DYNAMICS

QUANTITIES FOR THE DYNAMICS UNIT

For this unit copy and complete the table.

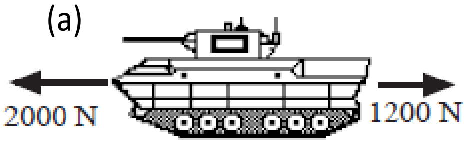
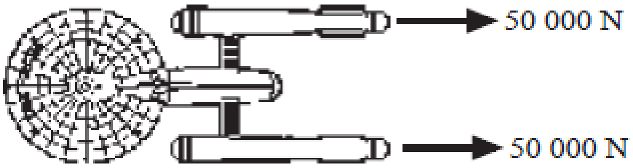
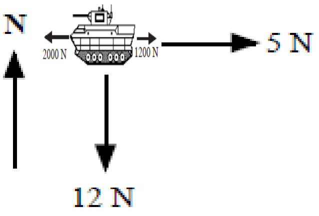
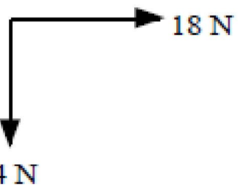
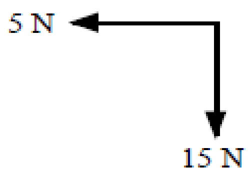
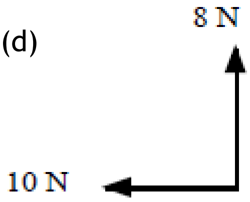
Quantity	Symbol	Unit	Unit Symbol	Scalar / Vector
Time	t	seconds	s	scalar
Speed	v	metres per second	ms^{-1}	scalar
Velocity	v	metres per second	ms^{-1}	vector
Acceleration	a	metres per second squared	ms^{-2}	vector
Distance	d	metre	m	scalar
Displacement	s	metre	m	vector
Force	F	Newton	N	vector
Weight	W	Newton	N	vector
Friction	F	Newton	N	vector
Gravitational Field Strength	g	Newtons per kilogram	Nkg^{-1}	vector
Energy	E	Joule	J	scalar
Work	E_w or W	Joule	J	scalar
Heat Energy	E_H	Joule	J	scalar
Gravitational Potential Energy	E_p	Joule	J	scalar
Kinetic Energy	E_k	Joule	J	scalar
Height	h	metre	m	scalar
Initial velocity	u	metres per second	ms^{-1}	vector
Final velocity	v	metres per second	ms^{-1}	vector
Average velocity	$\bar{v}$	metres per second	ms^{-1}	vector
Mass	m	kilogram	kg	scalar

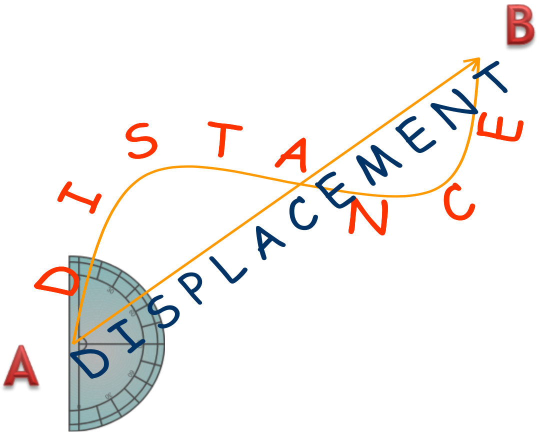
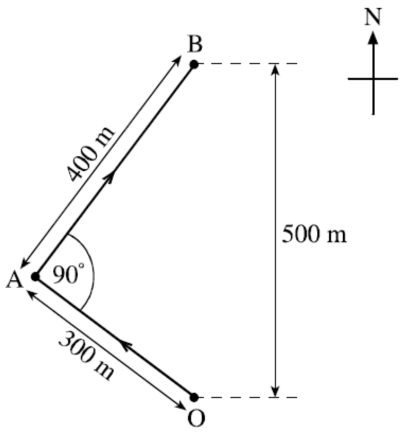
NB MAGNITUDE IS THE SIZE OF SOMETHING. THE MAGNITUDE OF A VECTOR QUANTITY IS THE SIZE, BUT NOT THE DIRECTION. KNOW THIS TERM, IT IS USED IN EXAMS.

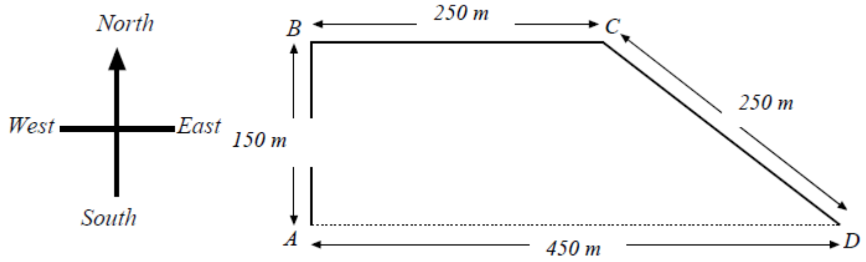
THE DYNAMICS UNIT IN NUMBERS

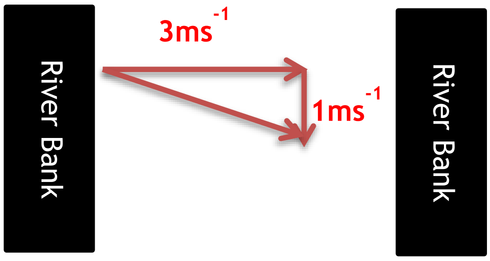
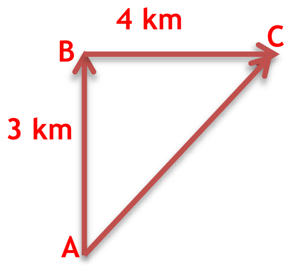
Quantity	Value
How many seconds in a minute?	**60 s**
How many seconds in an hour?	**3600 s**
What is the value of the gravitational field strength on Earth?	**9.8 Nkg^{-1}**
How many metres are there in a kilometre?	**1000 m**
How many metres are there in a mile?	**1609 m**
If 70 mph is equivalent to 31.29 ms^{-1} and 30 mph is equivalent to 13.41 ms^{-1}, what is the conversion factor to convert mph into ms^{-1}?	**÷2.2 or x0.45454545 etc**

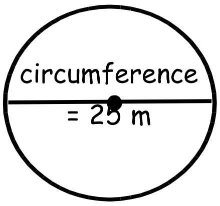
<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td colspan="2">Vectors and scalars</td></tr>
<tr><td>1.1</td><td>I can define scalar quantities and vector quantities.</td></tr>
<tr><td>1.1.1</td><td>A scalar quantity is fully described by a magnitude and unit</td></tr>
<tr><td>1.1.2</td><td>Define the term vector quantity. A vector quantity is fully described by a magnitude, unit and direction</td></tr>
<tr><td>1.1.3</td><td>Describe the difference between vector quantities and scalar quantities. A vector quantity requires a direction to fully describe it</td></tr>
<tr><td>1.2</td><td>I can identify vector and scalar quantities such as: force, speed, velocity, distance, displacement, acceleration, mass, time and energy.</td></tr>
<tr><td>1.2.1</td><td>Copy and complete the following table placing the quantities in the correct part of the table. <i>force, speed, velocity, distance, displacement, acceleration, mass, time and energy.</i>
<table>
<tr><th>Scalar</th><th>Vector</th></tr>
<tr><td>Speed</td><td>Force</td></tr>
<tr><td>Distance</td><td>Velocity</td></tr>
<tr><td>Mass</td><td>Displacement</td></tr>
<tr><td>Time</td><td>Acceleration</td></tr>
<tr><td>Energy</td><td></td></tr>
</table>
</td></tr>
<tr><td>1.3</td><td>I can calculate the resultant of two vector quantities in one dimension or at right angles.</td></tr>
</table>

No.	CONTENT
1.3.1	Define the term “resultant” in terms of two vector quantities. The resultant of a number of forces is the single force which has the same effect as the several forces actually acting on the object.
1.3.2	Explain how to calculate the resultant and direction of a pair of vectors at right angles. Scale Diagram- using the head to tail rule. Draw one vector to scale and on the head of the first vector draw the tail of the second. Join the direct route from tail to the final head. Find the length of this vector and scale up to get the resultant. Measrue the angle with a protractor from N or horizontal or vertical. Mark this on your diagram Pythagoras. Redraw the diagram to follow the head to tail rule. Use Pythagoras to find the hypotenuse, which will be the resultant and use tanθ to find the angle. Polar Coordinates (remember this method wont get you any intermediate marks so might be a better method of checking). Pol(x value, y value)= first answer is the resultant, second answer is the angle.
1.3.3	Determine the resultant of the following vectors (a)  (b)  (c)  (a) $F_1 + F_2 = F_R = 2000 + -1200 = 800N \textit{ to the left}$ (b) $F_1 + F_2 = F_R = 700 + -600 = 100N \textit{ downwards}$ (c) $F_1 + F_2 = F_R = 50\,000 + 50\,000 = 100\,000N \textit{ to the right}$
1.3.4	 (b)  (c)  (d)  Find the resultant of each of the pairs of vectors, remember to quote the direction.

No.	CONTENT
	By Pythagoras and $tan\ \theta = \frac{opp}{adj}$ or on your calculator use rectangular to polar buttons (on a Casio calculator type Pol(x,y)) a) $R^2 = a^2 + b^2 = 5^2 + 12^2 = 169$ R=13N @67° South of East b) $R^2 = a^2 + b^2 = 18^2 + 24^2 = 900$ R=30N @53° south of East c) $R^2 = a^2 + b^2 = 5^2 + 15^2 = 250$ R=16N @72° South of West d) $R^2 = a^2 + b^2 = 8^2 + 10^2 = 164$ R=13N @39°
1.4	**I can determine displacement and/or distance using scale diagram or calculation.**
1.4.1	Explain the term distance. **Distance is the total length of path travelled.** **Distance is a measure of how far an object has travelled**
1.4.2	Explain the term displacement. **Displacement is the length and direction travelled in a straight line from the starting point to the finishing point.** **OR** **The shortest distance between the start and the finish in a direction towards the finish.** **OR a measure of how far an object has travelled in a straight line from its starting point in the direction of the object from its start to finish point .** **OR by diagram** 
1.4.3	The diagram shows the course taken by a boat during a race. The boat starts the race at O and sails to a marker buoy at A. The boat then turns through 90° and sails to a marker buoy at B. (i) Calculate the total distance travelled by the boat in going from O to B. **The boat has travelled a total distance of 700 m** **(300 m + 400 m)** (ii) On reaching the marker buoy at B, determine the displacement of the boat from O. **The boat has a displacement of 500 m due North** 

No.	**CONTENT**
1.4.4	An orienteer starts at A, runs to B, then C and finishes at D.  (i) Calculate the total distance travelled by the orienteer. distance = 150 + 250 + 250 = 650 m (ii) State the final displacement of the orienteer from point A. The final displacement is 450 m due East
1.5	**I can determine velocity and/or speed using scale diagram or calculation.**
1.5.1	Define the terms a) distance b) displacement Distance is "how far we've travelled", *symbol d, units metres, m, scalar quantity* Displacement = "how far we've travelled in a straight line in a particular direction (from A to B)" *symbol s, units, metres, m, vector quantity, must include the direction.*
1.5.2	Define the terms… a) Speed is the distance travelled every second. b) Velocity is the displacement travelled every second in a certain direction
1.5.3	State the difference between speed and velocity. Speed is a scalar quantity and is the distance travelled every second. Velocity is a vector quantity and is the displacement travelled every second.
1.5.4	A cyclist travels 500 m in a straight line and then turns directly around and travels 300 m back. (a) State the magnitude of the displacement of the cyclist from the start. The cyclist travels 500m up and then 300m back, so $\text{displacement}\ = 500 + \ -300\ m = 200\ m\ \text{straight ahead.}$ (b) If the cyclists takes 4 minutes and twenty seconds to travel the complete distance, calculate the magnitude of the cyclist's. $t = 4\ mins\ 20s = 4 \times 60 + 20 = 260\ s$ (i) speed and $v = \frac{d}{t} = \frac{500 + 300}{260} = 3.1\ ms^{-1}$

No.	CONTENT
	(ii) velocity. $v = \frac{s}{t} = \frac{200}{260} = 0.77\ ms^{-1}$ **Magnitude so no need to give the direction but no marks off providing the direction is correct. (straight ahead)**
1.5.5	A sculler is rowing his boat at 3 ms^{-1} *through the water* straight across a river which is flowing at 1 ms^{-1}. (a) Draw a vector diagram of these two motions. (b) Calculate the boat's **velocity** relative to the bank.  **a)** **b)** $R^2 = a^2 + b^2 = 3^2 + 1^2 = 10$ **R=3ms^{-1} @72° to the riverbank**
1.5.6	On an orienteering course, a girl runs due north from point A to point B, a distance of 3 km. She then heads in an easterly direction for 4 km to point C. (a) Calculate the distance the girl ran from A to C. (b) Calculate the girl's displacement from point A when she reaches C.  **(a) The girl has run a distance of 7 km** **(b) When the girl reaches C she is 5 km from the start at an angle of 53° from North.** $\tan\theta = \frac{opp}{adj} = tan\ \theta = \frac{4}{3}\ \theta = 53^{o}$

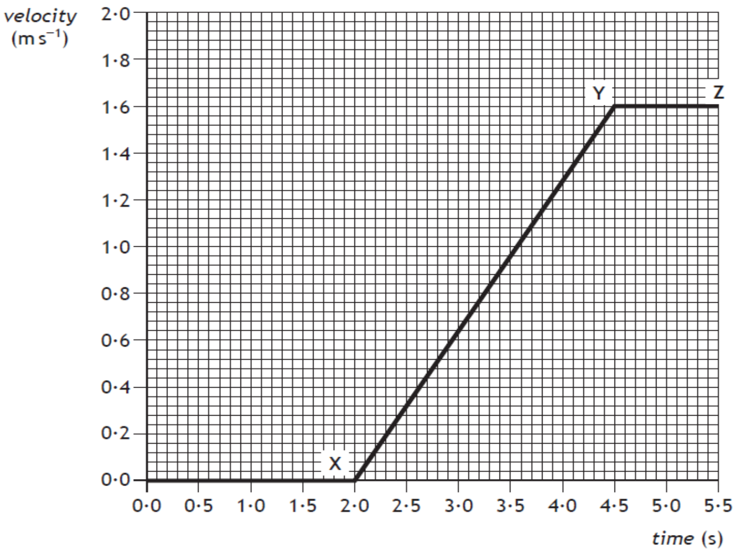
No.	CONTENT
1.5.7	The distance between the wickets on a cricket pitch is 20.12 m. On one pitch, the wicket has a north-south orientation. A batsman scores three runs off one ball.   (a) Calculate the distance he ran. **The cricketer has run a total distance of 3 x 20.12 m = 60.36 m** (b) Calculate his final displacement if the wicket at which he batted is at the south end. **His final displacement is 20.12 m South**
1.5.8	Ben jogs around the centre circle of a football pitch.  (i) Calculate the distance she travelled. **Ben has jogged the circumference of the circle = 25 m** (ii) State his displacement from the start. **Ben arrives back where he started so his displacement is 0 m from the start** Chris walks one and a half times around the circle in the same time (iii) Calculate the distance Chris travelled. **Chris has walked 1.5 circumferences = 25 × 1.5 = 38 m** (iv) State Chris' displacement from the start. **Chris' displacement is the diameter of the circle** **Circumference = πd** $d = \frac{25}{\pi} = 8.0m$
1.6	**I can perform calculations/ solve problems involving the relationship between speed, distance and time. ($d = vt$, and $d = \bar{v}t$)**
1.6.1	A car travels 100 miles in 2½hours. Calculate its speed in **mph**? $\bar{v} = \frac{d}{t}$ $\bar{v} = \frac{100\ miles}{2.5\ hours}$ $\bar{v} = 40\ miles\ per\ hour$

No.	CONTENT
1.6.2	A train travels 120 km in 45 minutes. (i) Calculate the speed of the train in kmh^{-1}? $(i)\ 45\ minutes = \frac{3}{4}\ hours = 0.75\ hours$ $\overline{v} = \frac{d}{t} = \frac{100\ km}{0.75\ h} = 160\ km/h$ (ii) Calculate the speed of the train in ms^{-1}? $(ii)\ 45\ minutes = 40\times60s = 2700s$ $100km = 100000m$ $\overline{v} = \frac{d}{t} = \frac{100000m}{2700s} = 37m/s$
1.6.3	A jet plane travels at an average speed of 300 ms^{-1}. (i) Calculate the distance the plane travels in an hour. $1\ hour = 60\times60s = 3600s$ $d = vt = 300\times3600 = 1080000m = 1080km$ (ii) Determine the time it would take to travel 500km from Edinburgh to London. $500km = 500000m$ $t = \frac{d}{v}$ $t = \frac{500000m}{300} = 1667s = 27.8\ minutes$
1.6.4	A runner completes a 200 m race in 25 s. Calculate the runner’s average speed. $\overline{v} = \frac{d}{t}$ $\overline{v} = \frac{200}{25}$ $\overline{v} = 8\ ms^{-1}$
1.6.5	An athlete takes 4 minutes 20 s to complete a 1500 m race. Calculate the average speed of the athlete in ms^{-1}. $t = 4\ min\ 20s = 4x60+20 = 260\ s$ $\overline{v} = \frac{d}{t}$ $\overline{v} = \frac{1500}{260}$ $\overline{v} = 5.8\ ms^{-1}$

No.	CONTENT
1.6.6	Bloodhound SSC is due to travel at 500 mph (approximately 230 ms^{-1}). At this speed, calculate the distance Bloodhound could travels in 25 s. $\bar{v} = \frac{d}{t}$ $230 = \frac{d}{25}$ $d = 5750\ m \approx 5.8\ km$
1.6.7	A girl can walk at an average speed of 2 ms^{-1}. Calculate the distance she walks in 20 minutes. *t = 20 min = 20 x 60= 1200 s* $\bar{v} = \frac{d}{t}$ $2 = \frac{d}{1200}$ $d = 2400\ m$
1.6.8	Calculate the time it takes a cyclist to travel 40 km at an average speed of 5 ms^{-1}. d = 40 km = 40 000 m $\bar{v} = \frac{d}{t}$ $5 = \frac{40\ 000}{t}$ $t = 8000\ s$
1.6.9	Calculate the time (to the nearest minute) the Glasgow to London shuttle will take if it flies at an average speed of 220 ms^{-1} for the 750 km flight. v=220 ms^{-1} d= 750 km = 750 000 m $\bar{v} = \frac{d}{t}$ $220 = \frac{750000}{t}$ t= 3409s = 56 mins 49 s

No.	CONTENT
1.6.10	Calculate the time to the nearest minute, a car will take to travel 50 km if its average speed is 20 ms^{-1}? *d=50 000 m* *v= 20 ms^{-1}* $\bar{v} = \frac{d}{t}$ $20 = \frac{50\,000}{t}$ *t=2500 s = 2500/60 = 42 mins*
1.7	**I can perform calculations/ solve problems involving the relationship between velocity, displacement and time ($s = \bar{v}t$) in one dimension**
1.7.1	A person walks 25 metres west along a street before turning back and walking 15 metres east. The journey takes 50 seconds. Calculate the: a) total distance travelled by the person  total distance = 25 +15 = 40 m b) displacement of the person displacement = 25+-15 = 10 m to the West c) average speed of the person $\bar{v} = \frac{d}{t}$ $\bar{v} = \frac{40}{50} = 0.8\ ms^{-1}$ d) average velocity of the person. $\bar{v} = \frac{s}{t}$ $\bar{v} = \frac{10}{50} = 0.2\ ms^{-1}\ West$

<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td>1.7.2</td><td>An Olympic runner runs one complete lap around an athletics track in a race.
The total length of the track is 400 metres and it takes 45 seconds for the runner to complete the race. Calculate the:
a) displacement of the runner at the end of the race.
Displacement = 0 m as the journey ends at the start
b) average speed of the runner during the race.
$\bar{v} = \frac{d}{t}$
$\bar{v} = \frac{400}{45} = 8.9\ ms^{-1}$
c) average velocity of the runner during the race.
$\bar{v} = \frac{d}{t}$
$\bar{v} = \frac{400}{45} = 8.9\ ms^{-1}$
Average velocity is 0 ms^{-1} as the displacement is zero</td></tr>
<tr><td>1.7.3</td><td>A car drives 15 kilometres East for 12 minutes then changes direction and drives 18 kilometres West for 18 minutes.
a) Calculate the total distance travelled by the car.
Total distance travelled = 15 + 18 = 23 km
b)Calculate the displacement of the car from the start of the journey.
Total displacement = 15 km + -18km = 3km west
c) Calculate the average velocity of the car, in metres per second.
Average velocity =
$\bar{v} = \frac{s}{t}$
t=18 x 60 = 1080s
$\bar{v} = \frac{3000}{1080}$
$\bar{v} = 2.8\ ms^{-1}$</td></tr>
</table>

No.	CONTENT
1.7.4	On a journey, a lorry is driven 120 kilometres west, 20 kilometres north then 30 kilometres east. This journey takes 2 hours to complete. a) Calculate the average displacement of the lorry, in km. b) Calculate the average velocity of the lorry, in km/h.  $R^2 = a^2 + b^2 = (120 - 30)^2 + 20^2 = 92\ km\ @\ 13^\circ$ $\bar{v} = \frac{s}{t}$ $\bar{v} = \frac{92}{2} = 46\ kmh^{-1} @ 13^\circ$
1.8	**I can determine average and instantaneous speed.**
1.8.1	Explain the term average speed. **The average speed of an object is defined as the total distance for the journey divided by the time for the journey, or the rate of covering a distance.**
1.8.2	Explain the term *instantaneous speed* **Instantaneous speed is the speed of an object at a particular instant of time.**
1.8.3	 State the instantaneous speed of the vehicle at **Reading from the graph** a) 0.5 s b) 3.0 s c) 4.0 s **$0\ ms^{-1}$** **$0{\cdot}6\ ms^{-1}$** **$1{\cdot}3\ ms^{-1}$**

No.	CONTENT
1.8.4	A runner takes 35 seconds to run round 250 metres of a track, calculate her erage speed. $\boldsymbol{v = \frac{d}{t}}$ $\boldsymbol{v = \frac{250}{35}}$ $\underline{\boldsymbol{v = 7.1\ ms^{-1}}}$
1.8.5	Calculate the average speed of a motor boat which takes 350 seconds to cover a 10 000 m course $\boldsymbol{v = \frac{d}{t}}$ $\boldsymbol{v = \frac{10\ 000}{350}}$ $\underline{\boldsymbol{v = 29\ ms^{-1}}}$
1.8.6	Calculate the distance a car travels in 300 seconds when it is travelling at a top speed of 30 ms^{-1}. $\boldsymbol{v = \frac{d}{t}}$ $\boldsymbol{30 = \frac{d}{300}}$ $\boldsymbol{d = 30 \times 300 = 9000\ m = 9.0\ km}$
1.8.7	Calculate the time it takes to walk to school if you walk at an average speed of 3ms^{-1} and you live 900 metres away? $\boldsymbol{v = \frac{d}{t}}$ $\boldsymbol{3 = \frac{900}{t}}$ $\boldsymbol{t = \frac{900}{3} = 300\ s}$
1.8.8	A train travels at 35 ms^{-1} and takes 15 seconds to pass through a tunnel, calculate the length of the tunnel. **This question is asking you to find the distance.** $\boldsymbol{v = \frac{d}{t}}$ $\boldsymbol{35 = \frac{d}{15}}$ $\boldsymbol{d = 35 \times 15 = 525\ m}$

No.	**CONTENT**
1.8.9	 Calculate the average speed of Sammy Snail who slithers 0·005 m in 4.0 s. $v=\frac{d}{t}$ $v=\frac{0.005}{4.0}$ *To 1 sig fig* $\underline{v=0.001\,ms^{-1}}$
1.8.10	Calculate the time a train takes to travel 60 km given that it goes at an average speed of 30 ms^{-1} d=60 km = 60 ×10^3 m $v=\frac{d}{t}$ $30=\frac{60\times10^{3}}{t}$ $t=\frac{60\times10^{3}}{30}=2000\,s$
1.8.11	A school bus takes 20.0 minutes to travel 15 km, calculate its average speed in ms^{-1}. ***d=15 km* == 15 ×10^3 m** ***t=20 mins = 20×60=1200 s*** $v=\frac{d}{t}$ $v=\frac{15\times10^{3}}{1200}$ To 2 sig fig $\underline{v=13\,ms^{-1}}$
1.8.12	A bird maintains an average speed of 11·2 ms^{-1} for 5 minutes. Calculate the distance it travels. ***t=20 mins = 5×60=300 s*** $v=\frac{d}{t}$ $11.2=\frac{d}{300}$ $d=11.2\times300=3000\,m=3\,km\,(to\,1\,sig\,fig)$

No. **CONTENT**

1.8.13

Calculate the time taken for a roller blader to travel 2 km if her average speed is 7 ms^{-1}

$d=2\ km = 2\times10^3$ m

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

$$7=\frac{2\times10^3}{t}$$

$$t=\frac{2\times10^3}{7}=300\ s\ to\ 1\ sig\ fig$$

1.8.14

A runner decides to analyse her track performance in order to improve her overall running time during the 400 m event. She sets up light gates at six points round the track so that she can work out her instantaneous speed at each point.
As the runner cuts the beam of light from the light gate the timer operates.

$$instantaneous\ speed=\frac{width\ of\ runner}{time\ to\ pass\ the\ point}$$

The results she recorded are shown below.

Position	*width of runner* (m)	*time* (s)	*instantaneous speed* (m/s)
A	0.2	0.025	8.0
B	0.2	0.026	7.7
C	0.2	0.030	6.7
D	0.2	0.029	6.9
E	0.2	0.025	8.0
F	0.2	0.024	8.3

Use the results to calculate her instantaneous speed at each position and hence determine the point is she running:

(*a*) fastest position F (*b*)slowest. position C

1.8.15

Civil engineers need to know the speed of a train as it enters a tunnel which they are planning to build. They set up their equipment to measure the length of a section of the train and time how long that section takes to pass the planned point of entry to the tunnel.

The length of train is 23.0 m and the time to pass the point of entry is recorded as 1·23 s. Calculate the instantaneous speed of the train.

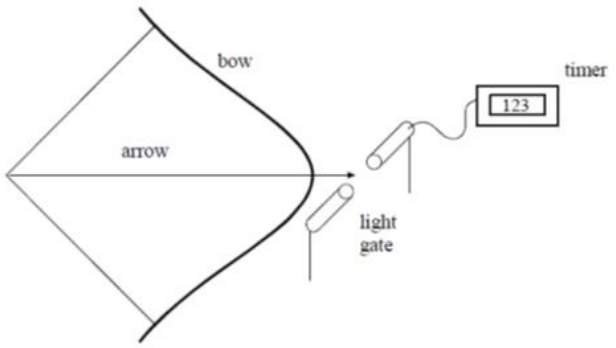
$$v=\frac{d}{t}$$

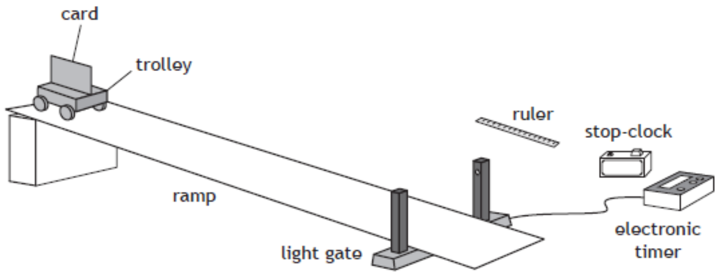
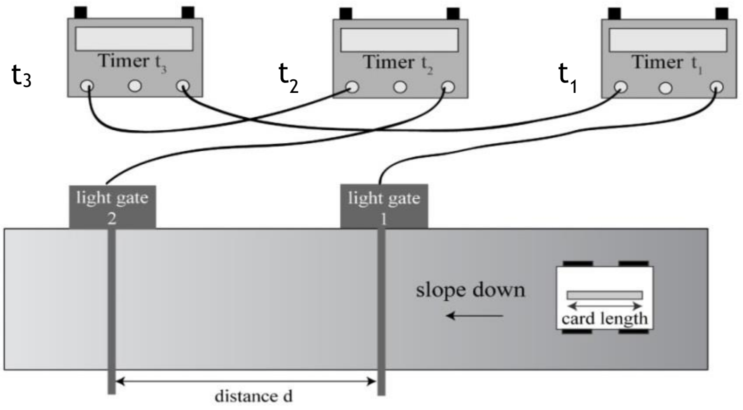
$$v=\frac{23.0}{1.23}$$

To 3 sig fig

$$\underline{v=18.7\ ms^{-1}}$$

No.	CONTENT
1.8.16	A coin is dropped from a height so that it passes through a light gate connected to a computer. The coin has a width of 0·02 m and it takes 0·005 seconds to pass through the light gate. Calculate the coin's instantaneous speed. $v = \frac{d}{t}$ $v = \frac{0.02}{0.005}$ *To 1 sig fig* $\underline{v = 4\ ms^{-1}}$
1.8.17	Two insulated wires are laid across the road 1.00 metres apart to test the instantaneous speed of cars as they travel between the wires. A Mondeo of wheelbase length 2.85 m takes 0.06 s to pass between the two wires. Calculate the instantaneous speed of the car. ***This question is asking for the instantaneous speed and it is the 1.00 m width that detects the wheels moving across it; it is independent of the length of the vehicle.*** $v = \frac{d}{t}$ $v = \frac{1.00}{0.06}$ $\underline{v = 17\ ms^{-1}}$
1.9	**I can describe experiments to measure average and instantaneous speed.**
1.9.1	Describe how you can measure the average speed of a runner. Include a list of the apparatus you would use, the measurements you would take, how you would carry these out, and the calculation needed to obtain a final value for the speed. *You may use a diagram to help you.* **To measure the average speed of the runner, you need to know the distance that they run, and the time this takes. The apparatus needed is therefore a stopwatch and a metre tape.** **You would measure the length of the track with the tape.** **You would then start the stopwatch when the gun was fired, and stop it when the runner crossed the finish line. You calculate the average speed by dividing the distance by the time.** $\bar{v} = \frac{d}{t}$

No.	CONTENT
1.9.2	(a) List various methods for measuring the instantaneous speed. (b) State of these methods is most accurate, *you must justify your answer* **(a) You can measure instantaneous speed by using light gates connected to an electronic timer. You measure how long it takes the object to move a small distance. You calculate the instantaneous speed by dividing the distance by the time (the time must be very small).** **(b) You can time how long it takes a vehicle to pass a point. Find the instantaneous speed by using the equation** $\boldsymbol{instantaneous\ speed = \frac{length\ of\ vehicle}{time\ to\ pass\ a\ point}}$ **Using an electronic timer is better as it removes any human error caused by reaction time.**
1.9.3	An arrow of length 0·8 m is shot from a bow.  A student designs an experiment to measure the instantaneous speed of the arrow, as it leaves the bow. The student places a light gate connected to a timer, as shown below. The student states that the speed of the arrow can be found from $speed\ of\ the\ arrow = \frac{length\ of\ arrown}{time\ on\ timer}$ (i) Explain why the method used by the student does not give the correct value for the speed of the arrow as it leaves the bow. **The length of the arrow is too great and during the time the arrow passes through the light gate the instantaneous speed can have changed. The time must be very short to measure instantaneous speed.** (ii) Suggest how the experiment could be modified to enable the speed of the arrow as it leaves the bow to be found. **Two light gates a few cm apart and measure the gap time. Or add a mask and raise the light gates so that only the mask blocks the light gates. This might have problems with the flight of the arrow.**

No.	CONTENT
1.9.4	 Copy and complete the diagram and state how the following can be determined: a) the instantaneous speed of the trolley at the bottom of the slope. **measure the length of the card with the ruler, time how long it takes the card to pass through the light gate at the bottom of the slope. To find instantaneous speed use the formula v= length of the card/time to pass through the light gate.** b) the average speed of the trolley down the ramp. **Use the ruler (not great) to measure the length of the slope. Time, with a stop clock how long it takes the trolley to roll down the slope use the formula average speed = length of slope/ time to travel down the slope** c) the acceleration of the trolley as it rolls down the ramp. **The instantaneous initial speed of the vehicle is 0. Measure the instantaneous speed at the bottom of the slope as explained in part a) Time how long the vehicle take to roll down the slope. Find the acceleration using** $$a = \frac{v-u}{t} = \frac{v-0}{t}$$
1.9.5	 From the diagram above, state what measurements are required to find: a) the average speed of the vehicle as it passes down the slope? **Average speed = distance d / time on timer 3** b) the instantaneous speed at the bottom of the slope? **Instantaneous speed = length of card / time on timer 2** State what pieces of equipment give the measurements to find:

No.	CONTENT
	c) the average speed of the vehicle as it passes down the slope? distance d and time on timer 3 d) the instantaneous speed at the bottom of the slope? length of card / time on timer 2 e) What additional equipment is required to complete these measurements? **Rule to measure the card length.**

Velocity- time graphs

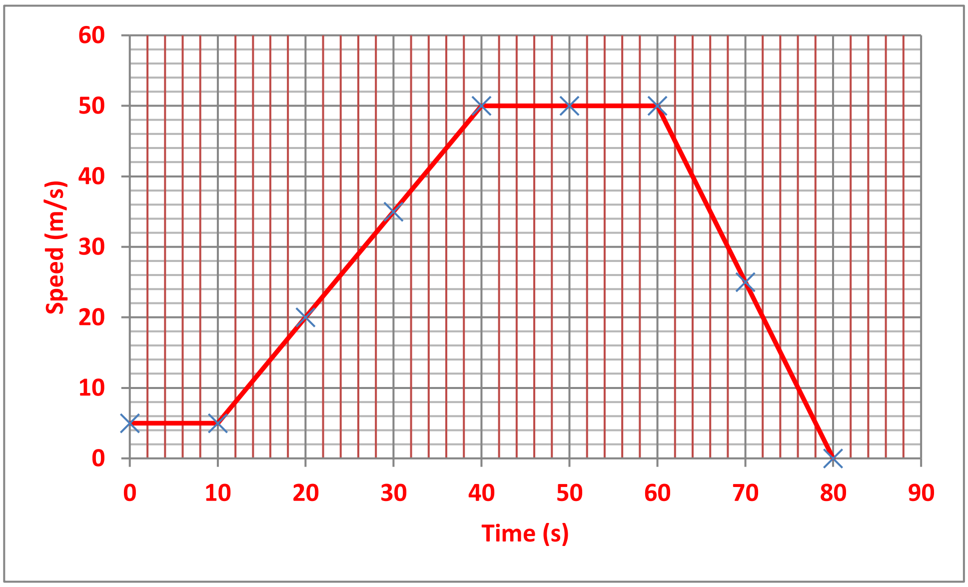
2.1 **I can draw velocity-time graphs for objects from recorded or experimental data.**

2.1.1

(a) On graph paper, draw a velocity-time graph of the race car's journey.
(b) Using the graph, describe the motion of the race car over the 80 seconds.

Time (s)	0	10	20	30	40	50	60	70	80
Speed (m/s)	5	5	20	35	50	50	50	25	0

(c) Using the graph you have drawn, calculate
- (i) The acceleration between 10 and 40 s.
- (ii) The total distance travelled by the race car.
- (iii) The average speed during the 80 seconds.

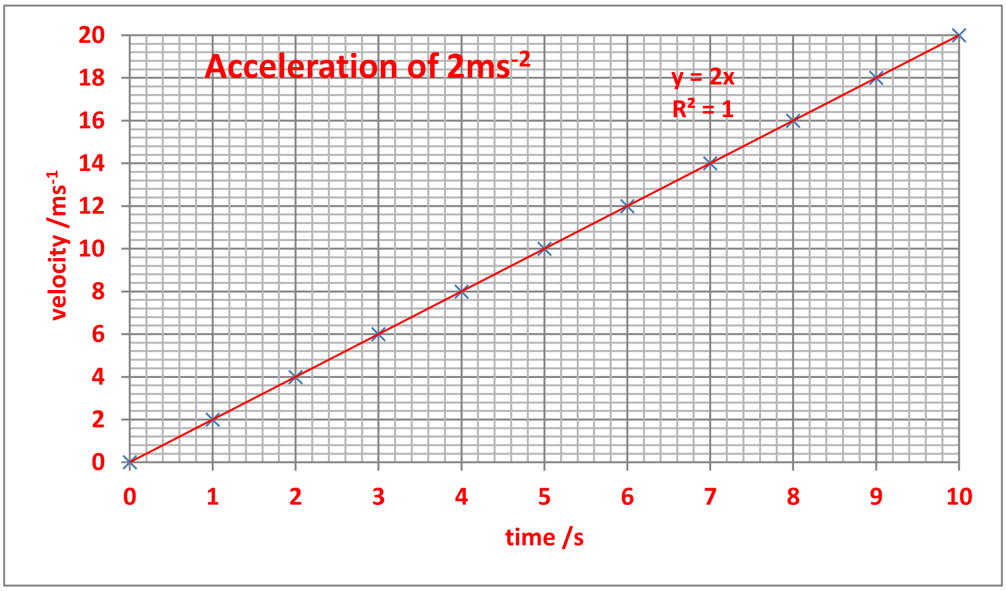


b. The car takes 10 s to start moving. It accelerates from 10 s to 40s and then from 40 s to 60 s moves at constant velocity. From 60 s to 80s the car has a constant uniform deceleration or negative acceleration until it reaches rest.

c.

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

$$a = \frac{50 - 5}{30} = 1.5\ ms^{-2}$$

No.	CONTENT
	d. Total distance = area under a v-t graph Area 1 + area 2 + area 3+ area 4 (40 x 5)+ (½ x 30 x 45)+(20 x 50)+ (½ x 20 x 50) = 2375 m e. $\bar{v} = \frac{d}{t}$ $\bar{v} = \frac{2375}{80} = 30\ ms^{-1}$
2.1.2	Draw a labelled speed-time graph showing an object (a) accelerating at 2 ms^{-2}, (b) travelling at a steady velocity of 6 ms^{-1}, (c) accelerating at -5ms^{-2}. a)  b)

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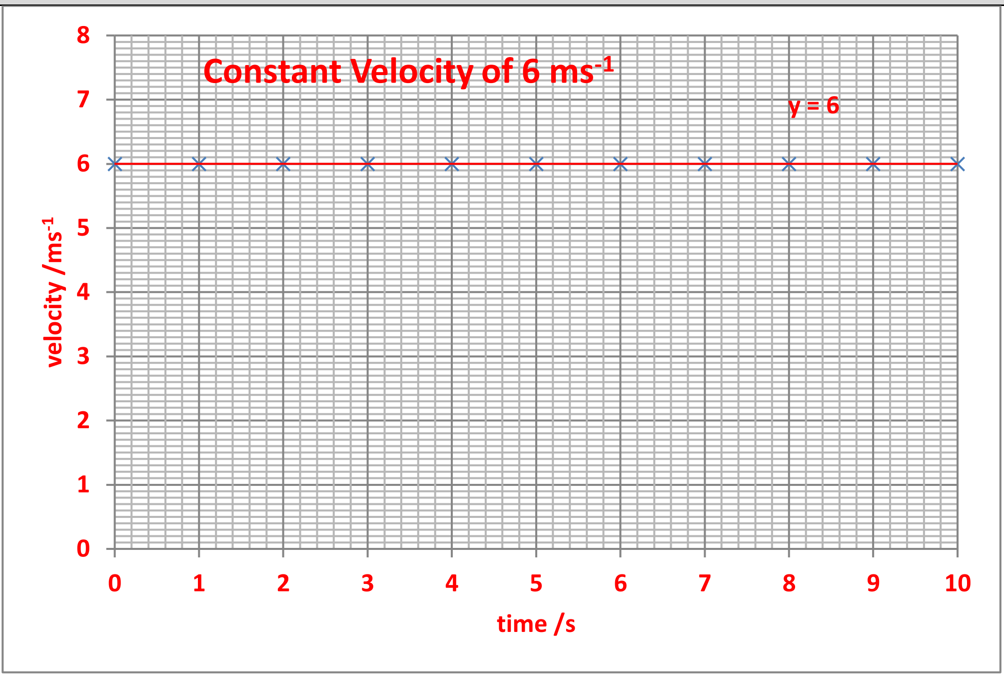
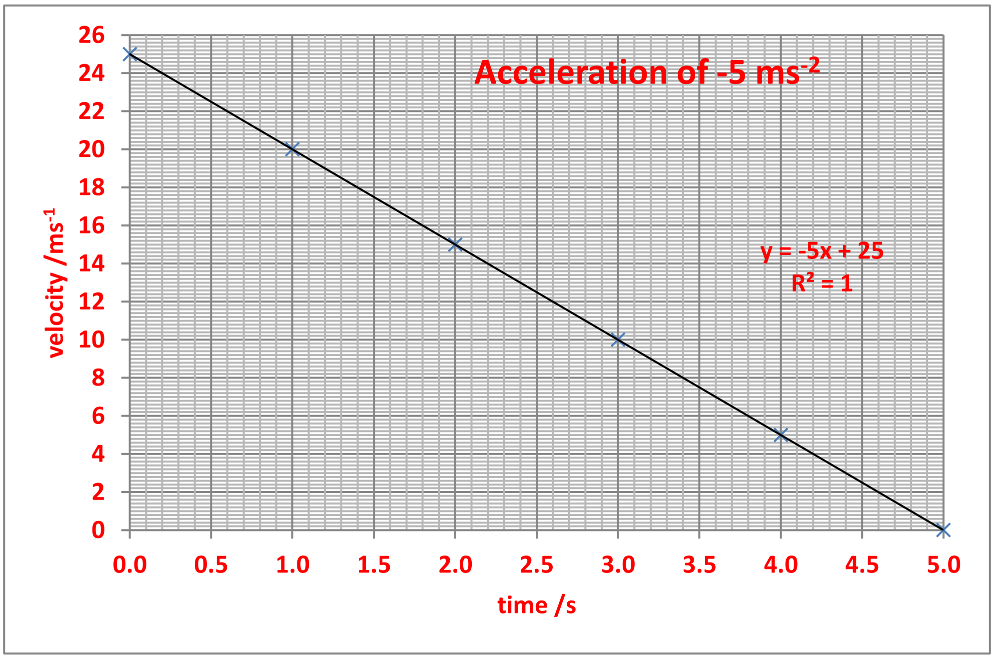
<tr><td></td><td>

c)


</td></tr>
<tr><td>2.1.4</td><td>During a test run, a car starts from rest on a straight, flat track. For the first 2 s it has a constant acceleration. It then maintains a constant velocity for a further 3 s. Sketch a velocity-time graph to show how the velocity of the car varies during the test run. Numerical values are only required on the time axis.</td></tr>
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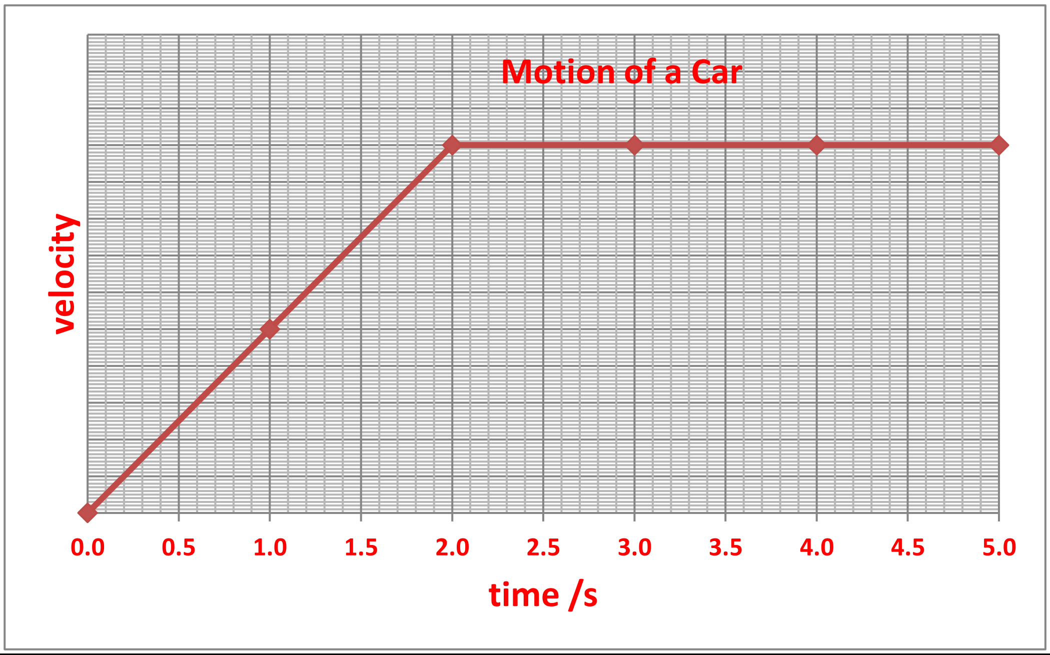
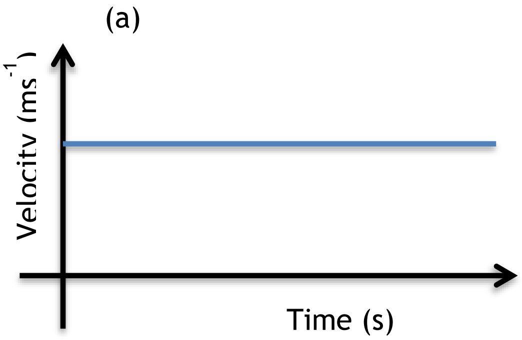
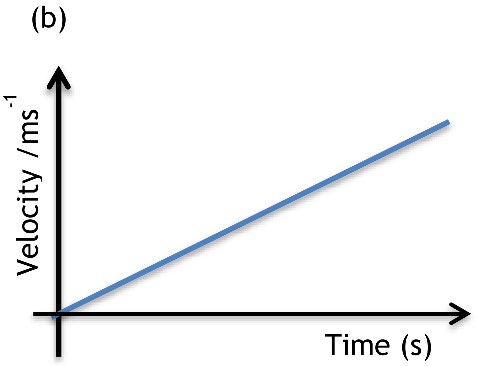
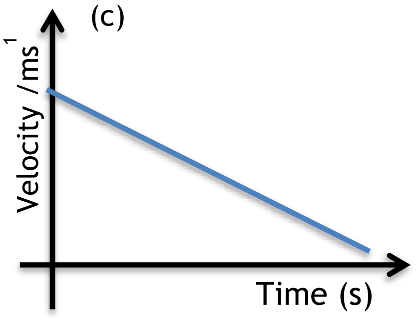


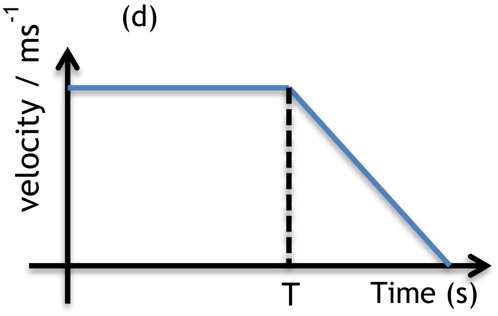
</td></tr>
<tr><td>2.2</td><td>I can interpret velocity-time graphs to describe the motion of an object.</td></tr>
<tr><td>2.2.1</td><td>

Fully describe the motion of the vehicles.









a) A vehicle travels at constant velocity.
b) a vehicle has a constant acceleration starting from 0 ms^{-1}.
c) A vehicle has a constant deceleration (or negative acceleration).
d) the vehicle has a constant velocity until time T when it uniformly accelerates to rest.

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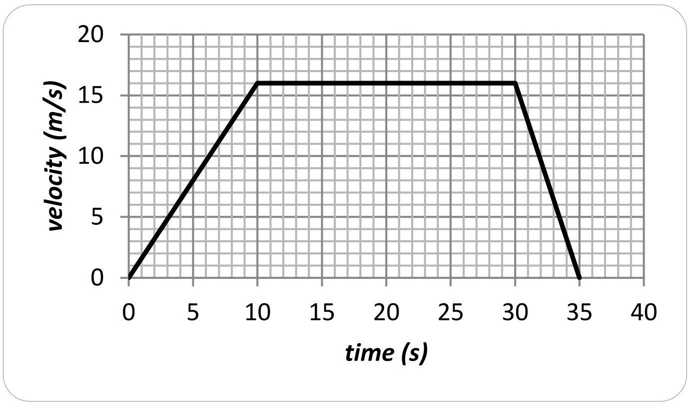
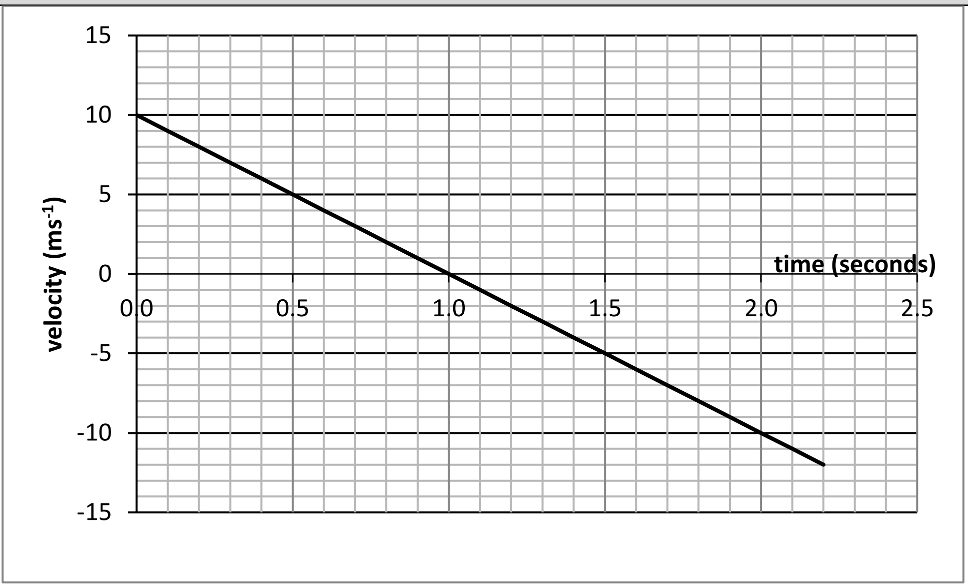
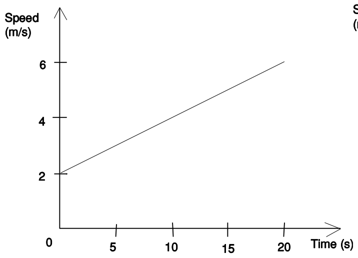
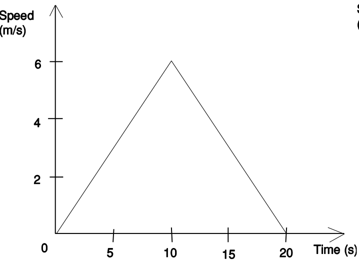
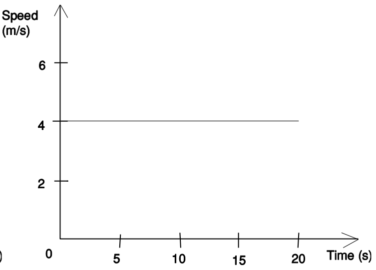
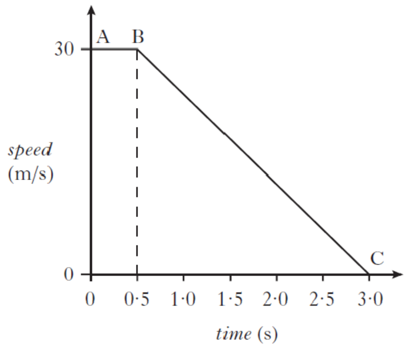
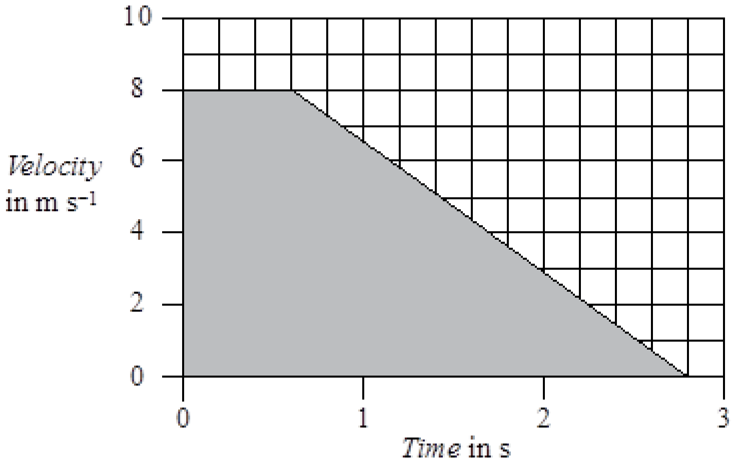
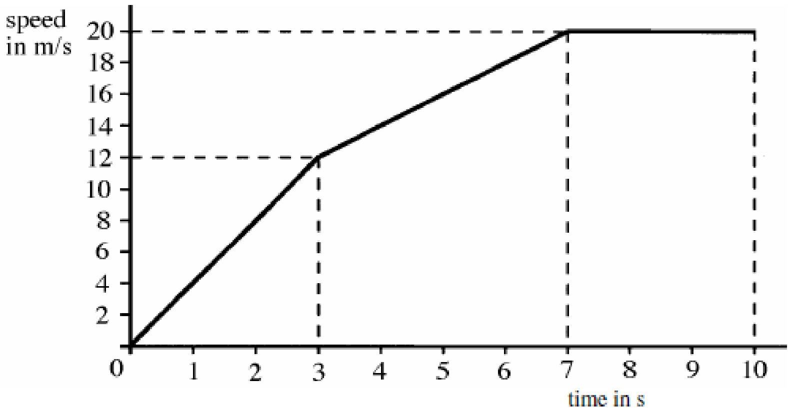
No.	CONTENT
2.2.2	 (a) Describe the motion of the car during the 35 seconds (b) Calculate the acceleration between 0 and 10 seconds (c) Calculate the acceleration between 30 and 35 seconds (d) Calculate the final displacement of the car from the starting position (e) Calculate the average velocity during the 35 seconds. **a) The car has a constant uniform acceleration of 1.6 ms^{-2} between 0 and 10s. the car then travels at constant velocity of 16 ms^{-1} for 20s and finally decelerates at -3.2 ms^{-2} for 5s (always give the values of a and v if this is possible!)** **b) as above (gradient of the graph) u=0 ms^{-1}, v=16 ms^{-1}, t=10s so a=1.6 ms^{-2}** **c) as above (gradient of the graph) v=0 ms^{-1}, u=16 ms^{-1}, t=10s so a=1.6 ms^{-2}** **d) Displacement = area under the v-t graph** **½ bh+bh+ ½ bh** **(½ × 10 × 16) + (20 × 16) + (½ × 5 × 16)** **s=1320 m** **e)** $$\bar{v} = \frac{s}{t}$$ $$\bar{v} = \frac{1320}{35} = 38\, ms^{-1}$$
2.1.3	The velocity-time graph shown below describes the motion of a ball which has been thrown straight up into the air then allowed to fall to the ground. From the graph below (i) Determine the time the ball reaches its maximum height. (ii) Calculate the maximum height that the ball reaches. (iii) Calculate the height from maximum to the ground. (iv) Use your answers to ii. and iii. to calculate the height above the ground that the ball was thrown from.

No.	CONTENT
	 (i) The ball reaches its maximum height at 1.0 s, when the velocity reaches zero ms^{-1} (ii) The maximum height reached is the area under the first part of the velocity time graph = ½ bh = ½ x 1 x 10 = 5 m (iii) The maximum height to the ground is the area under the lower part of the velocity time graph = ½ bh = ½ x 1.2 x 12 = 7.2 m The ball was thrown from a height of 7.2-5=2.2 m
2.2.4	(i) For each of the graphs shown below, find (a) the instantaneous speed at 10s (b) the distance travelled over the 20 second period (c) the average speed over the 20 second journey.    (*NB time axis scale has each major unit = 5s, velocity axis major unit is 2 ms^{-1}*) (ii) Compare the average speed with the instantaneous speed at ten seconds and comment on the difference (if any). (iii) In what situation will the instantaneous speed always be the same as the average speed?

No.	CONTENT
	distance = area under graph = area of Δ + area of □ = (½×4×20) + (2×20) = 80m $\bar{v} = \frac{d}{t} = \frac{80m}{20s} = 4m/s$ from the graph, speed at 10s = 4m/s so the average speed does equal the instantaneous speed at 10 seconds. distance = area under graph = area of Δ + area of Δ = (½×6×10) + (½×6×10) = 60m $\bar{v} = \frac{d}{t} = \frac{60m}{20s} = 3m/s$ from the graph, speed at 10s = 6m/s so the average speed does not equal the instantaneous speed at 10 s. distance = area under graph = area of □ = 4×20 = 80m $\bar{v} = \frac{d}{t} = \frac{80m}{20s} = 4m/s$ from the graph, speed at 10s = 4m/s so the average speed does equal the instantaneous speed at 10 s.
2.2.5	 A car travels along a motorway. A graph of the car's motion is shown. Describe the motion of the car: (a) Between A and B (a) Between B and C. **a) the car travels at a constant speed of 30 ms^{-1} for the first 0.5 s** **b) the car travels at constant acceleration of -10 ms^{-2} between B and C until reaching a speed of 0 ms^{-1}**

No.	CONTENT
2.2.6	 a) State what quantity is found by calculating the area under the velocity time graph b) Determine the area under this graph. **Displacement is found by calculating the area under the v-t graph. In this case the value is (0.6 x 8)+(½ x 2.2 x 8) = 13.6 m**
2.2.7	The graph below shows how the speed of a skier varies with time during the first 10 seconds of a downhill run.  **a)** (a) Calculate the acceleration of the skier during the first 3 seconds of the run. 2 $a = \frac{v-u}{t}$ $a = \frac{12-0}{3} = 4\ ms^{-2}$ **b)** (b) Suggest a possible reason for the change in the skier's acceleration after the first 3 seconds. **The change in acceleration could be due to the slope getting LESS steep, or the surface having an increase in friction.** **c)** (c) Describe the motion of the skier between 7 seconds and 10 seconds. **Between 7s and 10 s the skier travels at constant speed.** (d) Show that the average speed of the skier during the first 7 seconds of the run is 11·7 ms^{-1}.

No. **CONTENT**

d) distance travelled during the first 7s is found by the area under a v-t graph
area 1 + area 2+ area 3
½ bh + bh+ ½ bh
(½ ×3 × 12) + (4 × 12) + (½ × 4 × 8) = 82m
time = 7 s

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

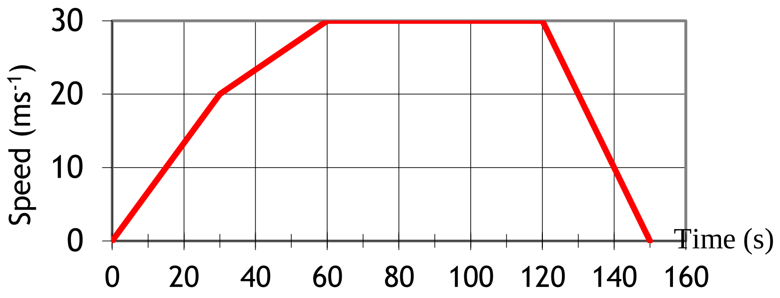
$$\bar{v} = \frac{82}{7} = 11.7\,ms^{-1}$$

2.3 **I can find displacement from a velocity-time graph.**

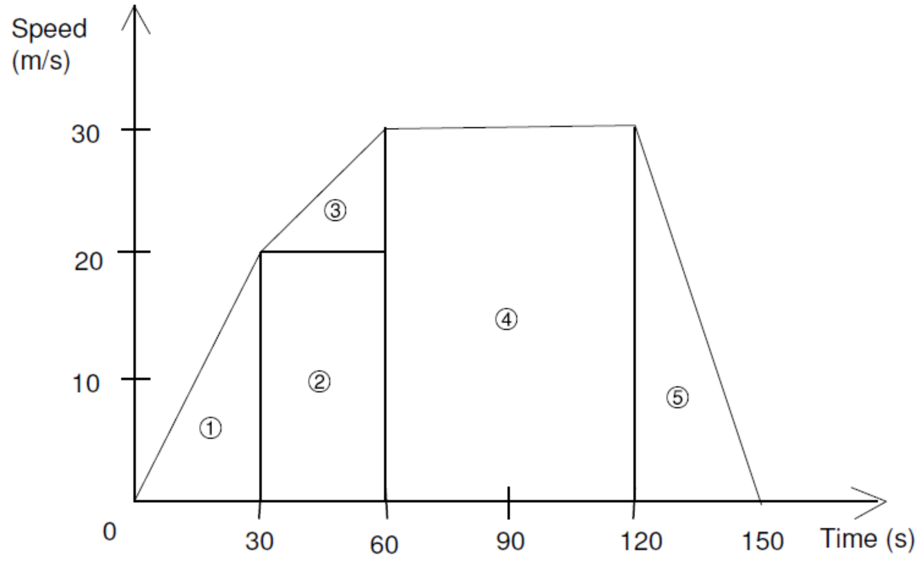
2.3.1 State how you calculate the displacement from a velocity-time graph.

Displacement is calculated from the area under a velocity time graph.

2.3.2



Calculate the distance the train travels in the 150 seconds shown in the graph above.

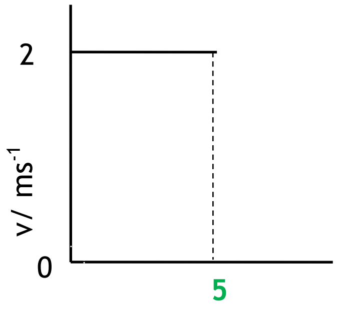


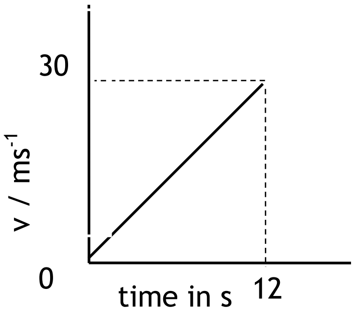
Distance travelled = area under graph
= area of Δ① + area of □② + area of Δ③ + area of □④ + area of Δ⑤
= (½×30×20) + (30×20) + (½×30×10) + (60×30) + (½×30×30)
= 300 + 600 + 150 + 1800 + 450
= 3300 m

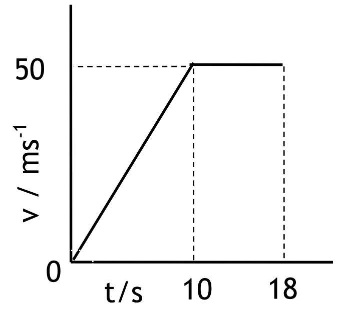
No. **CONTENT**

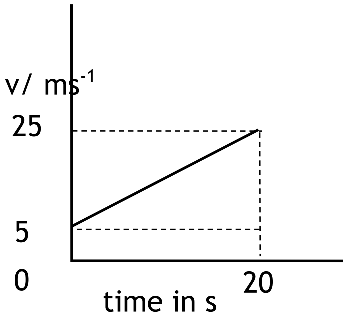
2.3.3

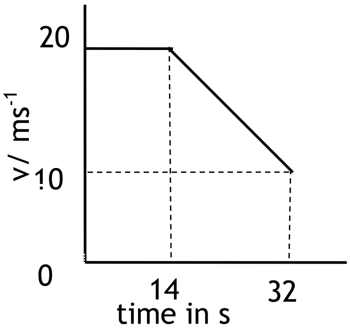
Use the velocity time graphs below to calculate the displacement travelled during each journey.

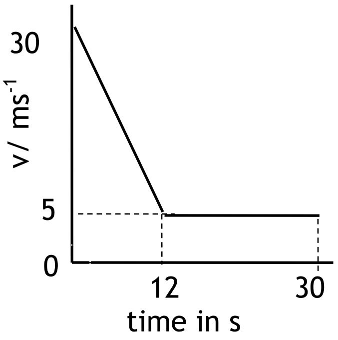












a $s = area\ under\ graph$ $s = bh$ $s = 2 \times 5$ $s = 10\ m$	b $s = area\ under\ graph$ $s = \frac{1}{2}bh$ $s = \frac{1}{2} \times 12 \times 30$ $s = 180\ m$	c $s = area\ under\ graph$ $s = \frac{1}{2}bh + bh$ $s = \frac{1}{2} \times 50 \times 10 + ((18 - 10) \times 50)$ $s = 650\ m$
d $s = area\ under\ graph$ $s = bh + \frac{1}{2}bh$ $s = (20 \times 5) +$ $\left(\frac{1}{2} \times (25 - 5) \times 20\right)$ $s = 300\ m$	$s = area\ under\ graph$ $s = bh + \frac{1}{2}bh + bh$ $s = (32 \times 10) +$ $\left(\frac{1}{2} \times (20 - 10) \times (32 - 14)\right)$ $+((20 - 10) \times 14)$ $s = 320 + 90 + 140$ $s = 550\ m$	d $s = area\ under\ graph$ $s = bh + \frac{1}{2}bh$ $s = (30 \times 5) +$ $\left(\frac{1}{2} \times (30 - 5) \times 12\right)$ $s = 150 + 150$ $s = 300\ m$

Acceleration

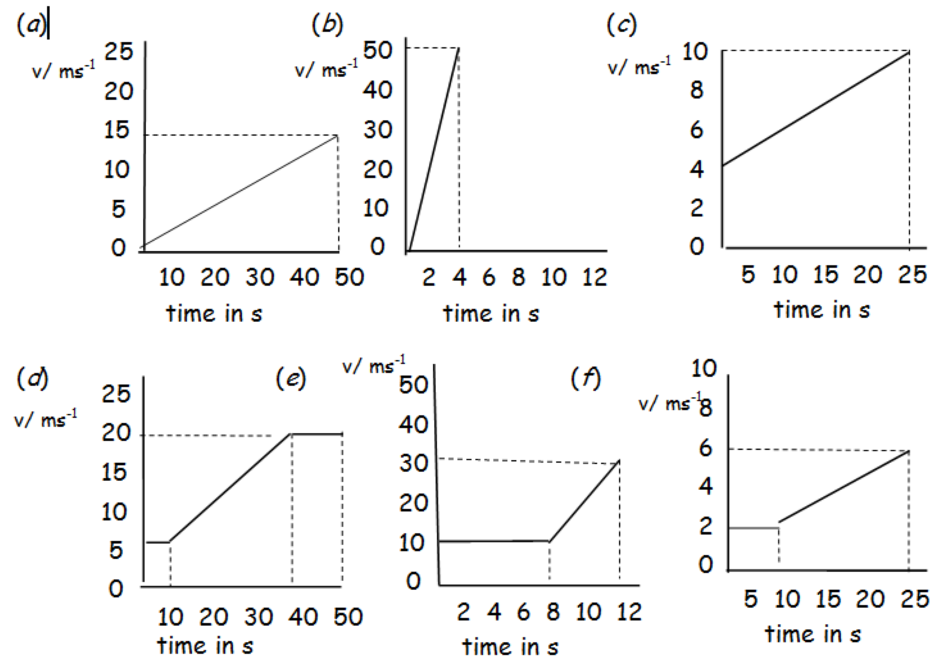
No.	CONTENT
3.1	**I can define acceleration as the final velocity subtract the initial velocity divided by the time for the change**
3.1.1	State the meaning of the term "acceleration". **Acceleration is the rate of change of velocity OR the change in velocity per second. It is measured in metres per second squared.**
3.1.2	Explain what is meant by a *uniform acceleration of 1.4 ms*$^{-2}$ ***A uniform acceleration of 1.4 ms***$^{-2}$ ***means that every second the velocity increases by 1.4 ms***$^{-2}$
3.2	**I can use the relationship involving acceleration, change in speed and time** **(a = Δv/t).**
3.2.1	A Jaguar can reach 27 ms^{-1} from rest in 9.0 s, calculate its acceleration. $a = \frac{v - u}{t}$ $a = \frac{27 - 0}{9} = 3\ ms^{-2}$
3.2.2	The space shuttle reached 1000 ms^{-1}, 45 s after launch, calculate its acceleration. $a = \frac{v - u}{t}$ $a = \frac{1000 - 0}{45} = 22\ ms^{-2}$
3.2.3	Starting from rest, a flea accelerates to 1·2 ms^{-1} in a time of 0·001 s. Calculate the acceleration of the flea. $a = \frac{v - u}{t}$ $a = \frac{1.2 - 0}{0.001} = 1200\ ms^{-2}$
3.2.4	A car reaches a velocity of 30 ms^{-1} from a velocity of 18 ms^{-1} in 6 s. Calculate its acceleration. $a = \frac{v - u}{t}$ $a = \frac{30 - 18}{6} = 2\ ms^{-2}$
3.2.5	A train moving at 10 ms^{-1} increases its speed to 45 ms^{-1} in 10 s. Calculate its acceleration. $a = \frac{v - u}{t}$ $a = \frac{45 - 10}{10} = 3.5\ ms^{-2}$

No.	CONTENT
3.2.6	A bullet travelling at 240 ms^{-1} hits a wall and stops in 0.2 s. Calculate its acceleration. $a = \frac{v-u}{t}$ $a = \frac{0-240}{0.2} = -1200\ ms^{-2}$
3.2.7	A car travelling at 20 ms^{-1} brakes and slows to a halt in 8 s. Calculate its acceleration. $a = \frac{v-u}{t}$ $a = \frac{0-20}{8} = -2.5\ ms^{-2}$
3.3	**I can use appropriate relationships to solve problems involving acceleration, initial velocity (or speed) final velocity (or speed) and time of change.**
3.3.1	State the formula linking velocity and acceleration. Explain what each letter stands for and the units of each. $a = \frac{\Delta v}{t}$ **a=acceleration in ms^{-2}, Δv = change in velocity in ms^{-1}, t = time for the change in seconds**
3.3.2	A girl is riding a bicycle. She starts at rest, and accelerates to 20 ms^{-1} in 8.0 seconds, calculate her acceleration. $a = \frac{\Delta v}{t}$ $a = \frac{20-0}{8} = 2.5\ ms^{-2}$
3.3.3	A car increases its velocity from 30 ms^{-1} to 80 ms^{-1} in 20 seconds. Calculate its acceleration. $a = \frac{v-u}{t}$ $a = \frac{80-30}{20} = 2.5\ ms^{-2}$

No.	CONTENT
3.3.4	When you drop a stone, it accelerates downwards at 9.8 ms^{-2}. If the stone is initially at rest, calculate its speed after falling for 1.5 seconds. $a = \frac{v-u}{t}$ $9.8 = \frac{v-0}{1.5}$ $v = 9.8 \times 1.5 = 15\ ms^{-1}\ to\ 2\ sig\ fig$
3.3.5	A racing car can accelerate at 7 ms^{-2}, calculate the time taken to increase its velocity from 20 ms^{-1} to 60 ms^{-1}. $a = \frac{v-u}{t}$ $7 = \frac{60-20}{t}$ $t = \frac{60-20}{7}$ $\underline{t = 5.7\ s}$
3.3.6	A rocket in orbit accelerates at 12 ms^{-2} for 15 seconds. If its final velocity is 300 ms^{-1}, calculate its initial velocity. $a = \frac{v-u}{t}$ $12 = \frac{300-u}{15}$ $300 - u = 12 \times 15$ $300 = 180 + u$ $u = 300 - 180$ $\underline{\underline{u = 120\ ms^{-1}}}$
3.3.7	On approaching the speed limit signs, a car slows from 30 ms^{-1} to 12 ms^{-1} in 5 s. Calculate its acceleration. $a = \frac{v-u}{t}$ $a = \frac{12-30}{5} = -3.6\ ms^{-2}$ $\underline{\underline{a=4\ ms^{-2}}}$ *to one sig fig*

No.	CONTENT
3.3.8	A bowling ball is accelerated from rest at 3 ms^{-2} for 1.2 s, calculate the final speed it will reach. $a = \frac{v - u}{t}$ $3 = \frac{v - 0}{1.2}$ $v = 3 \times 1.2 = 3.6\ ms^{-1}$ $\underline{v = \ 4ms^{-1}\ to1\ sig\ fig}$
3.3.9	Calculate the time it takes a car to increase its speed from 8 ms^{-1} to 20 ms^{-1} if it accelerates at 3 ms^{-2}. $a = \frac{v - u}{t}$ $3 = \frac{20 - 8}{t}$ $t = \frac{20 - 8}{3}$ $\underline{t = 4\ s}$
3.3.10	A cyclist can accelerate at 0.5 ms^{-2} when cycling at 4 ms^{-1}. Calculate the time taken to reach 5.5 ms^{-1}. $a = \frac{v - u}{t}$ $0.5 = \frac{5.5 - 4}{t}$ $t = \frac{5.5 - 4}{0.5}$ $\underline{t = 3\ s}$
3.3.11	The maximum deceleration a car's brakes can safely produce is 8 ms^{-2}, this is an acceleration of -8 ms^{-2}. Calculate the minimum stopping time if the driver applies the brakes when travelling at 60 mph (27 ms^{-1}). $a = \frac{v - u}{t}$ $0.5 = \frac{5.5 - 4}{t}$ $t = \frac{5.5 - 4}{0.5}$ $\underline{t = 3\ s}$

<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td>3.3.12</td><td>A car is stationary at a traffic light. When the light turns green the car accelerates, and reaches a speed of 30mph twenty seconds later.
(i) State the car’s initial velocity. 0 ms^{-1}
(ii) Calculate the car’s acceleration in miles per hour per second.
$a = \frac{v-u}{t}$ $a = \frac{30-0}{20} = 1.5\,ms^{-2}$</td></tr>
<tr><td>3.4</td><td>I can find the acceleration as the gradient of a velocity-time graph.</td></tr>
<tr><td>3.4.1</td><td>Use the velocity time graphs below to calculate the displacement travelled during each journey. Displacement is equal to the area under a v-t graph.



<table>
<tr><td>a
$s = area\ under\ graph$
$s = \frac{1}{2}bh$
$s = \frac{1}{2} \times 50 \times 15$
$s = 375\ m$</td><td>b
$s = area\ under\ graph$
$s = \frac{1}{2}bh$
$s = \frac{1}{2} \times 4 \times 50$
$s = 100\ m$</td><td>c
$s = area\ under\ graph$
$s = \frac{1}{2}bh + bh$
$s = (\frac{1}{2} \times 25 \times 6) + (4 \times 25)$
$s = 175\ m$</td></tr>
<tr><td colspan="2">d
$s = area\ under\ graph$
$s = bh + \frac{1}{2}bh + bh$
$s = (40 \times 5) + (\frac{1}{2} \times (40 - 10) \times 15)$
$+ (10 \times 20)$
$s = 200 + 225 + 200 = 625\ m$</td><td>e
$s = area\ under\ graph$
$s = \frac{1}{2}bh + bh$
$s = \frac{1}{2} \times 4 \times 20 + 12 \times 10$
$s = 40 + \ 120 += 160\ \ m$</td></tr>
</table>
</td></tr>
</table>

No. **CONTENT**

f

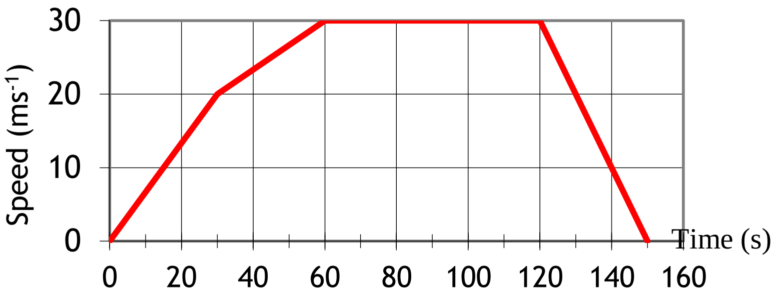
$$s = area\ under\ graph$$

$$s = \frac{1}{2}bh + bh$$

$$s = \frac{1}{2} \times 4 \times 20 + 15 \times 2$$

$$s = 40 + 30 = 70\ \ m$$

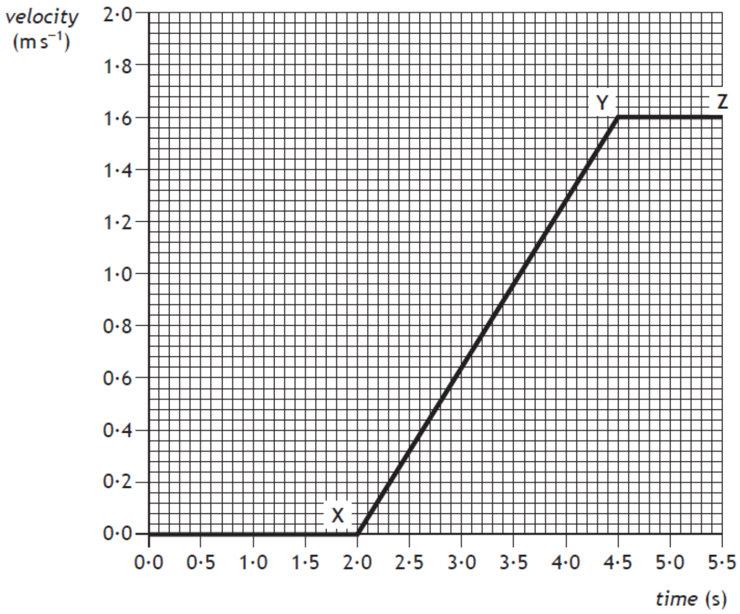
3.4.2 This speed-time graph shows the changes in the speed of a train. Describe as fully as possible how the train is moving.



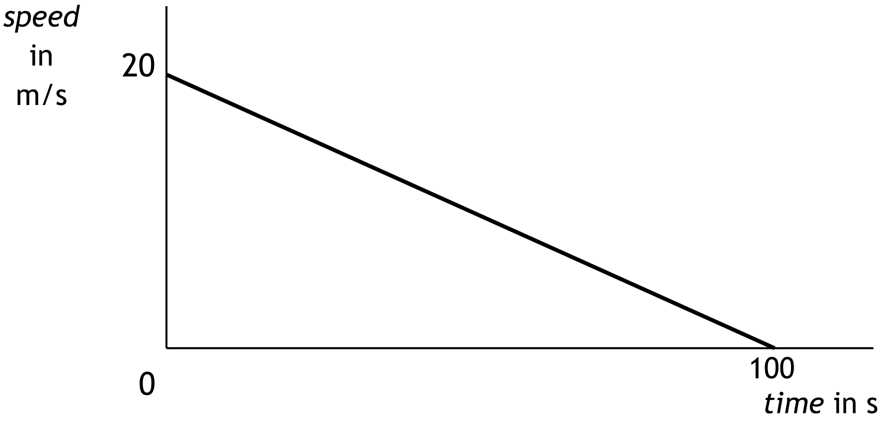
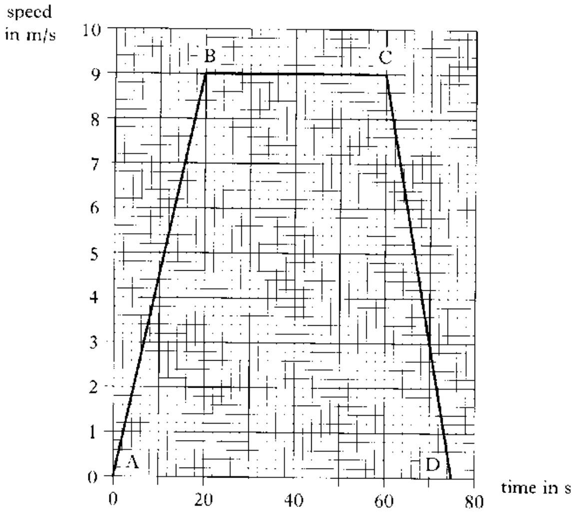
Using the graph above, calculate the acceleration of the train between ,

(a) 0 and 30 seconds	(b) 30 and 60 seconds,	(c) 120 and 150 seconds.
$v = 20\ ms^{-1}$, $u = 0\ ms^{-1}, t = 30\ s$ $a = \frac{v-u}{t}$ $a = \frac{20-0}{30} = 0.7\ ms^{-2}$	$v = 30\ ms^{-1}$, $u = 20\ ms^{-1}, t = 30\ s$ $a = \frac{v-u}{t}$ $a = \frac{30-20}{30} = 0.3\ ms^{-2}$	$v = 0\ ms^{-1}$, $u = 30\ ms^{-1}, t = 30\ s$ $a = \frac{v-u}{t}$ $a = \frac{0-30}{30} = -1.0\ ms^{-2}$

3.4.3



(a) Calculate the acceleration of the vehicle between X and Y.

No.	CONTENT
	a=gradient of a v-t graph $a=\frac{v-u}{t}=\frac{vertical}{horizontal}=\frac{1.6-0}{4.5-2.0}=0.64ms^{-2}$ (b) State the acceleration of the vehicle between Y and Z Between Y and Z the acceleration is 0 ms^{-2}
3.4.4	The speed-time graph below shows how the speed of the train changes from the instant its brakes are applied until it stops.  Calculate the average acceleration of the train as it slows down. $v=0\ ms^{-1}$, $u=20\ ms^{-1}, t=100\ s$ $a=\frac{v-u}{t}$ $a=\frac{0-20}{100}=-0.2\ ms^{-2}$
3.4.5	Exam Question The graph below represents the motion of a cyclist travelling between two sets of traffic lights. (a) Describe the motion of the cyclist i) between B and C between B&C the vehicle is moving at a constant velocity of 9ms^{-1}  ii) between C and D. $v=0\ ms^{-1}$, $u=9\ ms^{-1}, t=12\ s$ $a=\frac{v-u}{t}$ $a=\frac{0-9}{12}=-0.75$ $a=-0.8ms^{-2}$ $(as\ the\ scale\ is\ so\ poor$

No. **CONTENT**

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

$$a = \frac{9-0}{12} = 0.45$$

$$a = 0.5\,ms^{-2}$$

$$(as\ the\ scale\ is\ so\ poor$$

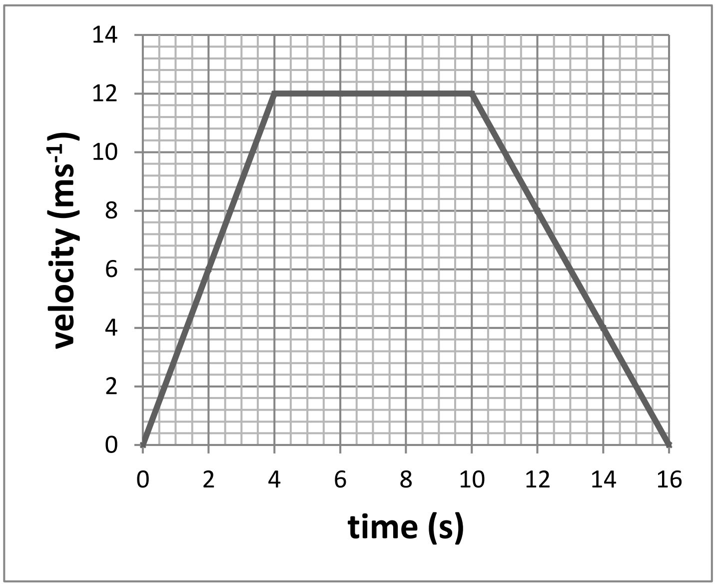
(c) Calculate the acceleration between A and B.

$$v = 0\,ms^{-1},$$

$$u = 9\,ms^{-1}, t = 20\,s$$

3.4.6

The graph shows how the speed of a car changes during a journey.



a) Complete the following table

Time (s)	0	2	4	6	8	10	12	14	16
Velocity (ms-1)	0	6	12	12	12	12	8	4	0

b) Calculate the acceleration during the first 4 seconds.

$$v = 12\,ms^{-1},$$

$$u = 0\,ms^{-1}, t = 4\,s$$

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

$$a = \frac{12-0}{4} = 3\,ms^{-2}$$

c) The car travelled a total distance of 132 metres. Calculate the average speed of the journey.

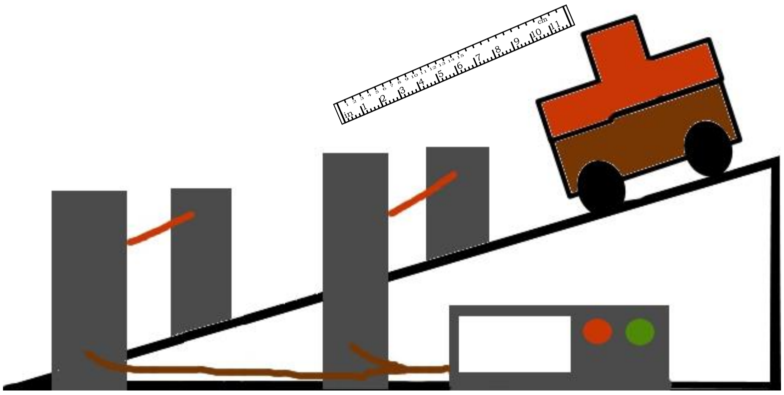
No. **CONTENT**

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

$$v = \frac{132}{16} = 8.3\ ms^{-1}$$

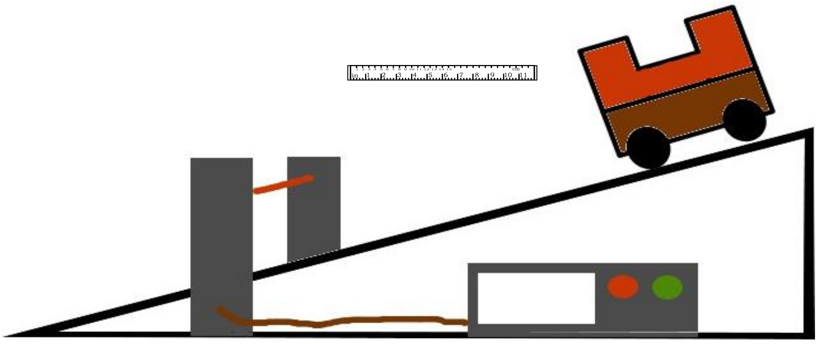
3.5 I can describe an experiment to measure acceleration

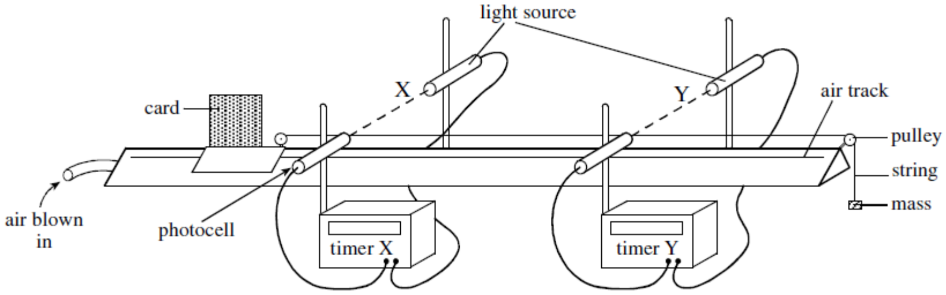
3.5.1 Describe an experiment using **two** light gates to measure the acceleration of a vehicle as it rolls down a slope. Draw a diagram of the set-up, note what measurements you would need to make and how the acceleration will be calculated.



Measurements	Calculations
t_1 time to pass first light gate	$u = \frac{l}{t_1}$
t_2 time to pass second light gate	$v = \frac{l}{t_2}$
t_3 time between light gate	$a = \frac{v - u}{t_3}$
length of mask measure with a ruler	l

3.5.2 Describe an experiment using **one** light gate to measure the acceleration of a vehicle as it rolls down a slope. Draw a diagram of the set-up, note what measurements you would need to make and how the acceleration will be calculated.



<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td></td><td>
<table>
<tr><th>Measurements</th><th>Calculations</th></tr>
<tr><td>t_1 time for first mask to pass through light gate</td><td>$u = \frac{l}{t_1}$</td></tr>
<tr><td>t_2 time for second mask to pass through light gate</td><td>$v = \frac{l}{t_2}$</td></tr>
<tr><td>t_3 time between first and second mask passing through light gate.</td><td>$a = \frac{v - u}{t_3}$</td></tr>
<tr><td>length of mask measure with a ruler</td><td>l</td></tr>
</table>
</td></tr>
<tr><td>3.5.3</td><td>


The apparatus shown in the Figure above is used to find the acceleration of a vehicle moving along a linear air track.

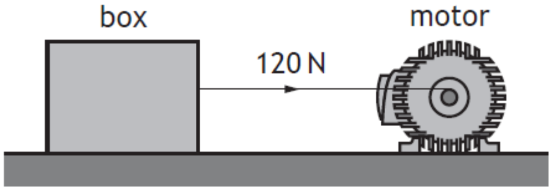
State two ways of modifying the experiment to produce an acceleration which is double the acceleration.

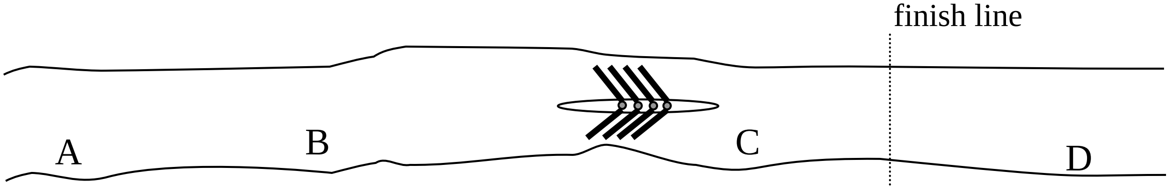
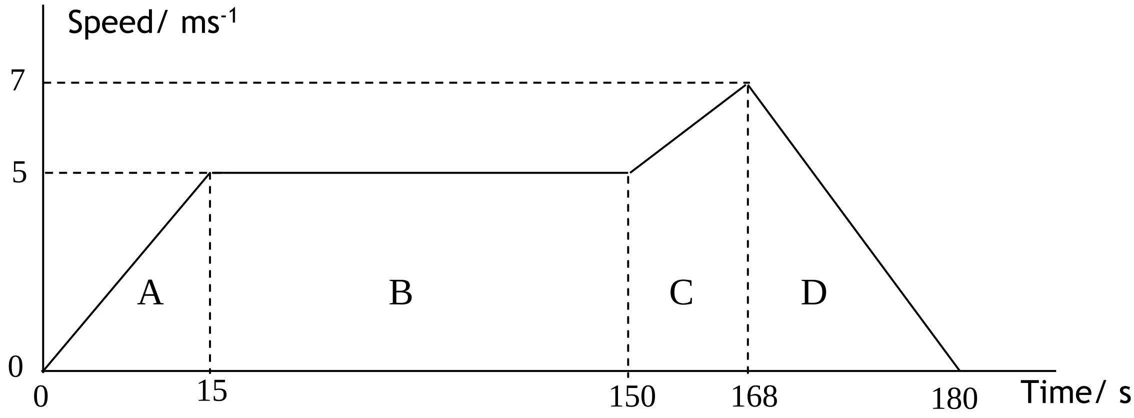
1) **Double the mass on the end of the pulley (doubling the Force)**
2) **Halve the mass of the vehicle**
</td></tr>
<tr><td colspan="2">

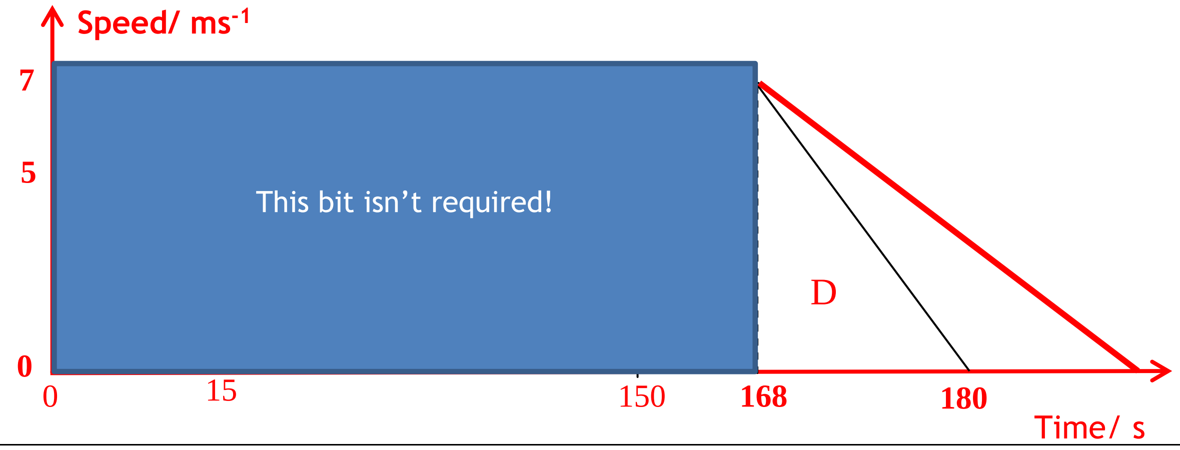
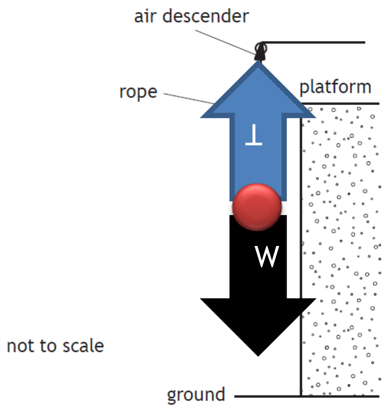
Newton's Laws

</td></tr>
<tr><td>4.1</td><td>I can give applications and use Newton's laws and balanced forces to explain constant velocity (or speed), making reference to frictional forces of this.</td></tr>
<tr><td>4.1.1</td><td>(a) State the meaning of the term force. A force is a push or a pull
(b) State the effects a force have on an object. A force can make an object change its speed, its shape, or its direction of travel.</td></tr>
<tr><td>4.1.2</td><td>Describe how you can measure a force. You can measure a force using a spring balance or Newtonbalance dynamometer. The extension of the spring is directly proportional to the applied force.</td></tr>
<tr><td>4.1.3</td><td>(a) State what is meant by the term friction.
Friction is a contact force which opposes motion. It is caused when one surface slides (or tries to slide) over another.
(b) State the effect of friction on movement?
Friction opposes motion and causes things to slow down. Friction will try to stop a moving object.</td></tr>
</table>

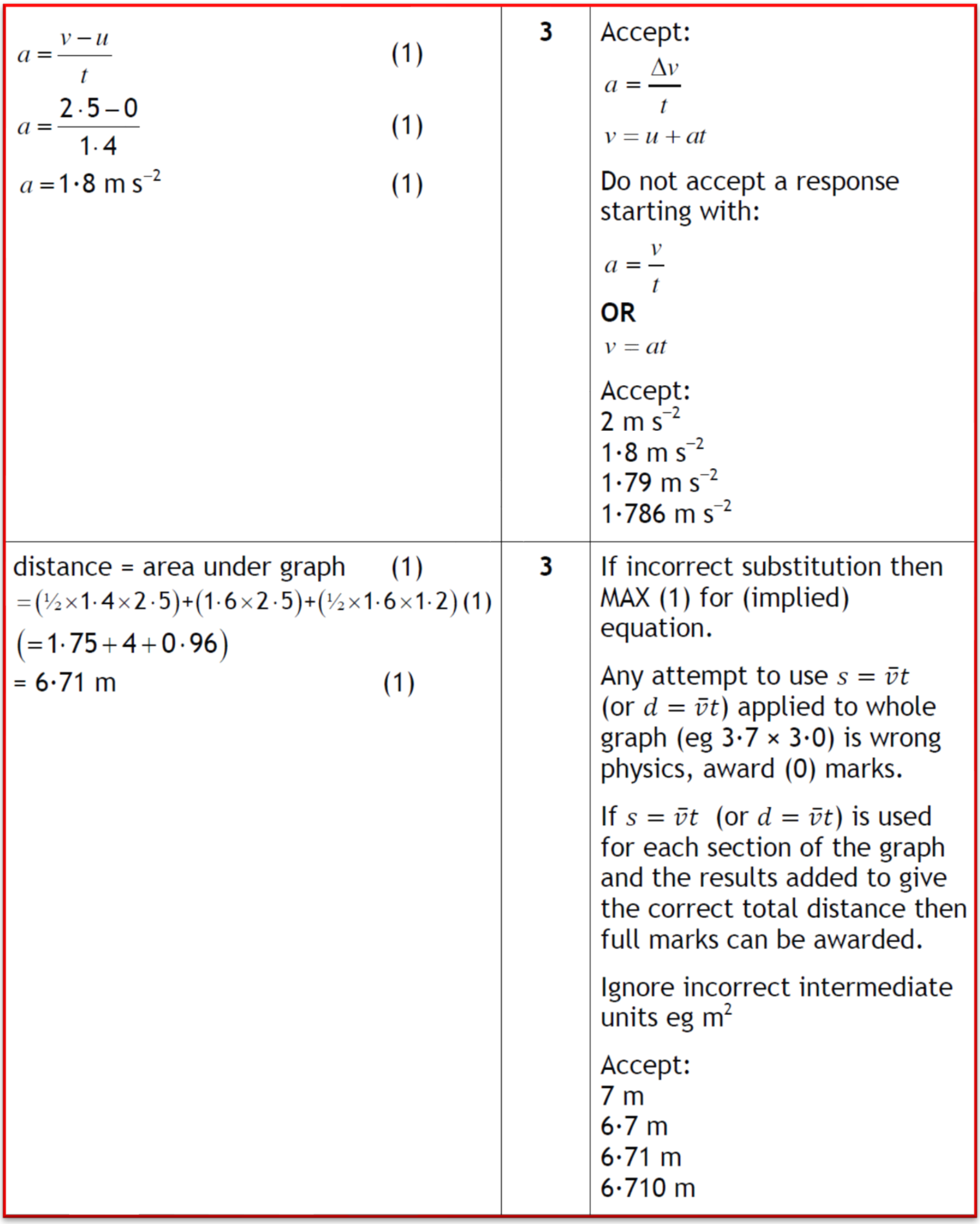
No.	CONTENT
4.1.4	List ways of reducing the force of friction between two surfaces. • Make the surfaces smoother • Put a lubricant between the two surfaces e.g. oil • Reduce the mass/weight pushing the surfaces together • Make the surfaces smoother. ... • Lubrication is another way to make a surface smoother. • Make the object more streamlined. • Reduce the forces acting on the surfaces. • Reduce the contact between the surfaces. • Roll the bodies instead of sliding them.
4.1.5	State ways you increase the force of friction between objects. • Create a "rougher" or more adhesive point of contact. • Press the two surfaces together harder. • Stop any relative motion. • Remove lubrication between the two surfaces. • Remove wheels or bearings to create sliding friction. • Increase the fluid viscosity.
4.1.6	Explain some of the ways friction is used in motor racing. Include at least two examples of where friction is increased and one where it is decreased. Air friction or drag is important because it determines how well the car slips through the air, as well as how well it plants itself to the ground - most of this effect comes from wings. Friction in the engine and driveline are important. Less friction will mean less loss of power and less heat, which will improve performance. And though less heat will mean better reliability, often times it becomes a balance between the two as some methods of protection will increase resistance Friction is also the important for the grip with the road. The tyres are the only part of the car in contact with the racing surface. Tyres obtain their grip through friction. With zero friction the car would be unable to propel itself forward, brake or turn.
4.1.7	Explain, in terms of friction how basic brakes work. Brakes usually use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat. The brakes will wear away due to the high friction and these will need to be replaced.
4.1.8	(a) If you increase the unbalanced force acting on an object while its mass remains constant, what happens to its acceleration? As $F=ma$ as F increases, a will increase if mass remains constant (b) If you increase the mass of an object, while keeping the unbalanced force the same, what happens to its acceleration? As $m=F/a$ as m increases, and F remains constant then a will decrease

No.	CONTENT
4.1.9	State Newton's First Law of Motion. **An object will remain at rest or move at steady speed in a straight line unless acted upon by an unbalanced force.** **Or** **Unless an unbalanced force acts on an object the object will move at constant velocity (which means constant speed in a straight line)** **Or** **An object will remain at rest or move at constant velocity unless acted upon by an unbalanced force.**
4.1.10	State Newton's Second Law of Motion. **Force=mass × acceleration** **F = m a**
4.1.11	Use Newton's first law to explain why a passenger in a train appears to be pushed backwards when the train suddenly starts, and why they appear to be pushed forwards when the train brakes. **When the train starts, the passenger remains stationary until the seat produces a force to accelerate them. Relative to the train, they appear to move backwards. When the train stops, the passenger continues to move forward until the seat applies a force to decelerate them. They appear to move forwards because of this.** ***When a train suddenly starts the people on the train will remain at rest as there is no force acting on them. The train will accelerate as the engine provides an unbalanced force. This makes the people appear to move backwards.*** ***When a train brakes, the people on the train will continue to move at their original speed until something provides a force to decelerate them.*** ***Hence the people appear to be pushed forward but are just remaining at the same speed.***
4.1.12	A boy of mass 45 kg pulls a sledge of mass 15 kg up a slope at a constant velocity of 0·5 ms^{-1}. Are the forces acting on the sledge balanced or unbalanced? Explain your answer. **The forces are balanced as the boy is moving at constant velocity.**
4.1.13	A motor is used to apply a force of 120 N to a box of mass 30 kg. The box moves at a constant speed across a horizontal surface.  State what you can tell about the forces on this box. **As the vehicle is going at constant speed the forces must be balanced.** State any other forces acting on the block. **Friction between the surface and the box. The weight of the block**

No.	**CONTENT**
4.1.14	A weightlifter applies an upwards force of 1176 N to a barbell to hold it in a stationary position as shown.  Describe how the upward force exerted by the weightlifter on the barbell compares to the weight of the barbell **The upwards force must also be 1176 N as the barbell is stationary (Newton's First Law)**
4.1.15	Exam Question A rowing team is taking part in a race on calm water.  The following graph shows how it is predicted that the speed of the boat will vary with time during the stages A, B, C and D of the race.  The prediction assumes that the frictional force on the team's boat remains constant at 800 N during the race. (a) (i) State the size of the forward force applied by the oars during stage B. **800 N (as the boat is travelling at constant speed so forces are balanced- N1L)** (ii) Calculate the acceleration of the boat during stage C $v = 7\ ms^{-1}$, $u = 5\ ms^{-1}, t = 18\ s$ $a = \frac{v-u}{t}$ $a = \frac{7-5}{18} = 0.1\ ms^{-2}$ (iii) The total mass of the boat and its crew is 500 kg. calculate the size of the forward force applied by the oars during stage C $F = ma$ $F = 500 \times 0.1 = 50\ N$

No.	CONTENT
	(iv) The boat crosses the line after 168 seconds. Calculate the distance the boat travels **from the instant it crosses the line** until it comes to rest. $\boldsymbol{distance = area\ under\ the\ speed\ time\ graph}$ $\boldsymbol{distance = \frac{1}{2}bh + bh + \frac{1}{2}bh}$ $\boldsymbol{distance =}$ $\boldsymbol{= \left(\frac{1}{2} \times 15 \times\ 5\right) + (5 \times (168 - 15)) + \left(\frac{1}{2} \times 18 \times 2\right)}$ $\boldsymbol{distance = 821\ m}$ (b) The frictional force acting on the boat during stage D becomes smaller as the speed decreases. (i) State the effect of this smaller frictional force on the time taken for the boat to come to rest. **The smaller the force of friction the greater the time taken for the boat to come to rest.** (ii) Sketch a graph of speed against time for stage D, assuming that the frictional force becomes smaller as the speed decreases. 
4.1.16	Exam Question During part of the drop the forces on the climber are balanced. Copy the diagram below show all the forces acting vertically on the climber during this part of the drop.  **T= tension in the cable** **W= weight** **Both forces are equal in size but opposite in direction.**

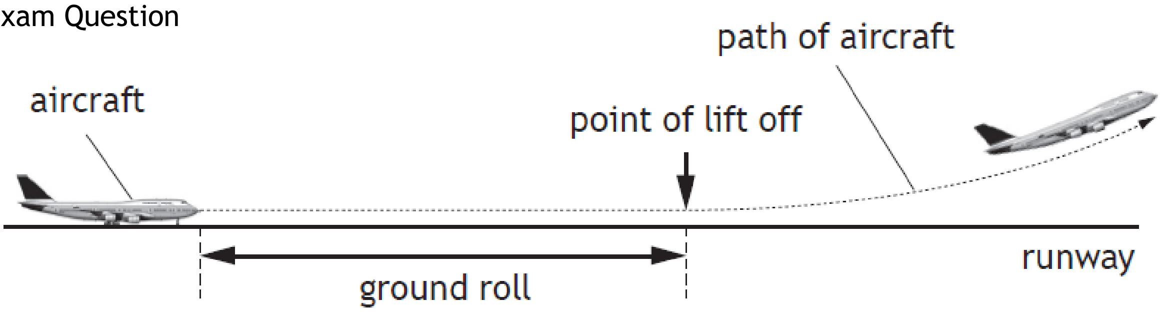
No.	**CONTENT**

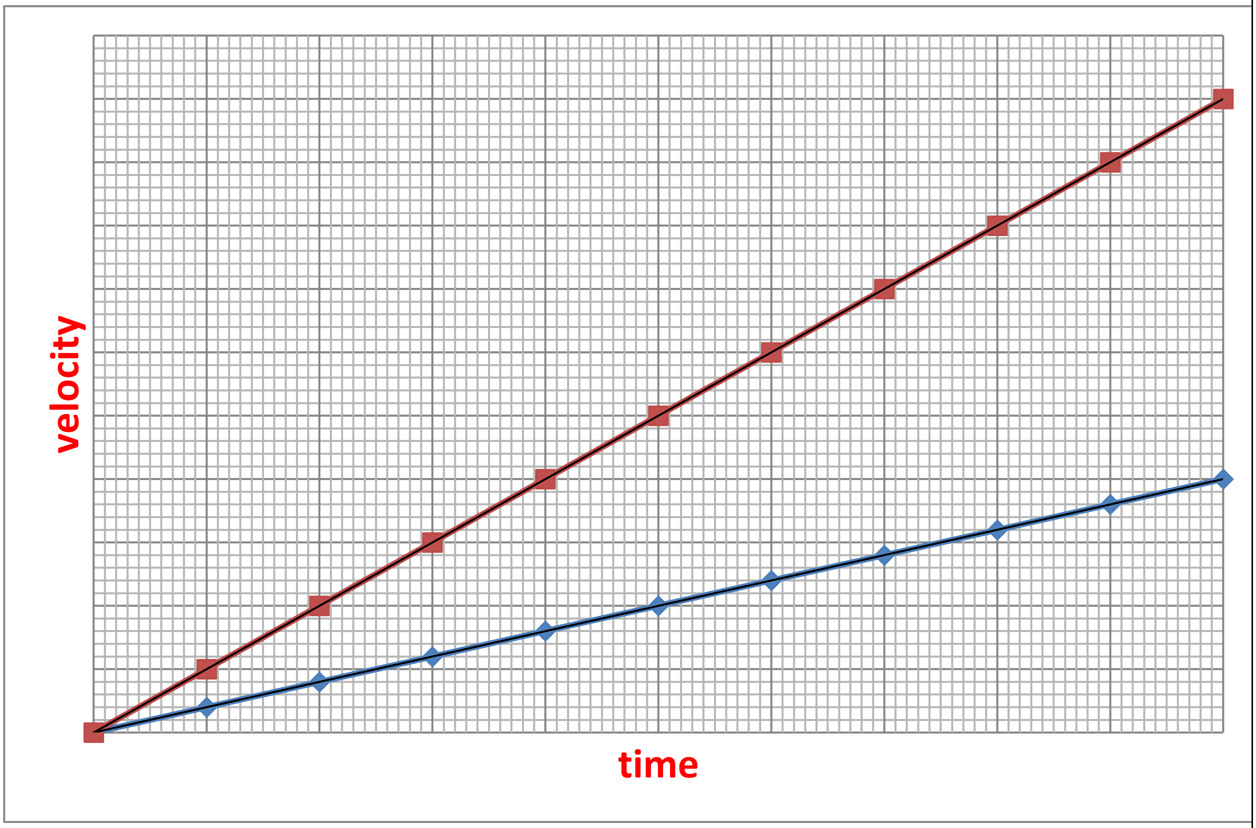


$a = \frac{v-u}{t}$ (1) $a = \frac{2\cdot5-0}{1\cdot4}$ (1) $a = 1\cdot8\ \text{m s}^{-2}$ (1)	**3**	Accept: $a = \frac{\Delta v}{t}$ $v = u + at$ Do not accept a response starting with: $a = \frac{v}{t}$ **OR** $v = at$ Accept: $2\ \text{m s}^{-2}$ $1\cdot8\ \text{m s}^{-2}$ $1\cdot79\ \text{m s}^{-2}$ $1\cdot786\ \text{m s}^{-2}$
distance = area under graph (1) $= (½ \times 1\cdot4 \times 2\cdot5) + (1\cdot6 \times 2\cdot5) + (½ \times 1\cdot6 \times 1\cdot2)$ (1) $(= 1\cdot75 + 4 + 0\cdot96)$ $= 6\cdot71$ m (1)	**3**	If incorrect substitution then MAX (1) for (implied) equation. Any attempt to use $s = \bar{v}t$ (or $d = \bar{v}t$) applied to whole graph (eg 3·7 × 3·0) is wrong physics, award (0) marks. If $s = \bar{v}t$ (or $d = \bar{v}t$) is used for each section of the graph and the results added to give the correct total distance then full marks can be awarded. Ignore incorrect intermediate units eg m^2 Accept: 7 m 6·7 m 6·71 m 6·710 m

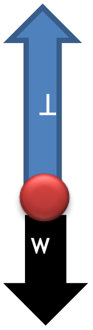
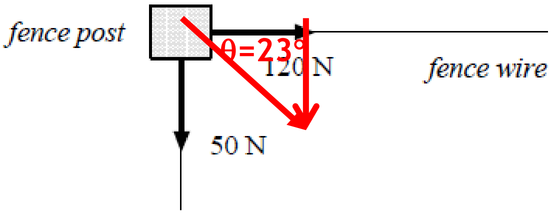
4.2	**I can give applications of Newton's laws and balanced forces to explain and or determine acceleration for situations where more than one force is acting, (*F=ma*)**

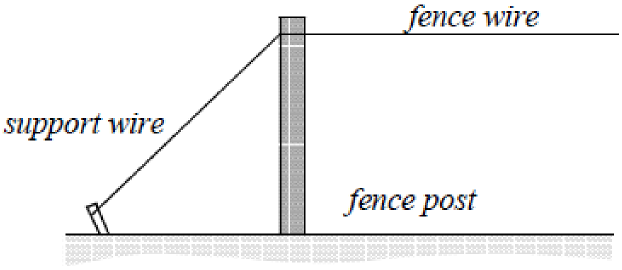
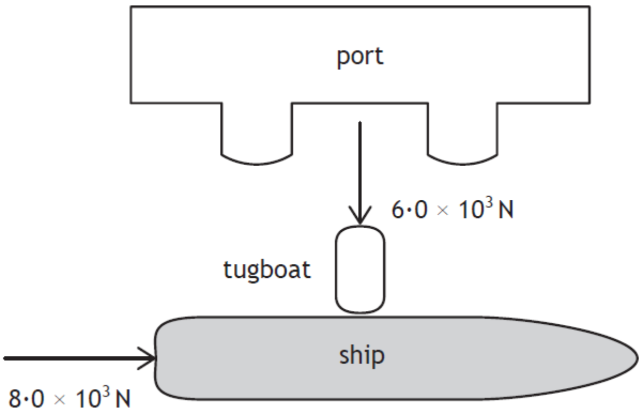
No.	CONTENT
4.2.1	Explain the term balanced forces. **Balanced forces are equal forces acting in opposite directions which are equivalent to no forces acting.**
4.2.2	Describe what happens to the speed of an object when there is **(a)** no force acting on it, **An object will continue at constant velocity or remain at rest.** **(b)** balanced forces acting on it. **An object will continue at constant velocity or remain at rest.**
4.2.3	A passenger in a lift has a mass of 50 kg. As the lift starts its journey, it applies an upwards force of 600 N to the passenger. (i) State the force of gravity on the passenger. **W = mg = 50kg × 9.8 Nkg^{-1} = 490N** (ii) Draw a diagram showing the forces acting on the passenger as the lift starts to move. (ii) State the unbalanced force on the passenger. **Unbalanced force = 600N - 490N = 110 N upwards** (iii) Calculate the acceleration of the passenger. $F = ma$ $110 = 50 \times a$ $\frac{110}{50} = a = 2.2 \cong 2\ ms^{-2}\ to\ 1\ sig\ fig$ (iv) State the direction of the acceleration **Upwards**
4.2.4	A boat has a mass of 700 kg, and can accelerate at 3.0 ms^{-2}. If the engines produce a force of 7000 N, what is the size of (i) the unbalanced force on the boat, and (ii) the drag force of the water on the boat? ***(i) F = ma = 700kg × 3ms^{-2} = 2100 N*** ***(ii) Drag force = 7000N - 2100N = 5800N***
4.2.5	(a) State the purpose of a seatbelt? **A seatbelt is a safety device. It prevents people being injured by certain things when a car crashes.** (b) Explain in terms of forces how a seatbelt fulfils this purpose. **When a car crashes, the car stops suddenly. The people in the car however will continue to move at their original speed until something provides a force to decelerate them. The seat belt provides this force.**

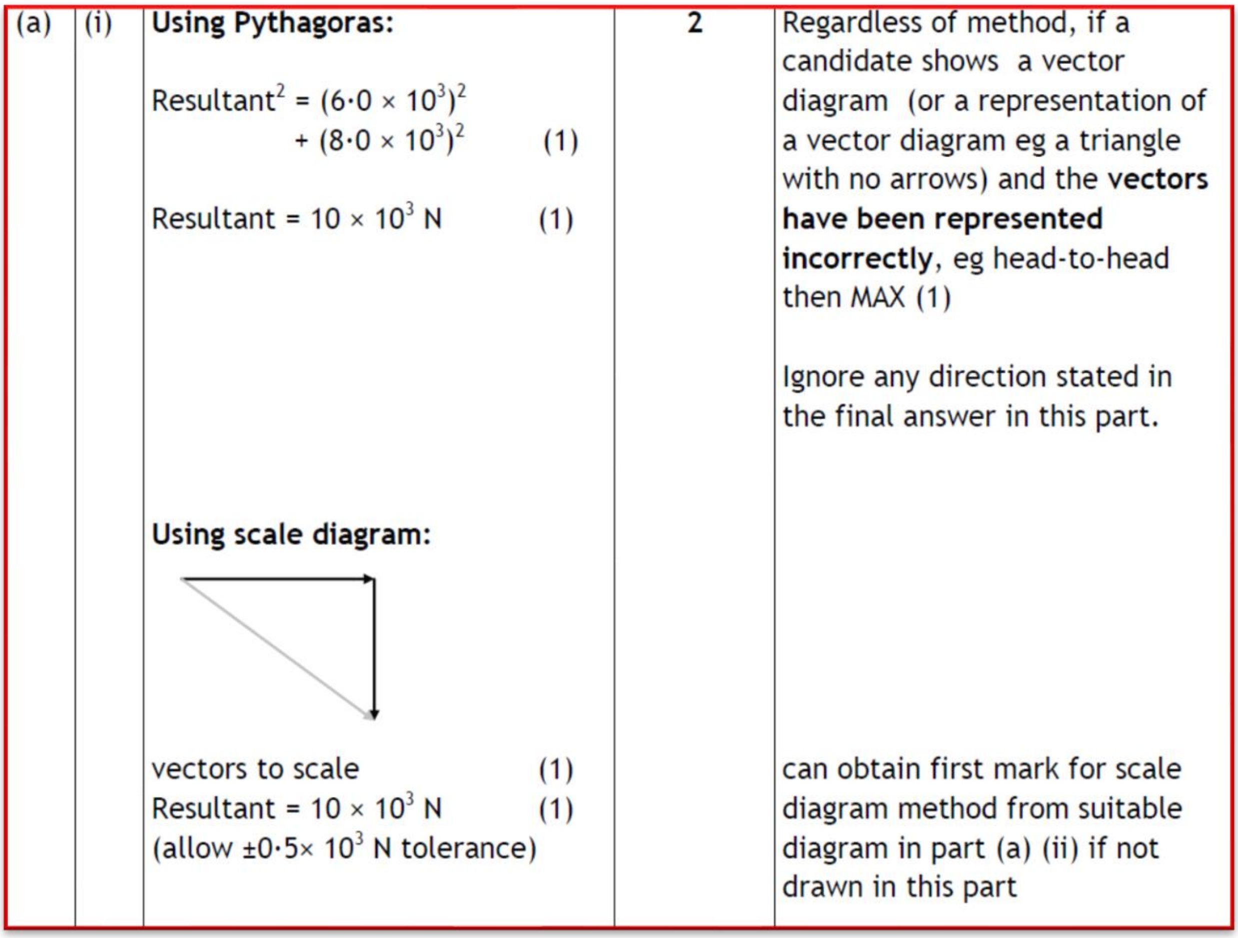
No.	CONTENT
4.2.6	The unbalanced force acting on an 800 kg car is 1900 N. Calculate its acceleration. $a = \frac{F}{m} = \frac{1900N}{800kg} = 2.375m/s^2$ $\underline{a = 2.4\ ms^{-2}}$
4.2.7	Calculate the unbalanced force needed to accelerate a 6000 kg lorry at 1.2 ms^{-2}. $F = ma = 6000kg \times 1.2ms^{-2} = 7200N$
4.2.8	The unbalanced force on an object is 49 N, and it accelerates at 9.8 ms^{-2}, calculate the mass of the object. $m = \frac{F}{a}$ $a = \frac{49N}{9.8\ ms^{-2}}$ $\underline{a = 50\ kg}$
4.2.9	Exam Question  The length of runway required for aircraft to lift off the ground into the air is known as the ground roll. The ground roll of an aircraft varies for each take-off. Use your knowledge of physics to comment on why the ground roll of an aircraft varies for each take-off. **F=ma** **Different loads on each plane= different mass, so with the same thrust have different accelerations. Lower acceleration will result in different take off distances or ground roll.** **You could mention** • **Lift** • **Take off speed** • **Fuel on board, depending on distance more fuel means greater mass, changing the mass, changes the acceleration for given thrust** • **Vectors, and winds, head winds, tail winds side winds and the vector addition of these meaning that ground roll would be different even if the mass and thrust was the same for two journeys** • **Position of the airport, could seaside airports have onshore breezes (similar to above)** • **Pilot saving fuel or going up for time,**

<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td></td><td>
How the flaps are set. Lift can be increased with greater flap, but this increases drag.
<p><i>You could draw a graph to show this on a v-t graph and show that the area under the graph would be equal to the distance.(see below)</i></p>
<p><i>At different accelerations it would be obvious to see that the distance is different.</i></p>
<p>Different planes will have different thrusts so for a fixed mass the ground roll will be different.</p>
<p>Show the area under these two accelerations is different</p>


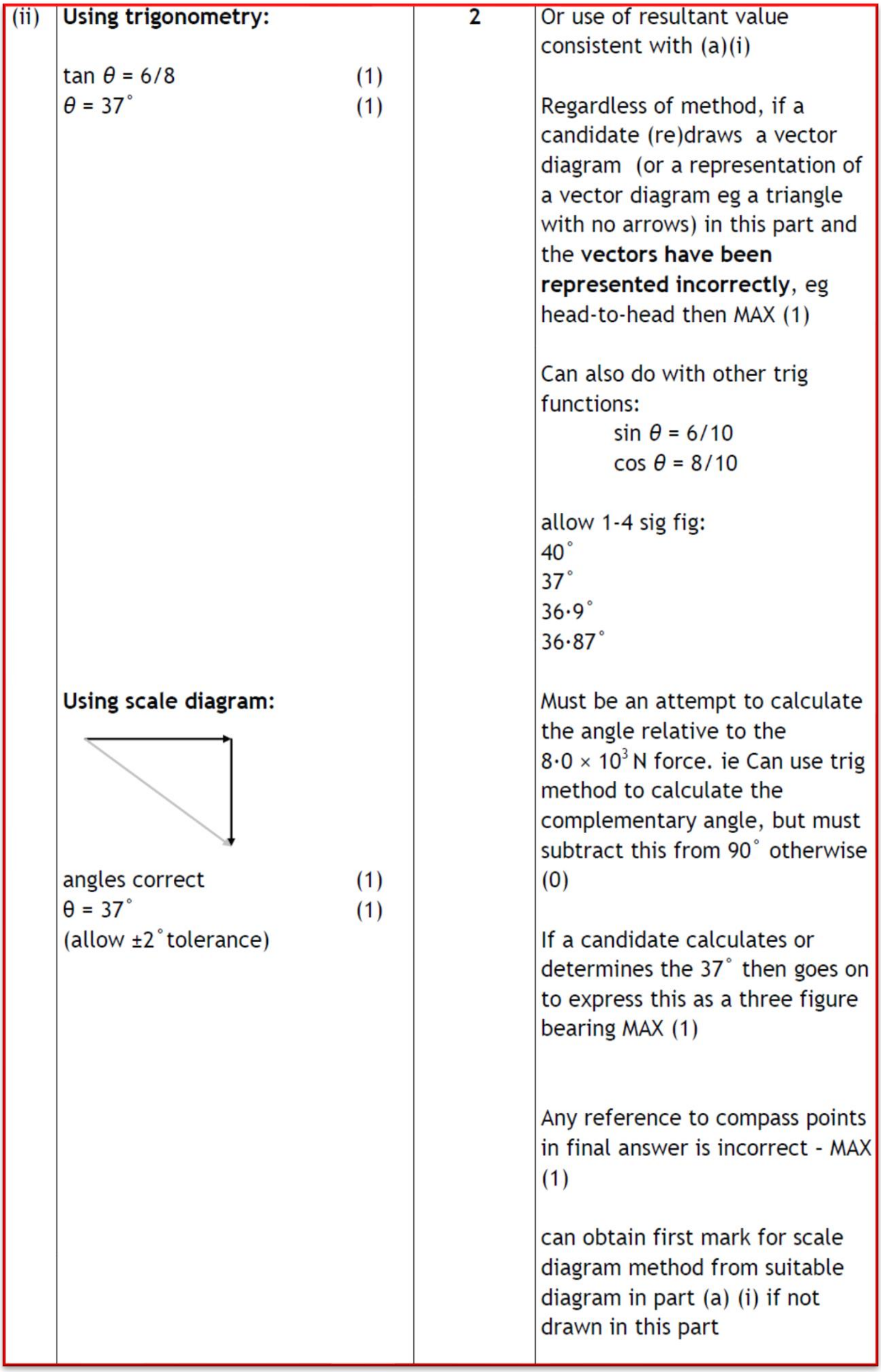
</td></tr>
<tr><td>4.3</td><td>I can use <i>F=ma</i> to solve problems involving unbalanced force, mass and acceleration for situations where more than one force is acting, in one dimension or at right angles.</td></tr>
</table>

No.	CONTENT
4.3.1	A rocket has a total mass of 500 kg and produces a thrust of 10 000 N. (i) Calculate the initial acceleration of the rocket.  **First work out the weight of the rocket.** $W = mg = 500 \times 9.8 = 4900\ N$ **Now work out the unbalanced Force on the rocket** $F_{un} = W + T$ $F_{un} = 10\,000 + (-4900) = 5100\ N$ **Now find the acceleration** $F_{un} = ma$ $5100 = 500 \times a$ $\frac{5100}{500} = a = 10.2ms^{-2}$ (ii) State what happens to the mass of the rocket as it burns its fuel. **mass of the rocket decreases** (iii) If the thrust remains constant, state what happens to the acceleration of the rocket as the fuel is burnt. **Acceleration increases.**
4.3.2	A space vehicle of mass 300.0 kg lifts off from the surface of Mars. At the instant of lift-off the acceleration of the vehicle is 6.0 ms^{-2} vertically upwards. (i) Calculate the unbalanced force acting on the space vehicle at lift-off from Mars. $F_{un} = ma$ $F_{un} = 300.0 \times 6.0 = 1800\ N$ (ii) Show that the force produced by the engine at lift-off is 3000 N. You must show clearly your working. ***Find g for Mars from the data sheet*** $W = mg = 300 \times 3.7 = 1110\ N$ $Thrust = F_{un} + W$ $Thrust = 1800 + 1110 = 2910N \approx 3000\ N$ ***(NB the answer is a little less than that given as this was taken from an Int 2 paper where g on Mars = 4Nkg^{-1}, but it is still correct to 1 sig fig)***
4.3.3	At the corner of a field two fencing wires meet at right angles. Both wires are joined to a fence post.  The wires exert forces of 50 N and 120 N on the fence post as shown. (i) Find by scale diagram or otherwise the magnitude of the resultant force exerted on the fence post by the wires and its direction with reference to the 50 N force. **Find by head to tail scale diagram or Pythagoras. Remember you need to move the vectors so they are head to tail** $c^2 = a^2 + b^2$

No.	CONTENT
	$c^2 = 50^2 + 120^2 = 16900$ $c = 130\ N$ The question asks for magnitude so no requirement to find the angle but for interest θ=23° (ii) At the corner of fields the fence posts usually have a support wire fitted as shown. The end of the support wire is pegged into the ground. Referring to the forces acting on the fence post explain why the support wire is fitted.  There is a resultant force on the two wires above, in this case 130N, an unbalanced force will result in an acceleration and the wires would collapse. Adding the support wire will create a force of 130 N balancing out the forces so that the fence wire does not move and remains stationary.
4.3.4	**Exam Question SQA N5 2015 Q7** A ship of mass 5·0 × 10^6 kg leaves a port. Its engine produces a forward force of 8·0 × 10^3 N. A tugboat pushes against one side of the ship as shown. The tugboat applies a pushing force of 6·0 × 10^3 N.  (a) (i) By scale drawing, or otherwise, determine the size of the resultant force acting on the ship. (ii) Determine the direction of the resultant force relative to the 8·0 × 10^3 N force. (iii) Calculate the size of the acceleration of the ship.

No.	CONTENT
	

(a)	(i)	**Using Pythagoras:** Resultant^2 = $(6{\cdot}0 \times 10^3)^2 + (8{\cdot}0 \times 10^3)^2$ (1) Resultant = 10×10^3 N (1)	**2**	Regardless of method, if a candidate shows a vector diagram (or a representation of a vector diagram eg a triangle with no arrows) and the **vectors have been represented incorrectly**, eg head-to-head then MAX (1) Ignore any direction stated in the final answer in this part.
		Using scale diagram: vectors to scale (1) Resultant = 10×10^3 N (1) (allow $\pm 0{\cdot}5 \times 10^3$ N tolerance)		can obtain first mark for scale diagram method from suitable diagram in part (a) (ii) if not drawn in this part



No.	CONTENT		
(ii)	**Using trigonometry:** $\tan \theta = 6/8$ (1) $\theta = 37^{\circ}$ (1) **Using scale diagram:** angles correct (1) $\theta = 37^{\circ}$ (1) (allow ±2° tolerance)	**2**	Or use of resultant value consistent with (a)(i) Regardless of method, if a candidate (re)draws a vector diagram (or a representation of a vector diagram eg a triangle with no arrows) in this part and the **vectors have been represented incorrectly**, eg head-to-head then MAX (1) Can also do with other trig functions: $\sin \theta = 6/10$ $\cos \theta = 8/10$ allow 1-4 sig fig: 40° 37° 36·9° 36·87° Must be an attempt to calculate the angle relative to the $8{\cdot}0 \times 10^{3}$ N force. ie Can use trig method to calculate the complementary angle, but must subtract this from 90° otherwise (0) If a candidate calculates or determines the 37° then goes on to express this as a three figure bearing MAX (1) Any reference to compass points in final answer is incorrect - MAX (1) can obtain first mark for scale diagram method from suitable diagram in part (a) (i) if not drawn in this part

No.	CONTENT

(iii)	$F = ma$ (1) $10\times10^3 = 5\cdot0\times10^6\times a$ (1) $a = 2\cdot0\times10^{-3}$ m s^{-2} (1)	3	or consistent with (a) (i)

4.3.5 **Exam Question**

A weightlifter applies an upwards force of 1176 N to a barbell to hold it in a stationary position as shown.

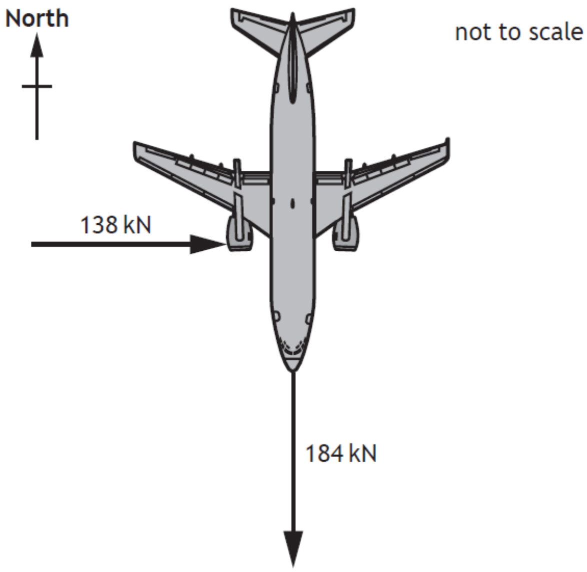
(a) Describe how the upward force exerted by the weightlifter on the barbell compares to the weight of the barbell. (see 4.1.14)

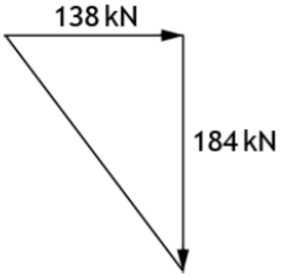
(b) Calculate the mass of the barbell.

(c) The weightlifter increases the upward force on the barbell to 1344 N in order to lift the barbell above their head.

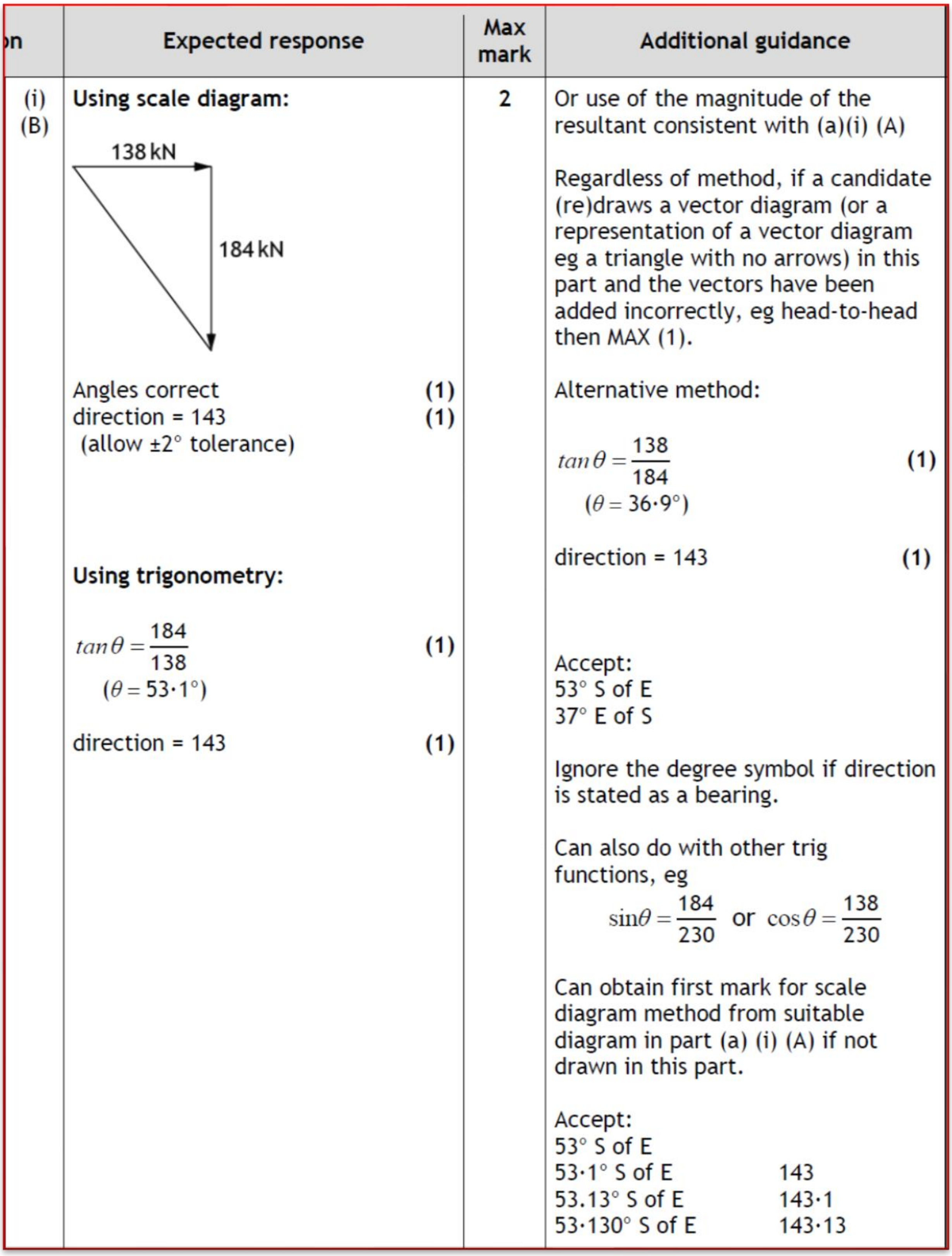
Calculate the initial acceleration of the barbell.

Question			Answer	Max mark	Additional guidance
9.	(a)		(The forces are) equal (in size) and opposite (in direction).	1	Accept: '(The forces are) balanced'
	(b)		$W = mg$ (1) $1176 = m\times9\cdot8$ (1) $m = 120$ kg (1)	3	Use of $F=ma$ is wrong physics - award (0 marks)
	(c)		$F = 1344 - 1176 = 168$ (N) (1) $F = ma$ (1) $168 = 120\times a$ (1) $a = 1\cdot4$ m s^{-2} (1)	4	Or consistent with (b) Accept 1-4 sig fig: 1 m s^{-2} 1·40 m s^{-2} 1·400 m s^{-2}

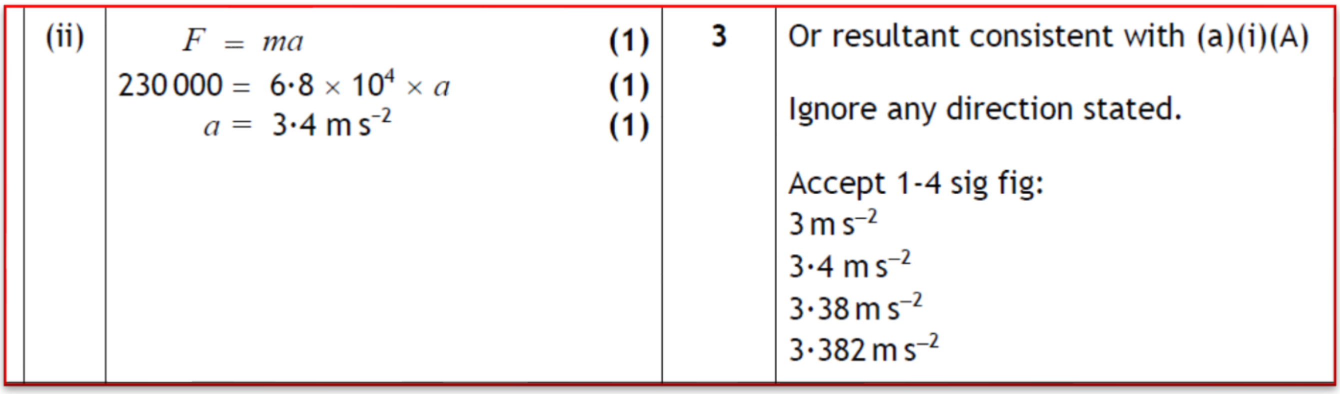
No.	CONTENT
4.3.6	**Exam Question SQA N5 2018** A passenger aircraft is flying horizontally. At one point during the flight the aircraft engines produce an unbalanced force of 184 kN due south (180).  At this point the aircraft also experiences a crosswind. The force of the crosswind on the aircraft is 138 kN due east (090). (i) By scale diagram, or otherwise, determine: (A) the magnitude of the resultant force acting on the aircraft; (B) the direction of the resultant force acting on the aircraft. (ii) The mass of the aircraft is 6·8 × 10^4 kg. Calculate the magnitude of the acceleration of the aircraft at this point.

Question			Expected response	Max mark	Additional guidance
1.	(a)	(i) (A)	**Using scale diagram:**  Vectors to scale **(1)** Resultant = 230 kN **(1)** (allow ±10 kN) **Using Pythagoras:** Resultant^2 = 184^2 + 138^2 **(1)** Resultant = 230 kN **(1)**	**2**	Regardless of method, if a candidate shows a vector diagram (or a representation of a vector diagram eg a triangle with no arrows) and the vectors have been added incorrectly, eg head-to-head then MAX (1). Ignore any direction stated in the final answer in this part. Can obtain first mark for scale diagram method from suitable diagram in part (a) (i) (B) if not drawn in this part.

No.	CONTENT



n	Expected response	Max mark	Additional guidance
(i) (B)	**Using scale diagram:** 138 kN 184 kN Angles correct (1) direction = 143 (1) (allow ±2° tolerance) **Using trigonometry:** $\tan\theta = \frac{184}{138}$ (1) $(\theta = 53{\cdot}1°)$ direction = 143 (1)	2	Or use of the magnitude of the resultant consistent with (a)(i) (A) Regardless of method, if a candidate (re)draws a vector diagram (or a representation of a vector diagram eg a triangle with no arrows) in this part and the vectors have been added incorrectly, eg head-to-head then MAX (1). Alternative method: $\tan\theta = \frac{138}{184}$ (1) $(\theta = 36{\cdot}9°)$ direction = 143 (1) Accept: 53° S of E 37° E of S Ignore the degree symbol if direction is stated as a bearing. Can also do with other trig functions, eg $\sin\theta = \frac{184}{230}$ or $\cos\theta = \frac{138}{230}$ Can obtain first mark for scale diagram method from suitable diagram in part (a) (i) (A) if not drawn in this part. Accept: 53° S of E 53·1° S of E 143 53.13° S of E 143·1 53·130° S of E 143·13

No.	CONTENT
	 (ii) $F = ma$ (1) $230\,000 = 6{\cdot}8 \times 10^4 \times a$ (1) $a = 3{\cdot}4\ \text{m s}^{-2}$ (1) 3 Or resultant consistent with (a)(i)(A) Ignore any direction stated. Accept 1-4 sig fig: $3\ \text{m s}^{-2}$ $3{\cdot}4\ \text{m s}^{-2}$ $3{\cdot}38\ \text{m s}^{-2}$ $3{\cdot}382\ \text{m s}^{-2}$
4.4	**I can use *W=mg* to solve problems involving weight mass and gravitational field strength, including on different planets (where g is given on page 2 of section1 of the exam and in your compendium)**
4.4.1	Explain the difference between mass and weight. **Mass is the amount of matter in an object, it is measured in kilograms. Weight is the force of gravity on an object, pulling it towards the centre of a large mass. It is measured in Newtons.**
4.4.2	State the meaning of the phrase 'Gravitational Field Strength'. **Gravitational field strength is the weight per unit mass, or the weight per kilogram. It is measured in Nkg^{-1}**
4.4.3	*Mars, Jupiter and Earth* On which of the above planets would a 1.0 kg mass dropped near the surface of the planet have the greatest acceleration? Explain your answer. ***A 1 kg mass dropped on Jupiter would have the greatest acceleration as the gravitational field strength on Jupiter is the greatest. W=mg and F=ma are equivalent so the higher 'g', the higher 'a'***
4.4.4	Calculate the weight of a person on Earth with a mass of 65.0 kg. $W = mg$ $W = 65.0 \times 9.8 = 637\ N$
4.4.5	Calculate the mass of an object which has a weight of 7200 N on Earth. $W = mg$ $7200 = m \times 9.8$ $\frac{7200}{9.8} = m = 730\ kg$
4.4.6	State where in the solar system would your mass be greatest. **Wherever you go your mass stays the same, so there is no place in the solar system where your mass would be greatest.** State where in the solar system would your weight be greatest. **Your weight would be greatest near the place with the largest gravitational pull, so at the sun's surface, or on the planet Jupiter.**

No.	CONTENT

4.4.7

SQA N5 2016 Q12

On 12th November 2014, on a mission known as Rosetta, the European Space Agency successfully landed a probe on the surface of a comet.

Rosetta spacecraft data		
Launch mass	Orbiter Lander Propellant	$1{\cdot}23 \times 10^3$ kg $0{\cdot}10 \times 10^3$ kg $1{\cdot}67 \times 10^3$ kg
	Total	$3{\cdot}00 \times 10^3$ kg
Energy source	Solar array output	850 W at 3·4 AU 395 W at 5·25 AU
Trajectory control	24 Thrusters	10 N of force each

The main structure of the Rosetta spacecraft consists of an orbiter, a lander and propellant.

Calculate the total weight of the spacecraft on Earth.

Answer		Max Mark	Additional Guidance
$W = mg$	(1)	3	Do not accept 10 or 9·81 for g
$W = 3{\cdot}00 \times 10^3 \times 9{\cdot}8$	(1)		Accept: 3×10^4 N $2{\cdot}9 \times 10^4$ N $2{\cdot}94 \times 10^4$ N $2{\cdot}940 \times 10^4$ N
$W = 2{\cdot}9 \times 10^4$ N	(1)		

4.4.8

SQA N5 2014

A helicopter is used to take tourists on sightseeing flights.

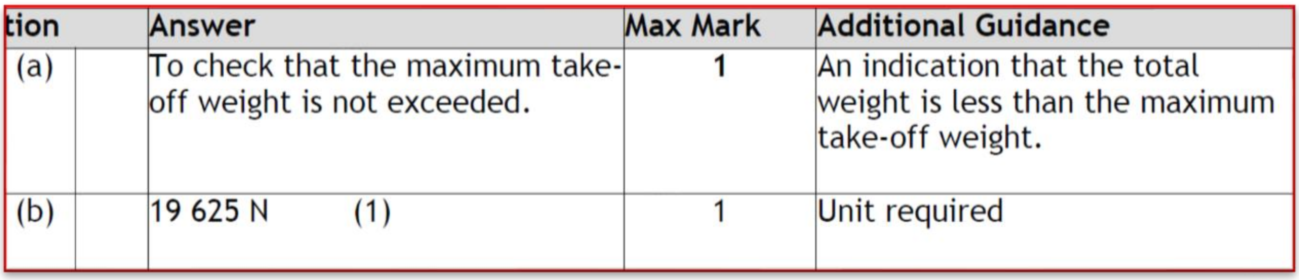
Information about the helicopter is shown in the table.

weight of empty helicopter	13 500 N
maximum take-off weight	24 000 N
cruising speed	67 m s^{-1}
maximum speed	80 m s^{-1}
maximum range	610 km

a) The pilot and passengers are weighed before they board the helicopter. Explain the reason for this.

b) Six passengers and the pilot with a combined weight of 6125 N board the helicopter. Determine the minimum upward force required by the helicopter at take-off.

No.	CONTENT



tion	Answer	Max Mark	Additional Guidance
(a)	To check that the maximum take-off weight is not exceeded.	1	An indication that the total weight is less than the maximum take-off weight.
(b)	19 625 N (1)	1	Unit required

b) combined weight of empty helicopter plus the weight of the pilot and passengers

4.5 **I can use Newton's 3rd law and its application to explain motion resulting from a 'reaction' force.**

4.5.1 State Newton's Third Law of Motion.

For every action there is an equal but opposite reaction.

Or

A & B are objects!

If A exerts a force on B, B exerts and equal but opposite force on A.

4.5.2 In terms of Newton's third law, what is the 'equal and opposite force' in each of these situations:-

(i) A ship's propeller pushes on the water, *the water pushing on the ship's propeller*

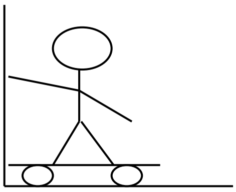
(ii) A rocket pushes on the exhaust gases, the exhaust gases on a rocket

(iii) The earth's gravitational pull on the moon, the moon pull on the Earth

(iv) The Earth's gravitational pull on an aeroplane. the aeroplane's pull on the Earth

4.5.3 Draw the following diagrams and in each case mark and state the reaction force.

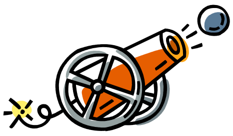
Swimmer pushes water to right (action force)
Water pushes swimmer to left (reaction force)



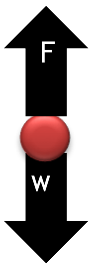
Skateboarder pushes wall to the left (action force)
Wall pushes skateboarder to the right (reaction force)

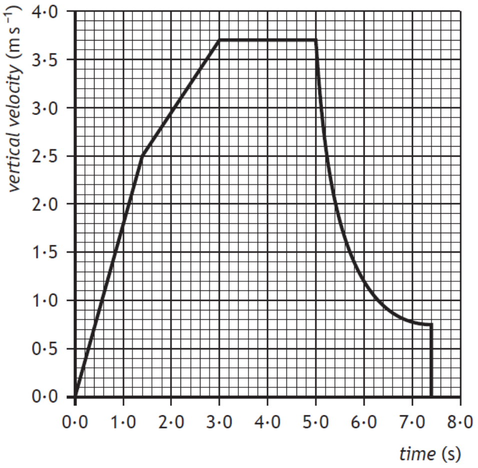
Cannon fires cannonball to the right (action force)

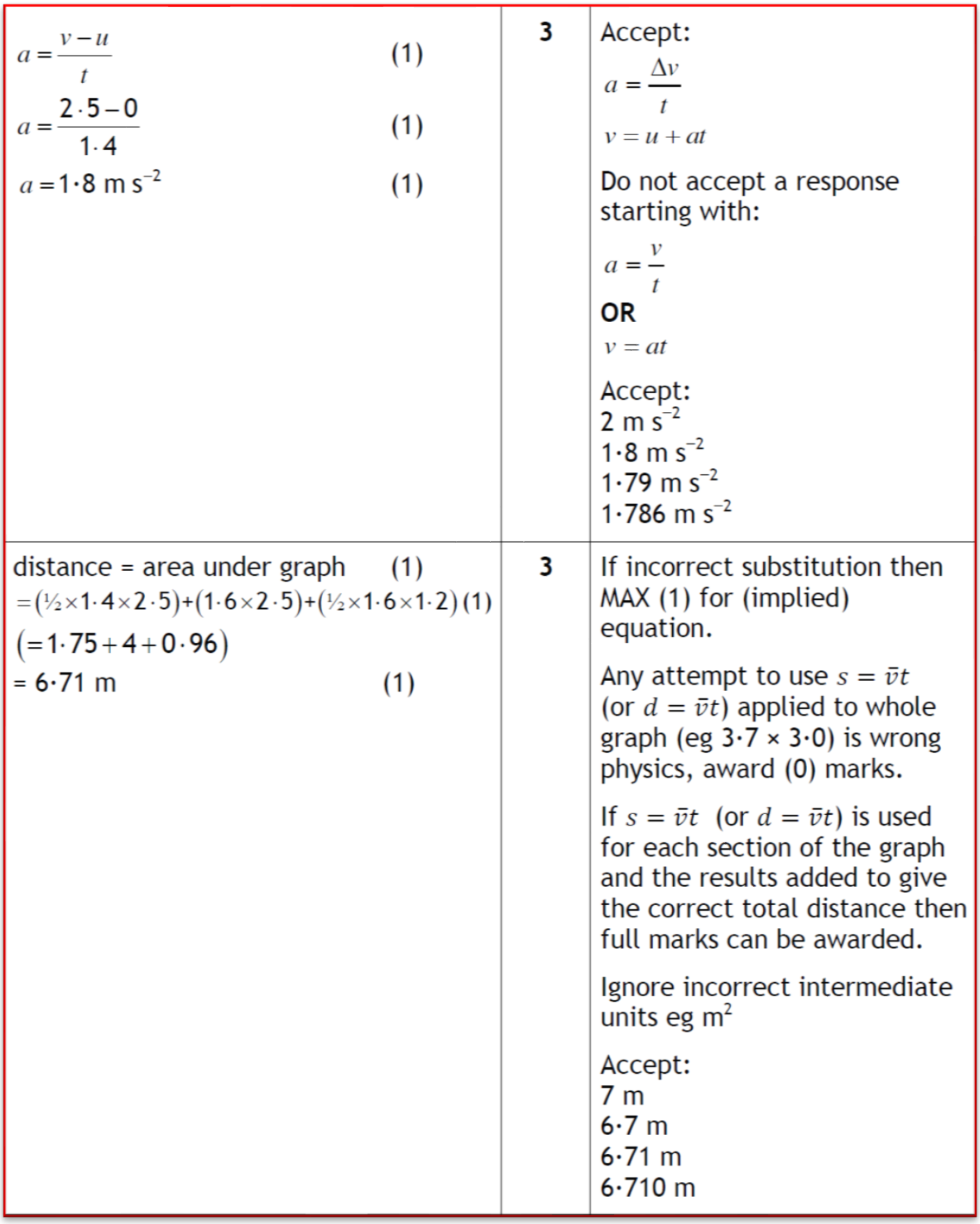
Cannonball pushes cannon to the left (reaction force)



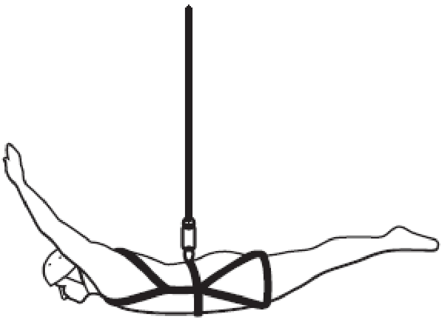
Rocket forces fuel downwards (action force)
fuel forces Rocket upwards (reaction force)

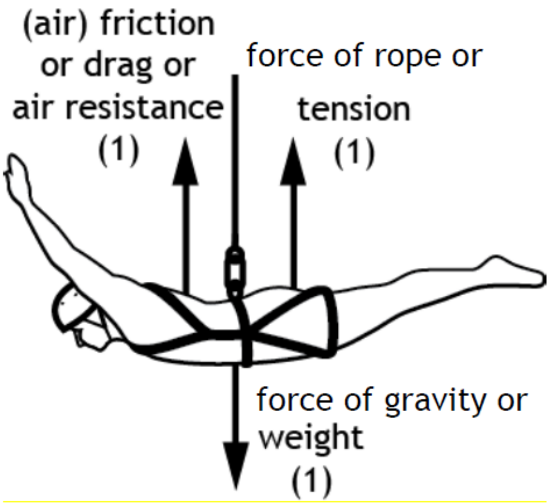
No.	CONTENT
4.5.4	 A person sits on a chair which rests on the Earth. The person exerts a downward force on the chair. State the reaction force. **The chair exerts an upwards force on the person.**
4.6	**I can use Newton's laws to explain free-fall and terminal velocity.**
4.6.1	State the meaning of the term free-fall. **free fall is any motion of a body where the force of gravity is the only force acting upon it causing an acceleration.**
4.6.2	State the meaning of the term terminal velocity. **When the force of gravity acting on a body is balanced by the frictional forces on the body, the forces are balanced and the body moves at a constant speed, called the terminal velocity.**
4.6.3	(i) State what happens to an object as it is dropped from a height above the Earth's surface. **The object will initially accelerate at 9.8 ms^{-2}, the frictional forces will rapidly increase as the speed of the object increases, until the object travels at terminal velocity.** (ii) State the cause of this. **The force of gravity pulls objects toward the Earth causing an acceleration, the acceleration decreases to zero when the object moves at terminal velocity as forces are balanced, according to Newton's First Law**
4.6.4	State the effects of an unbalanced (resultant) force on an object. **An unbalanced force causes an acceleration on the body**
4.6.5	A car is travelling at a constant speed along a flat level road. (a) State what you can say about the forces on the car. **The forces are balanced** (b) An unbalanced force is added to the car, state what happens to the motion of the car. **The car will accelerate**
4.6.6	A hot air balloon is falling at constant velocity to the ground.  (i) Draw a free body diagram and label the forces on the balloon. **W= weight, F= frictional forces.** (ii) State what you can say about the forces on the balloon. **These forces are equal in size and opposite in direction** (iii) A balloonist throws a sandbag over the side of the balloon basket, state what happens to the forces on the balloon. **The weight decreases** (iv) Describe the motion of the balloon when the sandbag is thrown overboard. **The balloon will accelerate upwards until a new terminal velocity is reached**

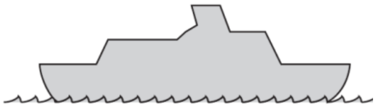
No.	CONTENT
4.6.7 A	 This question related to question 4.1.16. From the graph (i) State during which times the forces on the climber are balanced. (ii) Explain your answer to part (i) See below



$a = \frac{v-u}{t}$ (1) $a = \frac{2 \cdot 5 - 0}{1 \cdot 4}$ (1) $a = 1 \cdot 8 \text{ m s}^{-2}$ (1)	3	Accept: $a = \frac{\Delta v}{t}$ $v = u + at$ Do not accept a response starting with: $a = \frac{v}{t}$ **OR** $v = at$ Accept: 2 m s^{-2} 1·8 m s^{-2} 1·79 m s^{-2} 1·786 m s^{-2}
distance = area under graph (1) $= (\frac{1}{2} \times 1 \cdot 4 \times 2 \cdot 5) + (1 \cdot 6 \times 2 \cdot 5) + (\frac{1}{2} \times 1 \cdot 6 \times 1 \cdot 2)$ (1) $(= 1 \cdot 75 + 4 + 0 \cdot 96)$ = 6·71 m (1)	3	If incorrect substitution then MAX (1) for (implied) equation. Any attempt to use $s = \bar{v}t$ (or $d = \bar{v}t$) applied to whole graph (eg 3·7 × 3·0) is wrong physics, award (0) marks. If $s = \bar{v}t$ (or $d = \bar{v}t$) is used for each section of the graph and the results added to give the correct total distance then full marks can be awarded. Ignore incorrect intermediate units eg m^2 Accept: 7 m 6·7 m 6·71 m 6·710 m

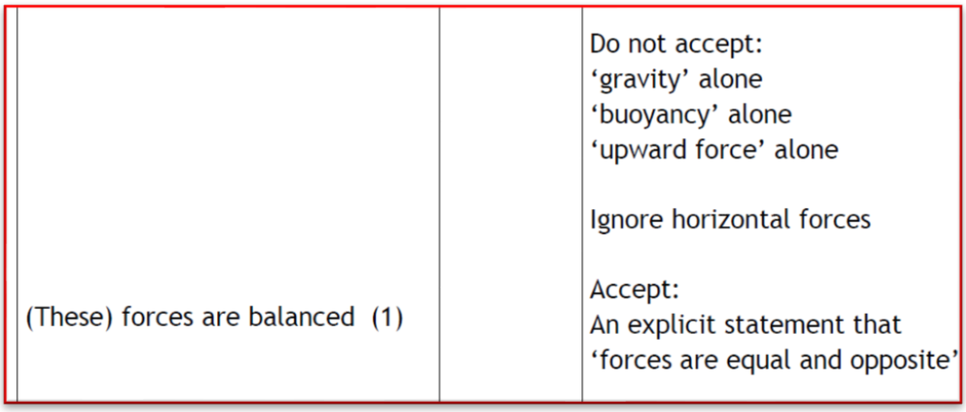
No.	CONTENT
4.6.7 B	 (iii) Copy the diagram of the climber and label the forces on the climber

	**3**	(1) for each force correctly labelled with corresponding direction. Accept: 'pull of rope' 'gravitational pull' 'pull of gravity' Do not accept: 'pull/force of air descender' 'gravity' alone 'upward force' alone Ignore horizontal forces

No.	CONTENT
4.6.8	Explain why a ship floats. 

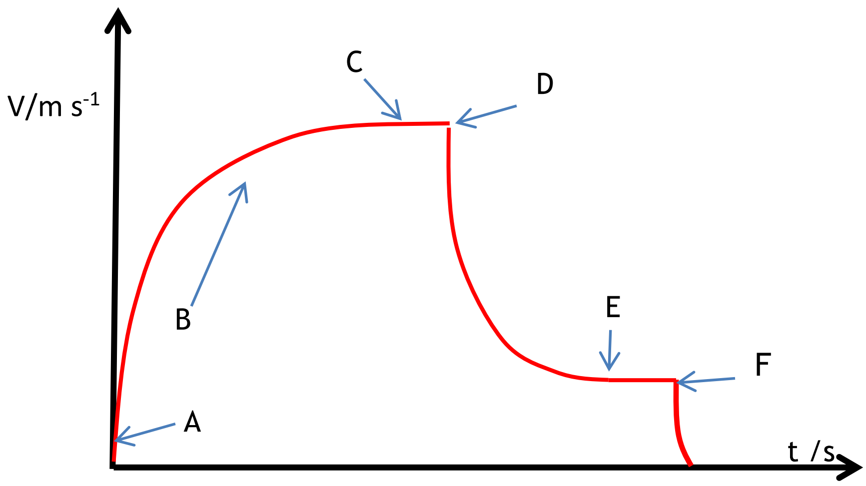
(b)		buoyancy force/upthrust/force of water on ship/flotation force (1)  weight/force of gravity (1)	**3**	Independent marks Must describe forces on ship (i.e. not 'ship pushes down on water') Allow a clear description without a diagram but must indicate direction of force(s) eg weight/force of gravity acts down on ship (1) buoyancy force/upthrust/force of water on ship acts up (1)

No.	CONTENT



(These) forces are balanced (1)		Do not accept: 'gravity' alone 'buoyancy' alone 'upward force' alone Ignore horizontal forces Accept: An explicit statement that 'forces are equal and opposite'

4.6.9



The diagram above shows the velocity time graph for a parachutist during her fall from when she exits the plane to when she lands.

(i) Describe the motion of the parachutist at each point

point	Forces and Motion
A	The skydiver accelerates at 9.8ms^{-2}
B	The skydiver accelerates with a reduced acceleration than at the start.
C	The skydiver falls at constant speed, terminal velocity.
D	The skydiver has a large deceleration (or negative acceleration) and is slowed down.
E	The skydiver falls at constant speed, terminal velocity
F	The skydiver experiences a great negative acceleration (slowing down)

(ii) State at which points she has reached terminal velocity.
C & E

(iii) Explain in terms of forces and Newton's Laws of motion why the parachutist reaches terminal velocity.

No.	CONTENT

The downwards force of weight is equal to the opposing frictional forces on the skydiver, and according to Newton's First Law an object will remain at constant velocity unless acted upon by an unbalanced force. This constant velocity is called terminal velocity.

(iv) Explain how can there be two points where she reaches terminal velocity when the weight of the parachutist hasn't changed.

Frictional forces increase with speed. The first terminal velocity occurs when the weight equals to the drag/ frictional forces/ air resistance and the parachute is closed. When the parachute opens the frictional forces are greater than the weight this causes the skydiver to slow down which reduced the frictional forces until they reach the same magnitude as the weight. When they are balanced a new terminal velocity is reached but this is less than before.

(v) Explain which of Newton's Laws of Motion explains the different parts of the graph.

point	Forces and Motion
A	Newton's 2nd Law F=ma *F=weight, m = mass of the skydiver and kit, a=acceleration.* Initial velocity in the vertical direction is zero, the object accelerates under the force of gravity at 9.8ms^{-2}. Initially no drag force.
B	Newton's 2nd Law F=ma *F_{un} =weight+drag (which is in the opposite direction), m = mass of the skydiver and kit, a=acceleration.* As vertical speed increases air resistance acting against the parachutist increases. At B weight is greater than drag so the skydiver accelerates with a reduced acceleration than at the start.
C	Newton's 1st Law *An object will move at constant velocity unless acted upon by an unbalanced force. The forces are balanced.* At C Weight = drag so the skydiver falls at constant speed, terminal velocity.
D	Newton's 2nd Law F=ma *Fun=weight+ frictional forces (which are much greater than weight so F is negative), m = mass of the skydiver and kit, a=acceleration.* The parachute is opened At D drag forces are much greater than the weight (the parachute has been opened) so there is a high deceleration (or negative acceleration)
E	Newton's 1st Law *An object will move at constant velocity unless acted upon by an unbalanced force. The forces are*

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<tr><td></td><td>
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<tr><td></td><td>*balanced.*
At E Weight = drag so the skydiver falls at constant speed, terminal velocity</td></tr>
<tr><td>F</td><td>Newton’s 2nd Law F=ma and Newton’s 3rd Law *For every action there is an equal but opposite reaction.*
Fun=weight+ forces from the ground, m = mass of the skydiver and kit, a=acceleration.
The skydiver touches the ground creating a large force on the ground (slowing down) The ground produced an equal but opposite force on the skydiver which cause a great negative acceleration</td></tr>
</table>
</td></tr>
<tr><td colspan="2">
<table>
<tr><th>Point</th><th>Forces and Motion</th></tr>
<tr><td>A</td><td>Initial velocity in the vertical direction is zero, the object accelerates under the force of gravity at $9.8ms^{-2}$. Initially no drag force.</td></tr>
<tr><td>B</td><td>As vertical speed increases air resistance acting against the parachutist increases. At B weight is greater than drag so the skydiver accelerates with a reduced acceleration than at the start.</td></tr>
<tr><td>C</td><td>At B Weight = drag so the skydiver falls at constant speed, terminal velocity.</td></tr>
<tr><td>D</td><td>The parachute is opened At E drag forces are much greater than the weight (the parachute has been opened) so there is a high deceleration (or negative acceleration)</td></tr>
<tr><td>E</td><td>At E Weight = drag so the skydiver falls at constant speed, terminal velocity</td></tr>
<tr><td>F</td><td>The parachutists touches the ground large forces cause a great negative acceleration (slowing down)</td></tr>
</table>
</td></tr>
<tr><td>4.6.10</td><td>Copy and complete using the correct ending….
A spacecraft completes the last stage of its journey back to Earth by parachute, falling with constant speed into the sea.
The spacecraft falls with constant speed because
…the air resistance is equal to the weight of the spacecraft.</td></tr>
</table>

No. **CONTENT**

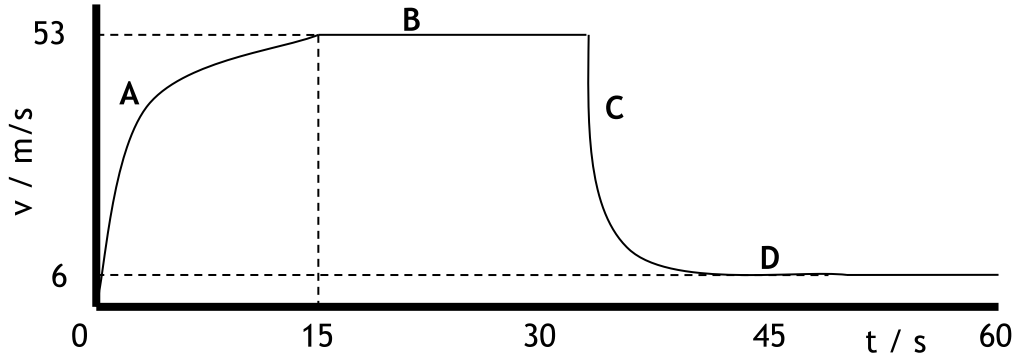
4.6.11 Explain the results of these experiments:

(a) When released from the same height on Earth, a hammer will hit the ground before a feather. **On Earth both objects initially accelerate at 9.8 ms^{-2}. As speed increases upwards frictional forces increase. There is a greater upwards frictional force on the feather than the hammer as it is less streamlined so the feather will reach terminal velocity in a shorter time, or will accelerate with a smaller acceleration than the hammer if terminal velocity is not reached.**

(b) When released from the same height on the moon, a hammer and feather will hit the ground at the same time.

On the Moon both objects initially accelerate at 1.6 ms^{-2}As there is no atmosphere on the moon there is no gas to provide frictional forces on either objects so they will continue to accelerate at 1.6 ms^{-2}until reaching the ground.

4.6.12 The diagram shows the vertical motion of a skydiver as he returns from a parachute jump



(a) State the two vertical forces acting on the sky diver during the jump. **weight and air resistance or drag**

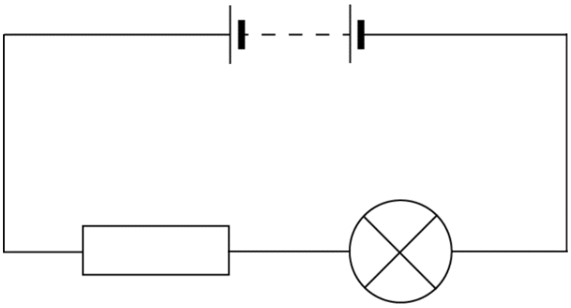
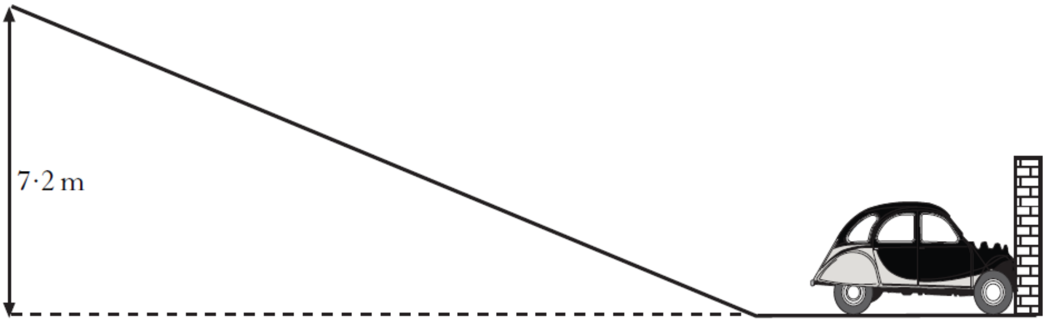
(b) State the value of the terminal velocity of the sky diver during the jump.

53 ms^{-1}

(c) Explain, in terms of vertical forces, the motion of the sky diver at each of the points indicated on the graph.

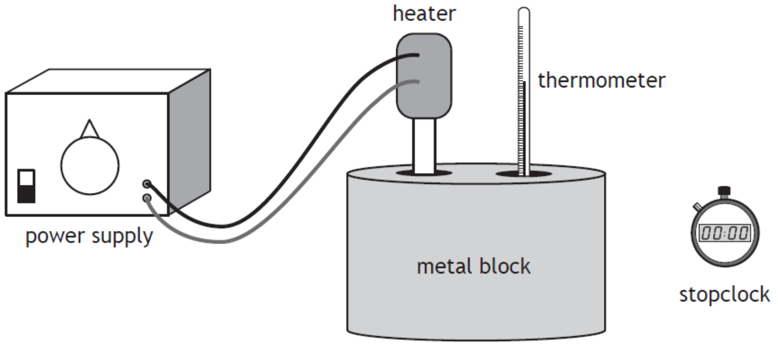
point	Forces and Motion
A	At A weight is greater than drag/ air resistance so the skydiver accelerated with a smaller acceleration than at the start.
B	At B Weight = drag so the skydiver falls at constant speed, terminal velocity of 53 ms^{-1}
C	At C drag forces are much greater than the weight (the parachute has been opened) so there is a high deceleration (or negative acceleration)
D	At D Weight = drag so the skydiver falls at constant speed, terminal velocity of 6 ms^{-1}

No.	CONTENT
Energy	
5.1	**I can state the Law of Conservation of Energy.**
5.1.1	State the Law of Conservation of Energy. **Energy can neither be created nor destroyed, it can only be transferred or transformed**
5.2	**I can identify and explain energy conversions and transfer.**
5.2.1	Describe the energy conversions when a pendulum swings back and forth. **At the top of the swing the pendulum has maximum gravitational potential energy and no kinetic energy. At the bottom of the swing the pendulum has max kinetic energy and no gravitational potential energy. In between these position the pendulum has the same total energy but it distributed between Ek and Ep**
5.2.2	Describe the energy conversions and transfers as a parachutist falls to Earth, from the time they jump from the plane to them safely landing on the ground **As the parachutist falls initially from the plane the Ep is at its maximum, Ek is at its minimum. As the parachutist falls Ep decreases and Ek increases. Not all the Ep is transferred to Ek as drag forces increase with increasing speed. Work is done against increasing frictional forces creating heat in the air. When the parachute is opened Ek is converted to E_H through friction/drag Ep continues to be lost as heat. On landing Ek is converted to heat and sound as work is done bringing the parachutist to a stop. .**
5.2.3	Describe the energy transfers and conversions when a light bulb is connected to a cell and the switch closed. **A cell is a store of chemical potential energy, when the switch closes this is transformed to electrical energy in the wires. The electrical energy is transformed to heat and light in the bulb.**
5.2.4	When an object is dropped from a height of 4.0 m it is found that not all its gravitational potential energy is transferred into kinetic energy. Explain this observation. **As speed increases frictional forces on the object increase so work is done on the object by these frictional forces heating up the object and the air surrounding it as it falls. Energy is neither created or destroyed but it is** **E_p $E_k + E_w$(as heat)**
5.2.5	Explain why all the electrical energy from a kettle element does not go in to heating the water in the kettle. **As the temperature rises in the water the heat is transferred to the body of the kettle and the surrounding air.as wel as the water in the kettle.**
5.2.6	State the energy transfer as four women row in an Olympic boat race. **Chemical energy in the women, transferred to kinetic energy in the oars, transferred to kinetic energy moving the boat forward. Some energy will be transferred as heat due to friction and air resistance.**
5.3	**I can apply the principle of 'conservation of energy' to examples where energy is transferred between stores.**

No.	CONTENT
5.3.1	In terms of energy, state what happens when a vehicle (a) accelerates**, Chemical energy in fuel is converted to kinetic energy** (b) moves at constant speed, (c) brakes, **E_k is converted to E_H in the brakes due to frictional forces when braking** (d) goes up a slope, **E_k is converted to E_P if the speed decreases or chemical potential energy is converted to E_p** (e) goes down a slope
5.3.2	State the energy transfers in the circuit below **Chemical energy in the battery is converted to electrical energy which is converted to light and heat in the lamp and heat in the resistor** 
5.3.3	 An early method of crash testing involved a car rolling down a slope and colliding with a wall. (i) State the energy changes as the car moves down the slope and collitdes with the wall.**gravitational potential energy is converted to kinetic energy with some work done against friction.** (ii) State why the mass of the car is not required for the calculation. $E_p\ lost = E_k\ gained$ $E_p = mgh, E_k = \frac{1}{2}mv^2$ $\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$ **The mass cancels out and is independent of the speed at the bottom of the slope.**

No.	CONTENT
5.3.4	Based on SQA N5 2014

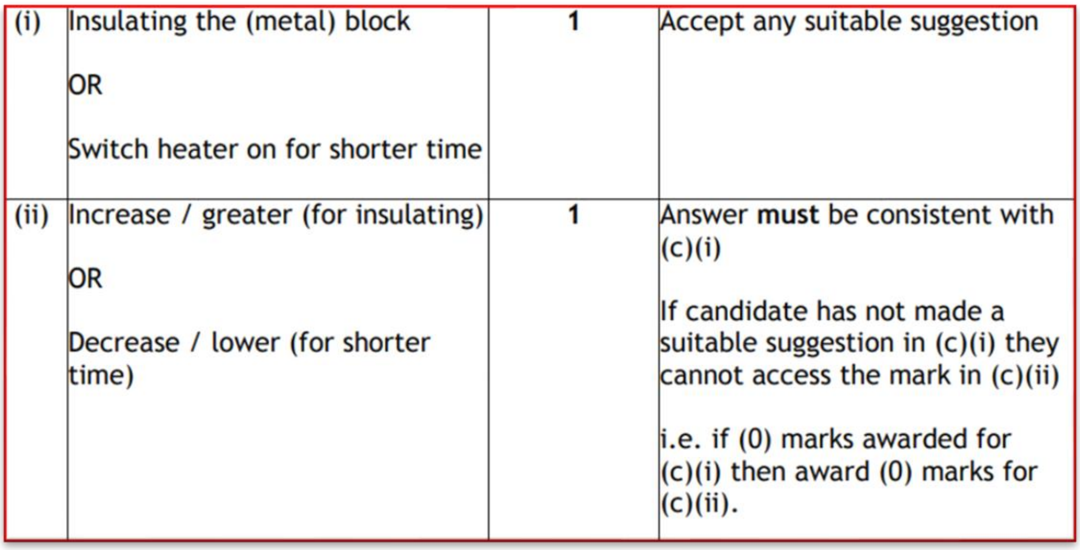
A student is investigating the specific heat capacity of three metal blocks X, Y and Z. Each block has a mass of 1·0 kg. A heater and thermometer are inserted into a block as shown.



When the student calculates the energy provided to the block using $E = Pt$ and uses this energy value to calculate the expected specific heat capacity $= cm\Delta T$.

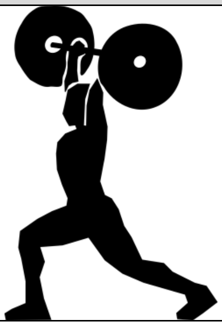
(i) When checking the answer against the specific heat capacity of the material it is discovered the specific heat capacities. Explain whether the experimental value is likely to be higher or lower than the accepted value. **Higher as the block is not insulated so some of the heat from the heater will warm the surrounding air.**

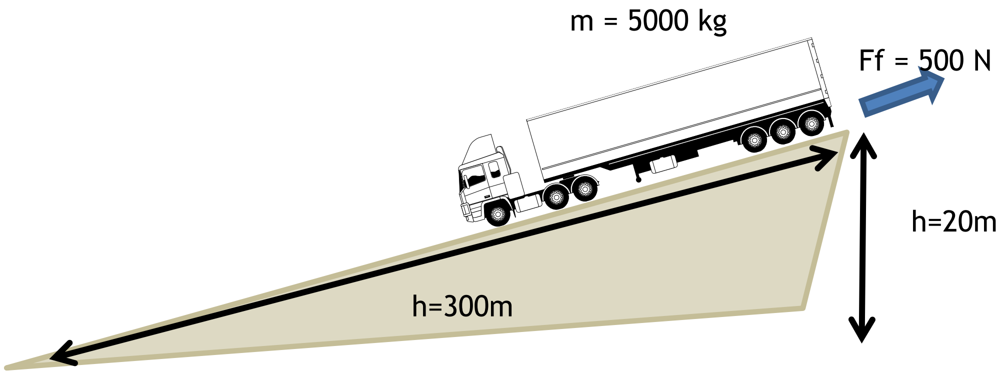
(ii) The student decides to improve the set up in order to obtain a value closer to the accepted value for each block. Suggest possible improvements that are likely to result in a calculated value closer to the accepted value.

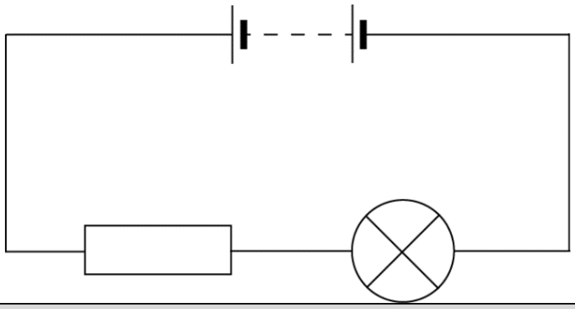


(i)	Insulating the (metal) block OR Switch heater on for shorter time	**1**	Accept any suitable suggestion
(ii)	Increase / greater (for insulating) OR Decrease / lower (for shorter time)	**1**	Answer **must** be consistent with (c)(i) If candidate has not made a suitable suggestion in (c)(i) they cannot access the mark in (c)(ii) i.e. if (0) marks awarded for (c)(i) then award (0) marks for (c)(ii).

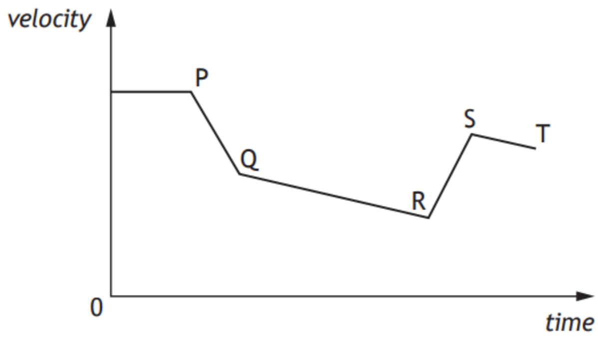
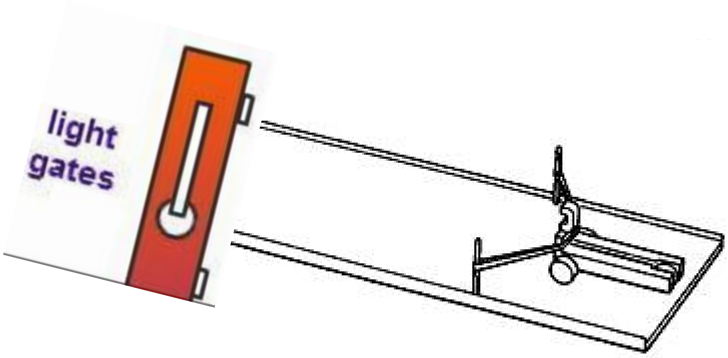
5.4	**I can use appropriate relationships to solve problems involving work done, unbalanced force, and distance or displacement. (*Ew=Fd*)**
5.4.1	State the appropriate relationship involving work done, unbalanced force, and distance or displacement. ***Ew=Fd*** ***Where Ew = work done in joules, F= Force in Newtons and d= distance in metres***

No.	CONTENT
5.4.2	 State if work is done if a girl holds a set of weights above her head, you must explain your answer. **No work is done as a force must move through a distance.** $Ew = F \times d$ $d = 0\ m, \therefore Ew = 0\ J$
5.4.3	A locomotive exerts a pull of 10000 N to pull a train a distance of 400 m. Calculate the work done. $Ew = F \times d = 10000 \times 400 = 4.0 \times 10^6 J$
5.4.4	A gardener does 1200 J pushing a wheelbarrow with a force of 100 N, calculate the distance she pushed the barrow. $E_w = F \times d$ $1200 = 100 \times d$ $d = 12m$
5.4.5	A man uses up 1000 J by pulling a heavy load for 20 m, calculate the force used. $E_w = F \times d$ $1000 = F \times 20$ $F = \frac{1000}{20} = 50\ N$
5.4.6	A girl is pushing her bike with a force of 80 N and uses up 4000 J of energy, calculate the distance she push the bike. $E_w = F \times d$ $4000 = 80 \times d$ $d = \frac{4000}{80} = 50\ m$
5.4.7	A man weighing 600 N climbs stairs in an office block which are 40 m high, calculate the work done. $E_w = F \times d = 600 \times 40 = 2.4 \times 10^4 J$
5.4.8	A worker pushes a 4 kg crate along the ground for 3 m using a force of 20 N, then lifts the crate up to a ledge 1 m high, calculate the total work done. $E_{Total} = E_w + E_P = (F \times d) + mgh = (20 \times 3) + (4 \times 9.8 \times 1)$ $E_{Total} = 60 + 39 = 100\ J$
5.4.9	An average force of 120 N is used to push a supermarket trolley 30m. Calculate the work done $E_w = F \times d = 120 \times 30 = 3.6 \times 10^3 J$
5.4.10	A force of 24 N is needed to pull open a drawer. If the drawer moves 35 **cm**, Calculate the energy used moving it. $E_w = F \times d = 24 \times 0.35 = 8.4\ J$

No.	CONTENT
5.4.11	A girl does 900 **kJ** of work cycling to school. If she uses an average force of 200N, calculate the distances she pedals. $E_w = F \times d$ $900 \times 10^3 = 200 \times d$ $d = \frac{900 \times 10^3}{200} = 4500\ m$
5.4.11	A boy does 5000 J of work climbing the stairs. If the distance climbed is 9m, calculate the force he is producing. $E_w = F \times d$ $5000 = F \times 9$ $F = \frac{900 \times 10^3}{200} = 4500\ N$
5.5	**I can identify and explain 'loss' of energy where energy is transferred.**
5.5.1	A lorry of mass 5000 kg rolls down a hill 20 m high. The lorry rolls a distance of 300 m, and is initially stationary. The average force of friction on the lorry is 500 N. (i) Draw a diagram showing the journey of the lorry and mark on it the information given above.  (ii) What is the change in the gravitational potential energy of the lorry as it rolls down the hill? $E_p lost = mgh$ $E_p lost = 5000 \times 9.8 \times 20 = 9.8 \times 10^5 J$ (iii) State what happens to this energy. **Some is converted to heat energy through friction and some if converted to kinetic energy in the lorry.** (iv) Calculate the work done against friction. $E_w = Fd$ $E_w = 500 \times 300 = 1.5 \times 10^4\ J$ (v) Calculate the change in the kinetic energy of the lorry. $E_p lost = E_w + E_k$ $9.8 \times 10^5 = 1.5 \times 10^5 + E_k$ $E_k = 8.3 \times 10^5\ J$

No.	CONTENT
	(vi) Calculate the speed of the lorry at the bottom of the hill.? $E_k = \frac{1}{2}mv^2$ $8.3 \times 10^5 = \frac{1}{2} \times 5000 \times v^2$ $\frac{2 \times 8.3 \times 10^5}{5000} = v^2$ $v = 18.2\ ms^{-1}$
5.5.2	Explain why the kinetic energy of the lorry at the bottom of the slope is not equal to the gravitational potential energy at the top of the slope. Some of the energy is converted to heat due to friction.
5.5.3	State where energy "losses" occur in the circuit below Energy is lost as heat in the battery, resistor, lamp and potentially wires. 
5.6	**I can define gravitational potential energy.**
5.6.1	Define the term gravitation potential energy. The energy an object possesses due to its position above the ground.
5.6.2	State the relationship used to calculate the gravitational potential energy, include what each term means and the units used to measure each term $E_p = mgh$ $E_p = gravitational\ potential\ energy\ in\ Joules$ $m = mass\ in\ kilograms$ $g = gravitational\ field\ strength\ in\ Newtons\ per\ kilogram$ $h = height\ in\ metres$
5.7	**I can solve problems on involving gravitational potential energy, mass, gravitational field strength and height.**
5.7.1	A mass of 4kg is released from a height of 2m. Calculate the gravitational potential energy of the mass before it is released. $E_p = mgh$ $E_p = 4 \times 9.8 \times 2 = 78.4\ J$
5.7.2	An object has a gravitational potential energy of 502J. It is dropped from a height of 20 m. $E_p = mgh$ $502 = m \times 9.8 \times 20$ $\frac{502}{196} = m = 2.6\ kg$

No.	CONTENT
5.7.3	A chairlift raises a skier of mass 60 kg to a height of 250 m. Calculate the potential energy gained by the skier. $E_p = mgh$ $E_p = 60 \times 9.8 \times 250 = 1.5 \times 10^5 J$
5.7.4	A brick of mass 3 kg rests on a platform 25 m above the ground on a building site. a) Calculate the potential energy stored in the brick. $E_p = mgh$ $E_p = 3 \times 9.8 \times 25 = 740 J$ **b)** If the brick falls 25 m to the ground, determine the potential energy it will lose. **740 J**. c) State the form of energy gained by the brick as it falls. **Kinetic energy (plus heat energy)**
5.7.5	Estimate how much gravitational potential energy you would gain if you were lifted 30m up to the top of a fun-ride. $E_p = mgh$ ***Assuming m=50 kg*** $E_p = 50 \times 9.8 \times 30 = 14700 J$
5.7.6	An apple, mass 100 g, has 300 J of potential energy at the top of the Eiffel Tower. Calculate the height of the Eiffel Tower. $E_p = mgh$ ***m=100g=0.1 kg*** $300 = 0.1 \times 9.8 \times h$ $\frac{300}{0.98} = h = 330 m$
5.7.7	An astronaut of mass 70 kg climbs to a height of 5 m on the moon and gains 560 J of gravitational potential energy. (i) Determine the gravitational field strength on the moon. $E_p = mgh$ $560 = 70 \times g \times 5$ $\frac{560}{70 \times 5} = g = 1.6 Nkg^{-1}$ (ii) If the same experiment were carried out on Earth state whether the astronaut would gain less, more or the same gravitational potential energy, you must justify your answer. **Gain more E_p as g=9.8 Nkg^{-1} so for 5 m she would gain 3430 J**
5.8	**I can define kinetic energy as the energy an object has because of its speed.**
5.8.1	State the meaning of the term kinetic energy. **Energy an object possesses by being in motion.**

No.	CONTENT
5.8.2	State how the kinetic energy of an object changes when (i) it's speed increases, and **Ek increases. Doubling speed quadruples the Ek** (ii) it's mass increases. **Ek increase (but doubling mass double the Ek)**
5.8.3	 A cyclist is travelling along a straight road. The graph shows how the velocity of the cyclist varies with time. State where the kinetic energy of the cyclist is at its greatest and explain your answer. **As the mass of the cyclist is not changing then the Ek will be greatest when the speed/velocity is greatest. This occurs at P.**
5.9	**I can use $Ek = \frac{1}{2} mv^2$ to solve problems involving kinetic energy, mass and speed**
5.9.1	You are provided with an air track and vehicles, a light gate and timer and some elastic bands. Describe how you could use this apparatus to establish how potential energy provided affects the velocity of the vehicle. Include details of any measurements you would take and any additional measuring equipment needed.  Set up a catapult across the runway by stretching a large elastic band between the dowel rods (or clamp stands). Firmly fix a single vertical dowel rod on the trolley and measure its width with a rule. Adjust the height of the elastic so that the vertical rod will catch the middle of it. Place the trolley on the runway. Pull it back a measured distance against the catapult so that the rubber is stretched. Release the trolley so that it is projected by the catapult along the runway and passes through the light gate. The width of the dowel rod, divided by the time to pass through the light gate will give the speed of the trolley. Add another elastic band, of the same thickness and length and repeat. Plot a graph of no. of elastic bands (an indication of the potential energy given to the trolley) against velocity squared. This should yield a straight line graph through the origin indicating the potential energy stored in the elastic bands is proportional to the kinetic energy (v^2). You need to measure, the dowel width, the time for this to pass through the light gate, the number of elastic bands, the distance it is pulled back. Calculate

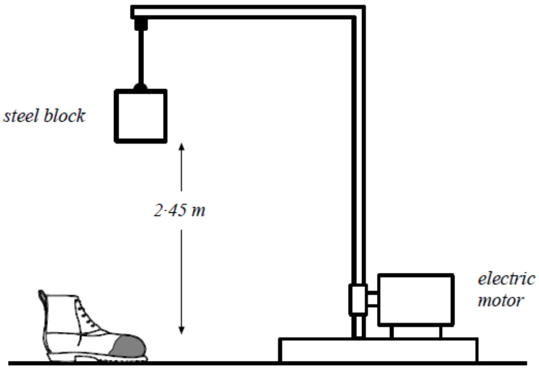
No.	CONTENT
	$velocity = \frac{dowel\ width}{time\ to\ pass\ the\ light\ gate}$
5.9.2	Calculate the kinetic energy of the following: a) a 5.0 kg bowling ball moving at 4.0 ms^{-1} $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 5 \times 4^2 = 40J$ b) a 50.0 kg skier moving at 20.0 ms^{-1} $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 50 \times 20.0^2 = 1.0 \times 10^4\ J$ c) a 0.020 kg bullet moving at 100.0 ms^{-1}. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 0.020 \times 100.0^2 = 100\ J$
5.9.3	a) Calculate the kinetic energy an 800 kg car has when travelling at a velocity of 10.0 ms^{-1}. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 0.020 \times 10.0^2 = 1.0\ J$ b) If it doubles its velocity to 20.0 ms^{-1}, calculate its new kinetic energy. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 0.020 \times 20.0^2 = 4.0\ J$ **Doubling the velocity quadruples the kinetic energy of an object**
5.9.4	A cyclist who is pedalling down a slope reaches a speed of 15 ms^{-1}. The cyclist and her cycle together have a mass of 80 kg. a) Calculate the total kinetic energy. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 80 \times 15^2 = 9000\ J$ b) Name two sources of this kinetic energy. **From the mechanical energy (kinetic energy) of the cyclist travelling down the slope; and the conversion of gravitational potential energy to kinetic energy as it moves down the slope.**
5.9.5	Calculate an **approximate** value for the kinetic energy of an Olympic 100 m sprinter as he crosses the line (time for race is about 10 s).

No.	CONTENT
	$E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 100 \times 10^2 = 5.0\ kJ$
5.9.6	What is the velocity of a stone of mass 2 kg if it has 36 J of kinetic energy? $E_k = \frac{1}{2}mv^2$ $36 = \frac{1}{2} \times 2 \times v^2$ $v^2 = \frac{2 \times 36}{2}$ $v = 6\ ms^{-1}$
5.9.7	A motor cyclist and his bike have a total mass of 360 kg and kinetic energy of 87120 J. What is his speed? $E_k = \frac{1}{2}mv^2$ $87120 = \frac{1}{2} \times 360 \times v^2$ $\frac{2 \times 87120}{360} = v^2$ $v = 22.0\ ms^{-1}$
5.9.8	A car has a mass of 900kg and is moving at 30ms^{-1}, calculate its kinetic energy. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 900 \times 30^2 = 4.0\ \times 10^5 J$
5.9.9	Calculate the kinetic energy of a rifle bullet with a mass of 20**g** and a speed of 400ms^{-1}. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 0.02 \times 400^2 = 1600\ J$
5.9.10	A car has a kinetic energy of 100**kJ** and a mass of 800kg, calculate its speed. $E_k = \frac{1}{2}mv^2$ $100 \times 10^3 = \frac{1}{2} \times 800 \times v^2$ $\frac{2 \times 100 \times 10^3}{800} = v^2 \qquad v = 16\ ms^{-1}$
5.10	**I can use *Ew=Fd*, *Ep=mgh*, *Ek=* ½ *mv*^{2} to solve problems involving conservation of energy**

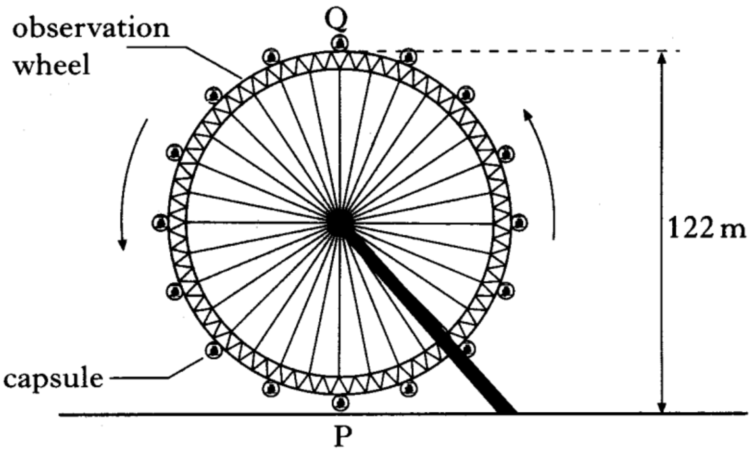
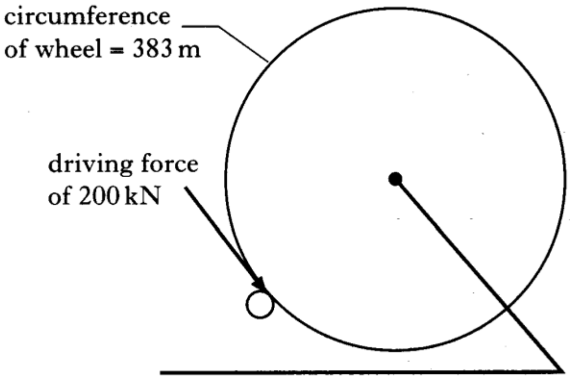
No.	CONTENT
5.10.1	A gardener pushes a wheelbarrow with a force of 250 N over a distance of 20 m. Calculate the work done. $E_w = Fd = 250 \times 20 = 5000\,J$
5.10.2	A stone falls from a cliff, which is 80 m high a) If air resistance can be ignored, calculate the speed at which it enters the water at the bottom of the cliff. $E_{p\,lost} = E_{k\,gained}$ $\cancel{m}gh = \frac{1}{2}\cancel{m}v^2 \qquad 2gh = v^2$ $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 80} = 40\ ms^{-1}$ b) If air resistance cannot be ignored, state the effect this will have on the speed of the stone as it enters the water. **The speed will be less/reduced as it enters the water** c) In practice, not all of the initial gravitational energy is transformed into kinetic energy. Other than kinetic energy, state the main form of energy produced. **Heat**
5.10.3	A librarian is placing books on to the library shelf which is 2 metres from the ground. He does 80 joules of work lifting the books from the floor to the shelf. (a) Calculate the weight of the books. $E_w = Fd$ $80 = W \times 2$ $W = 40\ N$ Or $E_p = mgh \quad 80 = W \times 2, \qquad W = 40J$ (b) Calculate the mass of the books. $W = mg$ $40 = m \times 9.8$ $\frac{40}{9.8} = m = 4\ kg$ **(c)** If each book has an average mass of 400 g calculate how many books the librarian places on the shelf. **400 g = 0.4 kg** $No\ of\ books = \frac{total\ mass}{mass\ of\ 1\ book} = \frac{4}{0.4} = 10$
5.10.4	A painter is painting the ceiling of a room. She fills her tray with paint and lifts it up the ladder. The weight of the full paint tray is 15.0 newtons and she lifts it a distance of 1.5 metres up the ladder. (a) Calculate the work done lifting the paint. $E_w = Fd$ $E_w = 15.0 \times 1.5 = 23\,J\ (2\ sig\ fig)$ (b) The painter drops the 0.64 kg roller to the floor from this height, calculate the gravitational potential energy it loses. ***NB This question is not about the paint tray so you cannot carry forward. Read the question!*** $E_p lost = mgh$

No.	CONTENT
	$E_plost = 0.64 \times 9.8 \times 1.5 = 9.4\,J$ (c) If all the gravitational potential energy is converted to kinetic energy calculate the speed of the roller when it lands on the dust sheet. $E_plost = E_kgained = \frac{1}{2}mv^2$ $9.4 = \frac{1}{2} \times 0.64 \times v^2$ $\frac{2 \times 9.4}{0.64} = v^2$ $v = 5.4\,ms^{-1}$
5.10.5	A car of mass 1000 kg is travelling at 20 ms^{-1}. (a) Calculate the kinetic energy of the car. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times 1000 \times 20^2 = 2.0 \times 10^5 J$ (b) If the maximum braking force is 5 kN, calculate the minimum braking distance. $E_klost = E_w\ in\ brakes = Fd$ $2.0 \times 10^5 = 5000 \times d$ $\frac{2.0 \times 10^5}{5000} = d = 40\,m$ (c) If the driver has a reaction time of 0.7 s, calculate the distance the car travels during this 'thinking time'. $v = \frac{d}{t}$ $20 = \frac{d}{0.7}$ $d = 20 \times 0.7 = 14\,m$ (d) Determine the total stopping distance. **Stopping distance = thinking distance + braking distance** **Stopping distance = 14m +40 m = 54 m**

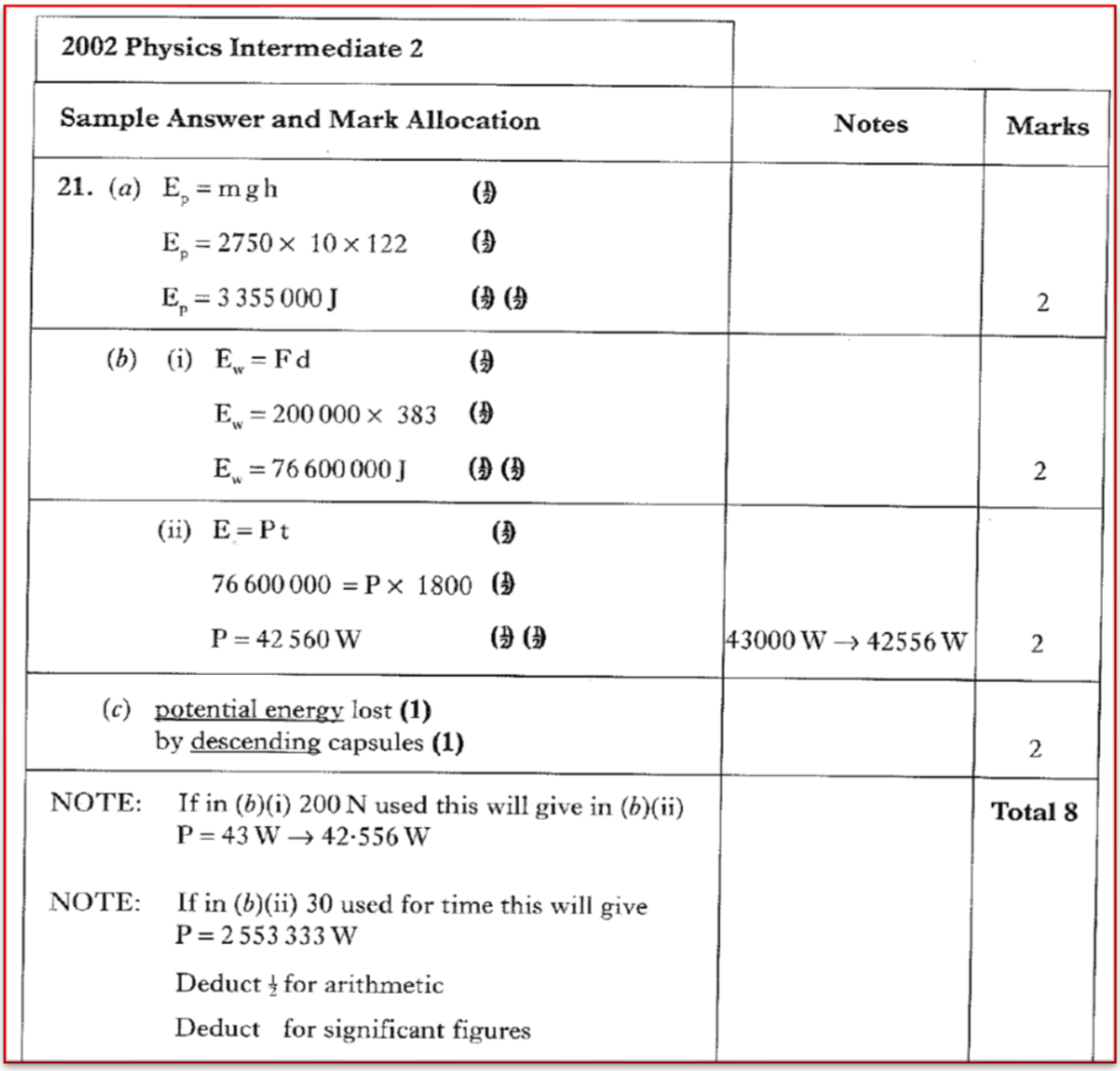
No.	CONTENT
5.10.6	A boy of mass 45 kg pulls a sledge of mass 15 kg up a slope at a constant velocity of 0·5 ms^{-1}. The boy then lies on the sledge and slides down the slope. When the boy and sledge are moving with a speed of 4·0 ms^{-1}, they run into a small snow drift which brings them to rest in a distance of 3·5 m. (i) Calculate the kinetic energy of the boy and sledge together, when they are travelling at a speed of 4·0 ms^{-1}. $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2} \times (45+15) \times 4^2 = 480\,J$ (ii) Calculate the average force required to bring the sledge and the boy to rest in 3·5 m. $E_k lost = E_w\ by\ snow = Fd$ $480 = \bar{F}\ \times 3.5$ $\frac{480}{3.5} = \bar{F} = 137\ N$ Average Force is 140 N (to 2 sig fig)
5.10.7 Repeat	See 5.5.1 (or thereabouts!) A lorry of mass 5000 kg rolls down a hill 20m high. The lorry rolls a distance of 300m, and is initially stationary. The average force of friction on the lorry is 500N. (i) Draw a diagram showing the journey of the lorry and mark on it the information given above. (ii) Calculate the change in the gravitational potential energy of the lorry as it rolls down the hill. (iii) State what happens to this energy as it rolls down the slope (iv) Determine the work done against friction (v) Determine the change in the kinetic energy of the lorry. (vi) Calculate the speed of the lorry at the bottom of the hill.

No.	CONTENT
5.10.8	An arrow of mass 60**g** is fired vertically upwards with a speed of 30ms^{-1}. The arrow rises upwards, reaches its maximum height, and then falls straight downwards. Assuming there is no air resistance, calculate (i) the initial kinetic energy of the arrow, $E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2}\times 0.060\times 30^2 = 27\,J$ (ii) the kinetic energy of the arrow at its highest point, **at its highest point *v* = 0 ms^{-1} so E$_k$ = 0 J** (ii) the potential energy of the arrow at its highest point, $E_k lost = E_p\ gained\ \therefore E_p = 27\,J$ (iii) the position of the highest point. $E_p = mgh$ $27 = 0.060\times 9.8\times h$ $\frac{27}{0.060\times 9.8} = h = 46\,m$
5.10.9	 The toe protectors in safety boots are tested by dropping a 30 kg steel block through a height of 2·45 m onto the boots. (a) Calculate the potential energy of the steel block just before it is released. $E_p = mgh$ $E_p = .30\times 9.8\times 2.45 = 720\,J$ (b) Calculate the speed of the steel block as it hits the toe protector. $E_p lost = E_k gained = \frac{1}{2}mv^2$ $720 = \frac{1}{2}\times 30\times v^2$ $\frac{2\times 720}{30} = v^2$ $v = 6.9\,ms^{-1}$

No.	CONTENT
5.10.10	A model train takes 30 seconds to travel along a 5 m section of track, which rises by 0.3 m. The train has a mass of 0.50 kg and the motor has a power of 3.0 W. The train is initially at rest, and has a final velocity of 0.5 ms^{-1}. Calculate (i) the energy supplied by the motor $E = Pt = 3.0 \times 30 = 90J$ (ii) the gain in kinetic energy $E_k gained = \frac{1}{2}mv^2$ $E_k gained = \frac{1}{2} \times 0.5 \times 0.5^2 = 0.6\,J$ (iii) the gain in Ep. $E_p = mgh$ $E_p = 0.5 \times 9.8 \times 0.3 = 1.5\,J$ (iv) the work done against friction, and $E_e = E_w + E_k + E_p$ $E_w = Ee - (Ek + Ep)$ $E_w = 90 - (0.6 + 1.5) = 88\,J$ (v) the average force of friction. $E_w = Fd$ $88 = F \times 5$ $F = \frac{88}{5} = 18\,N$
5.10.11	An apple of mass 100g is dropped from the top of the Eiffel Tower, a height of approximately 300m. a) Calculate the loss of potential energy as the apple falls through 300 m $E_p = mgh$ $E_p = 0.100 \times 9.8 \times 300 = 294\,J \cong 300J$ b) Calculate the expected kinetic energy it should have just before hitting the ground. $Ep\ lost = E_k gained = 300\,J$ c) Calculate the expected velocity as of the apple as it hits the ground. $300 = \frac{1}{2} \times 0.1 \times v^2$ $\frac{2 \times 300}{0.1} = v^2$ $v = \sqrt{\frac{2 \times 300}{0.1}} = 77\,ms^{-1}$ d) In reality explain if the speed is likely to be greater than/ less than / or the same as that expected, you must justify your answer. **Less, this calculation assumes there is no transfer of energy due to friction of the apple falling through the air. In reality there will be heat losses due to air resistance.**

No.	CONTENT
5.10.12	Int 2 2002 An observation wheel rotates slowly and raises passengers to a height where the can see across a large city. The passengers are carried in capsules.  (a) Each capsule is raised through a height of 122 m as it moves from P to Q. Each capsule with passengers has a total mass of 2750 kg. Calculate the gravitational potential energy gained by a capsule with passengers (b) The wheel is rotated by a driving force of 200 kN For one revolution, the driving force is applied through the circumference of the wheel, a distance of 383 m.  Calculate the work done by the driving force for one revolution.

No.	CONTENT



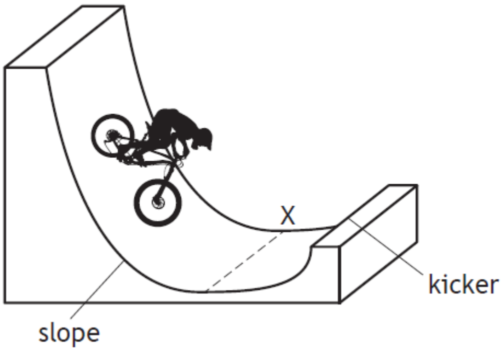
2002 Physics Intermediate 2

Sample Answer and Mark Allocation	Notes	Marks
21. (*a*) $E_p = mgh$ (½) $E_p = 2750 \times 10 \times 122$ (½) $E_p = 3\,355\,000$ J (½) (½)		2
(*b*) (i) $E_w = Fd$ (½) $E_w = 200\,000 \times 383$ (½) $E_w = 76\,600\,000$ J (½) (½)		2
(ii) $E = Pt$ (½) $76\,600\,000 = P \times 1800$ (½) $P = 42\,560$ W (½) (½)	43000 W → 42556 W	2
(*c*) potential energy lost **(1)** by descending capsules **(1)**		2
NOTE: If in (*b*)(i) 200 N used this will give in (*b*)(ii) $P = 43$ W → 42·556 W NOTE: If in (*b*)(ii) 30 used for time this will give $P = 2\,553\,333$ W Deduct ½ for arithmetic Deduct for significant figures		**Total 8**

5.10.13

SQA 2018

During a BMX competition, a cyclist freewheels down a slope and up a 'kicker' to complete a vertical jump.



The cyclist and bike have a combined mass of 75 kg.

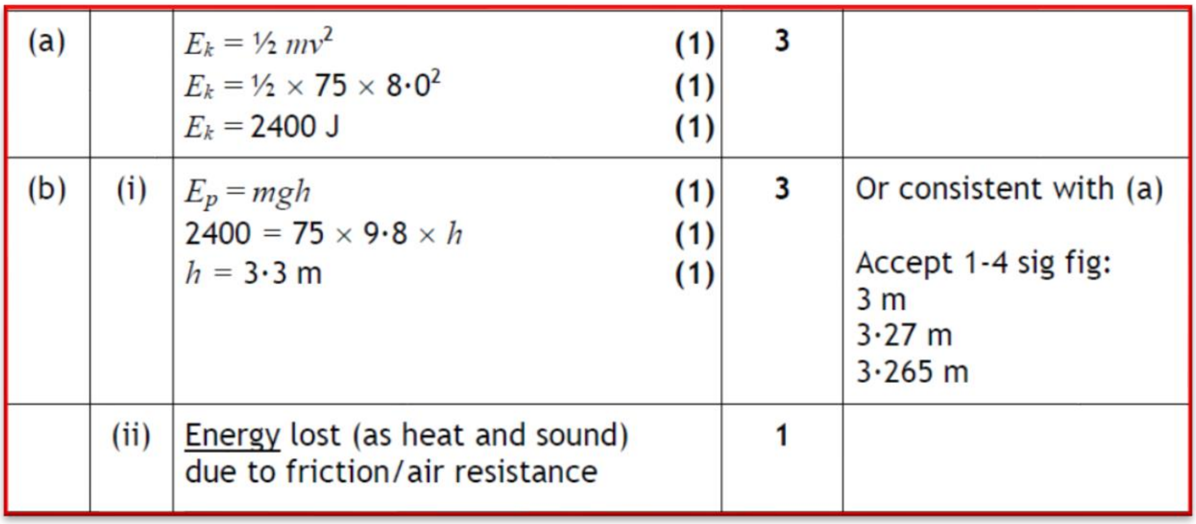
At point X the cyclist and bike have a speed of 8·0 m s^{-1}.

(a) Calculate the kinetic energy of the cyclist and bike at point X.

(b) (i) Calculate the maximum height of the jump above point X.

(ii) Explain why the actual height of the jump above point X would be less than the height calculated in (b) (i).

No.	CONTENT

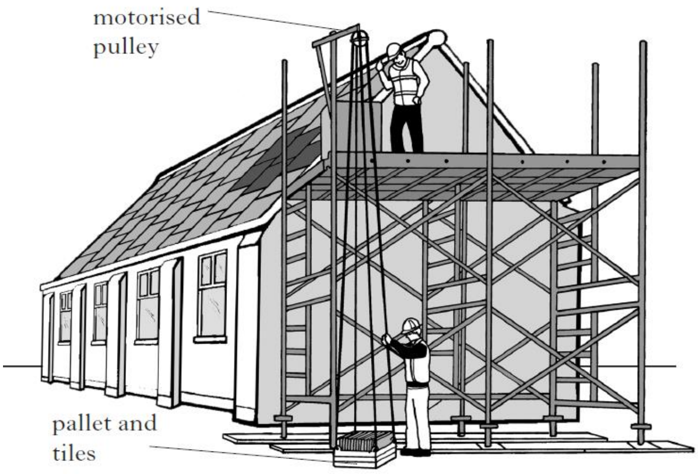


(a)		$E_k = ½\, mv^2$ (1) $E_k = ½ \times 75 \times 8{\cdot}0^2$ (1) $E_k = 2400$ J (1)	3	
(b)	(i)	$E_p = mgh$ (1) $2400 = 75 \times 9{\cdot}8 \times h$ (1) $h = 3{\cdot}3$ m (1)	3	Or consistent with (a) Accept 1-4 sig fig: 3 m 3·27 m 3·265 m
	(ii)	Energy lost (as heat and sound) due to friction/air resistance	1	

5.10.14

SQA SG CREDIT 2012 Q9

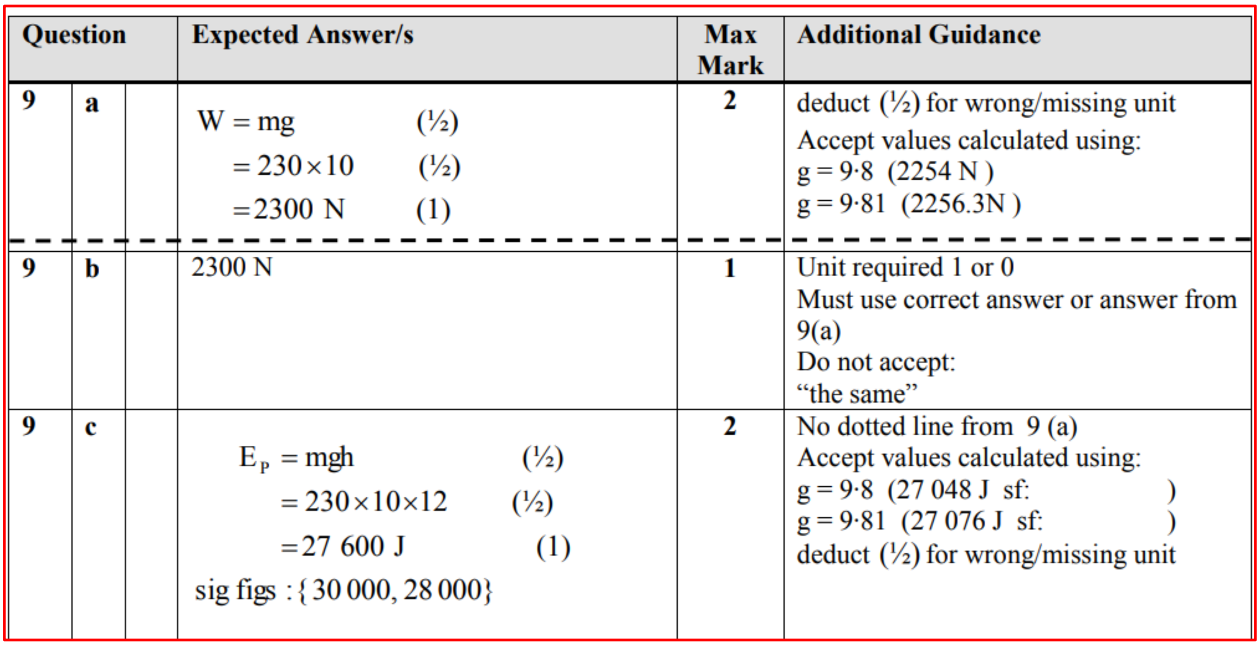
While repairing a school roof, workmen lift a pallet of tiles from the ground to the top of the scaffolding. This job is carried out using a motorised pulley system.



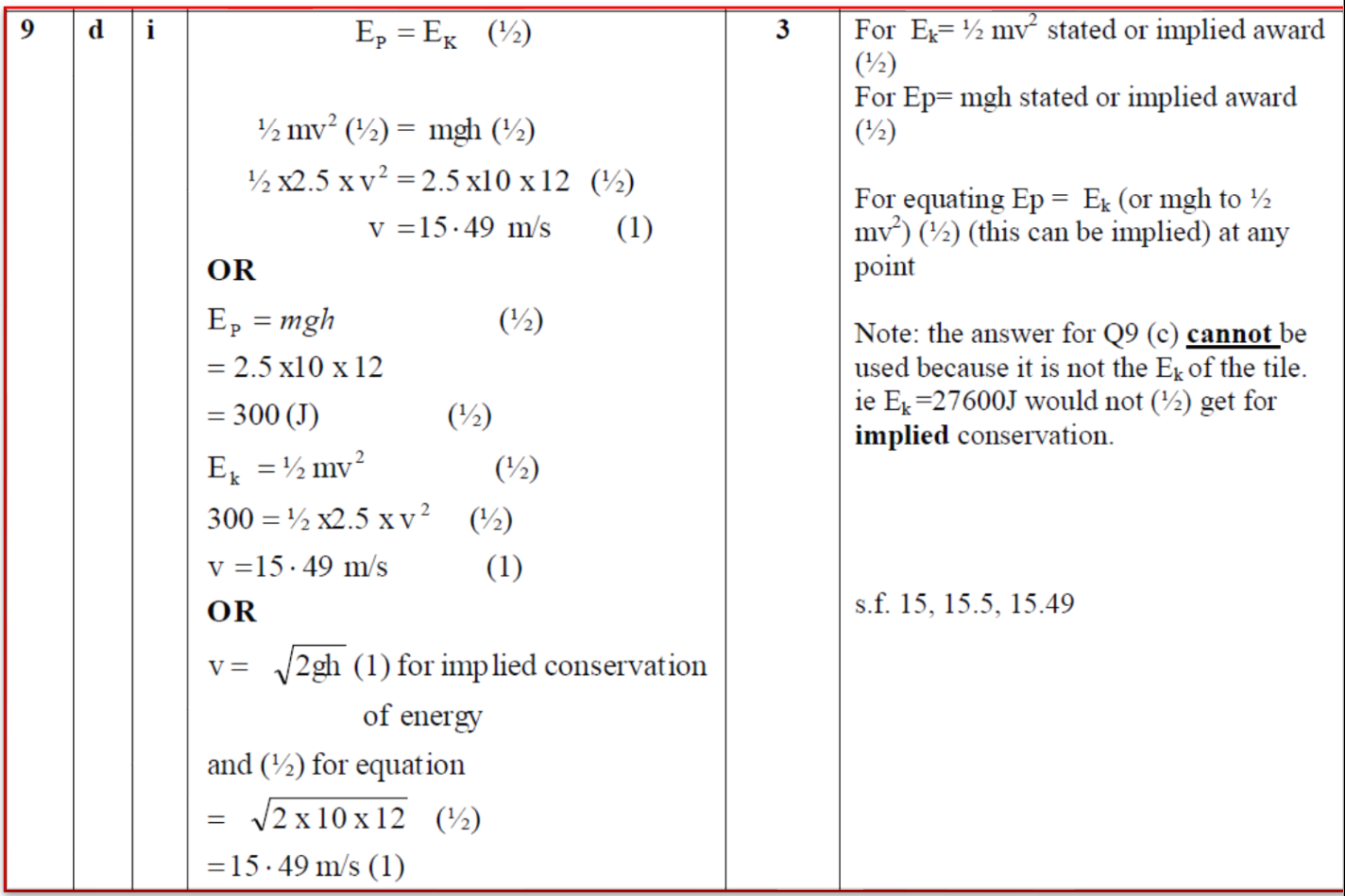
The pallet and tiles have a total mass of 230 kg.

(a) Calculate the weight of the pallet and tiles.
(b) State the minimum force required to lift the pallet and tiles.
(c) The pallet and tiles are lifted to a height of 12 m. Calculate the gravitational potential energy gained by the pallet and tiles.
(d) When the tiles are being unloaded onto the scaffolding, at a height of 12 m, one tile falls. The tile has a mass of 2·5 kg.
  (i) Calculate the final speed of the tile just before it hits the ground. Assume the tile falls from rest.
  (ii) Explain why the actual speed is less than the speed calculated in (d)(i).

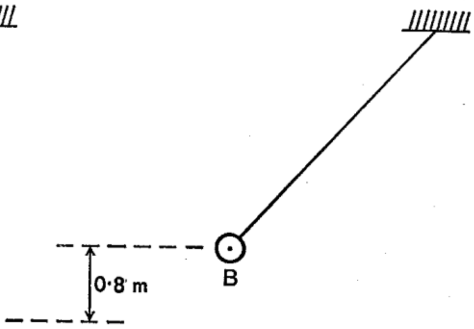
No.	CONTENT



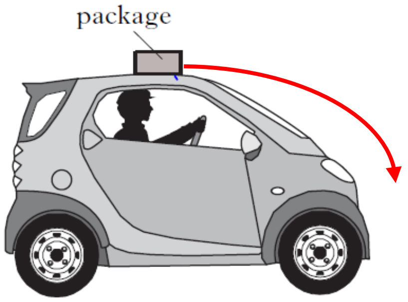
Question			Expected Answer/s	Max Mark	Additional Guidance
9	a		W = mg (½) $= 230 \times 10$ (½) $= 2300$ N (1)	2	deduct (½) for wrong/missing unit Accept values calculated using: g = 9·8 (2254 N) g = 9·81 (2256.3N)
9	b		2300 N	1	Unit required 1 or 0 Must use correct answer or answer from 9(a) Do not accept: "the same"
9	c		$E_P = mgh$ (½) $= 230 \times 10 \times 12$ (½) $= 27\ 600$ J (1) sig figs : {30 000, 28 000}	2	No dotted line from 9 (a) Accept values calculated using: g = 9·8 (27 048 J sf:) g = 9·81 (27 076 J sf:) deduct (½) for wrong/missing unit

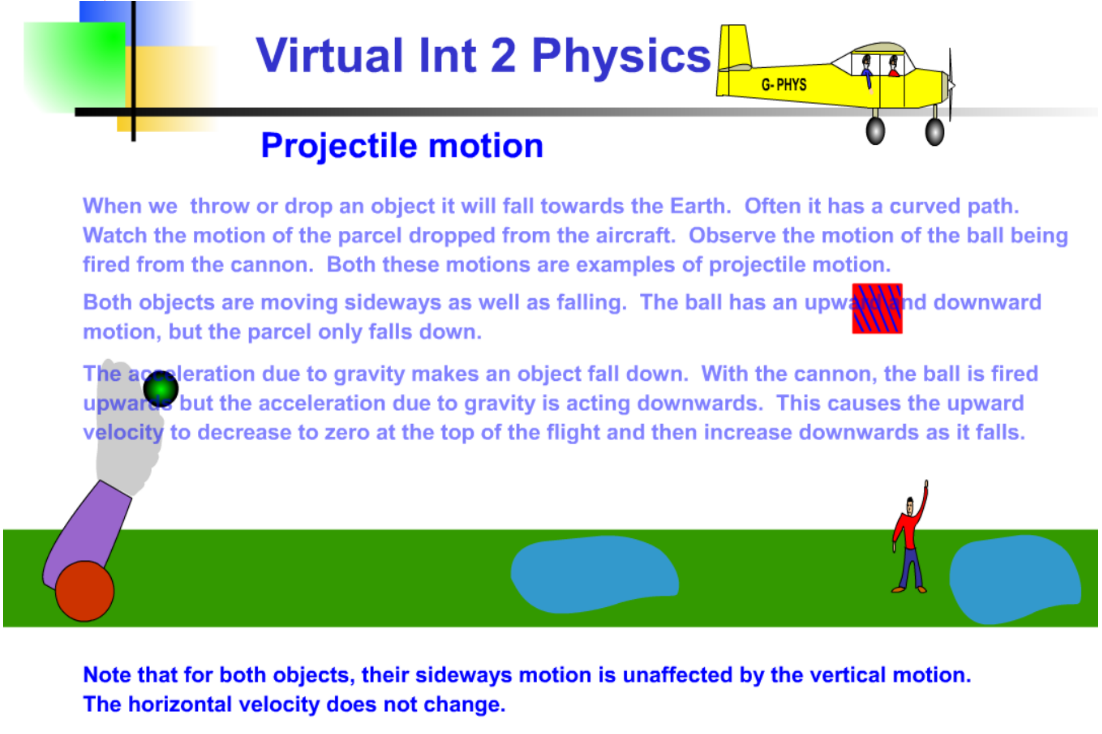


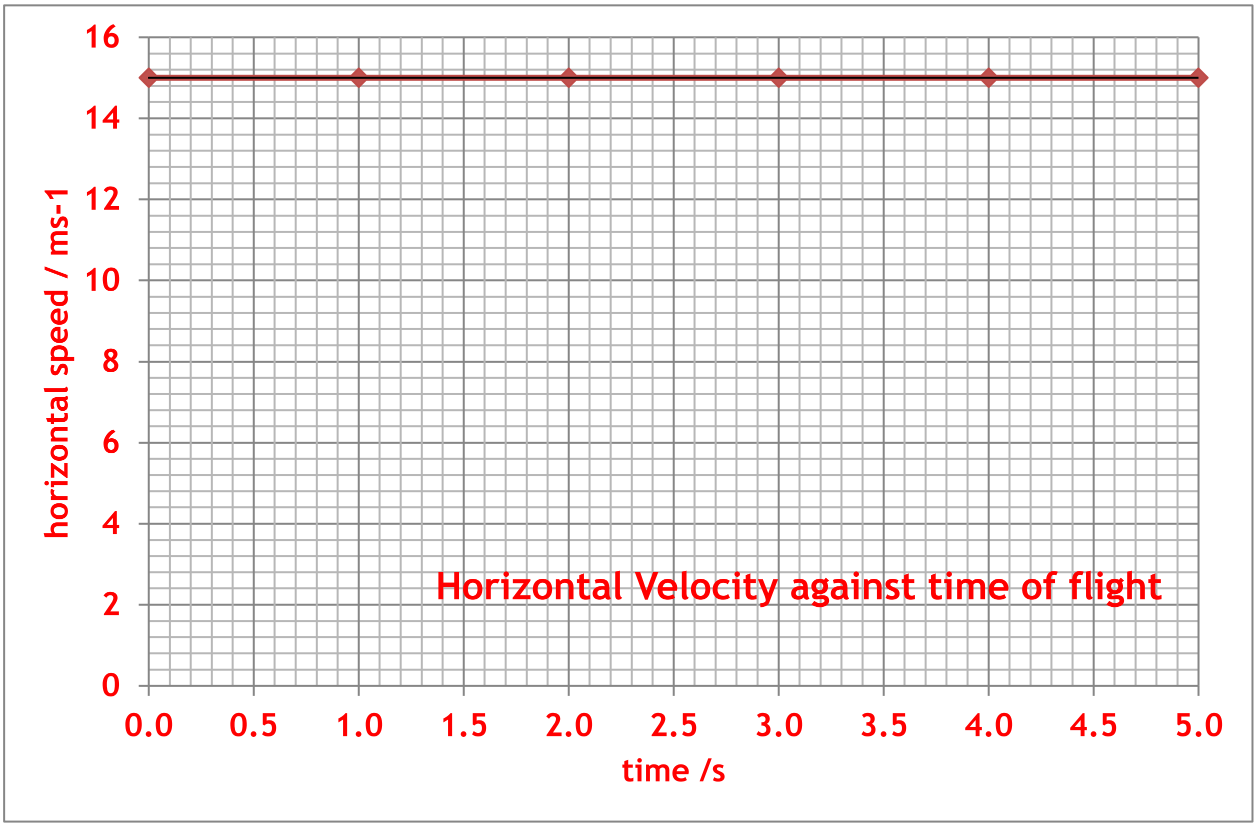
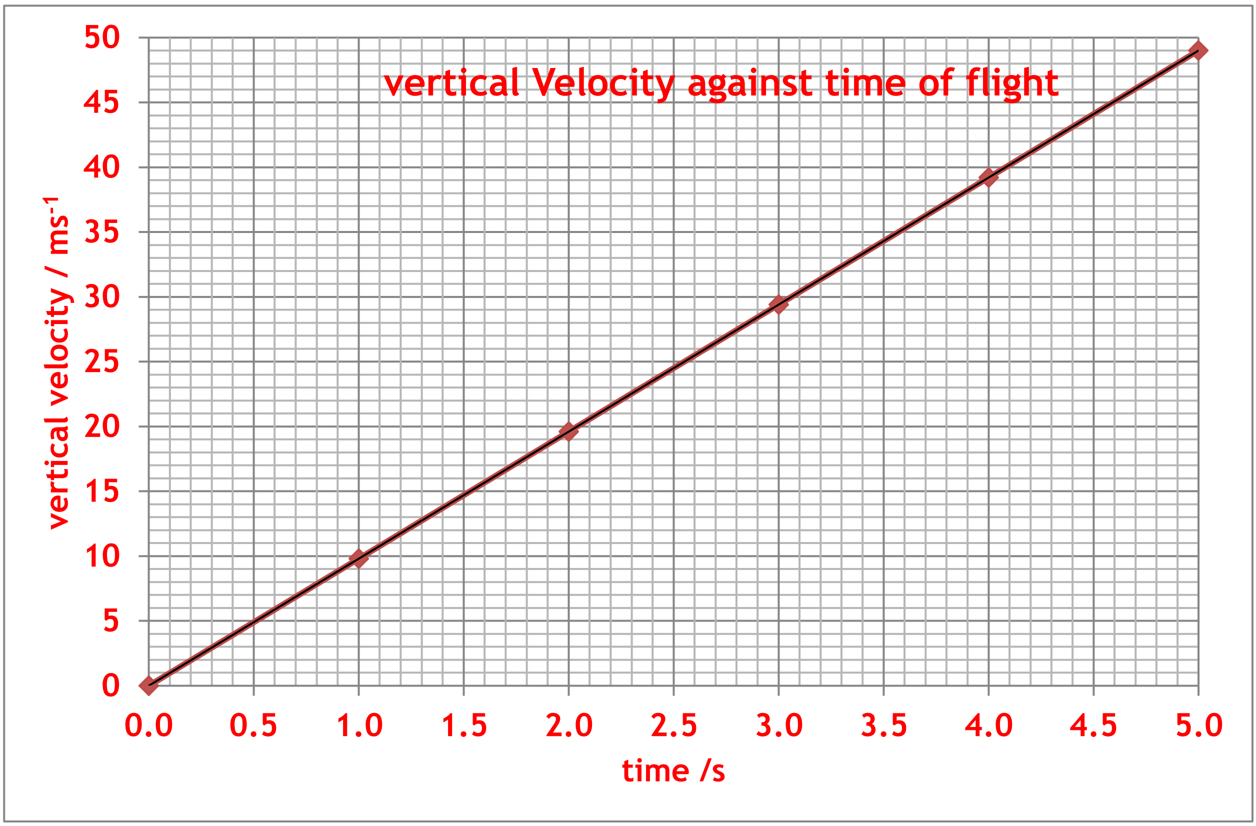
9	d	i	$E_P = E_K$ (½) $\frac{1}{2} mv^2$ (½) = mgh (½) $\frac{1}{2} \times 2.5 \times v^2 = 2.5 \times 10 \times 12$ (½) $v = 15 \cdot 49$ m/s (1) **OR** $E_P = mgh$ (½) $= 2.5 \times 10 \times 12$ = 300 (J) (½) $E_k = \frac{1}{2} mv^2$ (½) $300 = \frac{1}{2} \times 2.5 \times v^2$ (½) $v = 15 \cdot 49$ m/s (1) **OR** $v = \sqrt{2gh}$ (1) for implied conservation of energy and (½) for equation $= \sqrt{2 \times 10 \times 12}$ (½) $= 15 \cdot 49$ m/s (1)	3	For $E_k = \frac{1}{2} mv^2$ stated or implied award (½) For Ep= mgh stated or implied award (½) For equating Ep = E_k (or mgh to ½ mv^2) (½) (this can be implied) at any point Note: the answer for Q9 (c) **cannot** be used because it is not the E_k of the tile. ie E_k=27600J would not (½) get for **implied** conservation. s.f. 15, 15.5, 15.49

No.	CONTENT
5.10.15	Figure 1 shows a pendulum in its rest postion A. The pendulum bob has a mass of 0.3 kg. The bob is pulled to one side as shown in Figure 2 and held at position B, which is 0.8 m above the rest position. The bob is released from position B and swings to and fro until it comes to rest.  fig. 1  fig. 2 a) Calculate the gain in potential energy of the bob when it is moved from position A to position B. $E_p = mgh = 0.3 \times 9.8 \times 0.8 = 2.4\,J$ b) State in which position the bob has greatest kinetic energy. At the bottom of the swing where the Ep has been transformed to Ek c) Estimate the maximum speed of the bob. If all the gravitational potential energy is converted to Ek we can work out the speed. $E_p lost = E_k gained = \frac{1}{2}mv^2$ $2.4 = \frac{1}{2} \times 0.30 \times v^2$ $\frac{2 \times 2.4}{0.30} = v^2$ $v = 4.0\,ms^{-1}$ d) Describe the energy changes which take place from the time the bob is released until it comes to rest. The bob has gravitational Ep at the top of the swing, but as the speed is zero at this point it has zero Ek, as the pendulum drops the Ep is converted to Ek. As the pendulum bob moves up the other side the kinetic energy is converted back into gravitational potential energy. This would continue forever but it doesn't so there must be a further energy transformation. Some of the energy is converted to heat through friction with the pendulum and the air. This is why the pendulum eventually stops.
5.10.16	An object is dropped from a height of 0.75 m from the surface of the Earth. Calculate the velocity on landing. (No you don't need to know the mass, but start with the two formulae) $E_{p\ lost} = E_{k\ gained}$ $\cancel{m}gh = \frac{1}{2}\cancel{m}v^2 \qquad 2gh = v^2$ $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.75} = 3.8\,ms^{-1}$

Projectile Motion

No.	CONTENT
6.1	I can explain projectile motion
6.1.1	Explain the term projectile. **A projectile is an object thrown at an angle so that it has both horizontal and vertical motion.**
6.1.2	Explain what is special about the motion of a projectile. **It has both horizontal and vertical motion. Horizontal motion is steady/constant speed, vertically it accelerates downwards at 9.8 ms^{-2}**
6.1.3	SG – Credit – 2011 – Q13  A driver accidentally leaves a package on the top of a vehicle. When he notices he brakes suddenly and the package falls off the car. (i) Sketch the path taken by the package as it falls off the car. (ii) Describe both the horizontal and vertical motions of the package in as much detail as possible. **Horizontally the package moves forward at constant velocity/speed at the same speed that the package leaves the car (the speed the vehicle was travelling when the package left the top of the car- the speed the car was travelling before braking.** **Vertically the package moves with constant acceleration of 9.8 ms^{-2} from an initial vertical velocity of zero.**
6.2	I can use appropriate relationships to solve problems involving projectile motion from a horizontal launch, including the use of motion graphs.
6.2.1	A stone thrown horizontally from a cliff lands 24 m out from the cliff after 3.0 s. Find: a) the horizontal speed of the stone $\boldsymbol{v=\frac{d}{t}=\frac{24}{3}=8\ ms^{-1}}$ b) the vertical speed at impact. $\boldsymbol{v=u+at}$ $\boldsymbol{v=0+9.8\times 3=29\ ms^{-1}}$
6.2.2	A ball is thrown horizontally from a high window at 6 $ms^{-1}$and reaches the ground after 2.0 s. Calculate a) the horizontal distance travelled $\boldsymbol{v=\frac{d}{t}}$ $\boldsymbol{6=\frac{d}{2}}$ $\boldsymbol{d=6\times 2=12\ m}$ b) the vertical speed at impact. $\boldsymbol{v=u+at}$ $\boldsymbol{v=0+9.8\times 2.0=20\ ms^{-1}}$

No.	CONTENT
6.2.3	An aircraft flying horizontally at 150 ms^{-1}, drops a bomb which hits the target after 8.0 s. Find: a) the distance travelled horizontally by the bomb. $v = \frac{d}{t}$ $150 = \frac{d}{8.0}$ $d = 150 \times 8.0 = 1200\,m$ b) the vertical speed of the bomb at impact $v = u + at$ $v = 0 + 9.8 \times 8.0 = 78\,m$ c) the distance travelled horizontally by the aircraft as the bomb fell $d = 1200\,m$ The bomb was travelling horizontally at the same speed as the plane when it was dropped and continues at this speed, so providing the aircraft doesn't accelerate it too will have travelled the same horizontal distance as the bomb d) the position of the aircraft relative to the bomb at impact. The bomb will be directly under the aircraft.  Virtual Int 2 Physics Projectile motion When we throw or drop an object it will fall towards the Earth. Often it has a curved path. Watch the motion of the parcel dropped from the aircraft. Observe the motion of the ball being fired from the cannon. Both these motions are examples of projectile motion. Both objects are moving sideways as well as falling. The ball has an upw[illegible]nd downward motion, but the parcel only falls down. The acceleration due to gravity makes an object fall down. With the cannon, the ball is fired upwards but the acceleration due to gravity is acting downwards. This causes the upward velocity to decrease to zero at the top of the flight and then increase downwards as it falls. Note that for both objects, their sideways motion is unaffected by the vertical motion. The horizontal velocity does not change. *(from J Sharkey's Virtual Int 2 Physics)*
6.2.4	A ball is projected horizontally at 15 ms^{-1} from the top of a vertical cliff. It reaches the ground 5 s later. For the period between projection until it hits the ground, draw graphs with numerical values on the scales of the ball's a) horizontal velocity against time b) vertical velocity against time c) From the graphs calculate the horizontal and vertical distances travelled.

No.	CONTENT
a)	
b)	
c)	*horizontal distance* $= area\ under\ a\ v_h - \ t\ graph$ $Range\ = \ bh\ = 5.0\ \times 15\ = \ 75\ m$ *Vertical height=area under v-t graph* $height = \frac{1}{2}bh$ $height = \left(\frac{1}{2} \times 5.0 \times 49\right) = 123\ m$

<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td>6.2.5
repeat</td><td>
A projectile is fired horizontally at 100ms^{-1}. (See later for correct answers using g=9.8 ms-2

(i) How long will it take it to travel a horizontal distance of 50m?

$$time=\frac{distance}{speed}=\frac{d}{v}=\frac{50}{100}=0.5s$$

(ii) What will its vertical velocity be when it hits the ground?

$$a=\frac{v-u}{t} \text{ or } v=u+at$$

$$v=0+10\times 0.5=5m/s$$

(iii) What will be its average vertical speed?

$$\bar{v}=\frac{v+u}{2}=\frac{5+0}{2}=2.5m/s$$

(iv) How far will it fall in the 50m?

$$speed=\frac{distance}{time} \text{ or distance = speed } \times time$$

$$d = 1 \times 0.5=0.5m$$
</td></tr>
<tr><td>6.2.6</td><td>
A ball rolls along a flat roof at 2ms^{-1} and rolls off the edge.

(i) If the ball takes 1.5 seconds to fall what is the final vertical speed of the ball on landing?

$$a=\frac{v-u}{t} \text{ or } v=u+at$$

$$v=0+10\times 1.5=15m/s$$

(ii) How high is the roof from the ground?

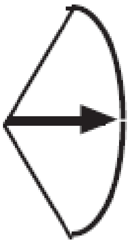
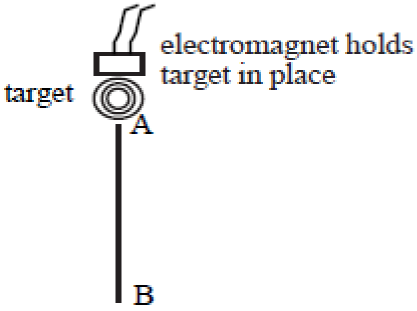
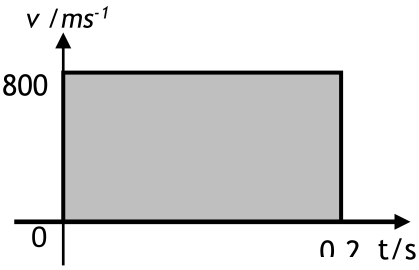
distance or height= average speed × time

$$d=\left(\frac{v+u}{2}\right)\times t=\left(\frac{v+u}{2}\right)\times t=\left(\frac{15+0}{2}\right)\times 1.5=11.25m$$

(iii) How far away from the base of the building will it land?

$$speed=\frac{distance}{time} \text{ or distance = speed } \times time$$

$$d = 2 \times 1.5=3m$$
</td></tr>
</table>

No.	CONTENT
6.2.7	In the experimental set-up shown below, the arrow is lined up towards the target. As it is fired, the arrow breaks the circuit supplying the electromagnet, and the target falls downwards from A to B.   a) Explain why the arrow will hit the target. **The arrow and the target are released at the same time. The initial vertical velocity of the arrow and the target are both 0 ms^{-1}. Both fall under the force of gravity and accelerate at 9.8 ms^{-2}, so all through the journey the target and the arrow are lined up.** b) Suggest one set of circumstances when the arrow would fail to hit the target. **If the distance from the arrow and target was large and the target either failed to drop or there was a delay in demagnetising the electromagnet the arrow would fail to hit the target as the target would not fall at the same instant as the arrow.** (you must assume it is always lined up correctly).
6.3	I can state what is represented by the area under v_h-t graph.
6.3.1	State what is represented by the area under v_h-t graph **The area under a vh-t graph gives the horizontal distance travelled by the object called the range.**
6.4	I can make calculations from the area under a v_h-t graphs
6.4.1	A bullet is fired from a gun and the horizontal velocity of the bullet is shown in the graph below. Calculate the range of the bullet. 
	$Range = area\ under\ a\ v_h - t\ graph$ $Range = bh = 800 \times 0.2 = 160\ m$

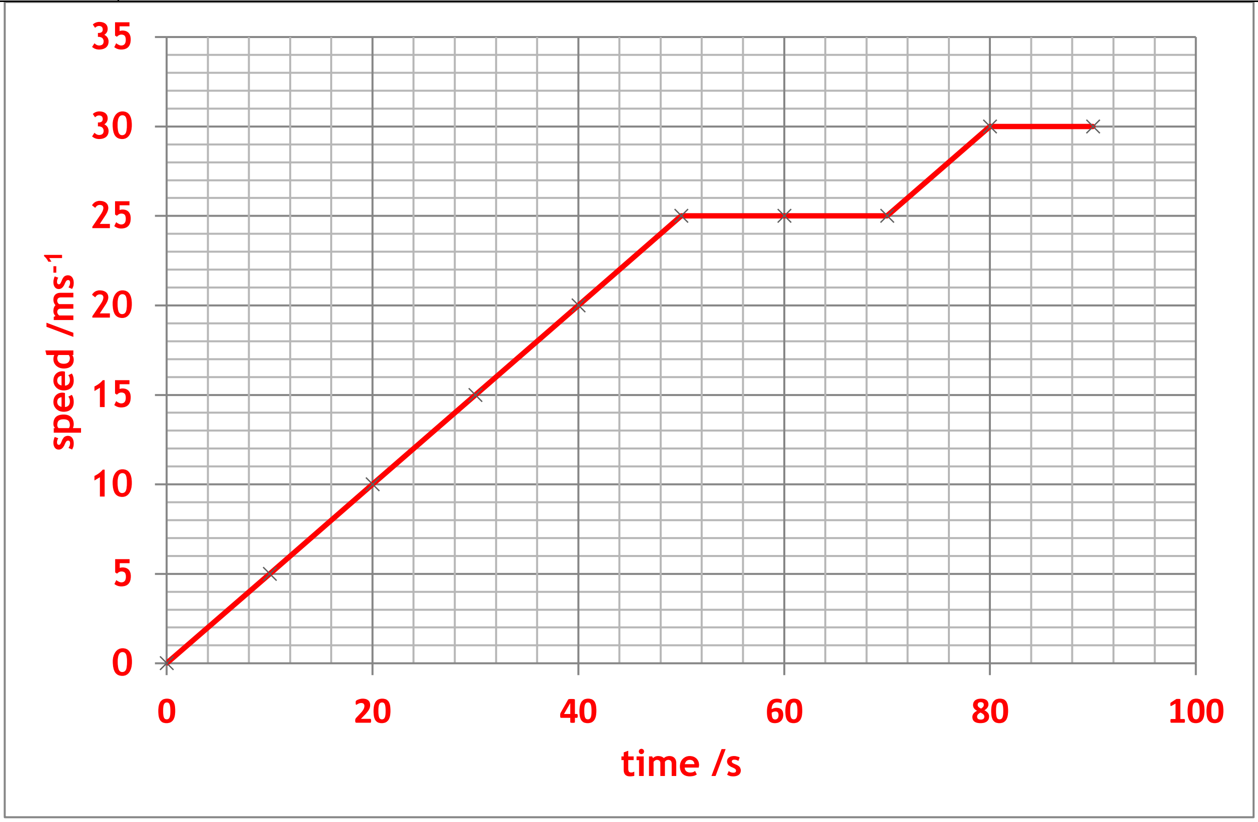
No.	CONTENT
6.4.2	Draw a speed time graph to represent the following motion recorded for a train leaving a station.

Time (s)	0	10	20	30	40	50	60	70	80	90
speed (m/s)	0	5	10	15	20	25	25	25	30	30

Use the graph to calculate:

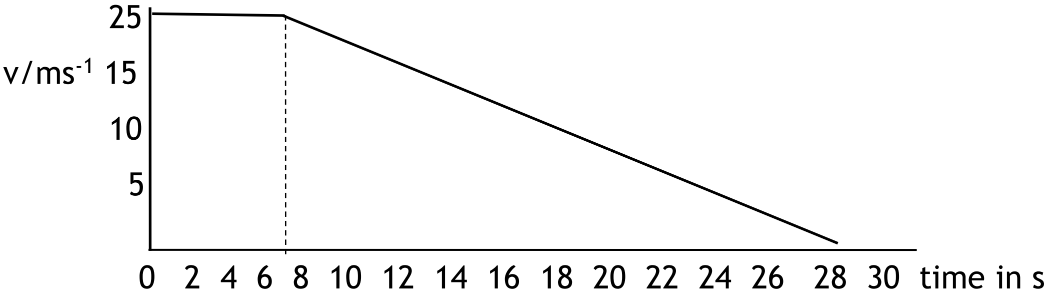
(*a*) describe the motion of the train during the 90 seconds

(*b*) the distance travelled by the train in 90 seconds.



<table>
<tr><th>No.</th><th>CONTENT</th></tr>
<tr><td>6.4.3</td><td>

While driving along a motorway a driver spots an accident and brakes. The speed time graph below represents the motion of the car from the instant the driver sees the accident.



(*a*) When did the driver brake? 7s

(*b*) Calculate how far the car travelled before braking.

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

d=area under v-t graph

$$d=v\times t=7\times 25=175\ m$$

(c) Calculate how far the car travelled after the driver braked

d=area under v-t graph

$$height=\frac{1}{2}bh$$

$$height=\left(\frac{1}{2}\times 21\times 25\right)=260\ m$$

</td></tr>
<tr><td>6.4.4</td><td>

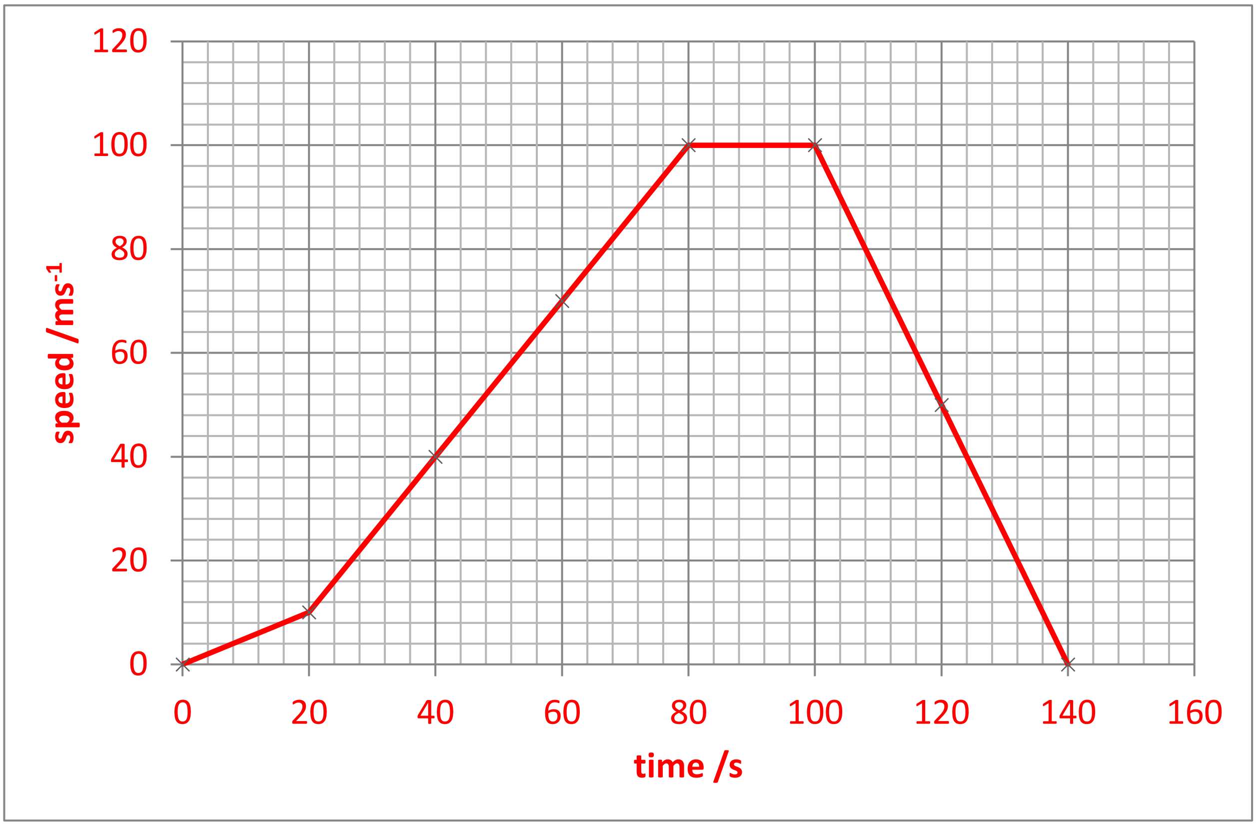
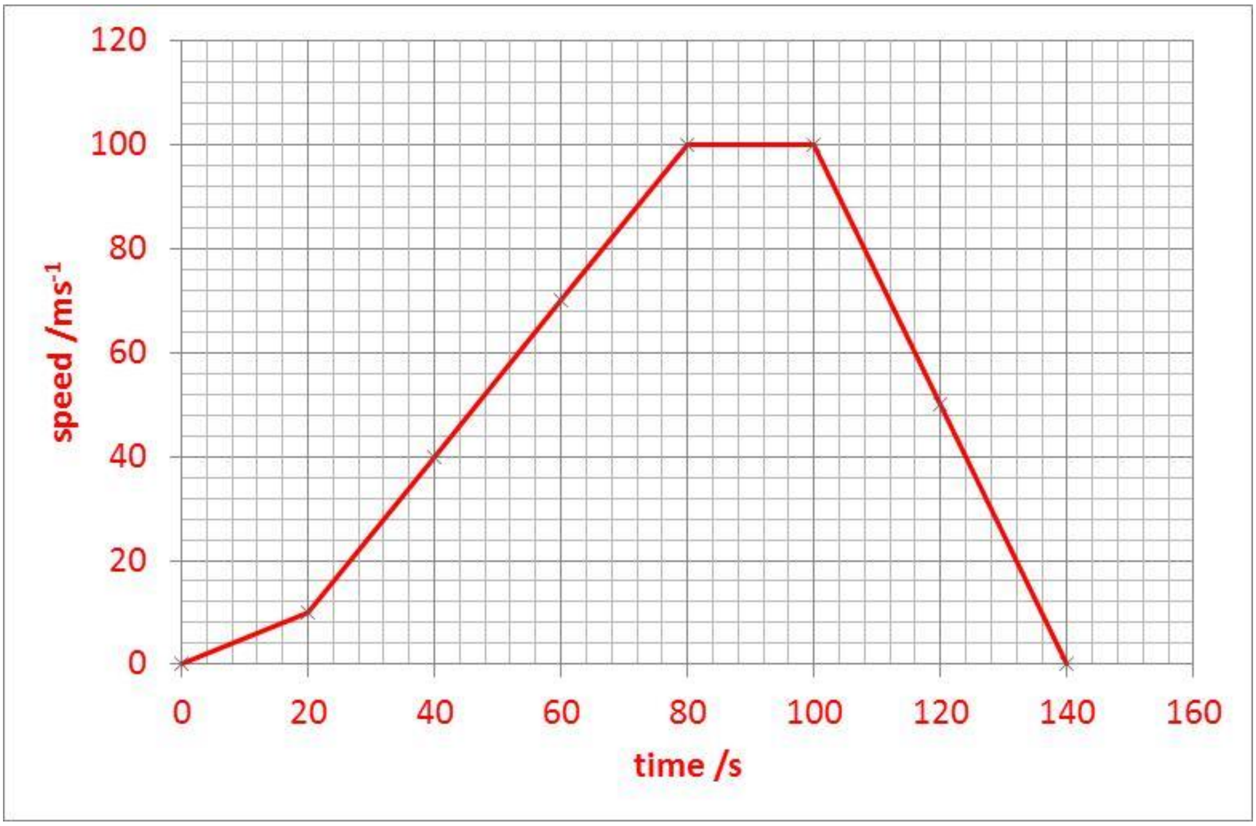
During a test run of a TACV (tracked air-cushioned vehicle or hovertain), its speed along a straight level track was recorded as shown in the table below.

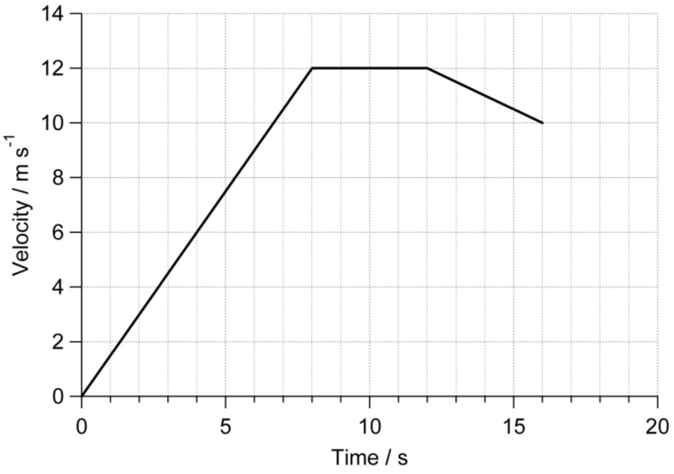
i) Draw a graph of the train's motion during the test run.

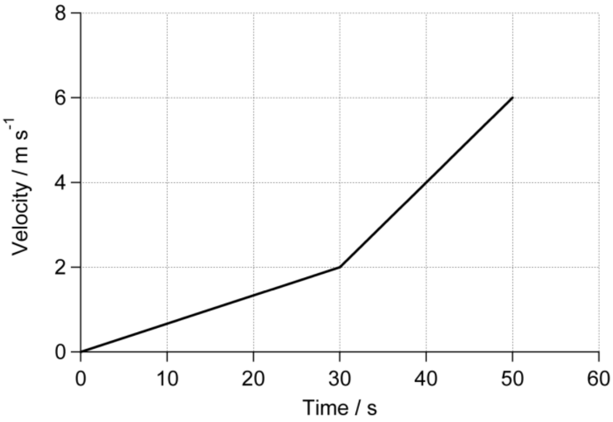
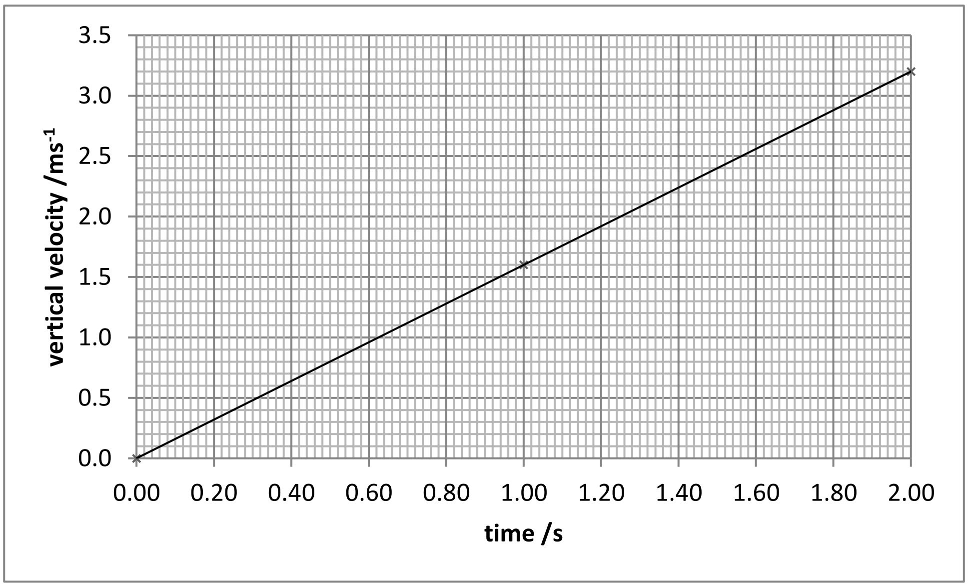
ii) Calculate the distance travelled during the test run.

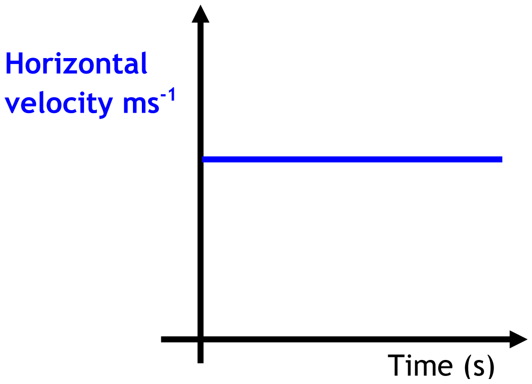
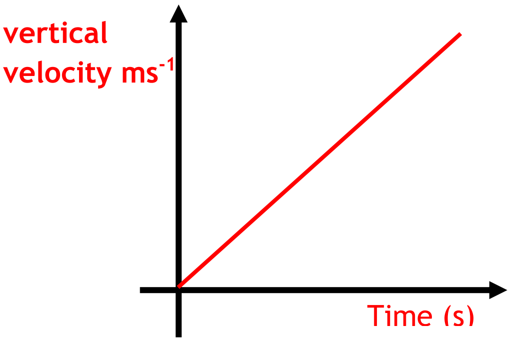
<table>
<tr><th>Time (s)</th><th>Speed (ms⁻¹)</th></tr>
<tr><td>0</td><td>0</td></tr>
<tr><td>20</td><td>10</td></tr>
<tr><td>40</td><td>40</td></tr>
<tr><td>60</td><td>70</td></tr>
<tr><td>80</td><td>100</td></tr>
<tr><td>100</td><td>100</td></tr>
<tr><td>120</td><td>50</td></tr>
<tr><td>140</td><td>0</td></tr>
</table>

</td></tr>
</table>

No.	CONTENT
	 II) Distance travelled = area under the v-t graph 

No.	CONTENT
6.4.5	 The graph shows the speed of a runner during a race. (a) Describe the motion of the runner. ***Motion should mention speed/ velocity or acceleration*** **The runner starts from rest and has a constant acceleration between 0 and 8 s until he reaches a velocity of 12 ms-1. He then travels at constant velocity between 8 and 12 s and then decelerates/negatively accelerates/ slows down at a constant rate from 12-16s** (b) Calculate the distance covered by the runner in the first eight seconds of the race. **Distance covered during first 8s = area under a v-t graph (0-8s)** **Distance = ½ bh = ½ × 8×12 = 48 m** (c) Calculate the distance she ran in the last four seconds. **Distance covered = area under a v-t graph (12-16s)** **Distance = ½ bh + bh = (½ × 4×2)+(10 ×4) = 44 m** (d) Calculate the length of the race. **Distance covered during 8 to 12 s** **= area under a v-t graph (between 8 and 12s)** **Distance = bh = 4×12 = 48 m** **Total distance travelled = total area under the v-t graph** **= 48+48+44 m = 140 m**
6.5	I can state what can be found from the area under v_V-t graph.
6.5.1	State what can be found from the area under v_V-t graph. **Height the object has fallen (vertical distance travelled)**
6.6	I can calculate the height, and acceleration from v_V-t graphs

No.	CONTENT
6.6.1	 A hot air balloon is released and accelerates upwards. During the lift, some sand bags are released, and the acceleration increases. The graph shows the vertical motion of the balloon during the first 50s of its flight. (a) Calculate the height of the balloon when the sandbags are released. **The sandbags were released at 30 s as this was when there was an acceleration. To find the height find the area under the graph from 0 to 30 s.** $height = displacement = area\ under\ v - t\ graph$ $height = \frac{1}{2}bh = \frac{1}{2} \times 30 \times 2 = 30\ m$ (b) Calculate the height of the balloon after 50 s. $height = displacement = area\ under\ v - t\ graph$ $height = \frac{1}{2}bh + bh + \frac{1}{2}bh$ $height = \left(\frac{1}{2} \times 30 \times 2\right) + \left(\frac{1}{2} \times (50 - 30) \times (6 - 2)\right) + 20 \times 2$ $height = 30 + 40 + 40 = 110\ m$
6.6.2	The graph below shows the motion of an object dropped just above the surface of a celestrial body.  a) Calculate the acceleration due to gravity of the object. **Remember choose points on the line and not given points. Find where the line cross the intersect of two gridlines.**

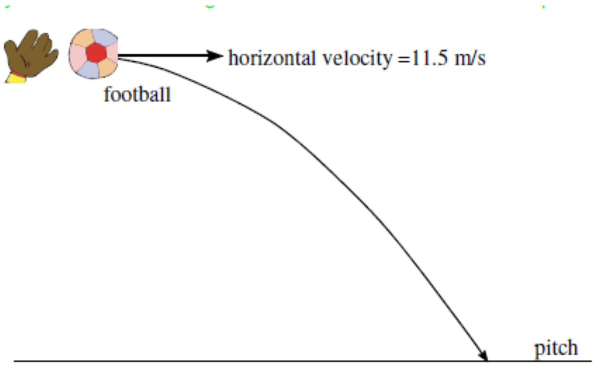
No.	**CONTENT**
	$acceleration = m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{3.0 - 0.9}{1.88 - 0.56} = 1.6\, ms^{-2}$ b) Using the data sheet find from which celestial body the object was dropped. **Acceleration due to gravity = g = 1.6 ms^{-2}, from the data sheet this is the moon.** c) Calculate the height above the surface from which the object was dropped. $height = displacement = area\ under\ v - t\ graph$ $height = \frac{1}{2}bh$ $height = \left(\frac{1}{2} \times 2.0 \times 3.2\right) = 3.2\, m$
6.7	I can state and use the relationships from v_h-t graphs and v_v-t graphs
6.7.1	State the equations required to find out range, speed and time for the horizontal component of projectiles. $Range\ = d = v_h t$ *Where d = range, v_h= constant vertical speed, t= time*
	 
6.7.2	State the equations required to calculate information for the vertical component of projectiles. $a = \frac{v_v - u_v}{t} = a = \frac{v_v - 0}{t}$ $where\ a = acceleration$ $v_v = vertical\ final\ velocity, u_v = initial\ vertical\ velocity\ (= 0\ ms^{-1}\ at\ N5)$ *t=time* *to find the average velocity over this time* $\overline{v} = \frac{v_v - u_v}{2}$ *to find the height fallen* $s_v = \overline{v} \times t$ *Or* $s_v = \frac{v_v - u_v}{2} \times t$

No.	CONTENT
6.7.3	A projectile is fired horizontally at 100 ms^{-1}. (a) Determine the time it takes to travel a horizontal distance of 50 m. $Range = d = v_h t$ $50 = 100 \times t$ $\frac{50}{100} = t = 0.5\ s$ (b) Calculate the vertical velocity when it hits the ground. $a = \frac{v_v - u_v}{t}$ $9.8 = \frac{v_v - 0}{0.5}$ $v_v = 9.8 \times 0.5 = 4.9\ ms^{-1}$ (c) Calculate its average vertical speed during the journey. $\overline{v} = \frac{v_v - u_v}{2}$ $\overline{v} = \frac{4.9 - 0}{2} = 2.5\ ms^{-1}$ (d) Calculate the height it falls in the 50 m. $s_v = \overline{v} \times t$ $s_v = 2.5 \times 0.5 = 1.3\ m$
6.7.4	A ball rolls along a flat roof at 2ms^{-1} and rolls off the edge. a) If it takes 1.5 s to fall to the ground determine its speed on landing. $a = \frac{v_v - u_v}{t}$ $9.8 = \frac{v_v - 0}{1.5}$ $v_v = 9.8 \times 1.5 = 15\ ms^{-1}$ *b)* Determine the height of the roof. $\overline{v} = \frac{v_v - u_v}{2}$ $\overline{v} = \frac{15 - 0}{2} = 7.5\ ms^{-1}$ $s_v = \overline{v} \times t$ $s_v = 7.5 \times 1.5 = 11\ m$ c) Calculate the distance from the base of the building to where it lands. $Range = d = v_h t$ $s_h = 2 \times 1.5 = 3.0\ m$

No. **CONTENT**

6.7.5

Jordan the goalkeeper punches a football which has been kicked across his goal mouth. The football leaves his glove with a horizontal velocity of 11.5 ms^{-1} to the right and takes 0.80 s to land on the pitch.



(a) Describe the horizontal velocity of the football from the instant it is punched to the instant it lands.

The ball travels with constant horizontal velocity of 11.5 ms^{-1}

(b) Show, by calculation involving horizontal motion, that the horizontal displacement travelled by the football during the 0.8 s is 9.2 m to the right.

$$s_h = v_h t$$

$$s_h = 11.5 \times 0.8 = 9.2\ m$$

NB for a show that question you mustn't use the answer given in your calculation but you must show that this is the final answer. Always start with a formula to get any marks

(c) At the instant the football leaves Jordan's hand, the downward vertical velocity of the football is 0 ms^{-1}. Calculate the downward vertical velocity of the football as it lands.

$$a = \frac{v_v - u_v}{t}$$

$$9.8 = \frac{v_v - 0}{0.8}$$

$$v_v = 9.8 \times 0.8 = 7.8\ ms^{-1}$$

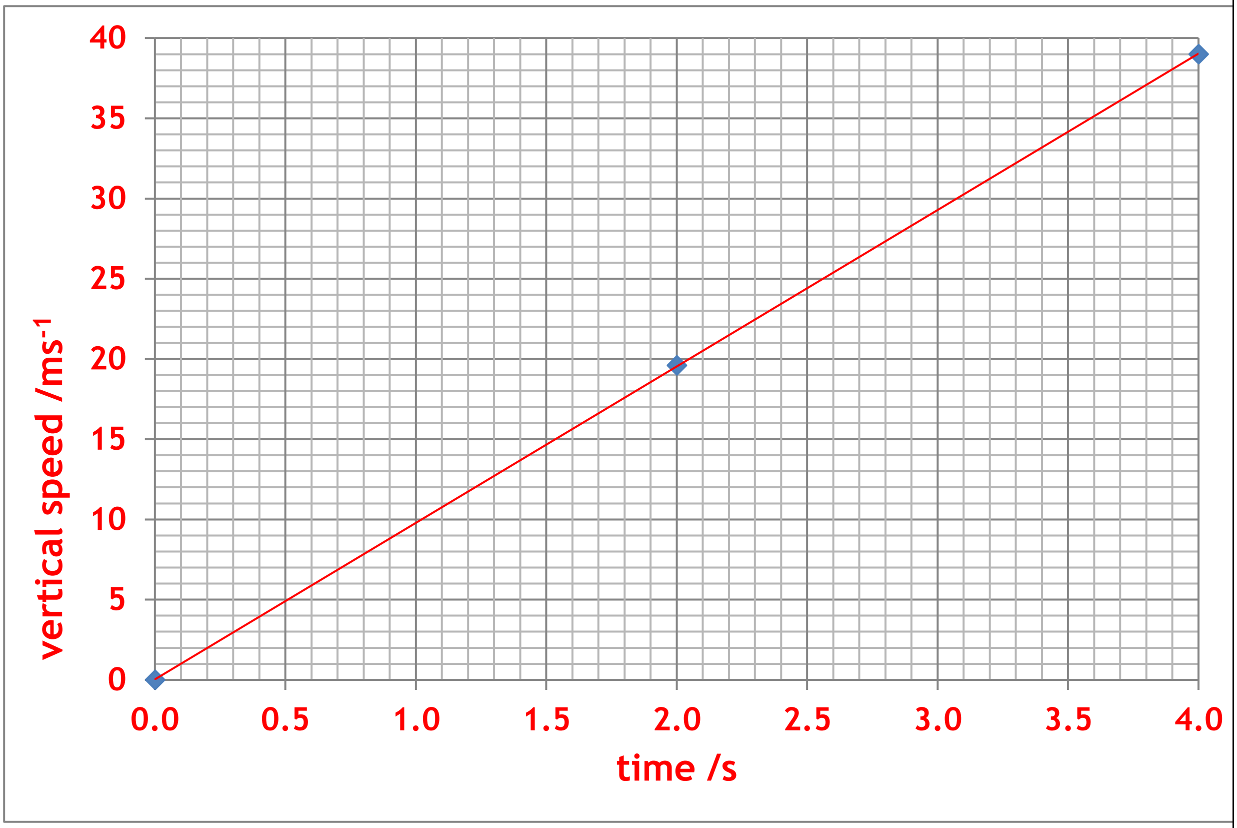
d) Determine the height of the roof.

$$\bar{v} = \frac{v_v - u_v}{2}$$

$$\bar{v} = \frac{7.8 - 0}{2} = 3.9\ ms^{-1}$$

$$s_v = \bar{v} \times t$$

$$s_v = 3.9 \times 0.8 = 3.1\ m$$

No.	CONTENT
6.7.6	A rocket is fired horizontally from a cliff top at 40 ms^{-1} to the right. The rocket hits the sea below after 4 s. a) State the rocket's horizontal component of velocity just before it hits the sea. **As the rocket is fired the horizontal motion remains constant for the journey at** 40 ms^{-1} to the right b) Calculate the rocket's range (horizontal displacement). $s_h = v_h t$ $s_h = 40 \times 4 = 160\ m$ c) Calculate the rocket's vertical component of velocity just before it hits the sea. $a = \frac{v_v - u_v}{t}$ $9.8 = \frac{v_v - 0}{4}$ $v_v = 9.8 \times 4 = 39\ ms^{-1}$ d) Sketch the velocity-time graph for the rocket's vertical motion.  e) Use the graph to determine the rocket's vertical displacement (the height of the cliff). **Area under the v-t graph is the vertical displacement** $height = \frac{1}{2}bh$ $height = \left(\frac{1}{2} \times 4.0 \times 39\right) = 190\ m$

No. **CONTENT**

6.7.7 Ellis kicks a football off a cliff with a horizontal velocity of 5 ms^{-1} to the right. The football lands on ground below the cliff 2.5 s later.

a) Calculate the ball's horizontal component of velocity just before it hits the ground.

5 ms^{-1} *as this remains constant*

b) Calculate the range of the ball (horizontal displacement).

$$s_h = v_h t$$

$$s_h = 5 \times 2.5 = 13\ m$$

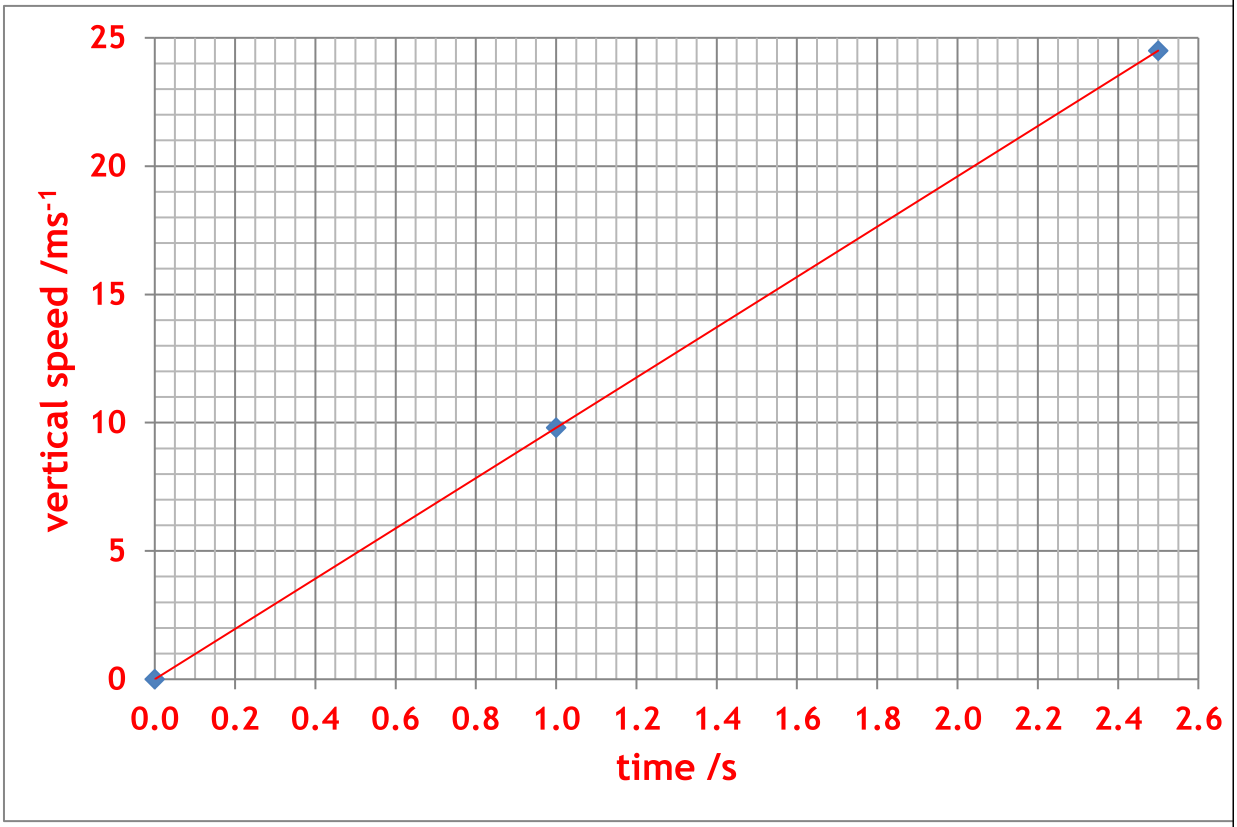
c) Calculate the vertical component of the ball's velocity just before it hits the ground.

$$a = \frac{v_v - u_v}{t}$$

$$9.8 = \frac{v_v - 0}{0.8}$$

$$v_v = 9.8\ \times 2.5 = 25\ ms^{-1}$$

d) Sketch the velocity-time graph for the ball's vertical motion.



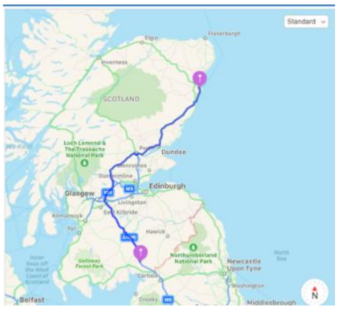
e) Use the graph to determine the ball's vertical displacement (the height of the cliff).

Area under the v-t graph is the vertical displacement

$$height = \tfrac{1}{2}bh$$

$$height = \left(\frac{1}{2} \times 2.5 \times 25\right) = 31\ m$$

No.	CONTENT
6.8	I can explain satellite orbits in terms of projectile motion, horizontal velocity and weight.
6.8.1	Explain how gravity keeps a satellite in orbit. The force of **gravity provides the force needed to maintain the stable orbit of both planets around a star and also of moons and artificial satellites around a planet.** **For an object to remain in a steady, circular orbit it must be travelling at the right speed. Too slow and it will spiral to earth, to high and it will leave the orbit..**
6.8.2	Explain why a satellite needs a horizontal motion and a vertical motion to stay in orbit. If a projectile has enough speed, it will move through space constantly falling towards the Earth in free fall. With the high constant horizontal speed the projectile falls around the curvature of the Earth. Without a horizontal speed the satellite would fall to Earth. Without the vertical motion (constant acceleration) the satellite would move away from the Earth at constant speed, leaving the gravitational field.

No.	CONTENT
6.8.3 OEQ	A group of students are watching a video clip of astronauts on board the International Space Station (ISS) as it orbits the Earth.  One student states, ‘I would love to be weightless and float like the astronauts do on the ISS.’ Using your knowledge of physics, comment on the statement made by the student. The key to this question are in the words **weightless** and **float** Possible answers  1) The members on the ISS are not weightless but are in freefall 2) Weightless would mean there is no force of gravity on the object 3) Freefall is falling under the acceleration due to gravity 4) The ISS is only between 330 km (205 mi) and 410 km (255 mi) up (that’s the approximate distance from Lockerbie to Aberdeen) 5) At the altitude of ISS (about 400 km), the gravitational field strength if about 0.885 g, or 8.7ms^{-2}. 6) Use W=mg for this calculation 7) (Not needed until Higher but to find this value you are using $F = \frac{GMm}{r^2}$) where r is the value from the centre of the Earth to the ISS 8) Not floating but all objects are falling at the same rate so that to an observer on the ISS a ball appears to float 9) The ISS is like a satellite with a horizontal velocity of approximately 27600 kmh^{-1} 10) Discuss the motion of a projectile with constant horizontal velocity and constant vertical acceleration 11) Discuss Newton’s Thought Experiment. 12) Finish with a flourish – would you like to be an astronaut on the ISS?