

Workbook Answers

Level 1 Science

Mechanics

Section One

1. Symbols and Definitions

- a.
 - i. v: velocity
 - ii. a: acceleration
 - iii. A: area
 - iv. d: distance
 - v. t: time
 - vi. P: power or pressure, depending on the context
 - vii. E: energy
 - viii. F: force
 - ix. m: mass or metres, depending on the context
 - x. W: work done
 - xi. g: acceleration due to gravity
 - xii. E_p : potential energy
 - xiii. E_k : kinetic energy
 - xiv. J: joule
 - xv. N: Newton
 - xvi. Δ : change in
- b. How fast an object is moving, $v = \frac{\Delta d}{\Delta t}$, measures how far it moves (distance covered) in a particular amount of time; "distance over time".
- c. A change in velocity (the object might speed up, or slow down) either way its velocity changes.
- d. A push or a pull acting on an object causing it to accelerate.
- e. The amount of matter ("stuff"/atoms) in an object. More matter means more mass.

2. Formulae

- a. $a = \frac{\Delta v}{\Delta t}$
- b. $F_{\text{net}} = ma$
- c. $P = \frac{F}{A}$

$$\text{d. } W = Fd \text{ (or } F = \frac{W}{d} \text{)}$$

$$\text{e. } \Delta E_p = mg\Delta h$$

$$E_p = 5 \times 10 \times 4$$

$$E_p = 200\text{J}$$

$$\text{f. } P = \frac{W}{t} \text{ so } t = \frac{W}{P}$$

$$t = \frac{1000}{50}$$

$$t = 20\text{s}$$

3. Motion

a. Distance: Metres (m)

Speed: Metres per second (ms^{-1})

Acceleration: Metres per second squared (ms^{-2})

$$\text{b. } 100\text{m} = d$$

$$12\text{s} = t$$

$$v = \frac{\Delta d}{\Delta t}$$

$$v = \frac{100}{12}$$

$$v = 8.33\text{ms}^{-1}$$

$$\text{c. } 8\text{s} = t$$

$$\Delta v = \text{final } v - \text{initial } v = 20 - 0 = 20$$

$$a = \frac{\Delta v}{\Delta t}$$

$$a = \frac{20}{8}$$

$$a = 2.5 \text{ ms}^{-2}$$

$$\text{d. } 0.12\text{ms}^{-1} = v$$

$$45\text{s} = t$$

$$v = \frac{\Delta d}{\Delta t} \text{ so } \Delta d = v\Delta t$$

$$\Delta d = 0.12 \times 45$$

$$\Delta d = 5.4\text{m}$$

e. $2\text{ms}^{-1} = a$

$4\text{s} = t$

$1\text{ms}^{-1} = \text{initial velocity}$

$a = \frac{\Delta v}{\Delta t}$ so $\Delta v = a \Delta t$

$\Delta v = 2 \times 4$

$\Delta v = 8\text{ms}^{-1}$ So final speed = initial velocity + new velocity = $1 + 8 = 9\text{ms}^{-1}$

- f. This is a distance-time graph. We can tell because distance is on the y-axis and time is on the x-axis. It represents the distance that an object has travelled in a particular amount of time. From the graph, we can see that an object travels about 0.40m in 25s.

Using $v = \frac{d}{t}$, we can calculate the velocity (v) of the object during this time: $v = \frac{0.40}{25} = 0.016\text{ms}^{-1}$. We can calculate the gradient of the line on the graph using $\text{gradient} = \frac{\text{rise}}{\text{run}}$. The line rises up from 0 to 0.40, giving a rise of 0.40. The line moves across from 0 to 25, giving a run of 25. $\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{0.40}{25} = 0.016$ - which is the same as the velocity. The gradient of the distance-time graph therefore is the same as the velocity of the object.

- g. This is a speed-time graph. We can tell because speed is on the y-axis and time is on the x-axis. It represents the speed of the object during a particular stretch of time. From the graph, we can see that the object starts at 9ms^{-1} for its speed and its speed is 0ms^{-1} after 6s.

Using $a = \frac{\Delta v}{t}$, we can calculate the acceleration (a) of the snail during this time: $a = \frac{9}{6} = 1.5\text{ms}^{-2}$. We can calculate the gradient of the line on the graph using $\text{gradient} = \frac{\text{rise}}{\text{run}}$. The line falls from 9 to 0, giving a rise of 9. The line moves across from 0 to 6, giving a run of 6. $\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{9}{6} = 1.5$ - which is the same as the velocity. The gradient of the distance-time graph therefore is the same as the velocity of the object.

- h. When the speed is not changing.

- i. The instantaneous speed is your speed at any particular second in time. The average speed is found by taking the total distance you travelled and the total time it took. It does not take into account what your speed at any particular moment during the journey was. For example, you might have been going faster at the start and slowed down, but with average speed its calculated on the total, so you won't see that.

j.

Section A	Melanie is accelerating (her speed is increasing). We can tell because the line is curved upwards, and the gradient of the line is becoming steeper.
Section B	Melanie is moving at a constant speed. We can tell because the line is straight, and the gradient of the line is not changing.
Section C	Melanie is decelerating (her speed is decreasing). We can tell because the line is curving downwards and the gradient of the line is decreasing.
Section D	Melanie is stationary (she is not moving). We can tell because the line is flat (no gradient).

k. i. $a = \frac{\Delta v}{\Delta t}$ (or rise/run)

$$\Delta v = 7$$

$$\Delta t = 10$$

$$a = \frac{7}{10} = 0.7\text{ms}^{-1}$$

ii. $a = \frac{\Delta v}{\Delta t}$ (or rise/run)

$$\Delta v = 7 - 2 = 5$$

$$\Delta t = 10$$

$$a = \frac{5}{10} = 0.5\text{ms}^{-1}$$

iii. $a = \frac{\Delta v}{\Delta t}$

$$\Delta v = -9$$

$$\Delta t = 6$$

$$a = \frac{-9}{6} = -1.5\text{ms}^{-1} \text{ (decelerating at } -1.5\text{ms}^{-2}\text{)}$$

iv. $a = \frac{\Delta v}{\Delta t}$

$$\Delta v = 2 - 7 = -5$$

$$\Delta t = 10$$

$$a = -\frac{5}{10} = -0.5\text{ms}^{-1} \text{ (decelerating at } 0.5\text{ms}^{-2}\text{)}$$

l. Snail 1

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta d = 0.40$$

$$\Delta t = 25$$

$$v = 0.40/25$$

$$= 0.016\text{ms}^{-1}$$

Snail 2

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta d = 0.35$$

$$\Delta t = 25$$

$$v = \frac{0.35}{25}$$

$$= 0.014\text{ms}^{-1}$$

Snail 3

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta d = 0.40$$

$$\Delta t = 20$$

$$v = \frac{0.40}{20}$$

$$= 0.02 \text{ms}^{-1}$$

m. i. Gabby is accelerating faster. The slope of the graph represents acceleration, and Gabby's graph has a steeper slope during the first 10 seconds.

ii. Gabby travels further during these 40 seconds.

The distance covered is represented by the area under the graph. Gabby's graph encloses a larger area so she has travelled further.

Alternatively: Gabby's speed is higher than Oliver's speed over the whole time period. Since they are in motion for the same amount of time, this means Gabby will cover more distance.

n. i. Distance covered = area under graph

Area of rectangle = base \times height

$$\begin{aligned}\text{Distance} &= 8 \times 30 \\ &= 240\text{m}\end{aligned}$$

ii. Distance covered = area under graph

Area of triangle = $\frac{1}{2} \times \text{base} \times \text{height}$

$$\begin{aligned}\text{Distance} &= \frac{1}{2} \times 8 \times 40 \\ &= 160\text{m}\end{aligned}$$

iii. Distance covered = area under graph

= area 1 (rectangle) + area 2 (triangle)

$$= (8 \times 20) + (\frac{1}{2} \times 8 \times 20)$$

$$= 160 + 80$$

$$= 240\text{m}$$

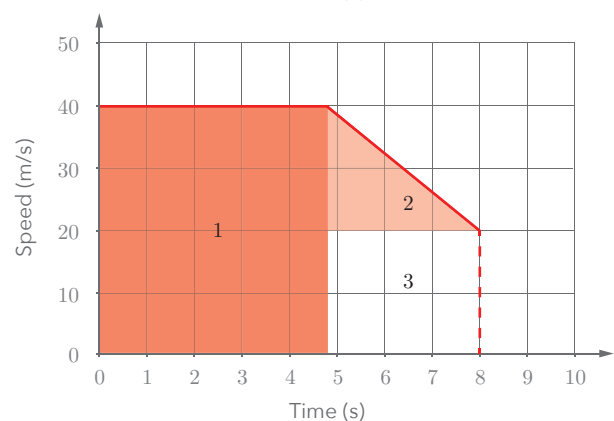
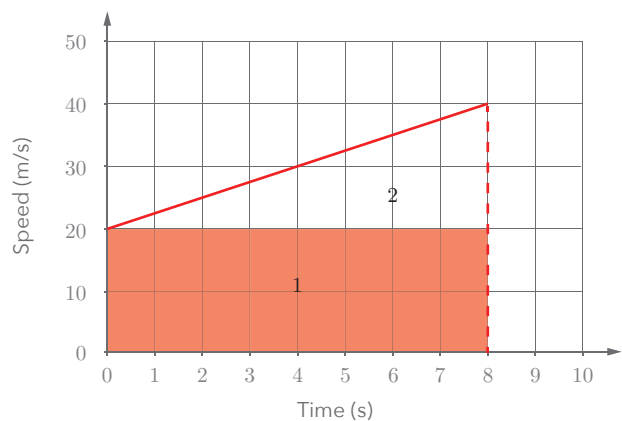
iv. Distance covered = area under graph

= area 1 (rectangle) + area 2 (triangle) + area 3

$$= (40 \times 5) + (\frac{1}{2} \times 20 \times 3) + (20 \times 3)$$

$$= 200 + 30 + 60$$

$$= 290\text{m}$$



4. Forces

a. Newtons, N

b. Watermelon:

$$F_{\text{net}} = 2 - 1 = 1\text{N}$$

Direction: Left

Carrot:

$$F_{\text{net}} = 1.6 - 0.2 = 1.4\text{N}$$

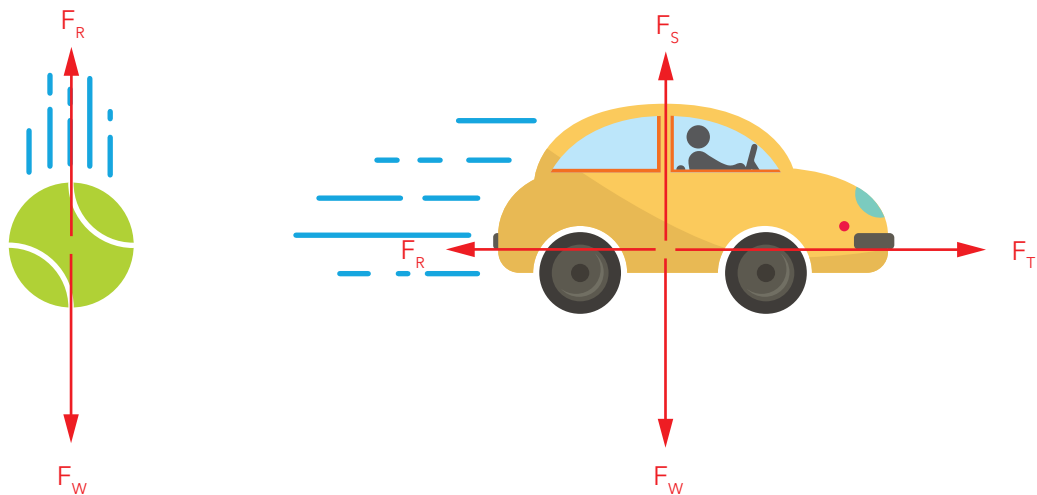
Direction: Downwards

Tomato:

$$F_{\text{net}} = 6 - 1 = 5\text{N}$$

Right (upwards and downwards forces are balanced).

c.



It is also fine to label the forces using words, e.g., “thrust”. The force arrows should show the rough sizes of forces in opposite directions (i.e., the weight force arrow on the falling ball should be longer than the air resistance arrow).

d. Mass is the amount of matter in an object, and is measured in kilograms (kg). It does not change depending on where the object is. Weight is the force due to gravity that an object experiences because of its mass. It is measured in Newtons (N) and can change depending on location.

e. i. $F_w = mg$ and $g = 10\text{Nkg}^{-1}$

$$F_w = 15 \times 10$$

$$= 150\text{N}$$

ii. $F_w = mg$

$$F_w = 0.9 \times 10$$

$$= 9\text{N}$$

$$\text{iii. } F_w = mg$$

$m = 450\text{g}$, but grams are not the SI unit for mass, so we need to convert to kilograms.

$$m = 0.450\text{kg} \quad (450/1000 = 0.450)$$

$$\begin{aligned} F_w &= 0.450 \times 10 \\ &= 4.5\text{N} \end{aligned}$$

$$\text{iv. } F_w = mg \text{ so } m = \frac{F_w}{g}$$

$$m = \frac{4}{10}$$

$$m = 0.4\text{kg}$$

$$\text{f. } F_{\text{net}} = ma$$

$$F_{\text{net}} = 715\,000 \times 30$$

$$F_{\text{net}} = 21\,450\,000\text{N}$$

$$\text{g. } F_{\text{net}} = ma \text{ so } a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{30}{0.75}$$

$$a = 40\text{ms}^{-2}$$

- h. If the snail is moving at a constant speed, then the forces on the snail must be balanced (so the net force is 0), according to Newton's first law of motion. Also, since $F_{\text{net}} = ma$, $a = \frac{F_{\text{net}}}{m}$. If the acceleration is 0, then the net force must be 0.

Note: this does not mean there are no forces acting on the snail.

- i. i. Vertical forces are balanced.

$$F_{\text{net}} = 50 - 40 = 10\text{N to the right}$$

$$F_{\text{net}} = ma \text{ so } a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{10}{17}$$

$$= 0.588\text{ms}^{-2} \text{ to the right.}$$

- ii. Horizontal forces are balanced.

$$F_{\text{net}} = 20 - 15 = 5\text{N upwards.}$$

$$a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{5}{0.5}$$

$$a = 10\text{ms}^{-2} \text{ upwards}$$

- iii. Horizontal forces are balanced.

$$F_{\text{net}} = 50 - 40 = 10\text{N downwards.}$$

$$a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{10}{0.0005}$$

$$a = 20,000\text{ms}^{-2} \text{ downwards.}$$

iv. Horizontal forces are balanced.

$$F_{\text{net}} = 100 - 20 = 80\text{N upwards.}$$

$$a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{80}{700}$$

$$a = 0.114\text{ms}^{-2} \text{ upwards.}$$

5. Pressure

a. i. Pascals (Pa) or Newton metres squared (Nm^2)

ii. Metres squared (m^2)

$$\text{b. } P = \frac{F}{A}$$

$$P = \frac{300}{0.5}$$

$$P = 600\text{Pa}$$

$$\text{c. i. } P = \frac{F}{A} \text{ so } F = PA$$

$$F = 2250 \times 0.00040 \text{ (make sure to use the } \text{m}^2 \text{ measurement)}$$
$$= 0.9\text{N}$$

ii. The pressure will decrease. Since $P = \frac{F}{A}$, pressure is proportional to force. If force decreases, pressure will also decrease.

$$\text{d. } P = \frac{F}{A}$$

The force in this question is the object's weight force, so $F = mg$.

$$F = 14 \times 10$$

$$= 140 \text{ N}$$

$$P = \frac{140}{0.05}$$

$$= 2800\text{Pa}$$

$$\text{e. i. } P = \frac{F}{A}$$

$$P = \frac{560}{0.008}$$

$$= 70\,000\text{Pa}$$

$$\text{ii. } P = \frac{F}{A}$$

$$A = 2 \times 0.0080\text{m}^2$$

$$A = 0.0160\text{m}^2$$

$$P = \frac{560}{0.016}$$

$$= 35\,000 \text{ Pa}$$

- iii. Higher pressure will cause her to leave deeper footprints (as the sand will be compressed under her feet). Therefore, her footprint will be deeper standing on one foot, compared to standing on both feet.

6. Energy

- a. Joules (J)
- b. Kinetic energy (E_k)
- c. Gravitational potential energy (E_p)
- d. Energy cannot be created or destroyed, it can only change forms. This means that the total energy is conserved.

e. $\Delta E_p = mg\Delta h$
 $\Delta E_p = 0.2 \times 10 \times 0.5$
 $= 1\text{J}$

f. $\Delta E_p = mg\Delta h$
 $m = \frac{\Delta E_p}{g\Delta h}$
 $\Delta h = \frac{1.5}{10 \times 0.5}$
 $\Delta h = \frac{1.5}{5}$
 $\Delta h = 0.3 \text{ kg}$

g. $\Delta E_p = mg\Delta h$
 $m = \frac{\Delta E_p}{g\Delta h}$
 $\Delta h = \frac{0.105}{0.003 \times 10}$
 $\Delta h = \frac{0.105}{0.03}$
 $\Delta h = 3.5\text{m}$

h. i. $\Delta E_k = \frac{1}{2}mv^2$
 $\Delta E_k = \frac{1}{2} \times 75 \times 6^2$
 $\Delta E_k = \frac{1}{2} \times 75 \times 36$
 $= 1350\text{J}$

$$\text{ii. } \Delta E_k = \frac{1}{2}mv^2$$

$$m = \frac{2E_k}{v^2}$$

$$m = \frac{2 \times 950}{6^2}$$

$$m = \frac{1900}{36}$$

$$m = 52.8\text{kg}$$

iii. Their kinetic energy will increase, as kinetic energy is proportional to speed squared. $E_k = \frac{1}{2}mv^2$, so if v increases, E_k also increases.

$$\text{i. } \Delta E_k = \frac{1}{2}mv^2$$

$$v^2 = \frac{2E_k}{m}$$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$v = \sqrt{\frac{2 \times 512}{64}}$$

$$v = \sqrt{\frac{1024}{64}}$$

$$v = \sqrt{16}$$

$$v = 4\text{ms}^{-1}$$

7. Work and Power

a. i. Joules (J)

ii. Watts (W)

b. $W = Fd$

$$W = 15 \times 5$$

$$= 75\text{J}$$

c. $W = Fd$ so $F = \frac{W}{d}$

$$F = \frac{1200}{45}$$

$$F = 26.7\text{N}$$

d. $P = \frac{W}{t}$

$$P = \frac{500}{8}$$

$$P = 62.5\text{W}$$

e. $W = Fd$

Work is being done against gravity, so the force needed is equal to the trolley's weight force ($F = 280\text{N}$) and the distance is equal to the upwards distance ($d = 1.8\text{m}$).

$$\begin{aligned} W &= 280 \times 1.8 \\ &= 504\text{J} \end{aligned}$$

f. i. $W = Fd$

The force needed is equal to Jessie's weight force as work is being done against gravity to allow her to climb.

$$\begin{aligned} F_w &= mg \\ F_w &= 51 \times 10 \\ &= 510 \text{ N} \end{aligned}$$

$$\begin{aligned} W &= 510 \times 2 \\ &= 1020 \text{ J} \end{aligned}$$

ii. $P = \frac{W}{t}$

$$P = \frac{1020}{10}$$

$$P = 102 \text{ W}$$

iii. The power exerted would be higher. Since $P = \frac{W}{t}$, if t is decreased and W stays the same, P will increase.

Section Two

1. Forces and Motion

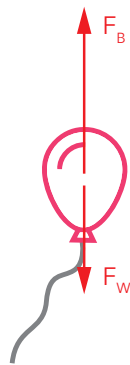
1. a. $0.005\text{kg} = \text{mass} = m$

$0.07\text{N} = \text{upwards force} = F$

Acceleration = a = what they want us to calculate

b. $F = ma$ Or $F_w = mg$ if the acceleration is due to gravity.

- c. The arrow for the force of buoyancy (F_b) should be longer than the arrow for the weight force (F_w). The length of the arrow shows the magnitude (size) of the force, so a bigger force gets a bigger arrow. Since the balloon is accelerating upwards, the net force must be upwards, so upwards force is bigger.



- d. For this, think about whether the equations you thought might be relevant at the start of the question will work. What is the symbol for weight force? F_w .

The equation $F_w = mg$ has F_w , what we want to find out, and m , which we have (0.005kg) in it. If we are anywhere on earth, $g = 10\text{ms}^{-2}$, so we also have g . This means we can use this equation to find the weight force.

$$F_w = mg$$

$$\begin{aligned} F_w &= 0.005g \times 10 \\ &= 0.05\text{N} \end{aligned}$$

- e. Firstly, what is the 'Net force'? In this case, it is the difference between the upwards force and downwards (weight) force. We already know the weight force (we just calculated it) and the upwards force was given to us in the question, so we just need to find the difference between these two.

$$F_{\text{net}} = 0.07 - 0.05$$

$$F_{\text{net}} = 0.02 \text{ N upwards}$$

- f. You want a formula that has both F_{net} or F in it (symbol for force) and a (symbol for acceleration).

$$F_{\text{net}} = ma$$

- g. Firstly, rearrange the formula so that it says 'a =', then put in the values that you know to calculate an answer. Some of the values are ones you have calculated in prior questions, and some were given in the information at the start of the question.

$$a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{0.02}{0.005}$$

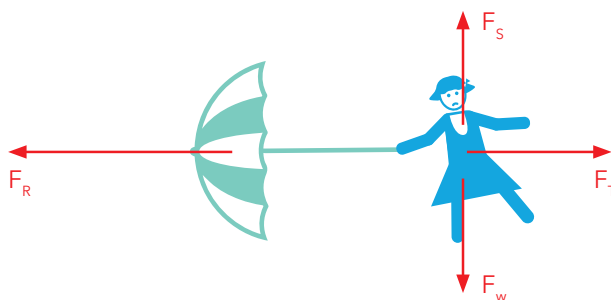
$$= 4\text{ms}^{-2}$$

2. a. She is travelling at constant speed (symbol for speed, including constant speed = v). After she opens the umbrella, she slows down (speed decreases). This is a change in speed ($\Delta v = a$). A change in speed means that there must be unbalanced forces somewhere. "Forces" comes up as a physics word. The symbol is F. No numbers are mentioned.

b. $F = ma$

$$a = \frac{\Delta v}{t}$$

- c. The arrow for the force of air resistance (F_R) should be longer than the arrow for the thrust force (F_T). Since Rimu is decelerating, the net force must be in the direction of air resistance. Gravity (F_w) is also acting on Rimu (downwards arrow) as is the support force (F_s) (upwards arrow). The size of the F_w and F_s arrows should be the same as these forces are balanced.



- d. Air resistance is acting (backwards), which comes from the wind.
Thrust force is acting forward, which comes from Rimu's muscles.
Rimu's weight force is acting downwards due to gravity, but it is balanced out by the support force acting upwards (from the ground).

Since Rimu's speed changes, she must have unbalanced forces acting on her. You cannot get a change in speed unless there are unbalanced forces. She slows down, which means that the force of the wind blowing against her must be greater than the thrust force she uses to walk forward. Don't forget that gravity (weight force, F_w) is always acting on Rimu while she is on Earth, and there is also the support force (F_s) that opposes the gravity and acts upward, from the ground.

e. $F_{\text{net}} = ma$

- f. When Rimu opens her umbrella, the force of air resistance is greater than her thrust force. This is because the umbrella has a large surface area. As a result, the direction of the net force is backwards (against her motion). Since $F_{\text{net}} = ma$, her acceleration is also backwards. Since her motion is forwards, this force causes her to decelerate.

g. If Rimu increases her thrust force to be equal to the force of air resistance, she will be able to walk at a constant speed. This is because if the thrust force and air resistance are balanced, the net force acting on Rimu and her umbrella will be 0.

As $F_{\text{net}} = ma$, if $F_{\text{net}} = 0$, then $a = 0$. If acceleration is 0, then Rimu's speed will be constant.

3. a. The arrow for the force of air resistance (F_R) should be shorter than the arrow for the weight force (F_W). Since the hailstone is accelerating downwards, the net force must be downwards.



b. $F_{\text{net}} = ma$

c. $F_{\text{net}} = ma$

$$F_{\text{net}} = 0.002 \times 3$$

$$F_{\text{net}} = 0.006\text{N (downwards)}$$

d. $F = mg$

$$F_W = 0.002 \times 10$$

$$= 0.02\text{N}$$

e. As we can see by referring to the force diagram in part (a), $F_{\text{net}} = F_W - F_R$.

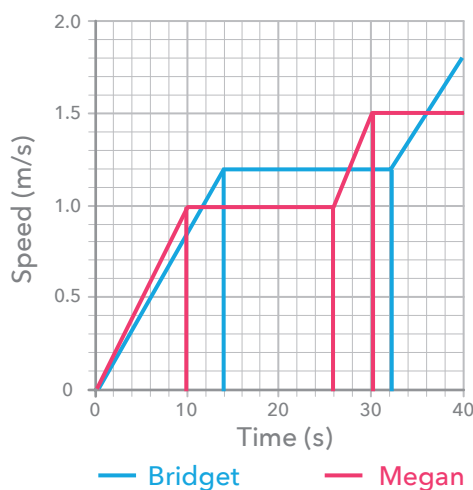
$$F_{\text{net}} = F_W - F_R$$

$$F_R = F_W - F_{\text{net}}$$

$$F_R = 0.02 - 0.006$$

$$= 0.014\text{ N}$$

4. a.



b. i. Each square on the grid represents 2 seconds, or 0.1ms^{-1}

$$\begin{aligned}\text{Area of triangle} &= \frac{1}{2} \times \text{base} \times \text{height} \\ &= \frac{1}{2} \times 14 \times 1.2 \\ &= 8.4\text{m}\end{aligned}$$

ii. Area of rectangle = base \times height

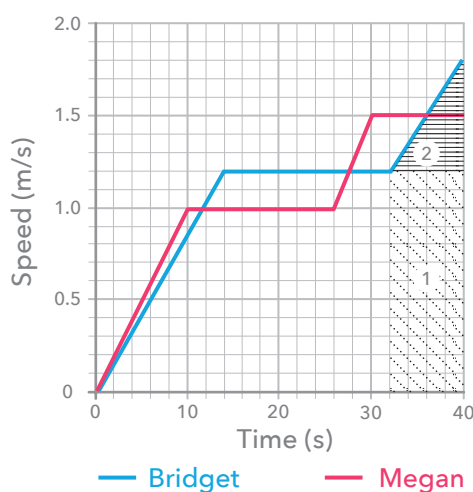
$$\begin{aligned}\text{The rectangle spans from 14 to 32 seconds, so its base is 18.} \\ &= 18 \times 1.2 \\ &= 21.6\text{m}\end{aligned}$$

iii. Total Area = Area 1 (rectangle) + area 2 (triangle).

$$\text{Area of rectangle} = 8 \times 1.2 = 9.6\text{m}$$

$$\text{Area of rectangle} = \frac{1}{2} \times 8 \times 0.6 = 2.4\text{m}$$

$$\text{Total Area} = 9.6 \times 2.4 = 12\text{m}$$



c. (i) Area of triangle = $\frac{1}{2} \times 10 \times 1$
= 5m

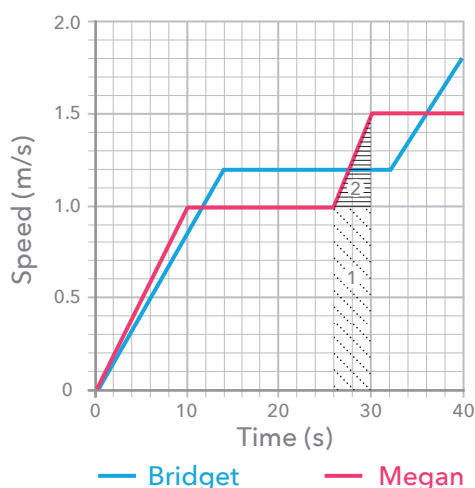
(ii) Area of rectangle = 16×1
= 16m

(iii) Total area = Area 1 (rectangle) + area 2 (triangle)

$$\text{Area of rectangle} = 4 \times 1 = 4\text{m}$$

$$\text{Area of triangle} = \frac{1}{2} \times 4 \times 0.5 = 1\text{m}$$

$$\text{Total area} = 4 + 1 = 5\text{m}$$



iv. Area of rectangle = 10×1.5
 $= 15\text{m}$

- c. Bridget's total distance = $8.4 + 21.6 + 12 = 42\text{m}$
 Megan's total distance = $5 + 16 + 5 + 15 = 41\text{m}$
 Bridget travelled further.

5. a. i. The cheetah is accelerating for the first 6 seconds of its motion.

- ii. This means the net force on the cheetah must be forwards, as we know that $F_{\text{net}} = ma$.
 Its thrust force (forwards) is larger than the forces of air resistance/friction (backwards).

b. i. The cheetah is moving at a constant speed for the next 12 seconds.

- ii. This means the net force on the cheetah must be 0, as its acceleration is 0.
 The forwards (thrust) and backwards (air resistance/friction) forces must be balanced - they have the same size in opposite directions.

c. i. The cheetah is decelerating for the next 12 seconds.

- ii. This means the net force on the cheetah must be backwards (in the opposite direction to its motion). The backwards forces of friction/air resistance are greater than the thrust force, leading to a negative acceleration, which causes the cheetah to slow down.

d. i. The cheetah is at rest (not moving) for the final 10 seconds on the graph.

Note: a common mistake would be to say the cheetah is 'coming to a stop' - this is not correct as it has already completely stopped in this section.

- ii. This means there must be 0 net force on the cheetah as it again has 0 acceleration. The backwards and forwards forces are either balanced or all equal to 0, leading to a net force of 0.

6. a. The second graph, or B is the correct representation of Leina's journey.

b. To start with, Leina is accelerating, which is represented by an upwards sloping line on the speed-time graph. Acceleration is shown by a curve on a distance-time graph.

c. Then, she moves at a constant speed, shown by a flat line on the speed-time graph. This is represented by a straight line on a distance-time graph.

d. She then decelerates, which is shown by a downwards slope on the speed-time graph. This is shown as a curve on a distance-time graph.

e. Finally, she stops moving, which is shown by a speed of 0. This is shown by a flat horizontal line on a distance-time graph.

f. The distance-time graph which matches all these sections is graph B.

2. Pressure

1. a. $P = \frac{F}{A}$

- b. The cat has four paws, so the total surface area is:

$$A = 0.0009 \times 4 = 0.0036\text{m}^2$$

Make sure you use the measurement in m^2 , not in cm^2 - both are often given in the question because the cm^2 measurement is easier to read, but m^2 is the correct SI unit for area.

c. $F_w = mg$
 $= 3.2 \times 10$
 $= 32\text{N}$

d. $P = \frac{32}{0.0036}$
 $= 8888.9\text{Pa}$

2. a. $P = \frac{F}{A}$

- b. The surface area of the tourist's skis is the same both on Earth and on Mars, since they are the same skis. This means that the value of A in the formula does not change.

- c. The tourist's weight force is lower on Mars than it is on Earth, even though her mass is the same, because gravity is weaker. This means that the value of F in the formula is lower on Mars.

- d. Pressure is given by $P = \frac{F}{A}$. Area is constant between Mars and Earth, but force (F) is lower on Mars. Pressure is proportional to force, so this leads to the tourist's skis exerting lower pressure on the snow on Mars, compared to Earth. As they exert less pressure, they compress the snow beneath them less, which is why the tourist does not sink as far into the snow.

3. a. $P = \frac{F}{A}$

- b. When Andrea switches to using a sharper knife, the force the knife exerts on the carrot is spread over a much smaller surface area (as the blade has a narrower edge). Therefore, the value of A in the formula is decreased.

- c. The same pressure is needed to cut through the carrots with either knife. However, it takes less force to apply this pressure using the sharper knife. We can rearrange the formula for pressure to $F = PA$. If pressure stays constant and area is reduced, then the force is also reduced.

- d. The force that the knife exerts on the carrot comes from the force that Andrea exerts on the knife. Therefore, as she does not need to exert as much force when using the sharp knife, she finds it easier to chop the carrots.

3. Energy

1. a. At the end of her dive, Siobhan's gravitational potential energy will have been converted into kinetic energy (since she will be moving). Kinetic energy is given by the formula: $E_K = \frac{1}{2} mv^2$

- b. If energy is conserved, then Siobhan's final kinetic energy will be equal to her original gravitational potential energy:

$$E_K = 7100.$$

$$7100 = \frac{1}{2}mv^2$$

$$7100 = \frac{1}{2} \times 71 \times v^2$$

$$2 \times 7100 = 71 \times v^2 \quad (\text{it is usually easiest to get rid of fractions first})$$

$$14200 = 71 \times v^2$$

$$\frac{14200}{71} = v^2$$

$$200 = v^2$$

$$\sqrt{200} = v$$

$$v = 14.14\text{ms}^{-1}$$

- c. Since $E_K = \frac{1}{2}mv^2$ and Siobhan's mass does not change, if she has lower velocity (v), then she must have less kinetic energy than was assumed. This means some of the energy she had at the start of her dive must have been lost.

- d. The energy Siobhan lost will mostly have been lost to the air as heat energy, and some will also be lost as sound energy. This happens because of air resistance and friction, when Siobhan falls she disturbs air particles, causing them to move and creating sound/heat.

2. a. Before the apple fell, it had gravitational potential energy.

This is given by the formula $\Delta E_p = mg\Delta h$.

- b. $\Delta E_p = mg\Delta h$.

$$\Delta E_p = 0.2 \times 10 \times 5$$

$$= 10\text{J}$$

- c. Difference in energy = $10\text{J} - 9\text{J} = 1\text{J}$.

The apple lost 1J of energy during its fall.

- d. The apple's heat was lost as heat and sound energy as a result of air resistance and friction. As it fell, the apple rubbed past air particles, which caused them to move and generated heat and sound energy. Because energy is conserved, when the air particles gained energy the apple lost energy.

3. a. Before the UFO falls, it has gravitational potential energy.

This is given by the formula $\Delta E_p = mg\Delta h$.

b. $\Delta E_p = mg\Delta h$

$$\begin{aligned}\Delta E_p &= 432 \times 10 \times 150 \\ &= 648,000 \text{ J}\end{aligned}$$

c. At the end of its fall, the UFO has kinetic energy, as it is moving (right before it hits the ground). This is given by the formula $E_k = \frac{1}{2}mv^2$.

d. As we assume energy is conserved, $E_k = E_p = 648000$

$$648\,000 = \frac{1}{2}mv^2$$

$$648\,000 = \frac{1}{2} \times 432 \times v^2$$

$$2 \times 648\,000 = 432 \times v^2$$

$$1296000 = 432 \times v^2$$

$$\frac{1296000}{432} = 432 \times v^2$$

$$3000 = 432 \times v^2$$

$$\sqrt{3000} = v$$

$$v = 54.77\text{ms}^{-1}$$

4. Work and Power

1. a. Work is given by $W = Fd$. In this question, we have been given the distance $d = 42\text{m}$. However, we are not given the force needed to accelerate the cheetah, so we need to calculate this before calculating work. We can do this using the relationship between force and acceleration.

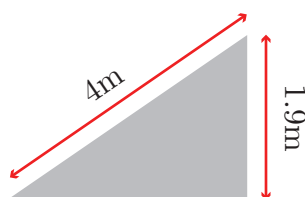
b. $F_{\text{net}} = ma$

$$\begin{aligned}F_{\text{net}} &= 47 \times 9 \\ &= 423\text{N}\end{aligned}$$

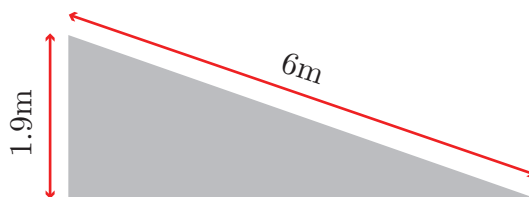
c. $W = 423 \times 42$
 $= 17,766 \text{ J}$

2. a. $W = Fd$

b. In this scenario, Mattias is doing work against the force due to gravity, which is a vertical force. Therefore, we only care about the height of the ramps, not their length - so the distance is 1.9m for both ramps.



Ramp A



Ramp B

c. The distance (d) in the formula is the same for both ramps. The force (F) is also the same for both ramps. This is because the force Mattias needs to counteract to get to the top of the ramp is the weight force of him and his bike. The weight force is the same regardless of the ramp. Therefore, it takes the same amount of work to get to the top of both ramps.

d. $P = \frac{W}{t}$

e. As we have already found, the work done is the same for both ramps. However, time is greater for ramp B (as stated in the question).

f. As t is greater for ramp B, power will be less, since $P = \frac{W}{t}$. W is constant between the ramps, so power is inversely proportional to t - as time increases, power decreases. Therefore, Mattias will have to exert more power to get to the top of ramp A, compared to ramp B.

3. a. Work is given by $W = Fd$.

Power is given by $P = \frac{W}{t}$

b. The force required to climb the ramp is equal to the weight force of Mattias and his bike.

Since $F_w = mg$, if mass is decreased by using a lighter bike, the force needed will also decrease.

c. When Mattias climbs the ramp, he is doing work against gravity.

As $W = Fd$, work is proportional to force. The distance remains the same, but the force is decreased when using the new bike. Therefore, it will take less work to climb ramp A when he uses the lighter bike.

d. Power is calculated using $P = \frac{W}{t}$. As stated in the question, it takes Mattias the same time to climb the ramp with the new bike, so t is constant. However, less work is done when climbing the ramp with the new bike. If W decreases, P also decreases, so less power will be exerted when Mattias uses his new bike.

Practice Exam

1. Question One

1. a. i. Mass is a measure of the amount of matter that an object has. An object's mass will be the same no matter how strong gravity is; it is measured in kg. Weight is a measure of the downwards force that acts on an object due to gravity. The weight of an object can change if the strength of gravity changes. For example on the moon where there is less gravity, you weigh less. Weight is measured in Newtons, since it is a force.

ii. **How to work this out:**

The question gives us the following information:

Height of half-pipe one: $3\text{m} = \text{distance } 1 = d_1$

Height of half-pipe two: $5\text{m} = \text{distance } 2 = d_2$

We need to find the work done, W , for two situations:

Work done reaching top of half-pipe one.

Work done reaching top of half-pipe two.

Which equation can we use that has work, W , in it, and d , distance, in it?

Work can be calculated by using $W = Fd$. To use this equation to calculate work, we need put in a force. When Harriet moves up the half-pipe, she is moving against gravity. To move upwards at a constant speed, her upwards force must be equal to the force of gravity on her (which is her weight force) and which acts in the opposite direction. If her upwards force was not equal to that of gravity, she would be pulled back down the half-pipe. So the force, F , here must be equal to the weight force (F_w) of Harriet and her skateboard.

This is calculated: $F = mg$, so her weight is 620N . We substitute this in for F in the equation.

For the 3m halfpipe she travels 3m upwards, so the work done is $W = 620\text{N} \times 3\text{m} = 1860\text{J}$

For the 5m halfpipe she travels 5m upwards, so the work done is $W = 620\text{N} \times 5\text{m} = 3100\text{J}$.

The force required to lift harriet and her skateboard is the same for each half-pipe (this is the upwards force she must generate to be equal to gravity). However, the distance is greater for the 5m high one and so more work is required.

The kind of answer you need to write:

$$W = Fd.$$

$$F = mg$$

$$= 62 \times 10 = 620\text{N}$$

For the 3m halfpipe she travels 3m upwards, so the work done is $W = 620\text{N} \times 3\text{m} = 1860\text{J}$

For the 5m halfpipe she travels 5m upwards, so the work done is $W = 620\text{N} \times 5\text{m} = 3100\text{J}$.

The force required to lift Harriet and her skateboard is the same for each half-pipe, the distance is greater for the 5m high one and so more work is required.

b. How to work this out:

Remember, we already have the following information:

Height of half-pipe two: $5\text{m} = \text{distance } 2 = d_2$

Work done reaching top of half-pipe two: $W = F \times d = 620\text{N} \times 5\text{m} = 3100\text{J}$

Mass of Harriet and skateboard = 62kg

Weight force on Harriet and skateboard = 620N

At the top of the ramp, Harriet has gravitational potential energy. When she drops in, this is converted to kinetic energy. When she reaches the bottom of the ramp, she will no longer have any gravitational potential energy; it all will have been converted to kinetic energy.

The formula for gravitational potential energy is $E_p = mg\Delta h$

The formula for kinetic energy is $E_k = \frac{1}{2}mv^2$

We could calculate her gravitational potential energy using $E_p = mg\Delta h$ because we have her mass, the value of gravity and her height. However, we know that the work done to get to the top is the amount of gravitational potential energy gained, because when work is done, an equivalent amount of energy is converted from one form to another. In this case, as Harriet did work moving up the ramp, her kinetic energy was converted into gravitational potential energy. Therefore:

$$E_p = 3100\text{J} = 62\text{kg} \times 10\text{Nkg}^{-1} \times 5\text{m}$$

Assuming that energy is conserved, her kinetic energy at the bottom of the ramp is equal to the gravitational potential energy that she has at the top so:

$$E_{P(\text{lost})} = E_{P(\text{gained})}$$

Which means her maximum kinetic energy is 3100J . We can use the equation for kinetic energy which depends on mass and velocity.

$$3100\text{J} = \frac{1}{2}mv^2 \text{ which we need to rearrange for velocity. This ends up being:}$$

$$\frac{2 \times 3100\text{J}}{62\text{kg}} = v^2$$

$$v = \sqrt{100}$$

$$v = 10\text{ms}^{-1}$$

The kind of answer you need to write:

At the top of the ramp, Harriet has gravitational potential energy. When she drops in, this is converted to kinetic energy. When she reaches the bottom of the ramp, she will no longer have any gravitational potential energy; it all will have been converted to kinetic energy.

$$E_p = mg\Delta h$$

$$E_k = \frac{1}{2}mv^2$$

$$E_p = 3100\text{J} = 62\text{kg} \times 10\text{kg}^{-1} \times 5\text{m}$$

Assuming that energy is conserved, her kinetic energy at the bottom of the ramp is equal to the gravitational potential energy that she has at the top so:

$$E_{p(\text{lost})} = E_{p(\text{gained})}$$

$$3100\text{J} = \frac{1}{2}mv^2$$

$$\sqrt{\frac{2 \times 3100\text{J}}{2}} = v$$

$$v = 10\text{ms}^{-1}$$

i. As Harriet moves down the ramp, the wheels of her skateboard encounter friction against the surface of the half-pipe and as air resistance. The friction is in the opposite direction to the direction she is moving in, so it acts to slow her down and causes some of her kinetic energy to be lost as heat (converted to heat energy). If Harriet does not exert a force to counteract the friction and supply more energy, there will be an unbalanced force and she will decelerate. This also means she has less kinetic energy, since $E_k = \frac{1}{2}mv^2$ reducing velocity but keeping mass the same means reducing the kinetic energy. So she has less kinetic energy as she moves up the other side of the ramp. When her kinetic energy is converted back into gravitational potential energy as she moves up the other side, she will have less E_p , since $E_{p(\text{lost})} = E_{p(\text{gained})}$. Since $E_p = mg\Delta h$, and her mass and the acceleration due to gravity haven't changed, so if E_p is reduced, the height she reaches must also be less.

c. Surface area = $A = 0.00125\text{m}^2$

$$\text{Pressure} = P = \frac{F}{A}$$

To calculate the pressure, we need to know the force. We are interested in the pressure that Harriet and the skateboard exert on the ground, so we are interested in the downwards force due to gravity, which is the weight force. We have calculated in a previous question that her weight force is 620N, so we can use that.

$$P = \frac{620}{0.00125}$$

$$P = 496,000 \text{ Nm}^{-1} \text{ (or Pa)}$$

- d. Pressure, $P = \frac{F}{A}$. The force Harriet and the skateboard exert on the ground is the weight force, 620N. This does not change, because Harriet's mass does not change, but the area of the wheels does change. When she uses wheels with less surface area, the pressure on the ground will be greater. This is because dividing the same force by a smaller number will end up with a larger number. But when she switches the wheels for ones with three times the area, she is dividing the same force by a bigger area which equals a smaller pressure. When she exerts a smaller pressure on the ground, the support force from the ground is able to counteract it better than when the pressure is greater, so she doesn't sink into the ground.

2. Question Two

- a. Harriet had a greater acceleration in the first 5 sections. We can tell this because for this section of the graph, the gradient of the line representing Harriet is steeper than that for Tama. The gradient of the line is equivalent to the acceleration because $a = \frac{v}{t}$ and the gradient = $\frac{\text{rise}}{\text{run}} = \frac{\text{speed}}{\text{time}}$ in this case, so a steeper line means more acceleration.
- b. Between 10 and 15s, Tama is travelling at a constant speed. We can tell this because his line is horizontal, flat, indicating that his speed is not changing but remaining constant. If Tama is travelling at a constant speed, the force acting on him must be balanced. Unbalanced forces cause an acceleration in the direction of the net force, since $F_{\text{net}} = ma$. Tama is not accelerating, so there are no unbalanced forces.
- c. For a speed-time graph, the distance travelled in a section is equal to the area under the graph for that section. Here, we are interested in how far they travelled for the whole time, so we need to find the area of each section and add these together to get a total, for each person. Then we can compare. Remember, the area of a triangle is $\frac{1}{2}bh$ and the area of a rectangle or square is $b \times h$.

$$\text{Tama: } (\frac{1}{2} \times 10 \times 12) + (5 \times 12) + (\frac{1}{2} \times 15 \times 12) = 60 + 60 + 90 = 210\text{m}$$

$$\text{Harriet: } (\frac{1}{2} \times 7.5 \times 10) + (12.5 \times 10) + (\frac{1}{2} \times 10 \times 10) = 37.5 + 125 + 50 = 212.5\text{m}$$

So, Harriet travelled the furthest and wins.

- d. As the height above the ground is the same, the same work is required to travel up the ramp as climbing straight up the ladder. If the same amount of work is done, the same amount of energy is gained. As $W = F \times d$, if d is increased, the amount of force required to do the same amount of work will be less. The actual distance Tama travels when walking up the ramp is greater, since the ramp takes him longer to walk up. Since the distance is greater, the force required by Tama is less for the same amount of work done. This means that the ramp allows the same amount of work to be done with a smaller force over a greater distance. When Tama climbs up the ladder, the distance is smaller, which means that if the work is equal, the force he exerts must be greater so he feels more tired.

When Tama climbs up the ladder or walks up the ramp, he is generating an upwards thrust force to overcome the downwards weight force due to gravity. When he climbs up the ladder, he has to generate a thrust force equal to the weight force. When he goes up the ramp, he only has to generate a thrust force equal to a component (part of) the gravity force, so he does not have to generate as much force, so he feels less tired.

3. Question Three

- a. Remember, acceleration due to gravity (g) is 10N on Earth. We will use $F_w = mg$. The weight is given to us (120N).

$$F_w = m \times g$$

$$120 = m \times g$$

$$120 = m \times 10$$

$$\frac{120}{10} = m$$

$$m = 12\text{kg}$$

- b. i. Remember, acceleration (a) is in the formula $a = \frac{\Delta v}{t}$. We have been given the time (t) as 6s .

The change in velocity (Δv) is the final velocity minus the initial velocity. The final velocity is 80.6ms^{-1} , initial is 0.00ms^{-1} . So the change in velocity is $80.6 - 0 = 80.6$.

$$a = \frac{\Delta v}{t}$$

$$a = \frac{80.6}{6}$$

$$a = 13.43\text{ms}^{-2}$$

- ii. Before the rocket begins its flight, it is stationary on the ground. Since it is not moving, there is no net force acting on it. This is because if there was a net force it would move in the direction of that net force. This means that the forces acting on the rocket must be balanced. The downwards weight force is balanced out by an equal and opposite upwards support force from the Earth.

During the first 6s of the rocket's flight, it accelerates. $F_{\text{net}} = ma$ which tells us that when there is a net or unbalanced forces acting on an object, the object will accelerate in the direction of the net force. In this case, the rocket accelerates, so it must have a net force acting on it, which means the forces must be unbalanced. If it is flying straight upwards, then there is a net force upwards and the thrust force must be greater than the weight force and the air resistance.

- c. i. For the answer, on the diagram:

For A: a downwards arrow which is longer than the upwards arrow

For B: the downwards arrow is the same length, but not the upwards arrow is also the same length

- ii. At point A, the speed of the rocket is increasing, which means it is accelerating. $F_{\text{net}} = ma$ which tells us that when there is a net or unbalanced forces acting on an object, the object will accelerate in the direction of the net force. In this case, the rocket accelerates, so it must have a net force acting on it, which means the forces must be unbalanced. Since it is falling, this means that at first it is falling faster and faster, so there is a net force downwards, and the downwards weight force must be greater than the upwards, opposing force of air resistance.

At point B, the speed of the rocket becomes constant, unchanging. At this point, there is no longer a net force. If there was a net force, it would cause the rocket to accelerate in the direction of that

force. Since there is no net force, this means that the forces acting on the rocket are balanced. This means that the weight force, which acts downwards, must be the same size as the air resistance force, which acts upwards.

- d. A short time after Point B, the line should plunge downwards quickly, to show that the rocket rapidly decelerates when the parachute is opened. After this, the line should even out and become flat again but closer to the x-axis, to show reaching a new, lower constant speed.
- d. i. The parachute increases the surface area. This in turn increases the air resistance, or drag force, against the rocket. Before the parachute was opened, at Point B, the rocket was at a constant speed which means that the forces (drag and weight force) were balanced and equal but opposite. Increasing the air resistance means that the forces are now unbalanced with the drag force being greater. This rocket therefore decelerates and slows down.