Solutions

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

2.1

(a) $u = 0$, $s = 20$ m, $a = 9.81$ m s^{-2} (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 $v^2 = u^2 + 2as$

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

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

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

(c) $\mathbf{-18}$ m s$^{\mathbf{-1}}$: the same speed as the throw, now downwards

2.3

(a) **3.0** m s$^{\mathbf{-1}}$ **upwards**, the velocity of the balloon

(b) $u = +3.0$ m s^{-1}, $a = -9.81$ m s^{-2}, $s = -45$ 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^2, 0.18 m) to (0.250 s^2, 1.08 m)

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

(accept 4.4 to 4.6)

(b) $g = 2 \times$ gradient $= \mathbf{9.0}$ m s$^{\mathbf{-2}}$ (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

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

- **A** is $g \times 1$ 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 $2g$

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

- **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; $g = 2\times$ gradient

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

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

(c) percentage uncertainties

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

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

(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) $s = -25$ m, $u = +8.0$ m s^{-1}, $a = -9.81$ 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 $+8.0$ m s^{-1} and crossing $v = 0$ at about 0.8 s
- ending at about -24 m s^{-1} at 3.2 s