Kinematics

Vertical Motion Under Gravity

A few assumptions need to be stated before continuing.

1. Objects will be treated as particles.
2. Motion will only be in a straight line.
3. No evidence of spinning or turning of objects.
4. Particles will have constant acceleration of g ($9.8ms^{-2}$).

If an object is projected vertically upwards and it falls 3m below the point of release then the time taken can be calculated by setting $s = -3$m and $a = -9.8$ and substitute the values into equation (3). A lot of students work out the time the object takes to reach the top, then the time to return to point of release and finally the -3m part, but this much more complicated than what you need to do!

It is also worth noting at this point that time taken to reach maximum height and fall back down to the point of release are the same. This type of question regularly appears on exam papers and it is far quicker to use the first method.

Example 4

A Kinder Surprise falls off a shelf which is 0.9 m above the floor. Find:

(a) the time it takes to reach the floor

(b) the speed with which it will reach the floor.

a) $s = 0.9$, $a = 9.8$, $u = 0$, $t = ?$

Using equation (3):

$$s = ut + \frac{1}{2}at^2$$

$$0.9 = \frac{1}{2} \times 9.8 \times t^2$$

$$s = 0.429\text{sec}$$

b) $s = 0.9$, $a = 9.8$, $u = 0$, $t = 0.429$, $v = ?$

Using equation (1):

$$v = u + at$$
$$v = 0 + 9.8 \times 0.429$$
$$v = 4.20\text{ms}^{-1}$$

Example 5

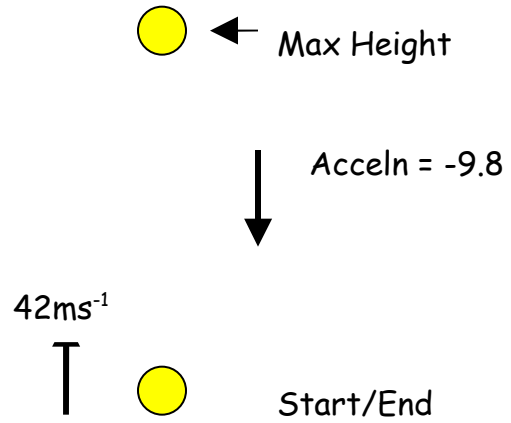
A bouncy ball B is projected vertically upwards from a point O with a speed of 42ms^{-1}. Find:

(a) the greatest height h above O reached by B

(b) the total time before B returns to O

(c) the total distance travelled by the particle.

With questions of this nature one has to be careful as to which direction is positive.



a) At the greatest height, $v = 0$,

$u = 42$, $a = -9.8$, $s = ?$

Using equation (4):

$v^2 = u^2 + 2as$

$0 = 42^2 - 2 \times 9.8 \times s$

$s = \frac{42^2}{19.6}$

$s = 90m$

b) When the ball returns to B its displacement will be zero!
$s = 0$, $a = -9.8$, $u = 42$, $t = ?$
Using equation (3):

$$s = ut + \frac{1}{2}at^2$$

$$0 = 42t - 4.9t^2$$

Factorising gives:

$$7t(0.7t - 6) = 0$$

Therefore $t = 0, t = 8.57sec$

c) In part (a) we found the distance to the top therefore we only need to double the answer.

Total distance = 180m

Example 6

A cricket ball is thrown vertically upwards with a velocity of $15ms^{-1}$. Modelling the ball as a particle moving under gravity alone, find for how long its height exceeds 10 m.

We need to find the times at which the ball has a displacement of 10m.
$a = -9.8$, $u = 15$, $s = 10$, $t = ?$

Using equation (3):

$$s = ut + \frac{1}{2}at^2$$

$$10 = 15t - 4.9t^2$$

$$4.9t^2 - 15t + 10 = 0$$

By using the quadratic formula we find the two values of t.

$$t = \frac{15 \pm \sqrt{225 - 4 \times 10 \times 4.9}}{9.8}$$

$$t = 2.08 \text{ or } 0.98.$$

Therefore the ball is above 10m for 1.1 second.