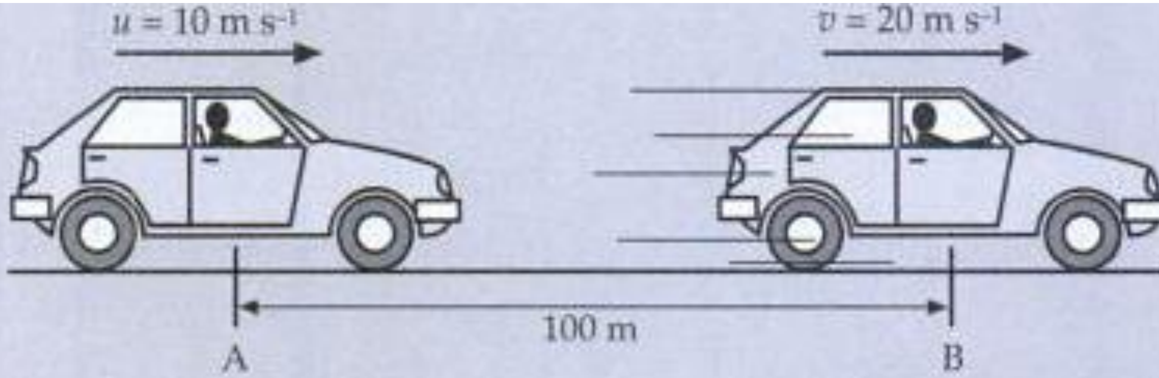
Test Review Questions Motion 5

Answers

Q1

A car travelling with uniform acceleration on a straight road passes two points, A and B, which are 100 m apart. Find the car's acceleration if it has a speed of 10 m s^{-1} when passing point A and a speed of 20 m s^{-1} when passing point B.



$u = 10$ m s^{-1}, $v = 20$ m s^{-1}, $s = 100$ m

Take direction to the right as positive

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

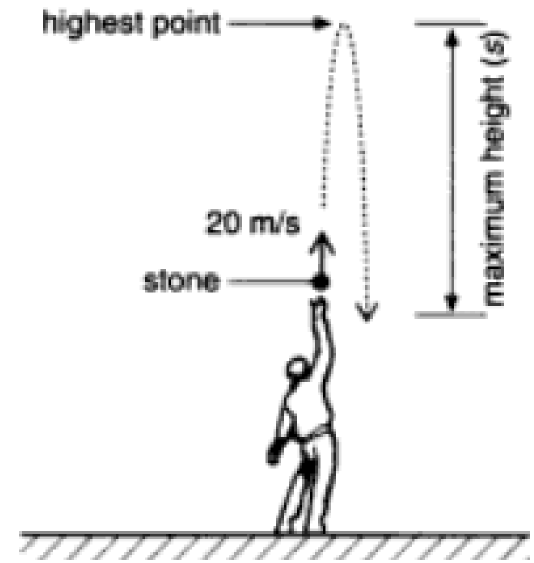
$$20^2 = 10^2 + 2a(100)$$

$$a = \frac{20^2 - 10^2}{2(100)}$$

$$= 1.5 \text{ m s}^{-2}$$

Q2

A stone is thrown upwards with an initial velocity of 20 m/s. What is the maximum height risen, and how long does it take to reach this height? (Take acceleration due to gravity as 9.8 m/s².)



Take g as a, the constant acceleration acting downwards. Draw a diagram (see right). List the information given, and pick the appropriate equation.

$u = 20\,m/s$	$s = ?$	$v^2 = u^2 + 2as$	$v = u + at$
$v = 0\,m/s$	$t = ?$	$0 = 20^2 - (2 \times 9.8s)$	$0 = 20 - 9.8t$
$a = -9.8\,m/s^2$		$s = 400/19.6 = \mathbf{20\,m}$	$t = 20/9.8 = \mathbf{2.0\,s}$

Q3

A ball is kicked horizontally off the edge of a cliff, 300 m high, at 10 m/s. Find the time taken for it to fall to the ground, and the horizontal distance travelled from the cliff base. ($g = 9.8\ m/s^2$.)

Start by drawing a diagram (see right). List the information in the vertical and horizontal directions, and then pick the appropriate equations.

Vertical motion

$u = 0$ m/s $\qquad s = ut + \frac{1}{2}at^2$

$s = 300$ m $\qquad 300 = 0 + (\frac{1}{2} \times 9.8 \times t^2)$

$a = 9.8$ m/s^2 $\qquad$ **$t = 7{\cdot}8$ s**

$t = ?$

$v = ?$

Horizontal motion

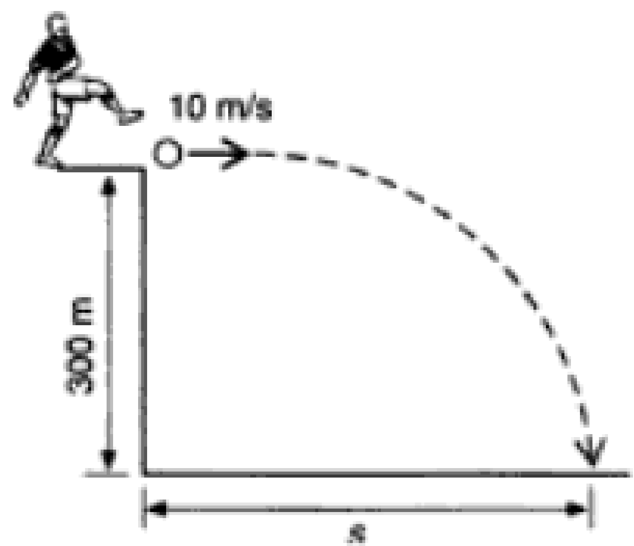
$u = 10$ m/s $\qquad s = ut + \frac{1}{2}at^2$

$t = 7{\cdot}8$ s $\qquad s = (10 \times 7{\cdot}8) + 0$

$v = u$ $\qquad$ **$s = 78$ m**

$a = 0$ m/s^2

$s = ?$



Q4

A pellet of mass 0.001 kg is fired from an air rifle at a speed of 110 m s^{-1} into a wood block. The pellet penetrates the block to a depth of 0.050 m. Calculate the impact force.

Initial speed $u = 110\,m\,s^{-1}$,

Final speed $v = 0$,

Distance $s = 0.050\,m$

To calculate the acceleration a, use $v^2 = u^2 + 2as$

which gives $0 = 110^2 + (2a \times 0.050)$

$$\text{so } a = \frac{-110 \times 110}{(2 \times 0.05)} = -1.21 \times 10^5\,m\,s^{-2}$$

To calculate the force F, use $F = ma$

which gives $F = -0.001 \times 1.21 \times 10^5 = -121\,N$ (− indicates deceleration).

Q5

A railway engine of mass 20 000 kg moving at $3\ \mathrm{m\,s^{-1}}$ collides with and couples to an initially stationary train of wagons of total mass 10 000 kg. Calculate,

(a) the speed of the engine and wagons just after impact.
(b) the loss of K.E. as a result of the impact.

(a) To calculate the speed v just after impact, use the principle of conservation of momentum which is true for any type of collision.

Total initial momentum $= 20\,000 \times 3$
$= 60\,000\ \mathrm{kg\,m\,s^{-1}}$

Total final momentum = Total mass $\times\, v = 30\,000v$

Since the total final momentum = the total initial momentum

$$30\,000v = 60\,000$$
hence $v = 2\ \mathrm{m\,s^{-1}}$

(b) The initial K.E. $= \frac{1}{2} \times 20\,000 \times 3^2 = 90\,000\ \mathrm{J}$
The final K.E. $= \frac{1}{2} \times 30\,000 \times 2^2 = 60\,000\ \mathrm{J}$
hence the loss of K.E. $= 30\,000\ \mathrm{J}$

Q6

A driver of a vehicle travelling at a speed of 30 m s^{-1} on a motorway brakes sharply to a standstill in a distance of 100 m. Calculate the deceleration of the vehicle.

$u = 30$ m s^{-1}, $v = 0$, $s = 100$ m,
$a = ?$

Solution
To find a, use $v^2 = u^2 + 2as$

Therefore $0 = u^2 + 2as$, because $v = 0$

Rearranging this equation gives:

$2as = -u^2$

$$a = \frac{-u^2}{2s} = \frac{-30^2}{2 \times 100} = -4.5 \text{ m s}^{-2}$$

Q7

A vehicle of mass 600 kg accelerates uniformly from rest to a speed of 8.0 m s^{-2} in 20 s. Calculate the force needed to produce this acceleration.

Acceleration, $a = (v - u)/t = \frac{(8.0 - 0)}{20} = 0.4 \text{ m s}^{-2}$

Force, $F = ma = 600 \times 0.4 = 240 \text{ N}$

Q8

A vehicle of mass 900 kg on a level road, travelling at a speed of 15 m s^{-1} can be brought to a standstill, without skidding, by a braking force equal to 0.5 × its weight. Calculate:

- **a** the deceleration of the vehicle,
- **b** the braking distance.

a Weight = 900 × 9.8 = 8800 N

Braking force = 0.5 × 8800 = 4400 N

$$\text{Deceleration} = \frac{\text{braking force}}{\text{mass}} = \frac{4400}{900} = 4.9 \text{ m s}^{-2}$$

b To calculate s, use $v^2 = u^2 + 2as$

$u = 15 \text{ m s}^{-1}$, $v = 0$, $a = -4.9 \text{ m s}^{-2}$

$$\therefore s = -\frac{u^2}{2a} = \frac{15^2}{2 \times 4.9} = 23 \text{ m}$$

Q9

On a fairground ride, the track descends by a vertical drop of 55 m over a distance of 120 m along the track. A train of mass 2500 kg on the track reaches a speed of 30 m s^{-1} at the bottom of the descent after being at rest at the top. Calculate

a the loss of potential energy of the train,

b its gain of kinetic energy,

c the average frictional force during the descent.

a Loss of potential energy = $mgh = 2500 \times 9.8 \times 55 = 1.35 \times 10^6$ J

b Its gain of kinetic energy = $\frac{1}{2}mv^2 = 0.5 \times 2500 \times 30^2 = 1.13 \times 10^6$ J

c Work done to overcome friction = $mgh - \frac{1}{2}mv^2 = 1.35 \times 10^6 - 1.13 \times 10^6$
$= 2.2 \times 10^5$ J

Because the work done to overcome friction = frictional force × distance moved along track,

$$\text{the frictional force} = \frac{\text{work done to overcome friction}}{\text{distance moved}} = \frac{2.2\times10^5\ \text{J}}{120\ \text{m}} = 1850\ \text{N}$$

Q10

An aircraft powered by engines that exert a force of 40 kN is in level flight at a constant velocity of 80 m s^{-1}. Calculate the output power of the engine at this speed.

Output power = force × velocity = 40 000 N × 80 m s^{-1} = 3.2×10^6 W

Q11

A rail wagon of mass 4500 kg moving along a level track at a speed of 3.0 m s^{-1} collides with and couples to a second rail wagon of mass 3000 kg which is initially stationary. Calculate the speed of the two wagons immediately after the collision.

Total initial momentum

$$= \text{initial momentum of A} + \text{initial momentum of B}$$

$$= (4500 \times 3.0) + (3000 \times 0) = 13\,500 \text{ kg m s}^{-1}$$

Total final momentum

$$= \text{total mass of A and B} \times \text{velocity } V \text{ after the collision}$$

$$= (4500 + 3000)\,V = 7500\,V$$

Using the Principle of Conservation of Momentum.

$$7500\,V = 13\,500$$

$$V = \frac{13\,500}{7500} = 1.8 \text{ m s}^{-1}$$

Q12

A mass has an initial velocity of 10.0 m s^{-1}. It moves with acceleration -2.00 m s^{-2}. When will it have zero velocity?

$$v = v_0 + at$$

$v = 0$ and so

$$0 = v_0 + at$$

Putting in the numbers we get

$$0 = 10 + (-2.00)t$$

so $t = 5.00$ s.

Q13

A ball of mass 0.250 kg moves on a frictionless horizontal floor and hits a vertical wall with speed 5.0 m s^{-1}. The ball rebounds with speed 4.0 m s^{-1}. If the ball was in contact with the wall for 0.150 s, find the average force that acted on the ball.

The magnitude of the change in the ball's momentum is (remember that momentum is a vector)

$$\begin{aligned}\Delta p &= p_f - p_i \\ &= 0.250 \times 4.0 - (-0.250 \times 5.0) \\ &= 1.0 - (-1.25) \\ &= 2.25 \text{ N s}\end{aligned}$$

$$\begin{aligned}\bar{F} &= \frac{\Delta p}{\Delta t} \\ &= \frac{2.25 \text{ N s}}{0.150 \text{ s}} \\ &= 15 \text{ N}\end{aligned}$$

Q14

A mass of 5.00 kg moving with an initial velocity of 12.0 m s^{-1} is brought to rest by a horizontal force over a distance of 12.0 m. What is the force?

The change in the kinetic energy of the mass is (final minus initial)

$$0 - \frac{1}{2}mv^2 = -\frac{1}{2} \times 5.00 \times 144$$
$$= -360 \text{ J}$$

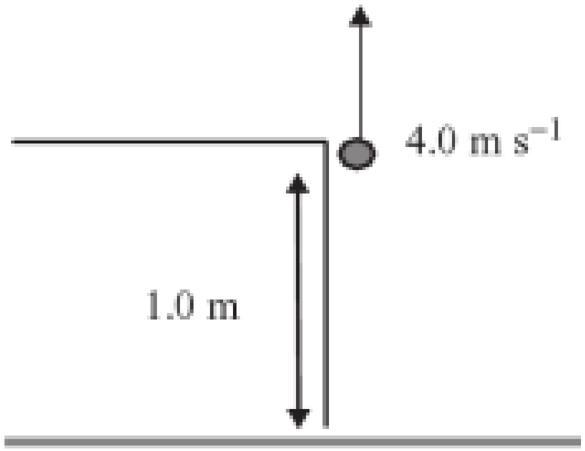
The work done by the force f is

$$-fs = -12f$$

$$-12f = -360$$
$$\Rightarrow f = 30.0 \text{ N}$$

Q15

A ball is thrown vertically upward with a speed of 4.0 m s^{-1} from a height of 1.0 m from the floor, as shown



With what speed does the ball strike the floor?

$$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgh$$

$$\Rightarrow u^2 = v^2 + 2gh$$

$$= 16 + 20$$

$$= 36$$

$$\Rightarrow u = 6.0 \text{ m s}^{-1}$$

Q16

What is the minimum power required to lift a mass of 50.0 kg up a vertical distance of 12 m in 5.0 s?

The work performed to lift the mass is

$$mgh = 50.0 \times 10 \times 12$$
$$= 6.0 \times 10^3 \text{ J}$$

The power is thus

$$\frac{6.0 \times 10^3}{5.0} = 1200 \text{ W}$$

This is only the minimum power required. In practice, the mass has to be accelerated from rest, which will require additional work and hence more power.