Exam 1 Review

Chapter 1: Introduction

Most of these topics are difficult to appreciate at the beginning of the class.

- Why Study Physics?
- Talking Physics
- The Use of Mathematics
    - Ratios and Proportions
- Scientific Notation and Significant Figures
- Units
- Dimensional Analysis
- Problem-Solving Techniques
- Approximation
- Graphs

Chapter 2: Motion Along a Line

Develop the vocabulary for describing motion in one dimension.

- **Position and Displacement**

$$\Delta x = x_f - x_i$$

- **Velocity: Rate of Change of Position**

$$v_{av,x} = \frac{\Delta x}{\Delta t}$$

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

The instantaneous velocity is the slope of a position vs. time graph. The displacement is the area under a velocity vs. time graph.

- **Acceleration: Rate of Change of Velocity**

$$a_{av,x} = \frac{\Delta v_x}{\Delta t}$$

$$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t}$$

The instantaneous acceleration is the slope of a velocity vs. time graph. The velocity is the area under an acceleration vs. time graph.

- **Motion Along a Line with Constant Acceleration**

  The equations for uniformly accelerated motion are

$$\Delta v_x = v_{fx} - v_{ix} = a_x \Delta t$$
$$\Delta x = \tfrac{1}{2}(v_{fx} + v_{ix})\Delta t$$
$$\Delta x = v_{ix}\Delta t + \tfrac{1}{2} a_x (\Delta t)^2$$
$$v_{fx}^2 - v_{ix}^2 = 2a_x \Delta x$$

  The average velocity can be useful for some problems

$$v_{av,x} = \tfrac{1}{2}(v_{fx} + v_{ix})$$

  Using these equations often involves matching the known parameters to the right equation.

- **Visualizing Motion Along a Line with Constant Acceleration**
  With a stroboscopic photograph, a feel for speed (and acceleration) can be found by comparing distances between adjacent images.

- **Free Fall**
  The acceleration due to gravity is

$$a_y = -g = -9.8\ \text{m/s}^2$$

  and is used in the equations for uniform linear motion.

Chapter 3: Motion in a Plane
Generalize one dimension motion by using vectors.

- **Graphical Addition and Subtraction of Vectors**
  Displacement is the prototype vector. Vectors are added by placing them head to tail.

- **Vector Addition and Subtraction Using Components**
  "We do not deal with vectors, we deal with their components."
  - A single vector is replaced by two components found by using sine and cosine functions.
  - Vectors have positive magnitude but components can be positive or negative.

- **Velocity**
  The vector equation is

$$\vec{\mathbf{v}} = \lim_{\Delta t \to 0} \frac{\Delta \vec{\mathbf{r}}}{\Delta t}$$

and components are

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \qquad v_y = \lim_{\Delta t \to 0} \frac{\Delta y}{\Delta t}$$

- **Acceleration**

$$\vec{\mathbf{a}} = \lim_{\Delta t \to 0} \frac{\Delta \vec{\mathbf{v}}}{\Delta t}$$

with

$$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} \qquad a_y = \lim_{\Delta t \to 0} \frac{\Delta v_y}{\Delta t}$$

- **Motion in Plane with Constant Acceleration**
  Choose axes so that the acceleration is along the *y*-axis only

***x*-axis:** $a_x = 0$

$\Delta v_x = 0$ (v_x is a constant)

$$\Delta x = v_x \Delta t$$

***y*-axis:** constant a_y

$$\Delta v_y = a_y \Delta t$$

$$\Delta y = \tfrac{1}{2}(v_{fy} + v_{iy})\Delta t$$

$$\Delta y = v_{iy}\Delta t + \tfrac{1}{2} a_y (\Delta t)^2$$

$$v_{fy}^2 - v_{iy}^2 = 2a_y \Delta y$$

For a projectile launched with velocity v_i at elevation θ, substitute

$$v_{ix} = v_i \cos\theta \qquad v_{iy} = v_i \sin\theta$$

along with

$$a_y = -g$$

into the above equations. Many projectile problems become finding the time for some event to occur in one dimension and using that time to find something out in the other dimension. Here are some useful equations for projectiles whose starting and ending heights are the same:

Time to reach highest point	$\Delta t_h = \dfrac{v_i \sin\theta}{g}$

Maximum height reached	$h = \dfrac{v_i^2 \sin^2\theta}{2g}$
Time of flight (twice time to highest point!)	$\Delta t_h = \dfrac{2v_i \sin\theta}{g}$
Range (Max range when θ = 45°)	$R = \dfrac{v_i^2 \sin 2\theta}{g}$

- **Velocity is Relative; Reference Frames**
  The basic relation is obvious:

$$\vec{\mathbf{v}}_{AC} = \vec{\mathbf{v}}_{AB} + \vec{\mathbf{v}}_{BC}$$

  Application requires a carefully considered diagram.

Chapter 4: Force and Newton's Laws of Motion
We learn that the motion is caused by forces.

- **Forces**
  Long range and contact forces.
    - The vector sum of all forces acting on the object is called the net force.
    - Use free-body diagrams with dealing with forces.

- **Inertia and Equilibrium: Newton's First Law of Motion**
  "An object's velocity vector $\vec{\mathbf{v}}$ remains constant if and only if the net force acting on the object is zero."
  Inertia is an object's resistance to changes in velocity. Mass is a measure of inertia.
  If the net force is zero, the object is in translational equilibrium. The condition for translational equilibrium is

$$\sum F_x = 0 \qquad\qquad \sum F_y = 0$$

- **Net Force, Mass, and Acceleration: Newton's Second Law of Motion**

$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

  In component form

$$\sum F_x = ma_x \qquad\qquad \sum F_y = ma_y$$

  The forces are found from FBD and the accelerations from the motion of the object.

- **Interaction Pairs: Newton's Third Law of Motion**

  "In an interaction between two objects, each object exerts a force on the other. These two forces are equal in magnitude and opposite in direction."
    - The forces act on different systems.

- **Gravitational Forces**
  Newton's law of universal gravitation (not one of his laws of motion)

$$F = \frac{Gm_1m_2}{r^2}$$

Gravitation is our first long range force. The universal gravitational constant

$$G = 6.674 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$$

is related to the acceleration due to gravity

$$g = \frac{GM_E}{R_E^{\,2}}$$

The weight is related to the mass by

$$W = mg$$

- **Contact Forces**
    - Normal force
    - Friction – directed to oppose motion. Static is greater than kinetic.
        - Kinetic

$$f_k = \mu_k N$$

        - Static

$$f_{s,\max} = \mu_s N$$

For a plane inclined at angle θ, it is necessary to replace the weight with components:

$$W_x = \pm W \sin\theta \qquad W_y = -W \cos\theta$$

- **Tension**
  "An ideal cord pulls in the direction of the cord with forces of equal magnitude on the objects attached to its ends as long as no external force is exerted on it anywhere between the ends. An ideal cord has zero mass and zero weight."
  A pulley changes the direction of the tension.

- **Applying Newton's Second Law**
  The picture is very important!!

- **Reference Frames**
  Newton's first law defines an inertial reference frame.

- **Apparent weight**
  Your true weight does not change. The normal force changes.

- **Air Resistance**
  Air resistance opposes the motion of the object. Is very difficult to deal with quantitatively.

- **Fundamental Forces**
  - Gravity
  - Electromagnetism
  - Weak nuclear
  - Strong nuclear

Chapter 5 Circular Motion
A special type of motion in a plane is described. A little of where it comes from is presented but more details will come in chapter 8.

- **Description of Uniform Circular Motion**
  In a rigid body the distance between any two points remains the same when the body is translated or rotated.
  Angular displacement

$$\Delta\theta = \theta_f - \theta_i$$

has a sign associated with it. The average angular velocity

$$\omega_{av} = \frac{\Delta\theta}{\Delta t}$$

Instantaneous angular velocity

$$\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$$

Angles are measured in radians. 2π radians = 360^o.
The speed of a point on an object rotating about a fixed axis is related to the angular speed of the rotating object

$$v = \omega r$$

The period (*T*) is the time needed for one revolution. The frequency (*f*) is the number of revolutions per unit time.

$$f = \frac{1}{T}$$

$$v = \frac{2\pi r}{T} = 2\pi r f$$

$$\omega = 2\pi f$$

- **Radial Acceleration**
  An object traveling around a circle at constant speed will experience an acceleration towards the center of the circle. The radial acceleration is

$$a_r = \frac{v^2}{r} = \omega^2 r$$

Newton's second law can be applied to uniform circular motion. Take one of the axes along the radial direction:

$$\sum F_r = ma_r$$

- **Unbanked and Banked Curves**
  Newton's second law for uniform circular motion analyzes the situation of a flat and a banked curve.
  - For an unbanked curve, the radial acceleration is supplied by (static) friction

$$v \le \sqrt{\mu_s r g}$$

  - For a banked curve, the radial acceleration is supplied by a component of the normal force

$$\tan\theta = \frac{v^2}{rg}$$

When a car does not travel at the ideal banked curve speed, friction supplies a portion of the radial acceleration.

- **Circular Orbits of Satellites and Planets**
  Newton' second law for uniform circular motion analyzes circular orbits. Gravitation supplies the radial force

$$F = \frac{Gm_1m_2}{r^2}$$

Newton was able to derive Kepler's Laws of Planetary Motion.
  - The planets travel in elliptical orbits with the Sun at one focus of the ellipse.
  - A line drawn from a planet to the Sun sweeps out equal areas in equal time intervals.
  - The square of the orbital period is proportional to the cube of the average distance from the planet to the Sun.

- **Nonuniform Circular Motion**
  There is now a tangential acceleration

$$a_t = \alpha r$$

to go with the radial acceleration

$$a_r = \frac{v^2}{r} = \omega^2 r$$

The net acceleration is

$$a = \sqrt{a_r{}^2 + a_t{}^2}$$

Newton's second law can be applied to these problems. Now the components are radial and tangential, not x and y.

- **Tangential and Angular Acceleration**
  The angular acceleration is

$$\alpha = \lim_{\Delta t \to 0} \frac{\Delta \omega}{\Delta t}$$

We have a set of equations for constant angular acceleration:

$$\Delta\omega = \omega_f - \omega_i = \alpha\Delta t$$

$$\Delta\theta = \tfrac{1}{2}(\omega_f + \omega_i)\Delta t$$
$$\Delta\theta = \omega_i \Delta t + \tfrac{1}{2}\alpha(\Delta t)^2$$
$$\omega_f^2 - \omega_i^2 = 2\alpha\Delta\theta$$

These equations can be used to solve a variety of problems.

- **Apparent Weight and Artificial Gravity**
  Because a spacecraft in orbit is a non-inertial reference frame, objects in the spacecraft appear weightless.
  Artificial gravity can be created by rotating the spacecraft.
  A centrifuge creates artificial gravity that can separate particles.