

## Solutions

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Each answer shows the steps, then the **result**.

### 2.1

(a)  $u = 0$ ,  $s = 20$  m,  $a = 9.81$  m s<sup>-2</sup> (down positive); use  $s = \frac{1}{2}at^2$

$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 20 \text{ m}}{9.81 \text{ m s}^{-2}}} = \mathbf{2.0 \text{ s}}$$

(b) use  $v^2 = u^2 + 2as$

$$v = \sqrt{2 \times 9.81 \text{ m s}^{-2} \times 20 \text{ m}} = \mathbf{20 \text{ m s}^{-1}}$$

### 2.2

(a) at the top  $v = 0$

$$s = \frac{0 - (18 \text{ m s}^{-1})^2}{2(-9.81 \text{ m s}^{-2})} = \mathbf{17 \text{ m}}$$

(b) time to the top, then double it: the flight is symmetrical

$$t_{\text{up}} = \frac{0 - 18 \text{ m s}^{-1}}{-9.81 \text{ m s}^{-2}} = 1.83 \text{ s}, \quad t = 2 \times 1.83 \text{ s} = \mathbf{3.7 \text{ s}}$$

(c)  $-18$  m s<sup>-1</sup>: the same speed as the throw, now downwards

### 2.3

(a) **3.0** m s<sup>-1</sup> **upwards**, the velocity of the balloon

(b)  $u = +3.0$  m s<sup>-1</sup>,  $a = -9.81$  m s<sup>-2</sup>,  $s = -45$  m in  $s = ut + \frac{1}{2}at^2$

$$-45 = 3.0t - 4.905t^2 \quad \Rightarrow \quad 4.905t^2 - 3.0t - 45 = 0$$

- quadratic formula (values in m and s)

$$t = \frac{3.0 + \sqrt{9.0 + 883}}{9.81} = \mathbf{3.4 \text{ s}}$$

### 2.4

(a) large triangle on the line, for example from (0.050 s<sup>2</sup>, 0.18 m) to (0.250 s<sup>2</sup>, 1.08 m)

$$\text{gradient} = \frac{1.08 \text{ m} - 0.18 \text{ m}}{0.250 \text{ s}^2 - 0.050 \text{ s}^2} = \mathbf{4.5 \text{ m s}^{-2}}$$

(accept 4.4 to 4.6)

(b)  $g = 2 \times \text{gradient} = \mathbf{9.0 \text{ m s}^{-2}}$  (accept 8.8 to 9.2)

(c) any one: every time reading is too long by the same amount, for example the ball is released a short time after the timer starts; or  $h$  is measured from the wrong point on the ball

### 3.1 B

- displacement after 3.0 s minus displacement after 2.0 s

$$\frac{1}{2}(9.81 \text{ m s}^{-2})(3.0 \text{ s})^2 - \frac{1}{2}(9.81 \text{ m s}^{-2})(2.0 \text{ s})^2 = 44.1 \text{ m} - 19.6 \text{ m} = \mathbf{25 \text{ m}}$$

- **A** is  $g \times 1 \text{ s}$ ; **C** is the speed at 3.0 s; **D** is the whole distance in 3.0 s

### 3.2 B

- from  $v^2 = u^2 + 2as$  with  $u = 0$ :  $v^2 = 2gh$ , so the gradient is  $2g$

$$g = \frac{19.4 \text{ m s}^{-2}}{2} = \mathbf{9.7 \text{ m s}^{-2}}$$

- **C** takes the gradient as  $g$ ; **A** and **D** use the wrong factor of 2

### 3.3

(a)

- measure  $h$  from the bottom of the ball to the trapdoor with the metre rule
- switching off the electromagnet releases the ball and starts the timer; the ball hitting the trapdoor stops it, giving  $t$
- repeat for several different heights, repeating each timing and taking the mean
- plot  $h$  against  $t^2$  and find the gradient;  $g = 2 \times \text{gradient}$

(b) the ball starts from rest, so  $h = \frac{1}{2}gt^2$

$$g = \frac{2h}{t^2} = \frac{2 \times 0.750 \text{ m}}{(0.393 \text{ s})^2} = \mathbf{9.71 \text{ m s}^{-2}}$$

(c) percentage uncertainties

$$\frac{0.002 \text{ m}}{0.750 \text{ m}} = 0.27\%, \quad \frac{0.005 \text{ s}}{0.393 \text{ s}} = 1.27\%$$

- the time is squared, so it counts twice:  $0.27\% + 2 \times 1.27\% = \mathbf{2.8\%}$
- $2.8\%$  of  $9.71 \text{ m s}^{-2}$  is  $0.27 \text{ m s}^{-2}$ , so  $g = \mathbf{9.7 \pm 0.3 \text{ m s}^{-2}}$

(d)

- the measured time is longer than the real time of fall
- $g = 2h/t^2$ , so the calculated value of  $g$  is too small

### 3.4

(a) at the top  $v = 0$

$$s = \frac{0 - (8.0 \text{ m s}^{-1})^2}{2(-9.81 \text{ m s}^{-2})} = \mathbf{3.3 \text{ m}}$$

(b)  $s = -25 \text{ m}$ ,  $u = +8.0 \text{ m s}^{-1}$ ,  $a = -9.81 \text{ m s}^{-2}$

$$-25 = 8.0t - 4.905t^2 \quad \Rightarrow \quad 4.905t^2 - 8.0t - 25 = 0$$

- quadratic formula, keeping the positive root

$$t = \frac{8.0 + \sqrt{64 + 490.5}}{9.81} = \mathbf{3.2 \text{ s}}$$

(c)

- a single straight line with a negative gradient
- starting at  $+8.0 \text{ m s}^{-1}$  and crossing  $v = 0$  at about  $0.8 \text{ s}$
- ending at about  $-24 \text{ m s}^{-1}$  at  $3.2 \text{ s}$