

## ACCELERATION DUE TO GRAVITY

- Freely falling objects accelerate downwards.
  - Measurement show acceleration as  $\approx 9.8 \text{ ms}^{-2}$
- If we were to measure velocities of a falling object at intervals of 1 s. we will get:

t	0	1	2	3	4	5
v	0	9.8	19.6	29.4	39.2	ms <sup>-1</sup>

recall  $v_f = v_o + at$

Thus acceleration when calculated is  $9.8 \text{ ms}^{-2}$  downward.

- Falling objects are mainly subjected to the pull of gravity.

ACCELERATION DUE TO GRAVITY is given the symbol : **g**

Its value varies from place to place on earth .

Worldwide average is  $9.81 \text{ ms}^{-2}$

At the Poles :  $9.83 \text{ ms}^{-2}$

At the Equator:  $9.78 \text{ ms}^{-2}$

- It is usually taken as  $9.80 \text{ ms}^{-2}$  for most calculations.

- Case of ball thrown up :  
ball's acceleration is  $9.8 \text{ ms}^{-2}$  whether rising or falling.

- **g is directed downwards**

## FREE FALL MOTION

A stone is dropped from a bridge. If it takes 3.0s to hit the water below, how high was the stone above the water before release?

Solution:

Given  $t = 3.0\text{s}$ ,  $v_0 = 0\text{ms}^{-1}$   
motion free fall!  $a = g = 9.8\text{ms}^{-2}$

Let distance travelled in 3.0s be:  $y$

assign downward as +ve, we could choose -ve provided then observe appropriate vector signs.

if we take up as +ve, then  $a = -9.8\text{ms}^{-2}$   
" " " " -ve, then  $a = +9.8\text{ms}^{-2}$

For distance travelled use eqn. which relates position & time directly.  
 $s = v_0 t + \frac{1}{2} a t^2$

ie.  $y = v_0 t + \frac{1}{2} a t^2$   $y = v_0 t + \frac{1}{2} a t^2$   
 $= (0)(3.0\text{s}) + \frac{1}{2} (9.8\text{ms}^{-2})(3.0\text{s})^2$   
 $= 44\text{m}$

Velocity before hitting water we use

$$\begin{aligned} v_f &= v_0 + at & v_f &= v_0 + at \\ &= 0\text{ms}^{-1} + (9.8\text{ms}^{-2})(3.0\text{s}) \\ &= 29.4\text{ms}^{-1} \end{aligned}$$

### EXAMPLE

A ball is thrown up with initial speed of 15.0 m/s and then falls, and is caught by the person who threw it.

- How high does the ball go?
- How fast is it going the instant before it is caught?
- How long was it in the air?

### SOLUTION

1. Motion is free fall, although with different initial conditions.

2. If we choose up as +ve, then  $v_0 = +15 \text{ m/s}$

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



At highest point B  $v_f = 0$

For upward movement, A to B

$v_0 = \text{final velocity} = v_f$

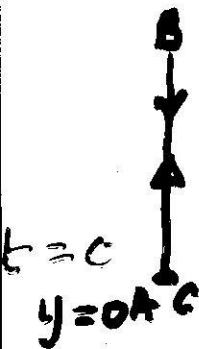
hence,  $v_f = 0$  can be used to get the value of  $y$ .

∴ for part a) we know  $v_0$ ,  $v_f$  &  $a$

can use  $v_f^2 = v_0^2 + 2ay$  height

$$\text{solving for } y = \frac{v_f^2 - v_0^2}{2a} = \frac{0 \text{ m}^2/\text{s}^2 - (15 \text{ m/s})^2}{2(-9.8 \text{ m/s}^2)}$$

$$= +11.5 \text{ m}$$



**N.B. our choice of up as +ve agrees with result.**

part b) Ball is caught at  $y=0$

using same initial conditions:

$$v_0 = +15.0 \text{ m/s}, a = -9.8 \text{ m/s}^2, y_0 = 0$$

relationship between  $y$  &  $v_f$  is in  $v_f^2 = v_0^2 + 2ay$

we solve eqn for  $v_f$  when  $y=0$

Solving this quadratic eqn. yields 2 answers

$v_f = +15\text{ m/s}$  &  $-15\text{ m/s}$ . Answer is:

$-15\text{ m/s}$  represents downward velocity

Different approach would be regarding the ball as falling from B to C through  $11.5\text{ m}$ .

in which case  $v_0 = 0$ ,  $y = -11.5\text{ m}$ ,  $a = +9.8\text{ m/s}^2$

Part c) Time of flight.

Use eqn which connects  $t$  with what is known.

$$y = v_0 t + \frac{1}{2} a t^2$$

$$t = 0$$

$$t = t$$

Find  $t$  when  $y = 0$

$$\Rightarrow 0 = (15\text{ m/s})t + \frac{1}{2} (-9.8\text{ m/s}^2)t^2$$

solving this quadratic eqn gives  $t = 0$

$$t = 3.06\text{ s}$$

Note 2 times  $y = 0$ , i.e. at start and end of flight.

$\therefore$  Correct answer is  $3.06\text{ s}$ .

Alternate solution for part c:

Object takes precisely as long to fall as it takes to rise. [on condition  $y = \text{max. ht at B}$ ]

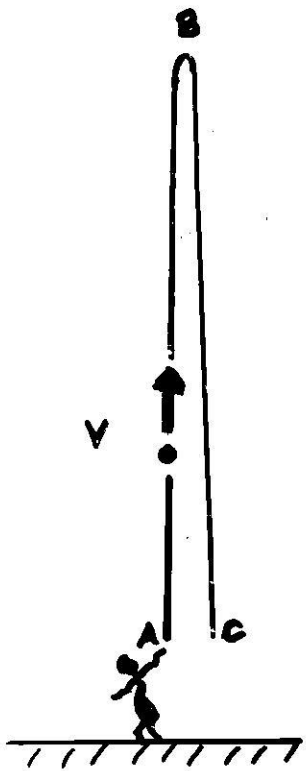
from  $y = \frac{1}{2} a t^2$  since  $v_0 t = 0$   $t = 0$  at  $y = 0$

We know  $y = 11.5\text{ m}$ ,  $a = -9.8\text{ m/s}^2$  take  $a = -g$

then  $a = -(-9.8\text{ m/s}^2) = 9.8\text{ m/s}^2$

$$t_{\text{up}} = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2 \times 11.5}{9.8}} \text{ s} = 1.53\text{ s}$$

up & down  
 $t = 3.06\text{ s}$



A to B ball rising velocity is decreasing at the rate of  $9.8 \text{ms}^{-2}$  up to summit.

At B, velocity is momentarily  $0 \text{ms}^{-1}$

B to C velocity is increasing at the rate of  $9.8 \text{ms}^{-2}$

If we choose up as +ve, then since  $g$  is directed downwards, then  $g = -9.8 \text{ms}^{-2}$

**ALWAYS REMEMBER TO KEEP TRACK OF SIGNS OF S, V, & a!!**

## SUMMARY - Free fall motion

- Remember to keep track of signs of displacement, velocity & acceleration
- Acceleration due to gravity is constant, hence motion is uniformly accelerated

- 5 eqns of linear motion apply:

1.0  $y = \frac{1}{2}gt^2$  - starting from rest

2.0  $\bar{v} = \frac{v_{0y} + v_f}{2}$

3.0  $v_{fy} = v_{0y} + gt$  - \*remember which direction is +ve

4.0  $v_{fy}^2 = v_{0y}^2 + 2gy$  "

5.0  $y = v_{0y}t + \frac{1}{2}gt^2$  "

e.g. if up is +ve then eqn 3.0 is:

$$v_{fy} = v_{0y} - gt$$