Physics 141: Fall 2013
Course Syllabus

General Course Information

Course Director: Robert G. Brown
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Recitation Instructors: Stephen Teitsworth (teitso at phy dot duke dot edu); Joshua Socolar (socolar at phy dot duke dot edu); Ying Wu (wu at phy dot duke dot edu); Chris Varghese (varghese at phy dot duke dot edu).

Chief Lab Instructor: Ken McKenzie (kam39 at phy dot duke dot edu)

Graders: TBD.

Primary Text:
Online Physics Textbook (free):

http://www.phy.duke.edu/~rgb/Class/intro_physics_1.php

The online textbook will occasionally be updated or corrected throughout the semester, so it is a good idea to bookmark this link. However, an inexpensive paper copy of the textbook (for students who do not like to read a textbook online even to save money) can be purchased here:

http://www.lulu.com/shop/robert-g-brown/introductory-physics-1/paperback/product-21025164.html

Secondary Text:
University Physics for the Physical and Life Sciences, Volume I, by Kesten and Tauck, ISBN-13: 978-1-4292-0494-4, ISBN-10: 1-4292-0493-1

This book is ***not required*** but may be useful to students who find the free online text cumbersome or who want a decent conceptual supplement.

Other Online Class Resources:

http://www.phy.duke.edu/∼rgb/Class/class.php

This toplevel link contains links to the textbook, a review guide containing quiz and exam problems given in previous years (a few of them "solved" to help you learn by example), a math review (incomplete, but still helpful) and links to video recordings of most of the lectures in this class made four years ago (useful if you are forced to miss lecture for e.g. a sports event).

Course Topics

In this course we will cover the following basic topics (basically a week by week summary of the course content). This content will be presented in three parts:

Elementary Mechanics

- **Dynamics:** We will learn *Newton's Laws* as the basis of *physical dynamics*, along with a number of simple force laws. Once we use Newton's Laws (and the force laws and a careful diagram) to obtain equations of motion, we will *solve them* using *calculus*. In the course of developing these solutions, we will learn a certain amount of calculus-derived *kinematics*. Kinematics is "mathematics with units" and is particularly concerned with changing one's frame of reference and determining the mathematical and geometrical consequences of e.g. circular motion.
- **Work, Kinetic and Potential Energy:** We often will be interested in relating a particle's *speed* to its *position* without caring much about time. We will convert Newton's Second Law into a time independent form called the *Work-Kinetic Energy Theorem*. We will learn to use work and energy to solve many time-independent problems, often integrating this usage with problems that also require the use of kinematics or dynamics from the previous two weeks so you get still more practice there as well.
- **Systems of Particles, Momentum, Collisions:** We will first define the *momentum* of a particle as a vector quantity of interest. We will

then learn the *conditional* Law of **Conservation of Momentum**, as well as define the *center of mass* of a system of particles and the related momentum of a system of particles. This will justify *a posteriori* our treatment of objects like baseballs or cars as "particles" in the first part of the course (even though they are in truth composed of many elementary particles themselves). We will use conservation of momentum (often in problems that mix in energy, kinematics and dynamics so you don't forget) to solve *collision problems* where two objects interact briefly and transfer momentum in accord with Newton's third law.

- **Rotation, Torque and Angular Momentum:** A "rigid body" made up of many particles can be described by the position of its center of mass plus *angles* that describe its orientation in three dimensions. Newton's Laws describe the motion of the center as a "particle" (as we learned in the previous week's work). A *rotational* form of Newton's Laws involving *torque* describes the vector motion of the rigid bodies about an axis through their center of mass (or axes parallel to such an axis). We will solve problems involving torque and angular acceleration, conservation of angular momentum in collisions, and the full application of *vector* torque to a rotating rigid body with *vector* angular momentum, where the resulting motion is the *precession* of its angular momentum vector. Precession of angular momentum is the basis (as we will see next semester) of *Magnetic Resonance Imaging* (MRI) so we will learn to solve the precession problem in some detail this semester.

- **Statics:** When (vector) force and torque on a rigid object balance, the object is said to be in *static equilibrium*. Static equilibrium problems are important in the context of engineering, medicine, and even mundane activities such as hanging a picture. At this point, this should be pretty easy, although some statics problems *can* be challenging. As always, we solve many problems.

Our first hour exam will cover all of the elementary mechanics from the first part of the course, through rotation. The second part of the course is concerned with the *application* of elementary mechanics to specific systems, each described by its own force laws. In some cases these laws are themselves elementary laws of nature (for example, gravitation). In others, they are force or energy laws that are deriveable from things we learned in the first part of the course plus some common sense.

Specific Systems and Force Laws

- **Fluids:** Fluids are distinct from rigid bodies in that their contact force exerted both internally and upon solid objects placed in or confining the fluid is the result of *pressure*. We will learn fluid statics: Archimedes' Principle, the Pascal Principle, as well as the simplest versions of fluid dynamics: Bernoulli's Equation, the Venturi effect, and briefly discuss laminar flow. Naturally, we will solve many problems in fluid statics or dynamics adding pressure-based forces to those we are already familiar with.

- **Oscillations:** Linear restoring forces are generally associated with small displacements away from any position of static equilibrium. A mass on a spring is the archetype for a linear restoring force in one dimension, and solving the resulting dynamical equation of motion leads us to the *simple harmonic oscillator* as the prototype for nearly *all* oscillating systems. We will study a variety of simple oscillators, including ones that are damped (so that they lose energy to e.g. drag forces over time) or damped and driven (by an external harmonic force). The latter system is characterized by the possibility of *resonance* that is extremely important in physics, medicine, and engineering applications.

- **Waves:** When mass is distributed in such a way that one bit of mass can exert an (approximately linear) force on its neighbors, for example all the bits of mass that make up a stretched string, the resulting dynamical equation motion of the string will turn out to be the *wave equation*. We will derive the wave equation for a stretched string and learn many things about the solution of the wave equation, in part to help us understand *light* as an *electromagnetic wave* next semester.

- **Sound:** Fluids or extended solids are another example of bits of mass that exert (approximately linear) forces on the neighboring bits. The resulting waves in are called *sound*. We study sound waves in air (and perhaps think a bit about sound waves in liquids such as water or solids) and such fluid wave phenomena as wave interference, beats, and the doppler shift.

- **Gravity:** We will study Newton's Law of Gravitation. Using it, we will solve a number of problems involving dynamics, kinematics (especially of circular motion to describe orbits), torque, and angular momentum. In due course we will see how Newton's Laws plus Newton's Law of Gravitation leads to an understanding of *Kepler's Laws of Planetary Motion* – a set of *empirical* laws that describe the approximate motion of planets and moons in our solar system.

Our second hour exam will cover all of these specific systems except gravity, and of course will still involve many of the concepts learned in the first part of the course.

The course will conclude with a final exam that is comprehensive and cumulative, testing all of the ideas learned throughout the semester. A mandatory question on gravity will be on the final.