Answers to Coursebook questions – Chapter 2.2

1 $v = u + at$. So $8.0 = 2.0 + a \times 2.0 \Rightarrow a = \dfrac{8.0 - 2.0}{2.0} = 3.0\ \text{m s}^{-2}$.

2 $s = ut + \dfrac{1}{2}at^2$. So $450 = \dfrac{1}{2}a \times 15.0^2 \Rightarrow a = \dfrac{900}{225} = 4.00\ \text{m s}^{-2}$. Then from $v = u + at$, $v = 4.00 \times 15.0 = 60.0\ \text{m s}^{-1}$.

3 From $v = u + at$, $11 = 5.0 + 1.5 \times t \Rightarrow t = \dfrac{11 - 5.0}{1.5} = 4.0\ \text{s}$.

4 From $v = u + at$, $28 = 0 + a \times 9.0 \Rightarrow a = \dfrac{28}{9.0} = 3.1\ \text{m s}^{-2}$; hence, from $s = ut + \dfrac{1}{2}at^2$ we have that $s = \dfrac{1}{2}3.1 \times 9.0^2 = 126\ \text{m} \approx 130\ \text{m}$.

5 From $v^2 = u^2 + 2as$ we get $0 = 12^2 + 2a \times 45 \Rightarrow a = -1.6\ \text{m s}^{-2}$.

6 From $s = ut + \dfrac{1}{2}at^2$ we get $16 = -6.0t + \dfrac{1}{2} \times 2.0 \times t^2$. Solving the quadratic equation gives $t = 8.0\ \text{s}$ (after rejecting the negative root).

7 Use $s = \dfrac{u + v}{2}t$ to get $24 = \dfrac{3.0 + 13}{2}t \Rightarrow t = \dfrac{48}{16} = 3.0\ \text{s}$.

8 The speed is $100 \times \dfrac{10^3}{3600} = 27.8\ \text{m s}^{-1}$.

Then, from $v = u + at$, $0 = 27.8 + a \times 0.100 \Rightarrow a = -278\ \text{m s}^{-2}$.

9 **a** The distance travelled before the brakes are applied is $s = 40.0 \times 0.50 = -20\ \text{m}$. Once the brakes are applied, the distance is given from $v^2 = u^2 + 2as$, i.e. $0 = 40^2 + 2 \times (-4.0) \times s \Rightarrow s = 200\ \text{m}$. The total distance is thus 220 m.

b 200 m as done in **a**.

c $s = 220 - 200 = 20\ \text{m}$.

d It would be less since the speed is less.

10 **a** From $v = u + at$, $12 = 24 - 10 \times t \Rightarrow t = \frac{12}{10} = 1.2\ \text{s}$.

b $-12 = 24 - 10 \times t \Rightarrow t = \frac{36}{10} = 3.6\ \text{s}$.

c At $t = 1.2\ \text{s}$, $s = ut + \frac{1}{2}at^2 = 24 \times 1.2 - 5.0 \times 1.2^2 = 21.6\ \text{m}$ and at $t = 3.6\ \text{s}$, $s = ut + \frac{1}{2}at^2 = 24 \times 3.6 - 5.0 \times 3.6^2 = 21.6\ \text{m}$.

d At $t = 1.50\ \text{s}$, $v = u + at = 24 - 10 \times 1.50 = 9.0\ \text{m s}^{-1}$.

e From $v^2 = u^2 + 2as$, $0 = 24^2 - 2 \times 10 \times s \Rightarrow s = \frac{24^2}{20} = 28.8\ \text{m} \approx 29\ \text{m}$.

11 **a** From $s = ut + \frac{1}{2}at^2$, $-50 = 10t - 5t^2$. Solving the quadratic equation we get $t = 4.32\ \text{s}$ (after rejecting the negative solution).

b From $v = u + at$, $v = 10 - 10 \times 4.32 = -33.2\ \text{m s}^{-1}$. So the speed is $33.2\ \text{m s}^{-1}$.

c The maximum height reached from the point of launch is found from $v^2 = u^2 + 2as$, i.e. $0 = 10^2 - 2 \times 10 \times s \Rightarrow s = \frac{10^2}{20} = 5.00\ \text{m}$. The distance is thus $5.00 + 5.00 + 50.0 = 60.0\ \text{m}$.

12 **a** Use $s = ut + \frac{1}{2}at^2$ to get $-25 = -5t + \frac{1}{2} \times (-10) \times t^2 \Rightarrow t = 1.79\ \text{s}$.

b $v = u + at = -5 - 10 \times 1.79 = -22.9 \approx -23\ \text{m s}^{-1}$. The speed is then $23\ \text{m s}^{-1}$.

13 Use $s = ut + \frac{1}{2}at^2$ to get $-1.5 = -3t + \frac{1}{2} \times (-10) \times t^2 \Rightarrow t = 0.324\ \text{s}$.

14 $s_1 = -\frac{1}{2} \times 10t^2 = -5t^2$ and $s_2 = u(t-1) - \frac{1}{2} \times 10(t-1)^2$. When $s_1 = -20\ \text{m}$, $5t^2 = 20 \Rightarrow t = 2.0\ \text{s}$. Hence, $-20 = u(2-1) - \frac{1}{2} \times 10(2-1)^2 \Rightarrow u = -15\ \text{m s}^{-1}$.

15 **a** $s_1 = -\frac{1}{2}\times 10t^2 = -5t^2$ and $s_2 = u(t-1) - \frac{1}{2}\times 10(t-1)^2$. When $s_1 = -40$ m, $5t^2 = 40 \Rightarrow t = 2.83$ s.

Hence, $-40 = u(2.83-1) - \frac{1}{2}\times 10(2.83-1)^2 \Rightarrow u = -12.7$ m s^{-1}.

b $v_1 = -10t = -28.3$ m s^{-1} and $v_2 = -12.7 - 10(t-1) = -31.0$ m s^{-1}.

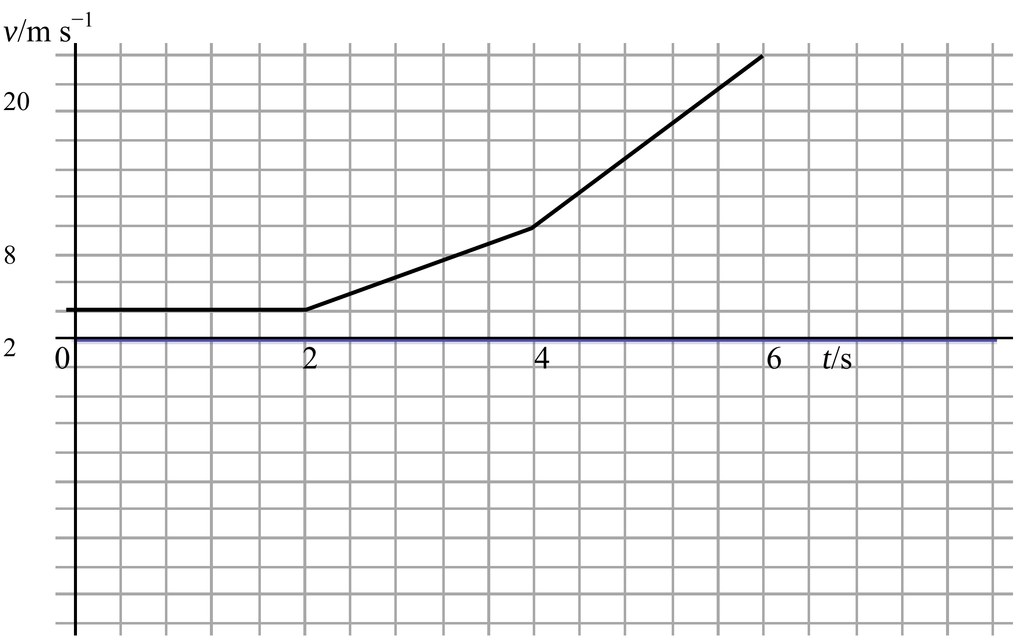
Thus, $\frac{v_2}{v_1} = \frac{31.0}{28.3} = 1.1$.

16 $s_1 = -\frac{1}{2}\times 10t^2 = -5t^2$ and $s_2 = -\frac{1}{2}\times 10(t-1)^2$. Two seconds after the second ball was dropped means that $t = 3.0$ s. Then, $s_1 = -45$ m and $s_2 = -20$ m. The separation is thus 25 m.

17 **a** The velocity at 2 s is $v_2 = 2 + 0\times 2 = 2.00$ m s^{-1}. The velocity at 4 s is $v_4 = 2 + 3\times 2 = 8.00$ m s^{-1}. The velocity at 6 s is $v_6 = 8 + 6\times 2 = 20.0$ m s^{-1}.

Alternatively, the area under the graph is 18.0 m s^{-1} and this gives the *change* in velocity. Since the initial velocity is 2.00 m s^{-1}, the final velocity is 20.0 m s^{-1}.

b



18 The acceleration is the slope of the velocity–time graph. Drawing a tangent to the curve at 2 s we find a slope of approximately $a = 2.0$ m s^{-2}.

19 Velocity is the slope of the displacement–time graph. So we observe that the velocity is initially positive and begins to decrease. It becomes zero at 1 s and then becomes negative. The displacement graph is in fact a parabola and so the velocity is in fact a linear function. Of course we are not told that, so any shape showing the general features described above would be acceptable here.

20 Velocity is the slope of the displacement–time graph. So we observe that the velocity is initially zero and becomes negative. It is assumes its (numerically) largest value at 1.5 s and becomes zero at 3 s. It then becomes positive, assuming its largest positive value at 4.5 s, then decreases to become zero again at 6 s. This explains the graph on page 790 in *Physics for the IB Diploma*.

21 Velocity is the slope of the displacement–time graph. So we observe that the velocity is initially very large and continues to decrease over time, approaching a small value. The slope and hence the velocity are always positive. This explains the graph in the answers on page 790 in *Physics for the IB Diploma*.

22 Velocity is the slope of the displacement–time graph. So we observe that the velocity is initially very small, becomes greatest at 1 s and starts decreasing, thereafter becoming very small again. The slope and hence the velocity are always positive. This explains the graph in the answers on page 791 in *Physics for the IB Diploma*.

23 Velocity is the slope of the displacement–time graph. So we observe that the velocity is initially very small, becomes greatest at just after 2 s and becomes zero at 3 s. It then becomes negative, achieving its least value at just before 4 s, and becomes very small in magnitude. This explains the graph in the answers on page 791 in *Physics for the IB Diploma*.

24 The acceleration is zero here, so $x = vt$, i.e. the graph of displacement is a linear function with a positive slope (that may or may not go through the origin, depending on the initial displacement).

25 Here we have a constant negative acceleration and so $x = ut - \frac{1}{2}at^2$, which is the graph of a (concave up) parabola.

26 Here we have a constant positive acceleration and so $x = ut + \frac{1}{2}at^2$, which is the graph of a (concave down) parabola.

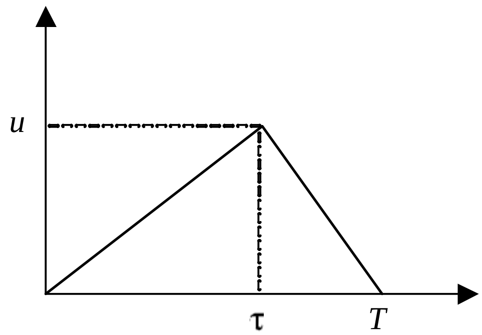
27 Up to 5 s, the displacement is given by the formula $x = \frac{1}{2}at^2 = \frac{1}{2}\frac{12}{5}t^2 = 1.2t^2$. At 5 s the displacement is 30 m. After the 5 s mark, the displacement is given by $x = 30 + 12t - \frac{1}{2}at^2 = 30 - 12t - 1.2t^2$. So we must use the calculator to plot

$$\begin{array}{rl} x = 1.2t^2 & t \le 5 \\ x = 30 - 12(t-5) - 1.2(t-5)^2 & t > 5 \end{array}$$

28 The acceleration is the slope of the velocity–time graph, which in this case is constant and negative.

29 The acceleration is the slope of the velocity–time graph. The slope is large and positive initially and decreases to become zero at 1 s. It then becomes negative, increasing in magnitude (i.e. becoming more negative).

30 You must push the car as hard as you can but then you must also pull back on it to stop it before it crashes on the garage. The velocity–time graph must be something like:



We know that: $u = 2\tau$. During pullback, we have that the velocity is given by $v = u - 3(t-\tau) = 2\tau - 3(t-\tau) = 5\tau - 3t$.

The velocity becomes zero at time T and so $0 = 5\tau - 3T$, i.e. $\tau = \frac{3T}{5}$.

The area under the curve (triangle) is 15 m and is given by

$\frac{1}{2}Tu = \frac{1}{2}T(2\tau) = \frac{1}{2}T\frac{6T}{5} = \frac{3T^2}{5}$.

Hence $\frac{3T^2}{5} = 15 \Rightarrow T^2 = 25 \Rightarrow T = 5$ s .

31 **a** The velocity is the slope of the displacement–time graph. Therefore the velocity is negative from A to B.

b Between B and C the slope and so the velocity is zero.

c From A to B the slope is increasing (from negative to less negative) and so the velocity is increasing.
Hence the acceleration is positive.

d From C to D the slope is increasing, meaning the velocity is increasing.
Hence the acceleration is positive.

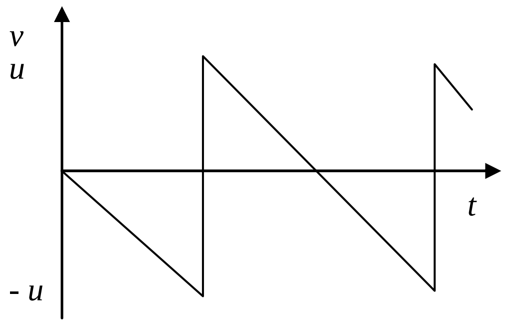
32 The solution is given in the answers on page 791 in *Physics for the IB Diploma*.

For the mathematically inclined:

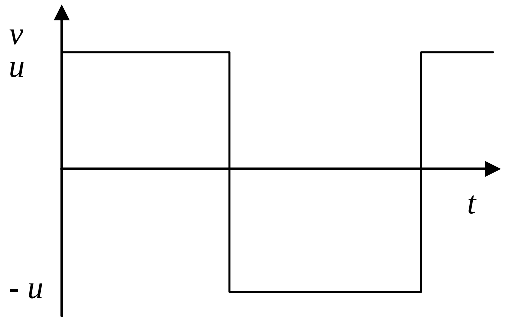
Let the displacement on the way up be given by the continuous function $x_1(t)$ and on the way down by the continuous function $x_2(t)$.
Let $t = 0$ correspond to 08:00 and let $t = 1$ correspond to 12:00.
Now consider the continuous function $f(t) = x_1(t) - x_2(t)$.
Then, $f(0) = x_1(0) - x_2(0) < 0$ and $f(1) = x_1(1) - x_2(1) > 0$.
By Bolzano's theorem there must exist a time T in between 0 and 1 such that $f(T) = 0$, i.e. $x_1(T) = x_2(T)$.

33 See graphs below.

a

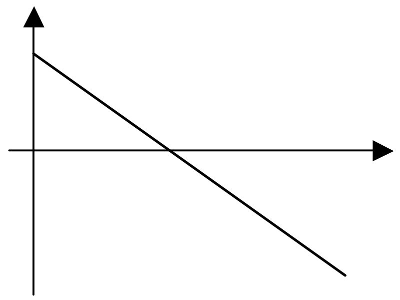


b



c See graph on page 86 in *Physics for the IB Diploma*, with curve going to zero abruptly during landing.

34 You can get various graphs here depending on what assumptions you make. If you assume, unrealistically, that the fan produces a constant force on the cart, then you will get a straight line graph:



A more realistic assumption would be to assume a force that increases with decreasing distance or a force that increases with the speed of the cart, in which case the graph would be a curve.

35 **a** Use $v^2 = u^2 + 2as$ to get $0 = 8^2 + 2 \times (-10) \times s \Rightarrow s = 3.2\ \text{m}$ from the cliff.

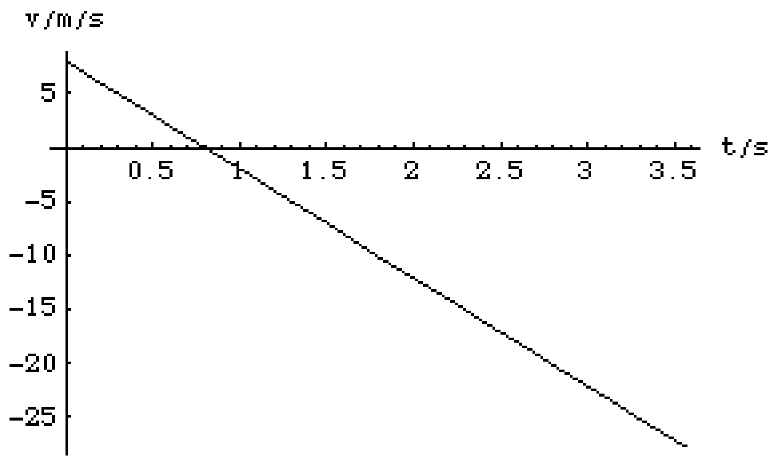
b Use $s = ut + \frac{1}{2}at^2$ to get $-35 = 8 \times t + \frac{1}{2}(-10) \times t^2$ and solve for time to get $t = 3.56\ \text{s}$.

c $v = u + at = 8 - 10 \times 3.56 = -27.6\ \text{m s}^{-1}$.

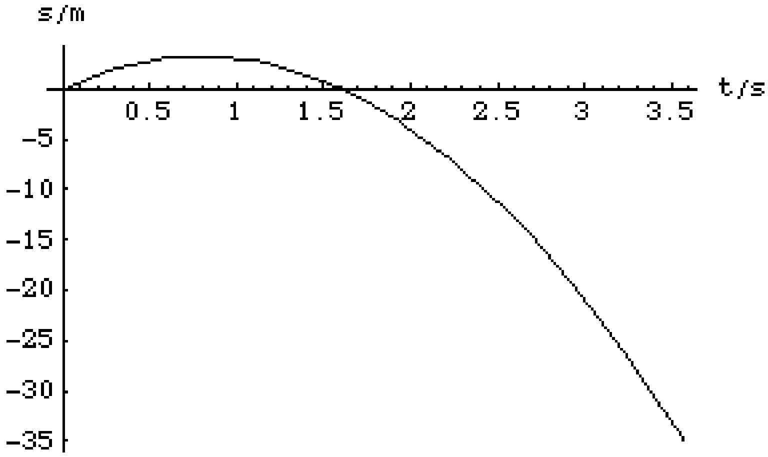
d $3.2 + 3.2 + 35 = 41.4\ \text{m}$.

e Average speed is $\frac{41.4}{3.56} = 11.6\ \text{m s}^{-1}$ and average velocity is $\frac{-35}{3.56} = -9.83\ \text{m s}^{-1}$.

f Graph the function $v = 8 - 10t$ to get



g Graph the function $s = 8t - 5t^2$ to get



36 a Use $s = ut + \frac{1}{2}at^2$ to get $s = 20 \times 6 + \frac{1}{2}(-10) \times 6^2 = -60\text{ m}$. The cliff is 60 m tall.

b $v = u + at = 20 - 10 \times 6 = -40\text{ m s}^{-1}$. The speed is then 40 m s^{-1}.

37 a During the 5 s of fuel burning, the rocket will reach a height given by $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 4 \times 5^2 = 50.0\text{ m}$. At that point it has an upward velocity of $v = u + at = 0 + 4 \times 5 = 20.0\text{ m s}^{-1}$. It will then continue upwards until the velocity becomes zero. This means an extra distance found from $v^2 = u^2 + 2as$, i.e. $0 = 20^2 + 2 \times (-10) \times s \Rightarrow s = 20.0\text{ m}$. The maximum height reached is then 70.0 m.

b The rocket reaches the maximum height *t* seconds after fuel burnout, where $v = u + at \Rightarrow 0 = 20 + (-10) \times t \Rightarrow t = 2.00\text{ s}$. The rocket will now drop a distance of 70 m in a time given by $s = \frac{1}{2}at^2 \Rightarrow -70 = \frac{1}{2} \times (-10) \times t^2 \Rightarrow t = 3.74\text{ s}$. The total time from the beginning is then $5.00 + 2.00 + 3.74 = 10.7\text{ s}$.

c Use the calculator to plot $v = 5t$ for the first 5 s and $v = 20 - 10(t - 5)$ afterwards to get the graph in the answers to the textbook.

38 a $v = u + at = 5 + (-10) \times 12 = -115\text{ m s}^{-1}$. The speed is 115 m s^{-1}.

b $s = s_0 + ut + \frac{1}{2}at^2 \Rightarrow 0 = s_0 + 5 \times 12 - \frac{1}{2} \times (-10) \times 12^2 \Rightarrow s_0 = 660\text{ m}$.

c The velocity of the sandbag after 6 s is $v = u + at = 5 + (-10) \times 6 = -55\text{ m s}^{-1}$. The relative velocity of the sandbag with respect to the balloon is then $-55 - 5.5 = -60.5\text{ m s}^{-1}$.