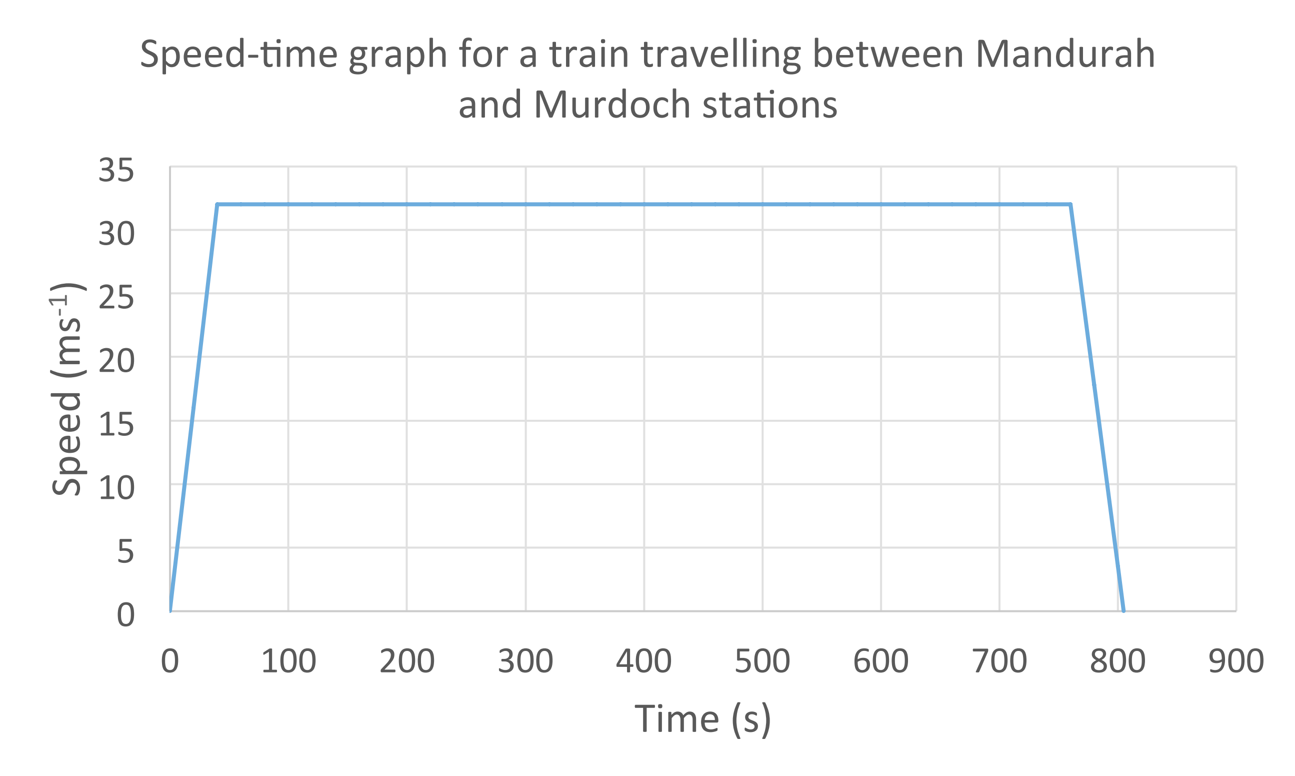
Problem Set 15: Accelerated Motion

15.1

[a]



[b]

Total time can be found by calculating the area under the graph, which is made up of two triangles and a rectangle:

$$s = \frac{40 \times 32}{2} + 32 \times 720 + \frac{45 \times 32}{2}$$

$$s = 24400 \text{ m}$$

$$s = 24.4 \text{ km}$$

[c]

To find the speed in kmh^{-1}, we can multiply the maximum speed by 3.6.

$$v = 32 \times 3.6$$

$$v = 115 \text{ kmh}^{-1}$$

[d]

$$v = \frac{s}{t}$$

$$v = \frac{24400}{805}$$

$$v = 30.3 \text{ ms}^{-1}$$

15.2

- Drop the stone into the well. As you release the stone, start the stopwatch.
- Stop the stopwatch once you hear the stone splash into the water.
- Use the time, along with $s = ut + \frac{1}{2}at^2$ to calculate the depth of the well.
- The calculated value will likely be smaller than the actual depth. This is because air resistance isn't taken into account and will slow the acceleration of the stone a little.

15.3

[a]

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

$$a = \frac{11.13 - 0}{3.15}$$

$a = 3.53$ ms^{-2}

[b]

$$v = \frac{45}{3.6}$$

$v = 12.5$ ms^{-1}

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

$$a = \frac{12.5 - 0}{2.65}$$

$a = 4.72$ ms^{-1}

15.4

[a]

$\Delta v = at$

$\Delta v = 21.3 \times 5.35$

$\Delta v = 114$ ms^{-1}

[b]

You would need to know the initial velocity of the rocket before it began accelerating.

15.5

[a]

$$t = \frac{s}{v}$$

$$t = \frac{50000}{200}$$

$t = 250$ s or 4 min 10 s

[b]

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

$$t = \frac{250 - 200}{2}$$

$t = 25$ s

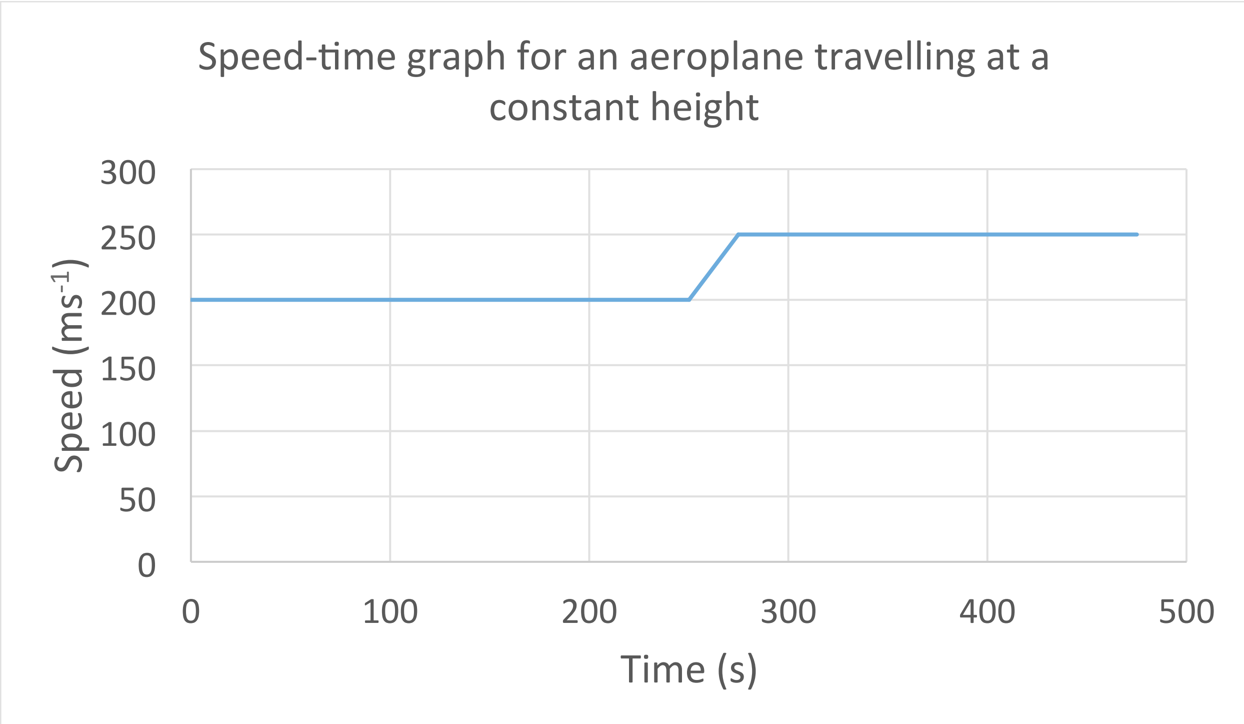
[c]

$$t = \frac{s}{v}$$

$$t = \frac{50000}{250}$$

$t = 200$ s or 3 min 20 s

[d]



[e]

To calculate the distance travelled in the acceleration phase, we can measure the area under the graph during the acceleration phase (which is a triangle).

$$s = \frac{25\times50}{2}$$

$s = 625$ m

15.6

$$v^2 = u^2 + 2as$$

$$7^2 = 0^2 + 2\times0.77\times s$$

$$s = \frac{49}{2\times0.77}$$

$s = 31.8$ m

15.7

[a]

First, we need to convert the speeds from kmh^{-1} to ms^{-1}:

$$u = \frac{21.8}{3.8} = 6.06 \text{ ms}^{-1}$$

$$v = \frac{28.6}{3.6} = 7.94 \text{ ms}^{-1}$$

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

$$a = \frac{7.94 - 6.06}{1.70}$$

$$a = 1.11 \text{ ms}^{-2}$$

[b]

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

$$t = \frac{17.4 - 7.94}{1.11}$$

$$t = 8.52 \text{ s}$$

15.8

Each ball will have an identical acceleration – 9.8 ms^{-2} towards the ground. While they may have different velocities, in each example there is no force other than gravity acting on the golf ball.

15.9

[a]

$$v^2 = u^2 + 2as$$

$$v = \sqrt{8^2 + (2 \times 9.8 \times 72)}$$

$$v = 38.4 \text{ ms}^{-1} \text{ downwards}$$

[b]

For the ball, which is accelerating:

$$v = u + at$$

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

$$t = \frac{38.4 - 8}{9.8}$$

$$t = 3.10 \text{ s}$$

For the skydiver, who is moving at constant velocity:

$$t = \frac{s}{v}$$

$$t = \frac{72}{8}$$

$$t = 9.00 \text{ s}$$

Therefore the skydiver will land 9.00 – 3.10 = 5.90 s after the ball lands.

15.10

[a]

$u = \frac{60}{3.6} = 16.7$ ms^{-1}

[b]

$s = vt$

$s = 16.7 \times 0.5$

$s = 8.33$ m

[c]

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

$a = \frac{0-16.7}{4.5}$

$a = -3.71$ ms^{-2} (3.71 ms^{-2} against his direction of travel)

[d]

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

$s = 16.7 \times 4.5 + \frac{1}{2} \times -3.71 \times 4.5^2$

$s = 37.6$ m

[e]

Stopping distance = reaction distance + braking distance. In this case, stopping distance = 8.33 + 37.6 = 45.9 m.

[f]

$u = \frac{55}{3.6} = 15.3$ ms^{-1}

Time taken to decelerate once brakes are applied:

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

$t = \frac{0-15.3}{-3.71}$

$t = 4.12$ s

This then needs to have the reaction time added, giving a total time to stop of 4.12 + 0.5 = 4.62 s.

Reaction distance:

$s = ut$

$s = 15.3 \times 0.5$

$s = 7.65$ m

Braking distance:

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

$s = 15.3 \times 4.12 + \frac{1}{2} \times -3.71 \times 4.12^2$

$s = 31.5$ m

Therefore, the total stopping distance will be 7.65 + 31.5 = 39.2 m.

[g]

$v = u + at$

$v = 16.7 - 3.71 \times 4.12$

$v = 1.41$ ms^{-1} or 5.08 kmh^{-1}

[h]

At first glance the difference appears minimal as there's only a 0.38 s difference in stopping time between the two speeds. However, the fact that there is a fixed reaction time where the car continues at constant velocity contributes to a 17% increase in the total stopping distance at the faster speed. Assuming the hazard is located 40 m in front of the car, the faster speed would result in the car hitting the hazard. While 5 kmh^{-1} is not likely to significantly damage the driver, a pedestrian may well sustain serious injuries if hit at this speed due to the much higher mass of the car.

15.11

Reducing the speed limit on roads next to schools by 10 kmh^{-1} during specific times is an effective way to reduce injuries to children who are making their way to school. Children are more likely to behave unpredictably due to their relative inexperience, and can easily misjudge whether or not they have sufficient time to cross the road when there is traffic. By reducing the speed limit, the stopping distance of drivers in these areas is significantly decreased, reducing the likelihood of an injury.

15.12

[a]

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

$a = \frac{50 - 0}{5}$

$a = 10$ ms^{-2}

This is reasonably close to the expected value of 9.8 ms^{-2} (acceleration due to gravity).

[b]

$v_{av} = \frac{s}{t}$

$v_{av} = \frac{ut + 0.5at^2}{t}$

$v_{av} = \frac{0.5 \times 10 \times 5^2}{5}$

$v_{av} = 25.0$ ms^{-1}

[c]

- That the rock was not affected by air resistance as it fell.
- That the rock had no initial velocity (i.e. Robyn just let go of the rock and did not throw it downwards).

15.13

[a]

Looking at just the first half of the ball's flight (from being thrown upwards to reaching its peak height), and taking the upwards direction as positive:

$v = u + at$

$u = v - at$

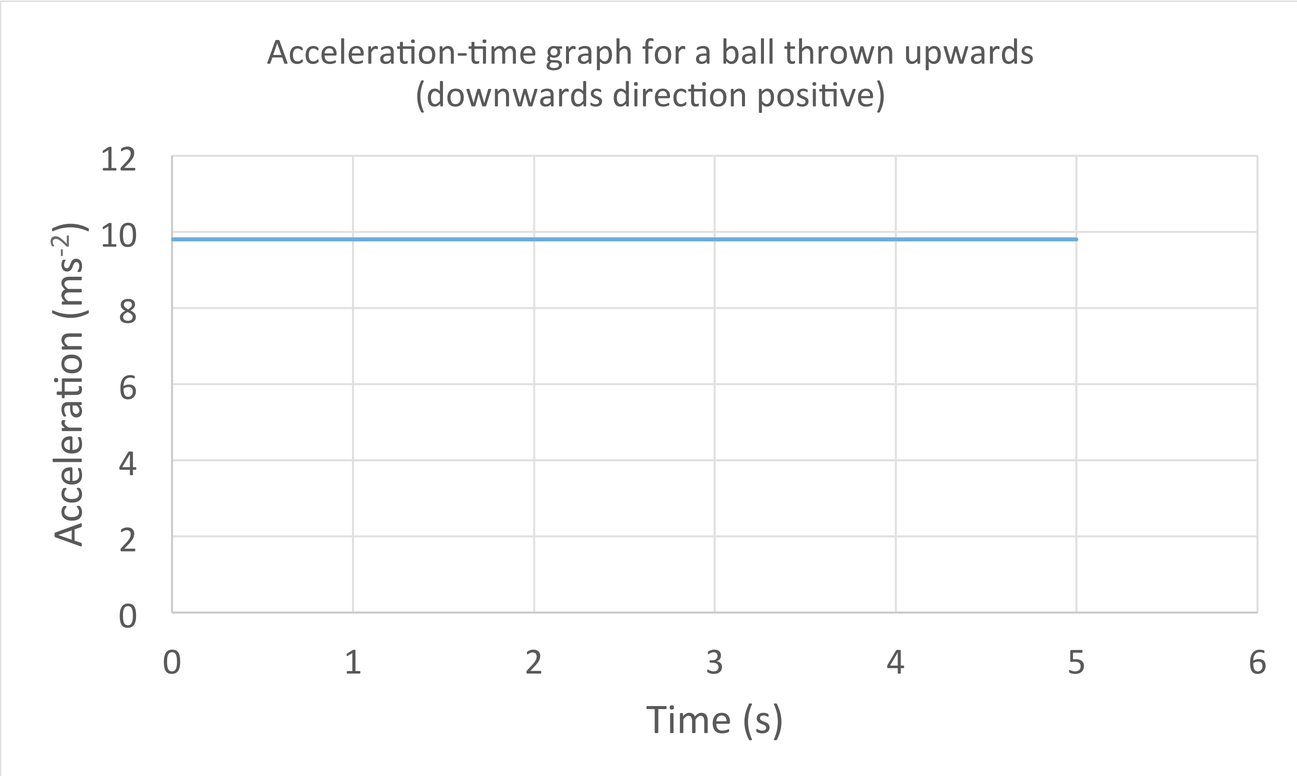
$u = 0 - (-9.8 \times 2.5)$

$u = 24.5$ ms^{-1} upwards

[b]

Assuming the ball has been thrown and caught from the same height above the ground, the velocity as it hits Terry's hands will be the same magnitude as he threw it with, but with an opposite direction – 24.5 ms^{-1} downwards.

[c]



15.14

[a]

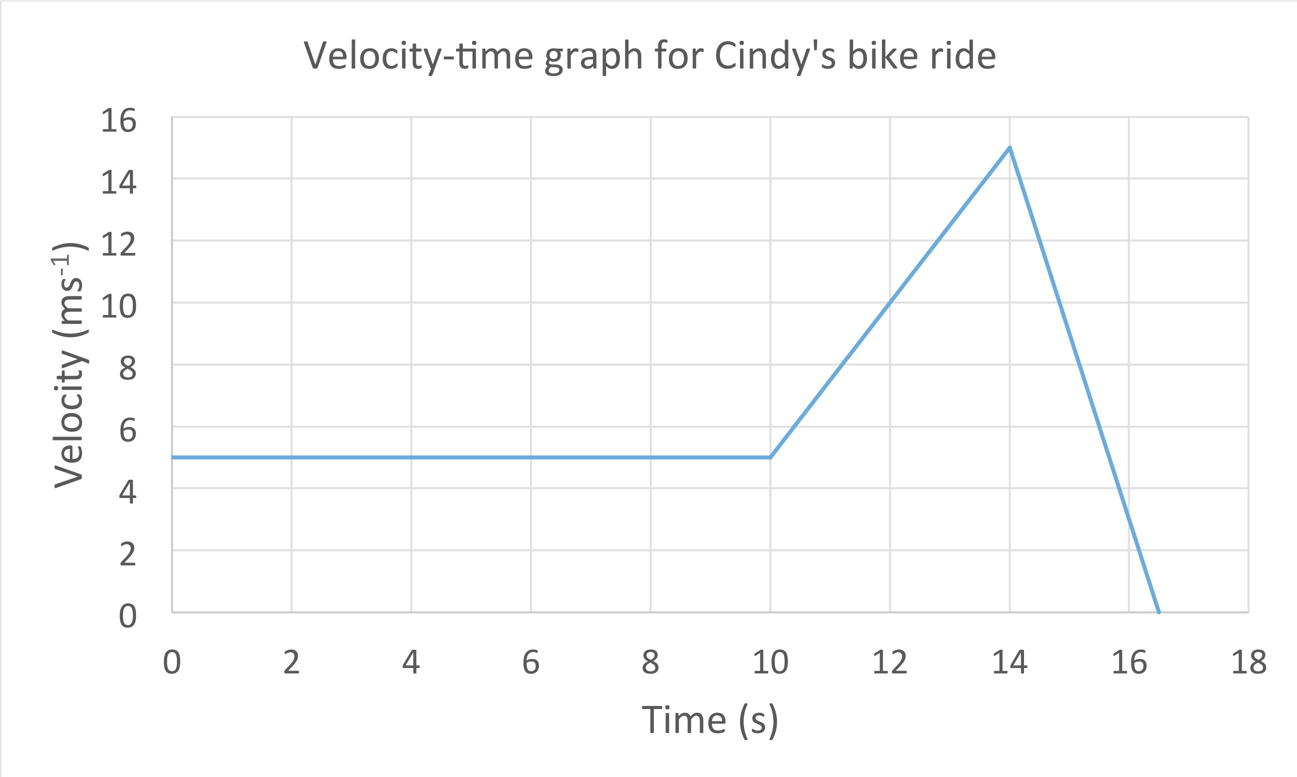
After 14 s, Cindy is at the end of her acceleration phase.

$v = u + at$

$v = 5 + 2.5 \times 4$

$v = 15.0\ ms^{-1}$

[b]



[c]

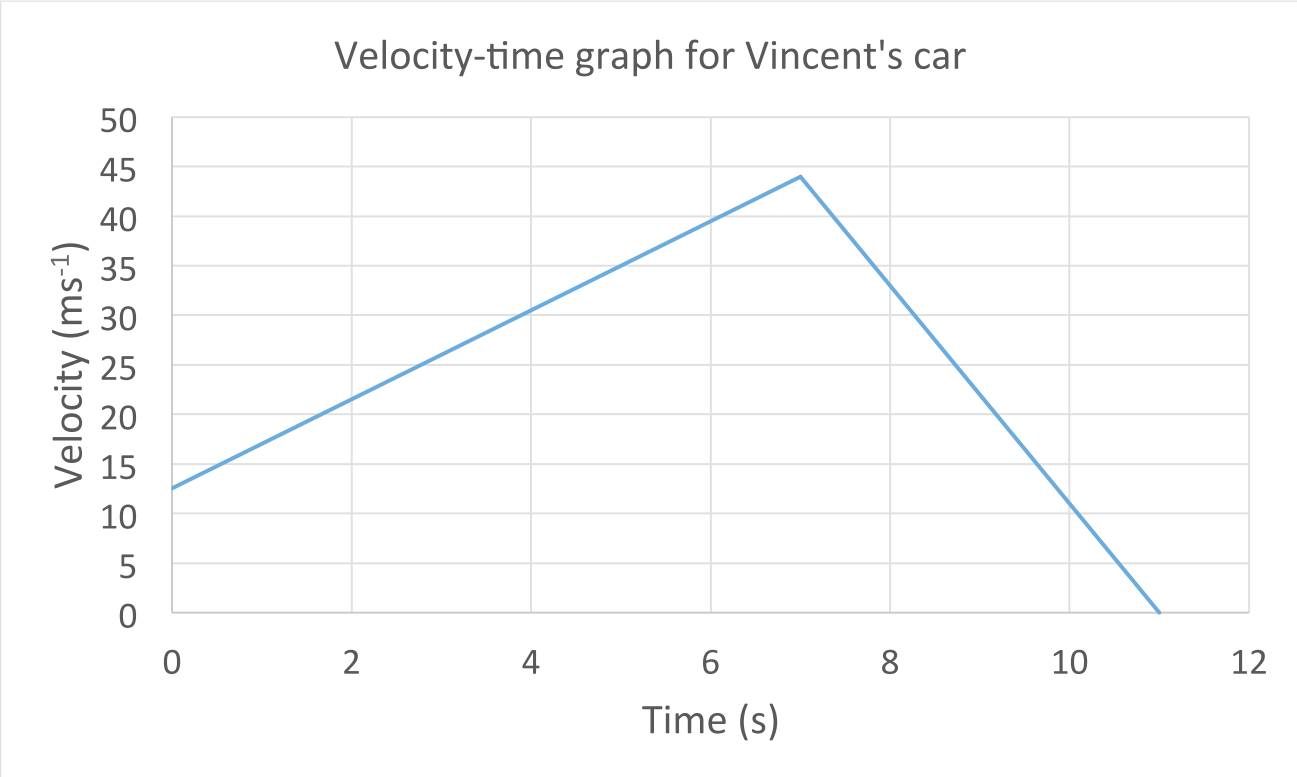
To calculate the total distance, we need to work out the area under the graph. This can be modelled with a rectangle and two triangles (for the acceleration and deceleration periods).

$$s = 14 \times 5 + \frac{4 \times 10}{2} + \frac{2.5 \times 15}{2}$$

$s = 109$ m

15.15

[a]



[b]

Again, we need to calculate the area under the graph, which can be modelled by two triangles and a rectangle.

$s = 12.5 \times 7 + \frac{7 \times 31.5}{2} + \frac{4 \times 44}{2}$ $\qquad s = 286$ m

15.16

Time taken to accelerate to 1.70 ms^{-1}, assuming he starts from rest:

$t = \frac{v - u}{a}$ $\qquad t = \frac{1.7 - 0}{0.11}$ $\qquad t = 15.5$ s

Distance travelled during this acceleration phase:

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

$$s = 0.055 \times 15.5^2$$

$$s = 13.2 \text{ m}$$

This means that the sailor still has to travel 30 – 13.2 = 16.8 m, at a constant speed of 1.7 ms^{-1}.

$t = \frac{s}{v}$ $\qquad t = \frac{16.8}{1.7}$ $\qquad t = 9.88$ s

Therefore, the total time he takes will be 15.5 + 9.88 = 25.4 s.