part of this course. As with most of physics you will never have a chance to understand the material without doing problems. The problem sets will be assigned usually on Fridays, and are due at the start of class the following Friday. Because solutions will be posted, late homework will not be accepted. The homework solutions will be posted on the board outside of my office. The solutions may be borrowed briefly for copying. Homework must be written neatly. If I have difficulties reading or following your homework, I will not go to great lengths to decipher it and you will lose points.

Course Assessment and Grading

Five mini exams will be given during lectures roughly every 3 weeks. The mini exams will consist of regular and/or multiple choice problems for you to work out. You will have around 15 to 20 minutes to work on the problems. The **mini exam dates** are:

Sept. 8, Sept. 22, Oct. 20, Nov. 3, and Dec. 8.

The mini exams will cover material and problems discussed in the home assignments and lectures. There will be two midterm exams and a final exam. The **midterm exams** will be on

October 11 and November 15

from 12:00-12:50 PM in room P 149. The **final exam** will be on

December 20,

from 10:30 AM-12:30 PM in room P 149. There will be no makeup exams or makeup mini exams. All exams are closed book closed notes. The exams will consist of traditional (no multiple choice) problems. Exams and quizzes will be graded on a partial credit basis. In grading problems, emphasis will be put on using the correct concepts, methods and formulas appropriate for the problem, over actually plugging the correct numbers into your calculator. To enhance your partial credit, make sure that your work is written neatly and clearly explained so that the grader can easily follow it.

Your final grade will be calculated as follows: Homework: 20%, mini exams: 20%, midterm exams I and II: 20% each, final exam: 20%

The letter grade scale will be as follows:

A+ > 95%, A > 90%, A- > 85%,

B+ > 80%, B > 75%, B- > 70%,

C+ > 65%, C > 60%, C- > 55%,

D+ > 50%, D > 45%, D- > 40%,

F < 40%

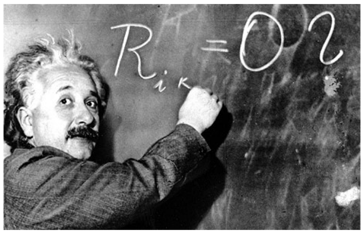
Other Course Policies

SYLLABUS STATEMENT for Students with Disabilities

If you are a student with a disability and believe you will need accommodations for this class, it is your responsibility to contact Student Disability Services at (619) 594-6473. To avoid any delay in the receipt of your accommodations, you should contact Student Disability Services as soon as possible. Please note that accommodations are not retroactive, and that accommodations based upon disability cannot be provided until you have presented your instructor with an accommodation letter from Student Disability Services. Your cooperation is appreciated**.**

ACADEMIC DISHONESTY

Honesty and integrity are integral components of the academic process. Students are expected to be honest and ethical at all time in their pursuit of academic goals in accordance with CSU'S Executive Order 1098 on Student Judiciary. Additionally, CSU Executive Order 1098 requires that instructors report academic dishonesty to the Center for Student Rights and Responsibilities (CSRR). For more information, visit the CSRR Academic Dishonesty website at http://csrr.sdsu.edu/student_affairs/srr/academic-dishonesty.aspx. Any student found in violation of the policy will receive an "F" in the course.



Physics 570
Relativity
Fall 2017

Dr. Fridolin Weber

Course Outline

Part I. Special Relativity

- **Chapter 1: Introduction**
  Historical remarks
  Relativistic particle physics
  Relativistic astrophysics

- **Chapter 2: Tensor Calculus**
  Vectors
  One-forms
  Dual basis
  Tensors
  Coordinate transformations
  Covariant and contravariant quantities

- **Chapter 3: Principles of Special Relativity**
  Inertial frames
  The principle of relativity
  Lorentz covariance
  Lorentz transformation and four vectors
  Space-time diagrams
  Time dilation, length contraction, twin paradox
  Relativity of simultaneity
  Addition of velocities
  Acceleration in special relativity

- **Chapter 4: Special Relativistic Mechanics**
  Special relativistic kinematics
  Special relativistic dynamics
  The relativistic variation principle

- **Chapter 5: Applications**
  Maxwell equations
  Relativistic quantum mechanics
  Relativistic field theory

Part II. General Relativity

- **Chapter 6: Foundations of General Relativity**
  Acceleration
  Curved Space-Time
  Gravity
  Geodesic equation

- **Chapter 7: Einstein's Field Equation**
  Energy-momentum tensor
  Covariant differentiation
  Parallel transport
  Riemann curvature tensor, Ricci tensor, scalar curvature
  The cosmological constant
  Classical limit of Einstein's field equation

- **Chapter 8: Relativistic Stars**
  Equation of state
  Neutron stars, white dwarfs, black holes
  Rotation in General Relativity

- **Chapter 9: Classical Tests of General Relativity**
  Perihelion motion of Mercury
  Bending of light

- **Chapter 10: Cosmological Models and the Universe**
  Robertson-Walker metric
  Gravitational radiation