PHYS 2211

Look over:
Chapter 2 Sections 1-9
Sample Problems 1, 2, 5, 7

PHYS 1111

Look over:
Chapter 2 Sections 1-7
Examples 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Topics Covered

1) Average Speed
2) Average Velocity
3) Instantaneous Velocity and Derivatives
4) Average Acceleration
5) Instantaneous Acceleration and Derivatives
6) Equations of motion in the Horizontal (x-direction)
1) Equations of motion in the Vertical (y-direction)

Average Speed

Speed is the rate at which an object covers distance.

$$\text{Speed} = \frac{\text{Total length of path traveled (a scalar)}}{\text{Time (a scalar)}}$$

$$\bar{v} = \frac{d}{t}$$

Speed has units of length divide by units of time.

Ex: $\frac{\text{miles}}{\text{hour}}$ (mph), $\frac{\text{meters}}{\text{second}}$ (m/s) $\frac{\text{km}}{\text{hour}}$ (km/hr)

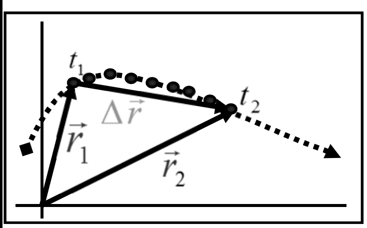
Average Velocity

The **Velocity** of a particle is the rate which position changes with time.

Velocity is a vector quantity so it has a direction as well as a magnitude associated with it.

$$\text{Averge Velocity} = \frac{\text{Displacement (a Vector)}}{\text{Elapsed Time (a Scalar)}}$$

Average Velocity



$$\vec{v}_{ave} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1}$$

The units of velocity are the same as the units of speed.

The Components of Velocity

If an object is moving in 3 dimensions then the average Velocity can be written as:

$$\vec{v}_{\text{ave}} = \frac{(r_{x_2} - r_{x_2})\hat{i} + (r_{y_2} - r_{y_1})\hat{j} + (r_{z_2} - r_{z_1})\hat{k}}{t_2 - t_1}$$

Two Different Definitions of Speed

We have defined speed as: $\text{Speed} = \frac{\text{Total length of path traveled}}{\text{Time}}$

But when we talk about the speed of an object we will mean the magnitude of the velocity of an object.

$$\text{Speed} = |\vec{v}|$$

Example 1

1) It normal takes you 10 min to travel 5.0 mi to school along a straight road. You leave home 15 minutes before class begins. Delays caused by a broken traffic light slow down traffic to 20 mi/hr for the first 2.0 mi of the trip. Will you be late for class?

Instantaneous Velocity

Instantaneous Velocity is how fast an object is going at any given of time.

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

$$v = |\vec{v}|$$

The Components of Instantaneous Velocity

$$\vec{v} = v_x \hat{i} + v_y \hat{j} + v_z \hat{k}$$

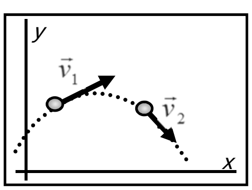
$$v_x = \lim_{\Delta t \to 0} \frac{\Delta r_x}{\Delta t} = \frac{d r_x}{dt}$$

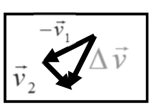
$$v_y = \lim_{\Delta t \to 0} \frac{\Delta r_y}{\Delta t} = \frac{d r_y}{dt}$$

$$v_z = \lim_{\Delta t \to 0} \frac{\Delta r_z}{\Delta t} = \frac{d r_z}{dt}$$

Acceleration

Just like we defined velocity to be the rate of change of position, we can also define the rate of change of velocity. This quantity is called **Acceleration**.





$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

Instantaneous Acceleration

Just like we did for velocity we can define the **Instantaneous Acceleration** which is the acceleration at any given instant in time.

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

$$a = |\vec{a}|$$

The Components of Instantaneous Acceleration

$$\vec{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$$

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

$$a_y = \lim_{\Delta t \to 0} \frac{\Delta v_y}{\Delta t} = \frac{dv_y}{dt}$$

$$a_z = \lim_{\Delta t \to 0} \frac{\Delta v_z}{\Delta t} = \frac{dv_z}{dt}$$

Equations of Motion With a Constant Acceleration in 1-Dimension

$$v_x = v_{x_0} + a_x t \qquad (\text{no } x\text{'s})$$

$$\Delta x = x - x_0 = \left(\frac{v_{x_0} + v_x}{2}\right) t \qquad (\text{no } a_x)$$

$$\Delta x = x - x_0 = v_{x_0} t + \tfrac{1}{2} a_x t^2 \qquad (\text{no } v_x)$$

$$v_x^2 = v_{x_0}^2 + 2a_x (x - x_0) \qquad (\text{no } t)$$

Problem Solving

1) **Read the entire problem carefully**. Then read it again to try to find out what you are being told.
2) **Draw a diagram of the physical situation**. Label the diagram with the information given in the problem. Be sure to include units. If some standard symbols have been introduced, label the parts of the diagram with them, too.
3) Only after you are sure you understand what is given after you have labeled the diagram should you **tackle the question**. It is often a good idea to briefly write down the question, using symbols.
4) The next step is to **find a mathematical relationship between the known and unknown quantities**. In most cases, you will need to write the relationship between the known and unknown quantities in the form of an equation, or perhaps several equations.

Problem Solving

5) Next you should **solve the equation, or equations, for the unknown quantity or quantities**. This means rearranging the formula in accord with the rules of algebra so that you have an equation with the unknown on the left-hand side of the equals sign and all the known quantities and constants on the right-hand side.
6) Now and only now should you **substitute numerical values into the equation**. Do not substitute just "bare numbers," but substitute both the numerical values and the units. Remember units are treated as if they are algebraic quantities.
7) As a final check, you should **consider whether your answer is reasonable**. You should make sure the answer comes out with the right units. If it does not you will need to see where the mistake was made.

Example 2

2) In coming to a stop, a car leaves skid marks on the highway *320 m* long. Assuming a deceleration of *10 m/s²* (roughly the maximum for rubber tires on dry pavement), estimate the speed of the car just before braking?

Example 3

3)On a highway at night you see a stalled car and brake to a stop. As you brake, the velocity of your car decreases at a rate of 5.0 m/s^2.

a) If your initial velocity is 15 m/s what is your stopping distance?

b) How much time does it take you to stop?

Free Fall

Galileo Galilei an Italian scientist was the first to measure that in the absence of air resistance all objects regardless of the size, weight, or composition, fall at the same acceleration at the same point on the earth's surface.

g, What a Special Acceleration

Near the surface of the earth objects are accelerated downwards due to the force of Gravity.

The value of the **Acceleration due to Gravity (g)** is:

$$g = 32 \frac{\text{ft}}{\text{s}^2} = 9.8 \frac{\text{m}}{\text{s}^2}$$

Free Fall Equations

$$v_y = v_{y_0} + a_y t \qquad (\text{no } y\text{'s})$$

$$\Delta y = y - y_0 = \left(\frac{v_{y_0} + v_y}{2}\right)t \qquad (\text{no } a_y)$$

$$\Delta y = y - y_0 = v_{y_0} t + \tfrac{1}{2} a_y t^2 \qquad (\text{no } v_y)$$

$$v_y^2 = v_{y_0}^2 + 2a_y\left(y - y_0\right) \qquad (\text{no } t)$$

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

If you throw an object straight up into the air

The object will return with the same speed that you throw it up with, but it will be moving in the down ward direction.

The speed at the objects highest distance will be zero.

Example 4

4) A student throws a set of keys vertically upward to her sorority sister, who is in a window *4.00 m* above. The keys are caught *1.50 s* later by the sister's outstretched hand.

a) With what initial velocity were the keys thrown?

b) What was the velocity of the keys just before they were caught?

Air Resistance

All things do not fall with the same acceleration. This is due to the resistance of the air that that fall through.

Air Resistance is the affect of having to push air out of the way as they fall.

What Affects Air Resistance

There are three main things that the air resistance depends on:

1)The shape of the object.
2)The mass of the object.
3)The speed at which an object is moving.

At some point the object can not be slowed down anymore due to air resistance and the object continues to fall at a constant speed called the terminal speed.

5)A woman is reported to have fallen *144 ft* from the 17th floor of a building, landing on a metal ventilator box, which she crushed to a depth of *18.0 in*. She suffered only minor injuries. Calculate:

a) the speed of the woman just before she collided with the ventilator box,
b) her average acceleration while in contact with the box, and
c) the time it took to crush the box.

Summary of 1-D Motion

- Kinematics is the description of how objects move with respect to a defined reference frame.
- Displacement is the change in position of an object.
- Average speed is the distance traveled divided by the time it took; average velocity is the displacement divided by the time.
- Instantaneous velocity is the limit as the time becomes infinitesimally short.

Summary of 1-D Motion

- Average acceleration is the change in velocity divided by the time.
- Instantaneous acceleration is the limit as the time interval becomes infinitesimally small.
- The equations of motion for constant acceleration are given in the text; there are four, each one of which requires a different set of quantities.
- Objects falling (or having been projected) near the surface of the Earth experience a gravitational acceleration of 9.80 m/s^2.