8 Motion and its measurement

Pages 146–149 Exam practice questions

1 C

2 A

3 B

4 C

5 C

6 B

7 A

8 B

9 A

10 C

11 a) The ball does not travel as far horizontally, or go as high vertically.

b) The drag slows both the vertical and horizontal components of velocity, so that both the height and range are reduced.

12 a) $v^2 = 2gs$

$= 2 \times 9.8 \text{ m s}^{-2} \times 19 \text{ m}$

$v = 19 \text{ m s}^{-1}$ (2 s.f.)

b) $s = ut + \frac{1}{2}gt^2$

$= 19 \times 3 - \frac{1}{2} \times 9.8 \times 9$

$s = 13$ m (2 s.f.)

c) The effects of drag have been ignored

13 a) i) $a = \frac{v-u}{t}$

$a = 10 \text{ m s}^{-2}$ downwards (2)

ii) $a = \frac{v-u}{t}$

$= \frac{10 \text{ m s}^{-1} - (-8) \text{ m s}^{-1}}{0.05 \text{ s}}$ (1)

$= 360 \text{ m s}^{-2}$ upwards (1)

b) i) d = area under the graph

$= \frac{1}{2} 10 \text{ m s}^{-1} \times 1 \text{ s}$ (1)

$= 5$ m (1)

ii) d = area under the graph

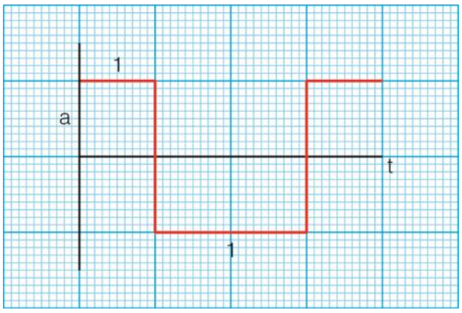
$= \frac{1}{2} 8 \text{ m s}^{-1} \times 0.85 \text{ s}$ (1)

$= 3.4$ m (1)

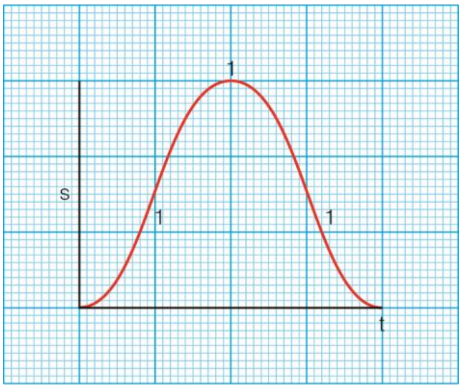
14 a) i) The gradient gives the acceleration. So it is positive, then negative, then positive. (2)

ii) The area under the graph gives displacement; so for the first half of the movement, displacement increases – and the rate of increase is large when the velocity is large. Then when the velocity is negative, it moves back to its starting place. So the displacement is zero by the end of the cycle.(2)

b)



c)



15 a) $a = \frac{v-u}{t}$ (1)

$= \frac{20\ \text{m s}^{-1}}{2\ \text{s}}$

$= 10\ \text{m s}^{-2}$ (1)

b) i) 3.2 (5) s (1)

when $v = 0$ (1)

ii) distance = area under the graph

$\approx$ 40 m (1)

iii) The 'area' under CDE is less than 40 m.

c) i) $a = 0$ (1)

i) The jumper is moving upwards with the rope slack being decelerated by the force of gravity. (1)

16 a) $s = ut + \frac{1}{2}gt^2$

$93 \text{ m} = 0 + \frac{1}{2} \times 9.8 \text{ m s}^{-2} \times t^2$

$\Rightarrow t^2 = (93/4.9) \text{ s}^{-2}$

$\Rightarrow t = 4.36$ s or 4.4 s (to 2 s.f.)

b) $v_h = \frac{1250 \text{ m}}{4.4 \text{ s}} = 284 \text{ m s}^{-1}$

c) $= 0 + 9.8 \text{ m s}^{-2} \times 4.4 \text{ s}$

$= 43.1 \text{ m s}^{-1}$

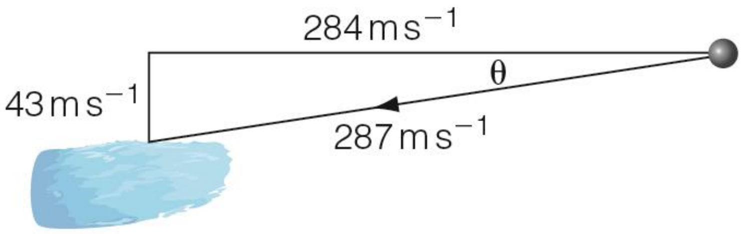
d) $v = (284^2 + 43^2)^{1/2}$

$= 287 \text{ m s}^{-1}$

$\tan \theta = 43/284 = 0.15$

$\Rightarrow \theta = 8.6°$

(1)



e) To increase the range of the ball, the cannon the barrel of the cannon is tilted upwards so that the ball goes upwards slightly.

18 a) The average values are: 0.14 s; 0.20 s; 0.25 s; 0.29 s; 0.32 s; 0.34 s.

b) i) about 7% – 1 part in 14 (1)

ii) about 3% – 1 part in 34.

Errors are reduced by repeating the measurements. (2)

c) This could be as low as 1 part in 100, but there are likely to be errors of ± 1 mm at either end. This produces an error of 2%. (1)

d) This method produces a random error, as it unlikely that the ball bearing will be in the same place each time it is released. So the ball bearing may have a small downwards speed as it passes the gate, which changes during each measurement. (2)

e) The gradient of the graph is ½ *g*.

The gradient allows g to be calculated at about 9.9 ± 0.5 m s^{-2}.

The final error is quite hard to judge and represents an uncertainty in the gradient of the graph. (5)

19 a) $s = \frac{1}{2}gt^2$

$= \frac{1}{2} \times 9.8 \text{ m s}^{-1} \times (3.7 \text{ s})^2$ (1)

= 67 m (1)

b) $s = vt$

$= 54 \text{ m s}^{-1} \times 3.7 \text{ s}$

= 200 m (to 2 s.f.)

c) i) $v_v = gt$

$= 9.8 \text{ m s}^{-2} \times 3.7 \text{ s}$ (1)

$= 36 \text{ m s}^{-1}$ (1)

ii) $v_{mag} = (54^2 + 36^2)^{\frac{1}{2}} \text{ m s}^{-1}$ (1)

$= 65 \text{ m s}^{-1}$ (1)

Pages 149–150 Stretch and challenge questions

20 When the boat catches the sandwich box, they have the same displacement (after time t).

Displacement of box = ut

u = river speed; t = time for the boat to catch the box.

Displacement of boat = $(u - v) \times 10 + (u + v)(t - 10)$

v = speed of boat relative to the water

When they meet, the displacement of the boat equals the displacement of the lunch box.

So $ut = (u - v) \times 10 + (u + v)(t - 10)$

$\Rightarrow 20v = vt$

$t = 20$ min $(\frac{1}{3}$ h$)$

So 1 km = $v \times \frac{1}{3}$ h

$v = 3$ km h^{-1}

21 Time to move from A to B is:

$$t = \frac{L - x}{3} + \frac{(x^2 + y^2)^{\frac{1}{2}}}{1}$$

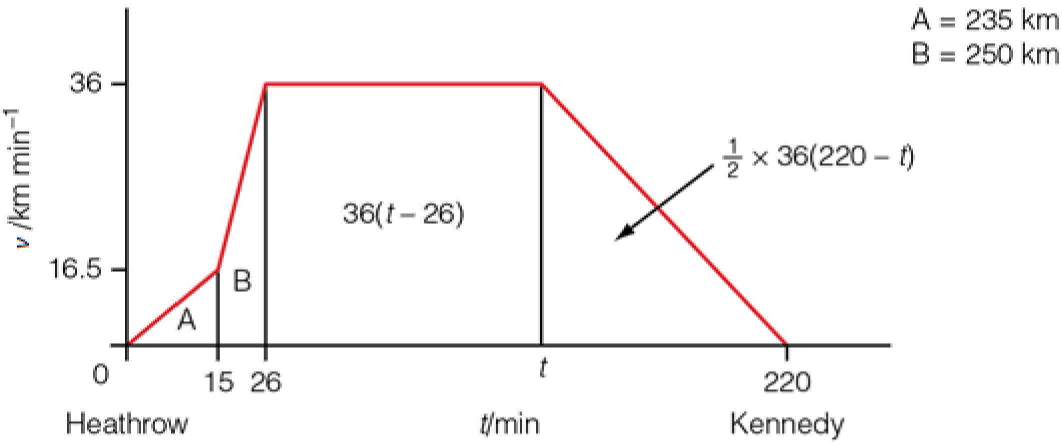
$$\frac{dt}{dx} = -\frac{1}{3} + \frac{\frac{1}{2}.2x}{(x^2 + y^2)^{\frac{1}{2}}}$$

The minimum time occurs when $\frac{dt}{dx} = 0$

$$\Rightarrow \frac{1}{3} = \frac{x}{(x^2 + y^2)^{\frac{1}{2}}} = \sin\theta$$

This is the path light would follow through a block of glass at the critical angle. Light always takes the quickest route.

22 By 26 minutes the distance travelled is 485 km. (This is the area marked A and B on the sketched graph. The exact shape of these areas does not matter – the important point in solving the problem is that the plane has travelled 485 km, after 26 minutes.)There are 5800 km – 485 km = 5315 km to travel to Kennedy airport. 1230 h is 120 min after the take off. This distance, 5315 km, is the area under the graph from 26 m to 220 m.



Working with the speed in km min^{-1}: $v = \frac{2160\text{ km}}{60\text{ min}}$ = 36 km min^{-1}

$5315 = 36(t - 26) + \frac{1}{2} \times 36(220 - t)$

$\Rightarrow 5315 = 36t - 936 + 3960 - 18t$

$\Rightarrow 18t = 2291$

$t = 127.3$ min

So the plane begins to decelerate after 127.3 min. After 120 m the plane is still travelling at 36 km min^{-1}.

So the distance travelled between 26 min and 120 min is:

d = 36 km min^{-1} × (120 – 26) min

= 3384 km

So the total distance from Heathrow at 12.30 = 3384 km + 485 km = 3869 km