PHYS011 - Kariapper
Chapter 2 Lecture Notes

Formulas:

$$v = v_0 + at$$
$$x = x_0 + v_0 t + (1/2)at^2$$
$$x = x_0 + (1/2)(v_0 + v)t$$
$$v^2 = v_0^2 + 2a(x - x_0)$$
$$\bar{v} = (v_0 + v)/2$$

Constants:

$$g = 9.80 \text{ m/s}^2$$

<u>Main Ideas:</u>
1. Define various physical quantities relating to motion.
2. Understand uniform (constant) accelerated motion (including falling bodies).
3. Learn how to solve problems.
4.

1. Definitions

1.1 Distance and Displacement

Distance is the total length that an object has moved. If I walk 2 km north, then 1 km south, the distance I have moved is 3 km. On the other hand, displacement is the net change in position. My displacement is only 1 km. If I go 3 km west and 4 km north my distance = 7 km and displaceLment = 5 km. For displacement $\Delta x = x_2 - x_1$.
The displacement and distance can be drawn on an axis.

1.2 Speed and Velocity

Average speed is defined as distance/time. $\bar{s} = d/t$.

<u>Problem:</u> If a jogger jogs for 1.5 hours at an average speed of 2.22 m/s, how far does he go?

Velocity is defined as a quantity which has a magnitude (or value) as well as a direction. Such a quantity is called a vector. In print a vector is usually designated by using bold face print. For instance, velocity might be written using the symbol **v**.

Average velocity is defined as displacement/time.

$$\bar{v} = \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}.$$

If it takes me 45 minutes to walk 2.0 km west, then 1.0 km east, my average speed is 3.0/0.75 = 4.0 km/hour while my average velocity is 1.0/.75 = 1.3 km/hour.

Problem: The land speed record was set by the car ThrustSSC in 1997 and is 341 m/s (763 miles/hour). This was the first land vehicle to travel faster than the speed of sound. For this record, the car is first driven one direction, then the other, and the two speeds are averaged. Suppose the car covered 1609 m in one direction, then turned around and covered the same distance. If the first pass is done in 4.74 s and the second in 4.69 s, what is his average velocity on each pass?

Instantaneous velocity is the velocity at a single instant. It is defined as the average velocity over a very short period of time as the period of time approaches an infinitesimal limit.

$$\mathbf{v} = \lim_{\Delta t \to 0} \frac{\Delta \mathbf{x}}{\Delta t} = \frac{d\mathbf{x}}{dt}.$$

Note that the magnitude of the instantaneous velocity is the instantaneous speed. Your car speedometer gives your instantaneous speed, but not instantaneous velocity. Why?

1.3 ACCELERATION

Average acceleration is defined as

$$\bar{\mathbf{a}} = \frac{\mathbf{v}_f - \mathbf{v}_i}{t_f - t_i} = \frac{\Delta \mathbf{v}}{\Delta t}.$$

Note that an object is accelerating if it changes speed or if changes direction since acceleration and velocity are vectors. Acceleration is the rate at which velocity changes, while velocity is the rate at which position changes.

Problem: A sports car accelerates from 0 to 60 mph in 6.0 seconds. What is its average acceleration?

Problem: You are driving 20 m/s when a dog runs across your path. You slam on your brakes and in 2 seconds slow to 5 m/s. What was your average acceleration?

Instantaneous acceleration is given by

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

2. Motion at Constant Acceleration

We now use these simple definitions to derive equations for the special case when **acceleration is a constant**. The equations we will derive can only be used when the acceleration is a constant. That means when the rate of change of the velocity is constant. It doesn't change. The velocity itself will change, but the rate of the change will always be the same. We start with the definition of acceleration and set the initial time $t_i = 0$, the final time $t_f = t$,, the initial velocity $v_i = v_0$ and the final velocity $v_f = v$.

$a = (v - v_0)/t. \Rightarrow$ $\boxed{v = v_0 + at}$

Remember, mathematical equations have a meaning. What does this one mean?

Setting $t_0 = 0$, we get $\bar{v} = (x - x_0)/t \Rightarrow x = x_0 + \bar{v}t$ or with $\bar{v} = (v_0 + v)/2 \Rightarrow$

$$\boxed{x = x_0 + \tfrac{1}{2}(v + v_0)t}$$

Since $v = v_0 + at$, we substitute this in the previous equation to get
$x = x_0 + (1/2)(v_0 + at + v_0)t$

$$\boxed{x = x_0 + v_0 t + (1/2)at^2}$$

Finally, from substituting t from first boxed into second boxed, we get
$x = x_0 + (1/2)(v + v_0)(v - v_0)/a$
$x = x_0 + (1/2)(v^2 - v_0^2)/a$

$$\boxed{v^2 = v_0^2 + 2a(x - x_0)}$$

Writing all the equations together gives

	x, x_0	a	v	v_0	t
$v = v_0 + at$		*	*	*	*
$x = x_0 + (1/2)(v_0 + v)t$	*		*	*	*
$x = x_0 + v_0 t + (1/2)at^2$	*	*		*	*
$v^2 = v_0^2 + 2a(x - x_0)$	*	*	*	*	

Another equation that is useful to know is $\bar{v} = (v_0 + v)/2$, and recall that $x - x_0$ is the distance traveled so often we set $x_0 = 0$ and just use x for the distance. **These only work when acceleration is a constant (Magnitude and Direction).** If you are given three known quantities and one unknown, you can chose one of these equations. If you are given two known quantities and two unknown ones, you will have to use two of these equations.

See Section 2-6 "Solving Problems" Solving problems will be a big part of this class.

1. Read the Problem Carefully.
2. Draw a Diagram
3. Write down what is known or given and what you want to know.
4. Think about the physics principles and make sure the equations are valid.
5. Do the calculation.
6. Think about the answer. Is it reasonable? (Order of magnitude)
7. Check the units.

<u>Problem:</u> Previously, we had seen that our sports car could accelerate at 4.5 m/s^2. (This is a constant acceleration). After 8 seconds how far has it gone?

<u>Problem:</u> What is the speed of the car after 10 seconds?

NOTE:
We often use the word deceleration to mean that an object is slowing down. What is deceleration? Is it the same as negative acceleration? NO! Negative acceleration means the sign of the acceleration is negative. *Deceleration is when the direction of acceleration is opposite the direction of motion.* Suppose a car is travelling in the negative direction. To decelerate it must have an acceleration in the positive direction. On the other hand it will gain speed when the acceleration is in the negative direction.

<u>Problem:</u> A car is traveling in the negative direction at -32 m/s. The driver applies his brakes and stops in 7.3 seconds. What was the car's acceleration?

<u>Problem:</u> Suppose a spacecraft is traveling with a speed of 3250 m/s, and it slows down by firing its retro rockets, so that a = -10 m/s^2. What is the velocity of the spacecraft after it has traveled 215 km?

<u>Problem:</u> Suppose a slow Texas lineman picks up a fumbled football on the 20 yard line and runs toward the end zone at 7.3 m/s. The safety is standing on the 23 yard line and needs to catch up to the lineman before he scores a touchdown.

If the safety can accelerate at a constant rate, what must be his minimum acceleration to catch the lineman? What will be the safety's final velocity?

3. Free Falling Bodies

One of the most important cases of uniform accelerated motion is the case of objects which are near to earth allowed to free fall. At first, it might seem that different objects accelerate at different rates near the earth depending on their weight. That is what people thought before Galileo did his experiments in the late 1500's. However, Galileo showed that objects of different weights dropped at the same rate.

The reason that some things drop slower **in the air** is because air resistance pushes against the moving object. If there was no air resistance then even the open paper would drop at the same rate. (On the moon, where there is no air, a feather and a hammer fell at the same rate). When an object is dropped, its velocity increases by 9.80 m/s every second. It continues to go faster. If there was no air resistance, this would continue every second. Because there is air resistance, the object eventually reaches a terminal velocity and doesn't go any faster. But for many applications, we can negelect air resistance. Then, everything near the surface of the earth accelerates toward the center of the earth with a consant acceleration. **Therefore, all of the equations we have derived for constant acceleration apply to an object in free fall, neglecting air resistance).** All objects fall with a constant acceleration of about 9.80 m/s^2 which we call *g*, the acceleration due to gravity.

<u>Problem:</u> A stone is dropped from a very tall building. What is its position and velocity after 3.00 seconds?

<u>Problem:</u> A boy throws a ball upward from the top of a building with an initial velocity of 20.0 m/s. The building is 50 meters high. Determine (a) the time needed for the stone to reach its maximum height (b) the maximum height (c) the time needed for the stone to reach the level of the thrower (d) the velocity of the stone at this instant (e) the velocity and position of the stone after 5.00 s (f) the velocity of the stone when it reaches the bottom of the building.

4.