Test Review Questions Motion 3

Answers

Q1

A car travels at 25 m s^{-1} for 5 minutes due north along a straight road. What is its displacement after this time?

STEP 1 Write down what you know, and what you want to know:
velocity v = 25 m s^{-1}, time t = 5 min = 300 s, displacement s = ?

STEP 2 Choose the form of the equation with displacement as its subject:
displacement = velocity × time $s = vt$

STEP 3 Substitute values and solve:
$s = 25\ \text{m s}^{-1} \times 300\ \text{s} = 7500\ \text{m} = 7.5\ \text{km}$

car's displacement is 7.5 km due north.

Q2

A car accelerates from 10 m s^{-1} to 18 m s^{-1} in 4 s. What is its acceleration?

STEP 1 Write down what you know, and what you want to know:

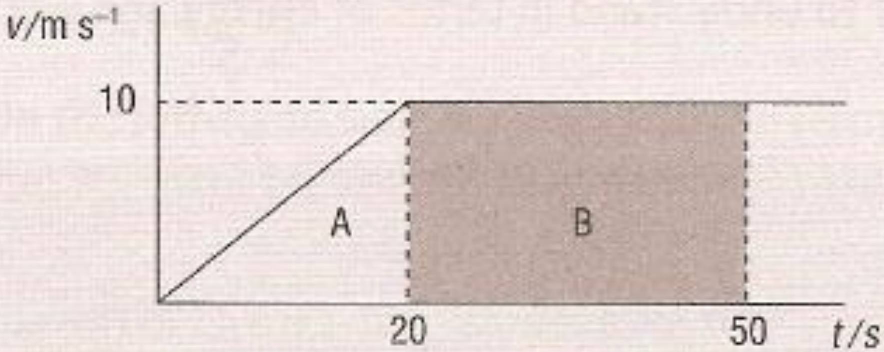
$u = 10\ \text{m s}^{-1}$, $v = 18\ \text{m s}^{-1}$, $t = 4\ \text{s}$, $a = ?$

STEP 2 Write down the equation, substitute and solve:

$$a = \frac{v-u}{t} = \frac{18\ \text{m s}^{-1} - 10\ \text{m s}^{-1}}{4\ \text{s}} = \frac{8\ \text{m s}^{-1}}{4\ \text{s}} = 2\ \text{m s}^{-2}$$

Q3

Find the displacement after 50 s of the object whose velocity–time graph is shown in the diagram.



STEP 1 Divide the area under the graph into a triangle and a rectangle.

STEP 2 Calculate the area of each part – see graph.

Triangle A: $\frac{1}{2}$ **base × height =** $\frac{1}{2} \times 20\ \text{s} \times 10\ \text{m s}^{-1} = 100\ \text{m}$**.**

Rectangle B: $30\ \text{s} \times 10\ \text{m s}^{-1} = 300\ \text{m}$**.**

STEP 3 Add these together to give total displacement = 400 m.

Q4

A car travelling at 20 m s^{-1} accelerates at 2 m s^{-2} for 5 s. How far will it travel in this time?

STEP 1 Write down what you know, and what you want to know:

$u = 20 \text{ m s}^{-1}, t = 5 \text{ s}, a = 2 \text{ m s}^{-2}, s = ?$

STEP 2 Choose the appropriate equation linking these quantities:

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

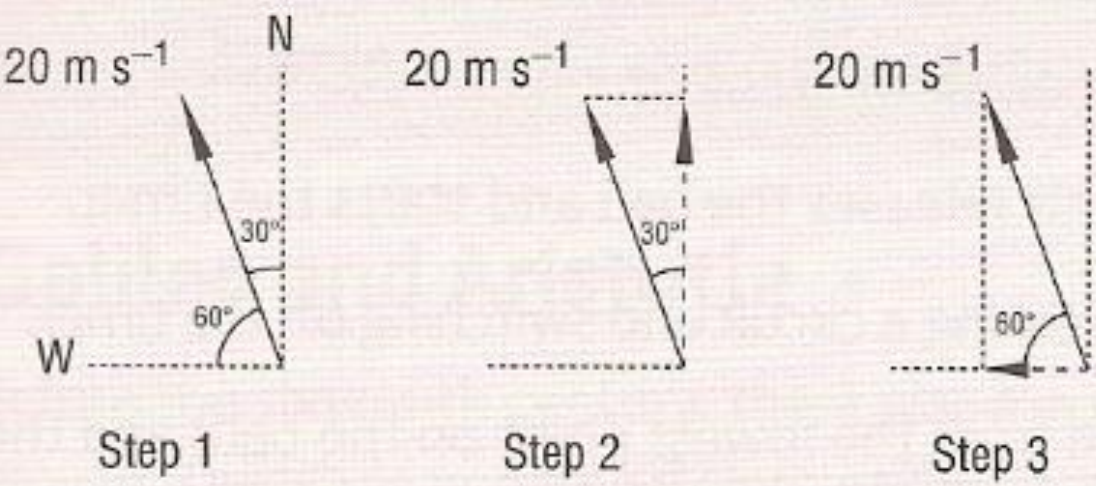
STEP 3 Substitute and solve.

$$s = [20 \text{ m s}^{-1} \times 5 \text{ s}] + [\frac{1}{2} \times 2 \text{ m s}^{-2} \times (5 \text{ s})^2]$$

$$= 100 \text{ m} + 25 \text{ m} = 125 \text{ m}$$

Q5

A car is travelling at 20 m s^{-1} at 30° W of N (see diagram). Calculate the components of its velocity due N and due W.



STEP 1 Draw a diagram; mark the relevant angles.

STEP 2 Calculate the component due N. (The angle here is 30°.)

Component due N = 20 m s^{-1} × cos 30° = 17.3 m s^{-1}

STEP 3 Calculate the component due W. (The angle here is 60°.)

Component due W = 20 m s^{-1} × cos 60° = 10.0 m s^{-1}

Q6

A ball is projected horizontally with an initial velocity of 2.0 m s^{-1}. It reaches the ground, a distance of 5.0 m below. Calculate the time taken and the horizontal distance it travels.

STEP 1 Find the components of its initial velocity. In this case, this is simple because it is moving horizontally at the start.

Horizontal component of u = 2.0 m s^{-1}

Vertical component of u = 0 m s^{-1}

STEP 2 Consider the ball's vertical motion, as this determines how long it takes to reach the ground. We know:

Initial velocity u = 0 m s^{-1}

acceleration a = 9.81 m s^{-2}

displacement s = 5.0 m

STEP 3 Choose the appropriate equation of motion, substitute values and solve:

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

$5.0 = 0 + 0.5 \times 9.81t^2$

$t^2 = 5.0/(0.5 \times 9.81) = 1.02$

$t = 1.01$ s

Hence the ball lands after 1.01 s

STEP 4 Now calculate the horizontal distance travelled in this time.

Distance = speed × time = 2.0 m s^{-1} × 1.01 s = 2.02 m

Q7

A car of mass 1000 kg is acted on by two forces: a forward force of 500 N provided by its engine, and a retarding (backward) force of 200 N caused by air resistance. What is its acceleration?

STEP 1 Draw a diagram to show the forces acting on the car. (It can help to draw a longer arrow for the larger force.)

STEP 2 Calculate the unbalanced force and note its direction.

$F = 500\text{ N} - 200\text{ N} = 300\text{ N}$ **forwards**

STEP 3 Calculate the acceleration by rearranging $F = ma$.

$$a = \frac{F}{m} = \frac{300\text{ N}}{1000\text{ kg}} = \frac{300\text{ kg m s}^{-2}}{1000\text{ kg}} = 0.3\text{ m s}^{-2}$$

So the car's acceleration is 0.3 m s^{-2} forwards.

Q8

A parachutist of mass 80 kg is falling through air. The force of air resistance on her is 1200 N. Calculate her acceleration.

STEP 1 Calculate the weight of the falling object.

weight = mg = 80 kg × 9.81 N kg^{-1} = 785 N

STEP 2 Draw a free-body force diagram for the object, and use it to calculate the resultant force acting on the object.

resultant force = 1200 – 785 = 415 N upwards

STEP 3 Calculate the acceleration using $F = ma$:

Acceleration $a = \frac{F}{m} = \frac{415\ \text{N}}{80\ \text{kg}} = 5.2\ \text{m s}^{-2}$ **upwards**

Q9

A car is travelling at a steady speed of 20 m s^{-1}. The driver sees an obstruction on the road ahead, and applies the brakes after a thinking time of 0.7 s. The car slows down with an acceleration of –4.0 m s^{-2}. Calculate the stopping distance.

STEP 1 Calculate the thinking distance:

Thinking distance = thinking time × speed = 0.7 × 20 = 14 m

STEP 2 Calculate the braking distance using $v^2 = u^2 + 2as$:

$$s = \frac{20^2}{2 \times 4.0} = 50 \text{ m}$$

STEP 3 Calculate the total stopping distance:

Stopping distance = 14 m + 50 m = 64 m

Q10

A car of mass 800 kg is moving at 15 m s^{-1}. What is its KE?

Substituting in $E_k = \frac{1}{2}mv^2$ gives:

$$E_k = ½ \times 800 \times 15^2 = ½ \times 800 \times 225 = 90\,000 \text{ J}$$

Q11

A stone falls from a height of 5 m.

How fast is it moving when it reaches the ground?

STEP 1 The *decrease* in the stone's GPE as it falls is equal to its *gain* in KE.

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

STEP 2 Cancel *m* from both sides:

$$gh = \frac{1}{2}v^2$$

STEP 3 Substitute values and solve for *v*:

$$9.81\ \mathrm{m\ s^{-2}} \times 5\ \mathrm{m} = 0.5v^2$$

$$v^2 = 98.1\ \mathrm{m^2\ s^{-2}}$$

$$v = 9.9\ \mathrm{m\ s^{-1}}$$

Q12

A motorist travelling at the legal speed limit of 28 m s^{-1} (60 mph) takes his foot off the accelerator as he passes a sign showing that the speed limit is reduced to 14 m s^{-1} (30 mph). The car decelerates at 2.0 m s^{-2}.

(a) For what time interval is the motorist exceeding the speed limit?

(b) How far does the car travel in that time?

(a) $t = \Delta v \div a$ [1] = 14 m s^{-1} ÷ 2 m s^{-2} = 7 s [1].

(b) distance = average speed × time [1] = 21 m s^{-1} × 7 s = 147 m [1].

Q13

A fountain is designed so that the water leaves the nozzle and rises vertically to a height of 3.5 m.

(a) Calculate the speed of the water as it leaves the nozzle.

(b) For how long is each drop of water in the air?

Take the value of free-fall acceleration, g to be $10\ m\,s^{-2}$.

(a) Use $v^2 = u^2 + 2as$ [1] $u^2 = -2 \times -10\ m\,s^{-2} \times 3.5\ m = 70\ m^2 s^{-2}$ [1] $u = 8.4\ m\,s^{-1}$ [1].
(b) Time travelling upwards, t = distance ÷ average speed = $3.5\ m \div 4.2\ m\,s^{-1} = 0.83\ s$ [1]

Time in air = 1.66 s [1].

Q14

An aircraft has a total mass, including fuel and passengers, of 70 000 kg. Its take-off speed is 60 $m\,s^{-1}$ and it needs to reach that speed before the end of the runway, which is 1500 m long.

(a) Calculate the minimum acceleration of the aircraft.

(b) Calculate the average force needed to achieve this acceleration.

(c) Explain how the resultant force on the aircraft is likely to change during take-off.

(a) Use $v^2 = u^2 + 2as$ [1] $a = v^2 \div 2s = (60\ m\,s^{-1})^2 \div 2 \times 1500\ m$ [1] $= 1.2\ m\,s^{-2}$ [1].
(b) $F = ma$ [1] $= 70\,000\ kg \times 1.2\ m\,s^{-2}$ [1] $= 84\ kN$ [1].
(c) As the aircraft gains speed the size of the resistive forces increases [1].
This causes the resultant force to decrease [1].

Q15

A crane lifts a 3 tonne (3000 kg) load through a vertical height of 18 m in 24 s. Calculate:

(a) the work done on the load

(b) the gain in gravitational potential energy of the load

(c) the power output of the crane

(d) the power input to the crane if the efficiency is 0.45.

(a) $W = F \times s$ [1] = 30 000 N × 18 m [1] = 540 kJ [1].
(b) 540 kJ [1]
(c) $P = W \div t$ = 540 kJ ÷ 24 s [1] = 22.5 kW [1].
(d) $P_{in} = P_{out} \div$ efficiency [1] = 22.5 kW ÷ 0.45 = 50 kW [1].