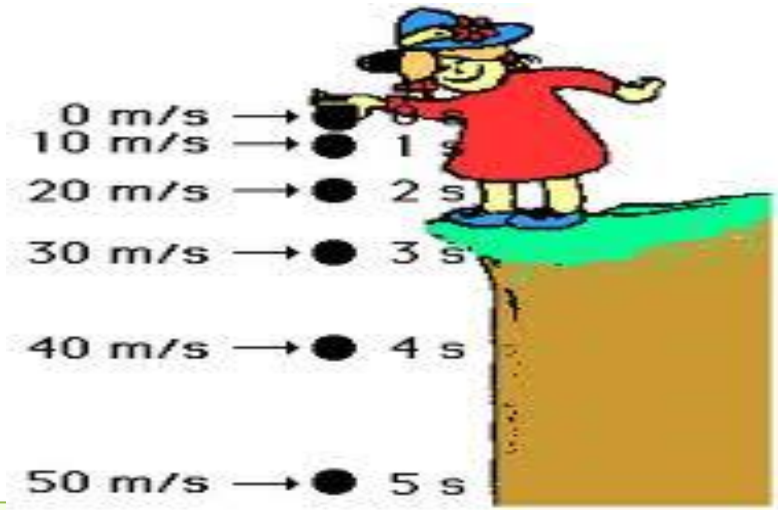


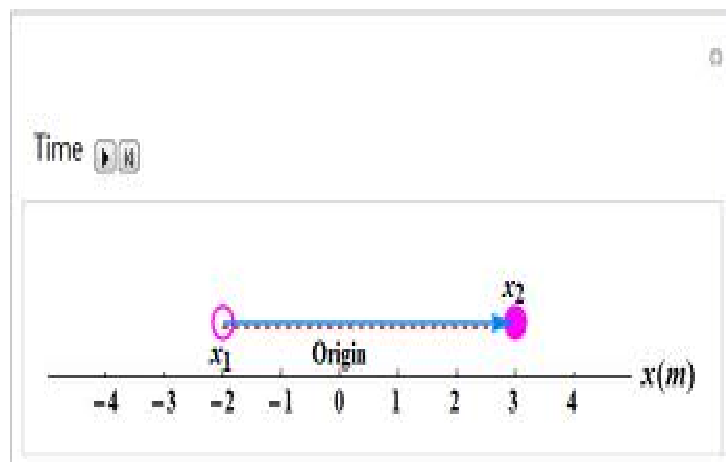
Chapter 2
Motion Along a Straight Line

By: Dr Wajood Diery

$$\Delta d = v_1 t + \frac{1}{2} a t^2$$

$$v_2 = v_1 + at$$

$$v_2^2 = v_1^2 + 2a(\Delta d)$$



2-2 Motion

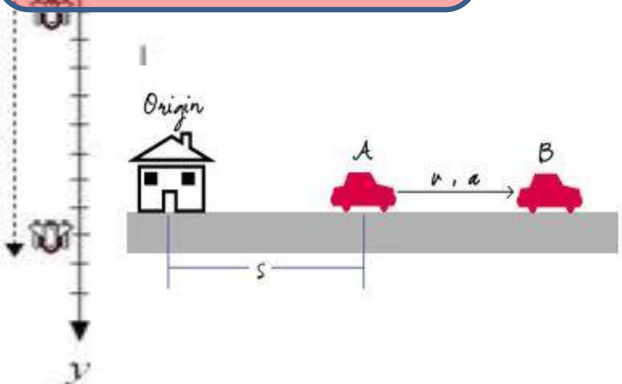
Mechanics

Kinematics
Motion it self

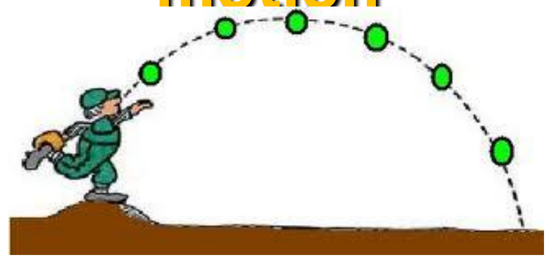
dynamics
Newton laws

statics

One dimensional motion



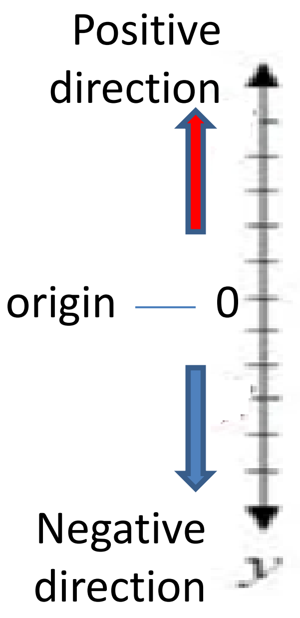
Two dimensional motion

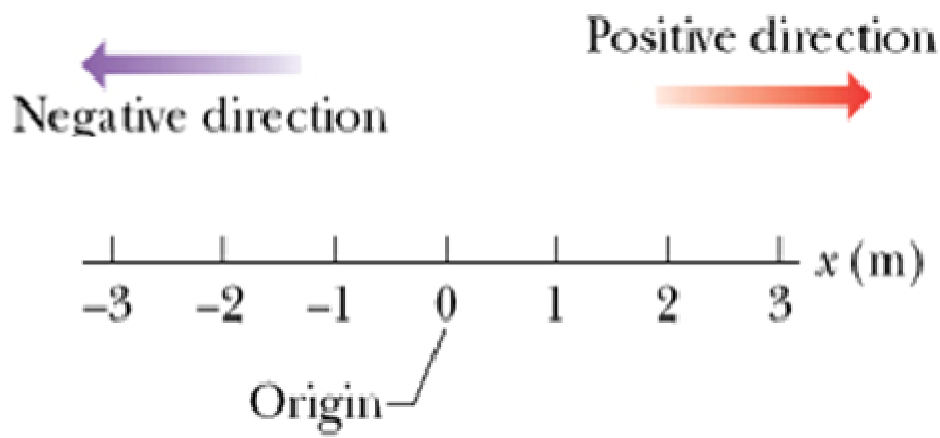


three dimensional motion

2-3 position and displacement

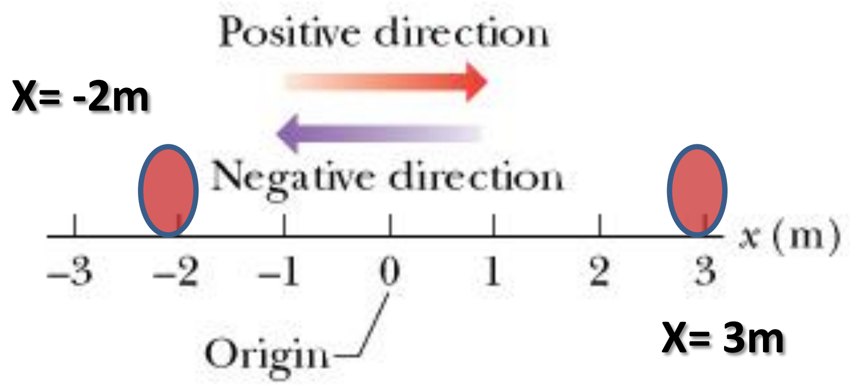
To locate an object means to find it's position relative to reference point origin (or zero point) of an axis .





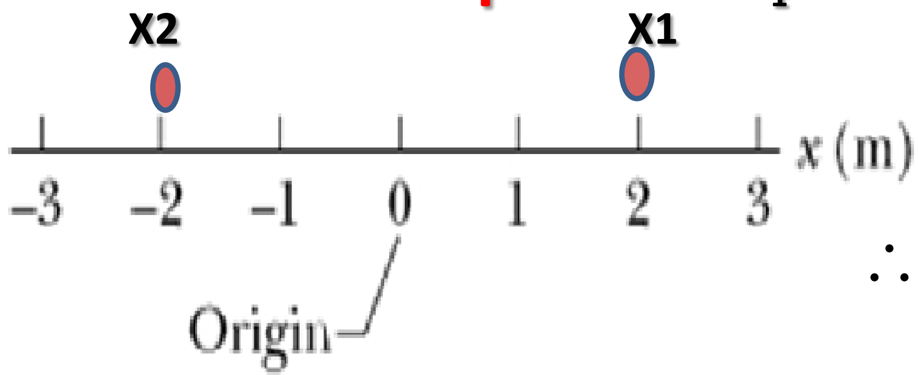
2-3 position and displacement

- Position: x
- Unit: m.



2-3 position and displacement

If the particle move from the position x_1 to the position x_2



$\Delta X = (-2) - (2) = -4m$

$\therefore\ \Delta x = 4m$ to the left

Displacement : $\Delta x = x_2 - x_1$

- **Unit: m.**
- **It is a vector quantity: has magnitude and direction.**
- **Direction: if Δx is positive $\Rightarrow$ moving to the right**
  if Δx is negative $\Rightarrow$ moving to the left

Distance : d

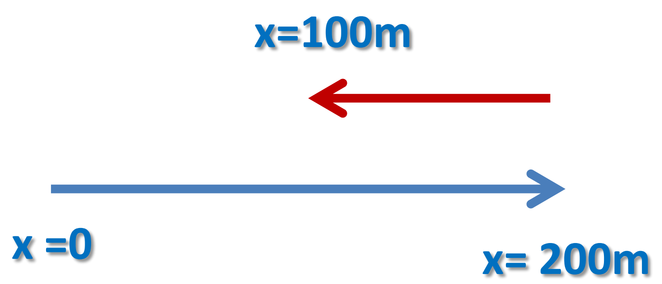
It is a scalar quantity: has no direction.

What is the difference between displacement and distance?

if a particle moves from x =0 m to x= 200m and then back to x=100m

d= 200+100=300 m

Δx= 100 – 0 =100 m



2-4 Average velocity and average speed

- The ratio of displacement that occurs during a particular time interval to that interval.

- Unit of is m/s.

2-4 Average velocity and average speed

Average speed S_{avg}

- The ratio of total distance that occurs during a particular time interval to that interval

- Unit of is m/s

Sample Problem

You drive a beat-up pickup truck along a straight road for 8.4 km at 70 km/h, at which point the truck runs out of gasoline and stops. Over the next 30 min, you walk another 2.0 km farther along the road to a gasoline station.

(a) What is your overall displacement from the beginning of your drive to your arrival at the station?

(b) What is the time interval Δt from the beginning of your drive to your arrival at the station?

Sample Problem

(c) What is your average velocity v_{avg} from the beginning of your drive to your arrival at the station? Find it both numerically and graphically.

Sample Problem

(d) Suppose that to pump the gasoline, pay for it, and walk back to the truck takes you another 45 min. What is your average speed from the beginning of your drive to your return to the truck with the gasoline?

2-5 Instantaneous velocity and speed

Instantaneous velocity

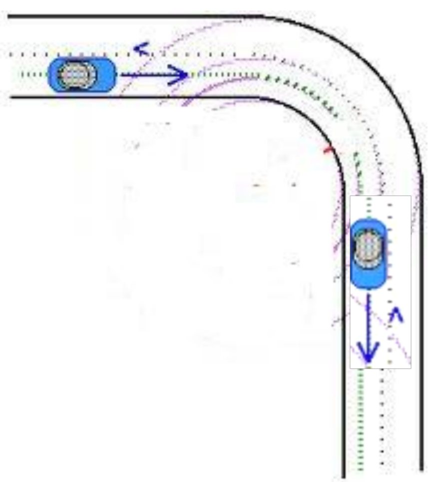
- Velocity at any instant.

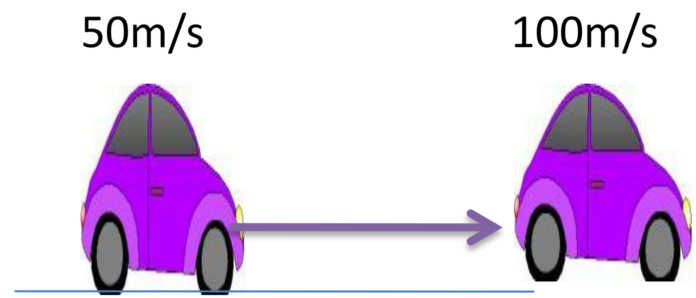
- Unit is m/s
- It is a vector quantity

$$x \rightarrow \Delta x \quad \rightarrow v_{avg}, v \quad \rightarrow ????$$

2-6 Acceleration

When an object’s velocity changes(**magnitude, or direction**),We say the particle undergoes an acceleration.



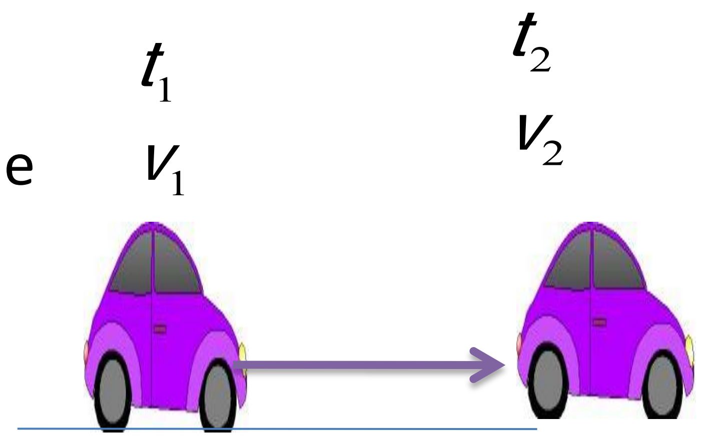


Average Acceleration

Instantaneous Acceleration

Average Acceleration

- is the ratio of a change in velocity to the time Interval in which the change occurs.



- $$a_{avg} = \frac{\Delta V}{\Delta t} = \frac{V_2 - V_1}{t_2 - t_1}$$

- $\text{Unit} : \text{m/s}^2$

- It is a vector quantity.

Instantaneous Acceleration

- $$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$
- $\text{Unit}: \text{m/s}^2$
- It is a vector quantity.
- $$a = \frac{dv}{dt} \qquad \text{but } v = \frac{dx}{dt}$$

$$a = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2 x}{dt^2}$$

$$a$$

$$\frac{dv}{dt} \qquad \frac{d^2 x}{dt^2}$$

To the left downward motion	motion upward To the right
Velocity increase a -ve	Velocity increases a +ve
Velocity decreases a +ve	Velocity decrease a -ve

sample problem (2-4)

2-7 Constant acceleration

☞ Constant acceleration does not mean the velocity is constant, it means the velocity changes with constant rate.

☞ Constant acceleration does not mean $a=0$. If $a=0 \Rightarrow v$ is constant.

Equations of motion

Equation	Missing Quantity
$v = v_0 + at$	$x - x_0$
$x - x_0 = v_0 + \frac{1}{2} at^2$	v
$v^2 = v_0^2 + 2a(x - x_0)$	t
$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
$x - x_0 = vt - \frac{1}{2} at^2$	v_0

$x_0 \rightarrow$ Initial position

$x \rightarrow$ final position

$v_0 \rightarrow$ Initial velocity

$v \rightarrow$ final velocity

$t \rightarrow$ time

$a \rightarrow$ Constant acceleration

- when the object starts from rest $\boxed{\Rightarrow V_0 = 0}$
- when the object stops $\boxed{\Rightarrow V = 0}$
- $X_0 = 0$ unless something else mentioned in the problem.

Sample Problem 2-5

The head of a woodpecker is moving forward at a speed of 7.49 m/s when the beak makes first contact with a tree limb. The beak stops after penetrating the limb by 1.87 mm. Assuming the acceleration to be constant, find the acceleration magnitude in terms of g.

$$v = v_0 + at$$

$$x - x_0 = v_0 + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t$$

$$x - x_0 = vt - \frac{1}{2}at^2$$

2-8 Free fall acceleration

- Free fall is the motion of an object under influence of Gravity and ignoring any other effects such as air resistance.

- All objects in free fall accelerate downward at the same rate and is independent of the object’s mass, density or shape.

- This acceleration is called **the free-fall acceleration**.

- $\boxed{g = 9.8\, m/s^2 \quad downward}$

Equations of motion

- The motion along y axis $x \rightarrow y$
- $a = -g$

$$v = v_0 + at \rightarrow$$

$$x - x_0 = v_0 + \frac{1}{2}at^2 \rightarrow$$

$$v^2 = V_0^2 + 2a(x - x_0) \rightarrow$$

$$x - x_0 = \frac{1}{2}(v_0 + v)t \rightarrow$$

$$x - x_0 = vt - \frac{1}{2}at^2 \rightarrow$$

$$v = v_0 - gt$$

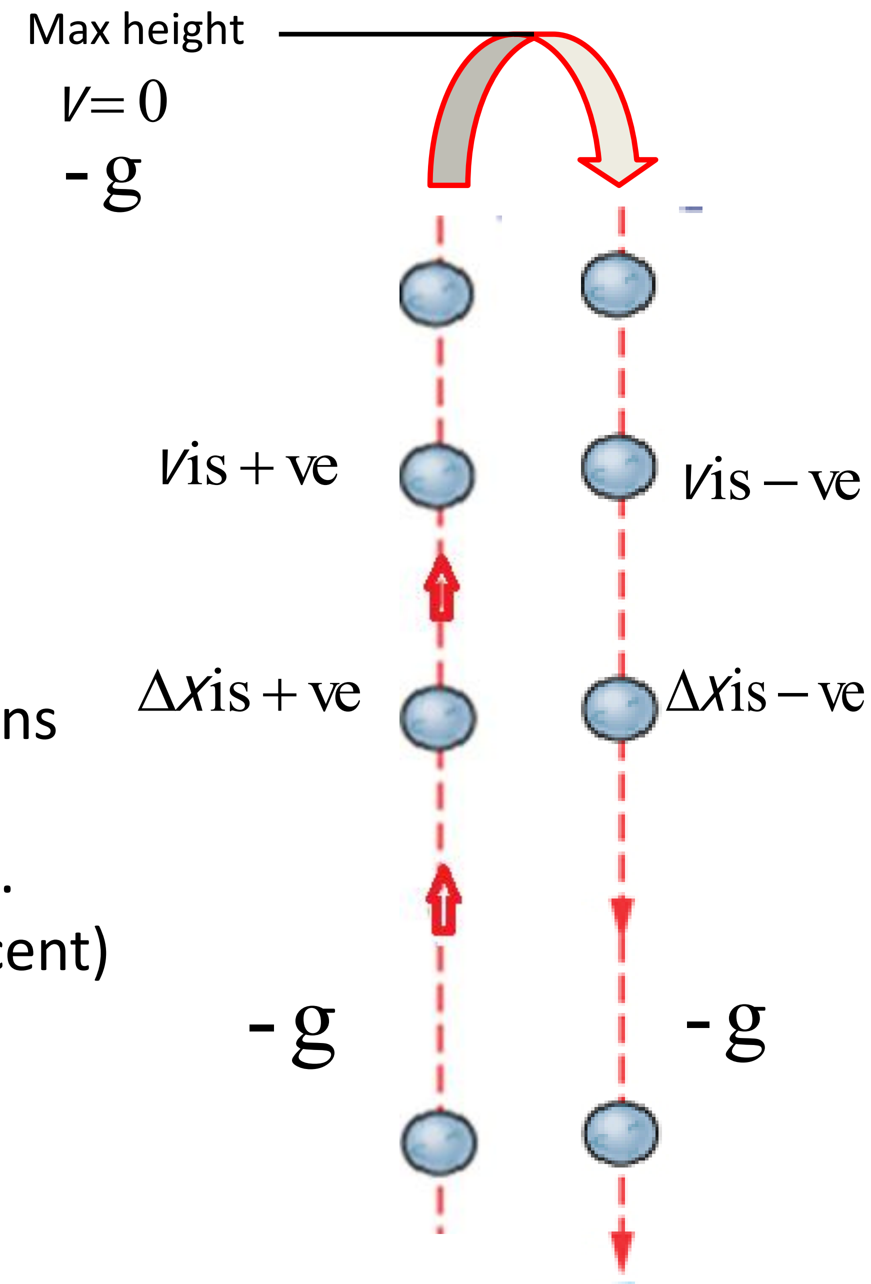
$$y - y_0 = v_0 - \frac{1}{2}gt^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2}gt^2$$

- When substituting for g in the equations
  g = 9.8m/s.
- when the object is moving up (ascent).
- When the object is moving down (descent)



Sample Problem 2-7

On September 26, 1993, Dave Munday went over the Canadian edge of Niagara Falls in a steel ball equipped with an air hole and then fell 48 m to the water (and rocks). Assume his initial velocity was zero, and neglect the effect of the air on the ball during the fall.

(a) How long did Munday fall to reach the water surface?

$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2} g t^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2} g t^2$$

(b) Munday could count off the three seconds of free fall but could not see how far he had fallen with each count. Determine his position at each full second.

$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2}gt^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2}gt^2$$

(c) What was Munday's velocity as he reached the water surface?

$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2}gt^2$$

$$v^2 = v_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2}gt^2$$

(d) What was Munday's velocity at each count of one full second? Was he aware of his increasing speed?

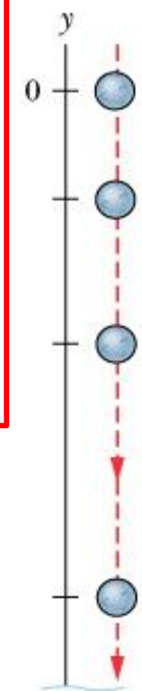
$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2}gt^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2}gt^2$$



t	y	v	a
(s)	(m)	(m/s)	(m/s^2)
0	0	0	–9.8
1	–4.9	–9.8	–9.8
2	–19.6	–19.6	–9.8
3	–44.1	–29.4	–9.8
	–48.0		–9.8

Sample Problem 2-8

In Fig. 2-12, a pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?

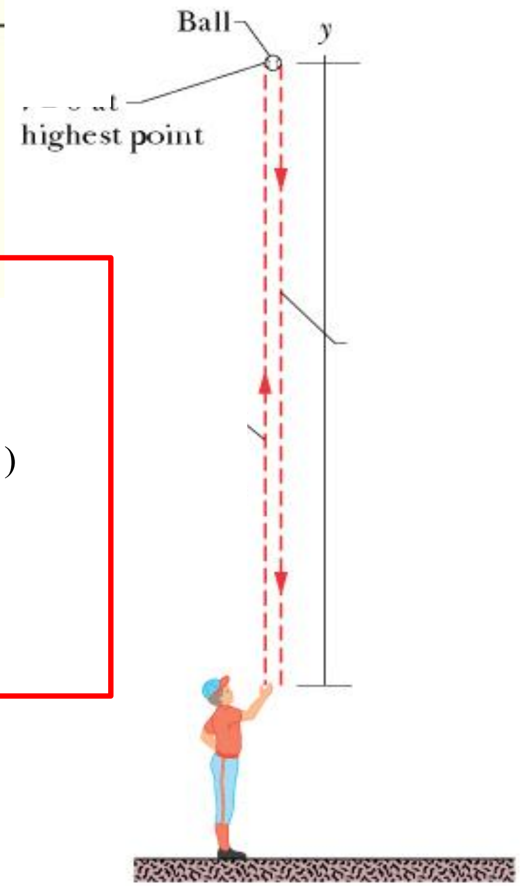
$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2} gt^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2} gt^2$$



(b) What is the ball's maximum height above its release point?

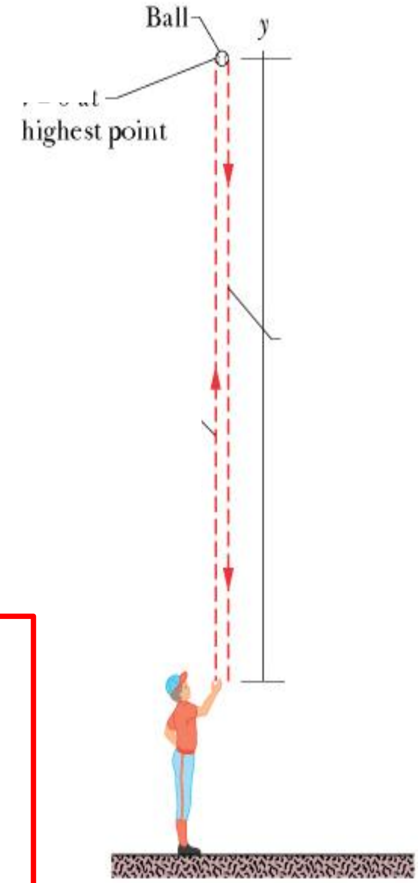
$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2}gt^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2}gt^2$$



(c) How long does the ball take to reach a point 5.0 m above its release point?

$$v = v_0 - gt$$

$$y - y_0 = v_0 - \frac{1}{2}gt^2$$

$$v^2 = V_0^2 - 2g(y - y_0)$$

$$y - y_0 = \frac{1}{2}(v_0 + v)t$$

$$y - y_0 = vt + \frac{1}{2}gt^2$$


THE
END