

SECTION A

Answer ALL questions.

All multiple choice questions must be answered with a cross for the correct answer from A to D.

If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

- 1 Select the row of the table that identifies an SI base unit and a derived unit.

	Base unit	Derived unit
<input type="checkbox"/> A	coulomb	ampere
<input type="checkbox"/> B	joule	volt
<input type="checkbox"/> C	newton	kilogram
<input type="checkbox"/> D	second	watt

(Total for Question 1 = 1 mark)

- 2 A constant current maintained in a copper wire causes the temperature of the wire to increase. Which of the following does **not** increase?

- A amplitude of vibration of the lattice ions
- B number of conduction electrons per unit volume
- C rate of collision of conduction electrons with lattice ions
- D rate of energy transfer from conduction electrons to lattice ions

(Total for Question 2 = 1 mark)

- 3 A car of mass 1.5×10^3 kg is travelling at a speed of 25 m s^{-1} . The driver applies the brakes and the car comes to rest.

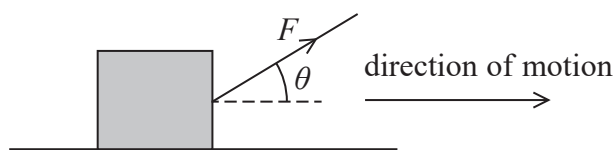
Which of the following gives the decrease in kinetic energy, in joules, as the car is brought to rest?

- A $750 \times (25)^2$
- B $750 \times \left(\frac{25}{2}\right)^2$
- C $1500 \times (25)^2$
- D $1500 \times \left(\frac{25}{2}\right)^2$

(Total for Question 3 = 1 mark)



- 4 A rope is used to apply a force F to a box as shown. The box is pulled a distance d along a horizontal surface.



Which of the following could be used to determine the work done on the box?

- A $Fd \sin \theta$
- B $\frac{Fd}{\sin \theta}$
- C $Fd \cos \theta$
- D $\frac{Fd}{\cos \theta}$

(Total for Question 4 = 1 mark)

- 5 A torch is switched on for 5 minutes. The current in the torch bulb is 6 mA.

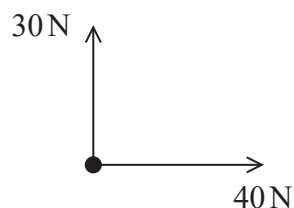
Which of the following gives the charge, in coulombs, that flows in this time?

- A $6 \times 10^{-3} \times 5$
- B $\frac{6 \times 10^{-3}}{5}$
- C $\frac{6}{300}$
- D $6 \times 10^{-3} \times 300$

(Total for Question 5 = 1 mark)



- 6 The diagram shows the two forces acting on a point mass.



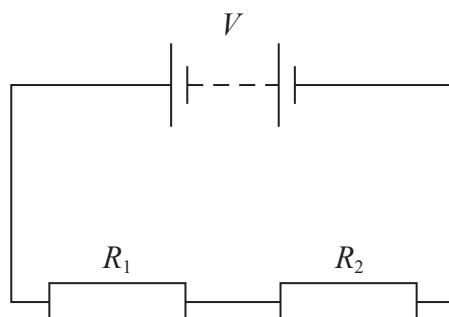
The mass accelerates.

Which of the following gives the angle between the direction of the acceleration and the 40 N force?

- A $\cos^{-1}(30/40)$
- B $\sin^{-1}(40/50)$
- C $\tan^{-1}(30/40)$
- D $\tan^{-1}(40/50)$

(Total for Question 6 = 1 mark)

- 7 Two resistors of resistance R_1 and R_2 are connected to a battery as shown. The terminal potential difference of the battery is V .



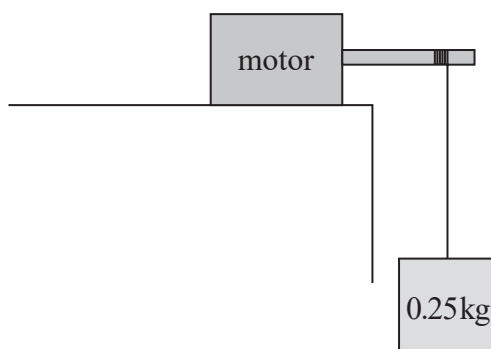
Which of the following gives the potential difference across the resistor of resistance R_1 ?

- A $\frac{R_1}{R_2} \times V$
- B $\frac{R_1}{R_1 + R_2} \times V$
- C $\frac{R_2}{R_1} \times V$
- D $\frac{R_2}{R_1 + R_2} \times V$

(Total for Question 7 = 1 mark)



- 8 A motor is used to lift an object as shown. The object is raised through a vertical height of 75 cm at a constant speed of 0.40 m s^{-1} .



Which of the following gives the rate of increase of potential energy of the object in watts?

- A $0.25 \times 9.81 \times 0.40$
- B 0.25×0.75
- C $0.25 \times 9.81 \times 0.75$
- D $0.5 \times 0.25 \times (0.40)^2$

(Total for Question 8 = 1 mark)

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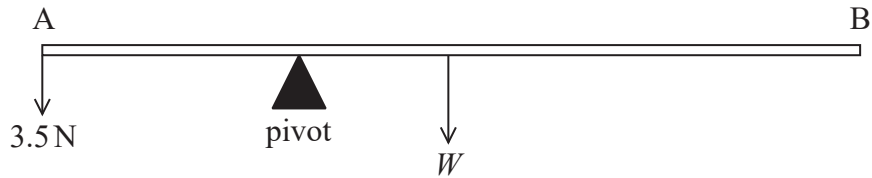
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- 9 A uniform rigid rod AB of length 1.50 m has a weight W of 6.5 N. A force of 3.5 N applied at A balances the rod on a pivot as shown.

Diagram not to scale



Calculate the distance of the pivot from A when the rod is in equilibrium.

(2)

Distance of pivot from A =

(Total for Question 9 = 2 marks)

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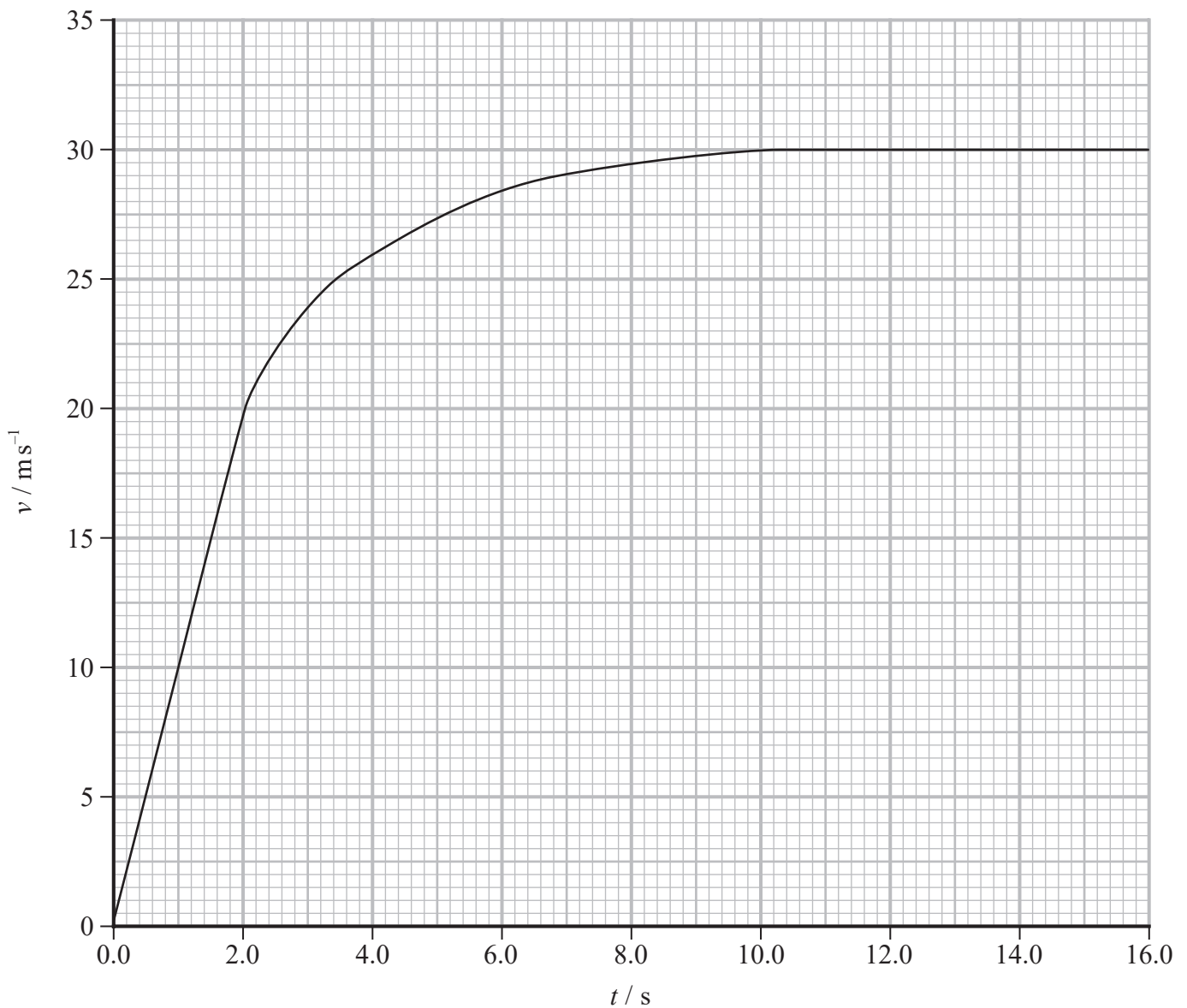


11 A skydiver made a skydive from a plane.



(Source: © Sky Antonio/Shutterstock)

The graph shows how the velocity v of the skydiver varied with time t , from the instant she left the plane to the instant just before the parachute opened.



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(a) Determine the acceleration of the skydiver when $t = 4.0$ s.

(3)

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Acceleration of skydiver =

(b) Determine an approximate value for the displacement of the skydiver over the first 16.0 s of the skydive.

(3)

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Displacement of skydiver =

(Total for Question 11 = 6 marks)



- 13 Two ice skaters are gliding across the horizontal ice surface at an ice rink.



(Source: © ITAR-TASS News Agency/Alamy Stock Photo)

- (a) Initially the skaters move together with a speed of 5.6 m s^{-1} .

The male skater pushes the female skater forwards. After being pushed, she has a forward speed of 7.5 m s^{-1} .

Calculate the speed of the male skater immediately after pushing the female skater forwards.

mass of male skater = 66 kg
mass of female skater = 52 kg

(3)

Speed of male skater =

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(b) Explain why the male skater experiences a change in his velocity when he pushes the female skater forwards.

You should make reference to Newton's laws of motion in your explanation.

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(c) When the male skater pushes the female skater forwards, the total kinetic energy of the skaters increases.

Explain why kinetic energy is not conserved in this interaction.

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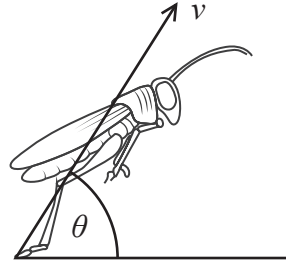
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(Total for Question 13 = 9 marks)



- 14 Grasshoppers can jump up to twenty times their length to escape predators. The magnitude of the launch velocity v does not vary significantly for a given grasshopper, so the length of the jump mostly depends on the launch angle θ .

The diagram shows a grasshopper at the instant it launches.



(Source: adapted from http://gclipart.com/grasshopper-clipart_28241/)

- (a) The grasshopper jumps from rest on level ground. The launch velocity is 2.6 m s^{-1} at an angle of 57° to the horizontal.

- (i) Show that the vertical component of the launch velocity is about 2 m s^{-1} .

(1)

- (ii) Assess whether the horizontal distance travelled by the grasshopper in the jump is about 20 times the grasshopper's length.

length of grasshopper = 5.0 cm

(5)

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(b) Grasshoppers with longer legs accelerate to their launch velocity over a longer time.

Leg length has a negligible effect on both the mass of a grasshopper and the energy released in a jump.

Explain how leg length affects the force exerted on the ground during a jump.

(4)

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(c) In a recent study it was discovered that grasshoppers, living in an environment with hunting spiders, increase their launch velocity on average by 20%. The jump length of these grasshoppers was more than doubled.

Assess whether a 20% increase in launch velocity alone is sufficient to double the jump length.

(4)

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(Total for Question 14 = 14 marks)

TOTAL FOR SECTION A = 54 MARKS



SECTION B

Answer ALL questions in the spaces provided.

15 A force meter measures force by making use of Hooke's Law.

The extension of a spring inside the force meter allows the magnitude of the force applied to be read from a scale.

(a) The spring in one type of force meter extends by 5.5 cm when a force of 2.5 N is applied.

(i) Show that the stiffness of the spring is about 50 N m^{-1} .

(2)

(ii) Two identical force meters of this type support a mass of 0.400 kg as shown.

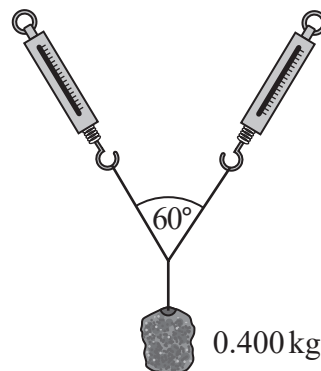


Diagram not to scale

(Source: adapted from <https://image.slidesharecdn.com/balancedunbalancedgravityfriction-170509114658/95/balanced-unbalanced-gravity-friction-14-638.jpg?cb=1494330595>)

Calculate the extension Δx of each spring.

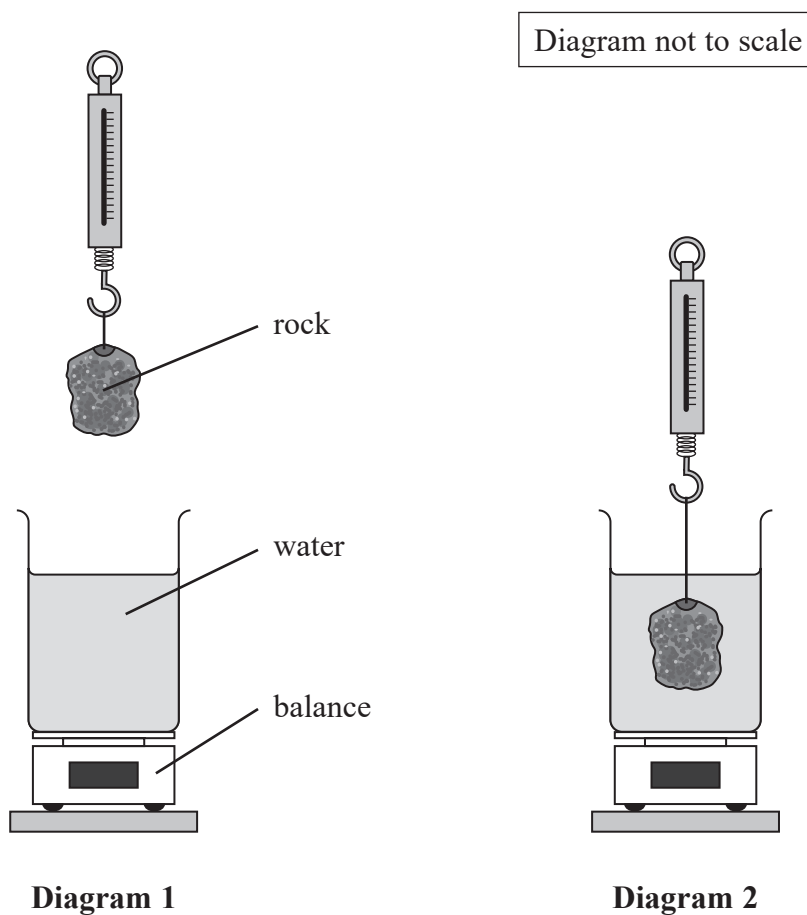
(4)

$\Delta x =$



- *(b) A beaker of water is placed on a balance and a rock is hung from a force meter as shown in diagram 1.

The initial reading on the balance is R , and the initial reading on the force meter is F . The rock is lowered gently into the beaker of water until it is completely submerged.



(Source: adapted from <https://passnownow.com/wp-content/uploads/2014/06/upthrust>)

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Explain any changes in the readings R and F as the rock is lowered into the water as shown in diagram 2.

(6)

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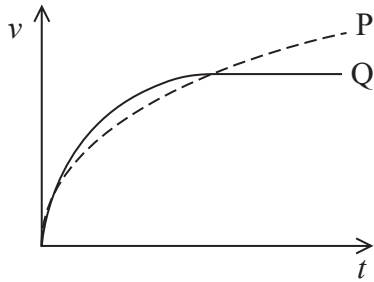
(Total for Question 15 = 12 marks)



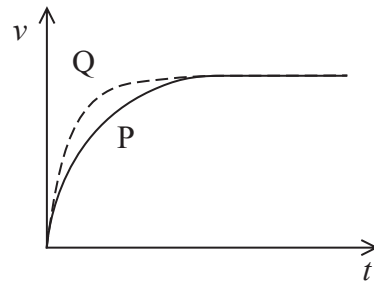
- 6 Two identical lorries, P and Q, carry different loads inside them so that the total mass of P is greater than the total mass of Q.

P and Q start from rest along the same road. The forward force from the engine of each lorry is the same.

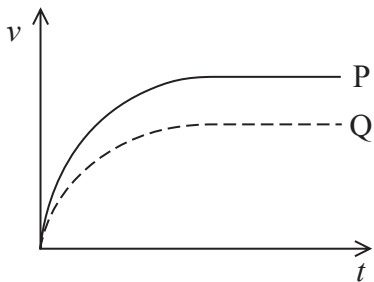
Which of the following graphs correctly shows how velocity v varies with time t for the two lorries?



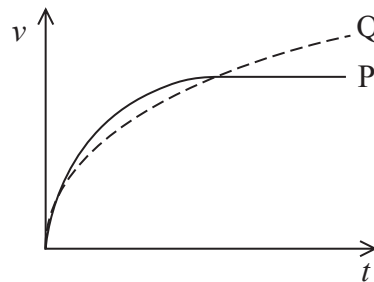
A



B



C



D

- A
- B
- C
- D

(Total for Question 6 = 1 mark)

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- 7 A cable is used to pull a mass of 2.5 kg vertically upwards with an acceleration of 4.3 ms^{-2} .

Which of the following expressions gives the tension in the cable in N?

- A 2.5×4.3
- B $(2.5 \times 4.3) - (2.5 \times 9.81)$
- C $(2.5 \times 4.3) + (2.5 \times 9.81)$
- D 2.5×9.81

(Total for Question 7 = 1 mark)

- 8 A power station provides electrical power at a mean rate of 3500 MW.

Which of the following gives the best estimate of the energy provided to consumers over a period of a year?

$$1 \text{ year} = 3.2 \times 10^7 \text{ s}$$

- A $1 \times 10^6 \text{ J}$
- B $1 \times 10^{11} \text{ J}$
- C $1 \times 10^{13} \text{ J}$
- D $1 \times 10^{17} \text{ J}$

(Total for Question 8 = 1 mark)

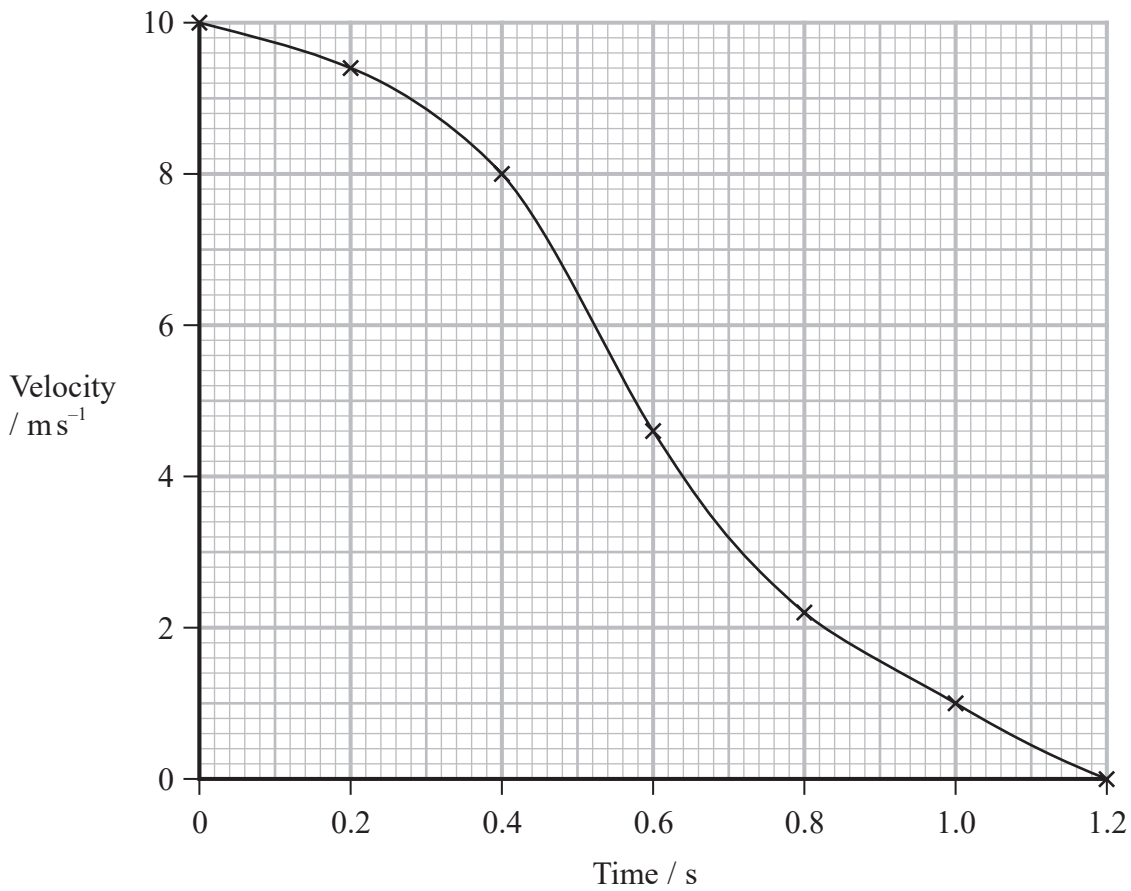
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10 A sprinter crossed the finish line of a race and then decelerated to rest. The graph shows how the velocity of the sprinter varied with time once the sprinter had crossed the finish line.



Determine the distance travelled by the sprinter whilst decelerating to rest.

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Distance = m

(Total for Question 10 = 3 marks)

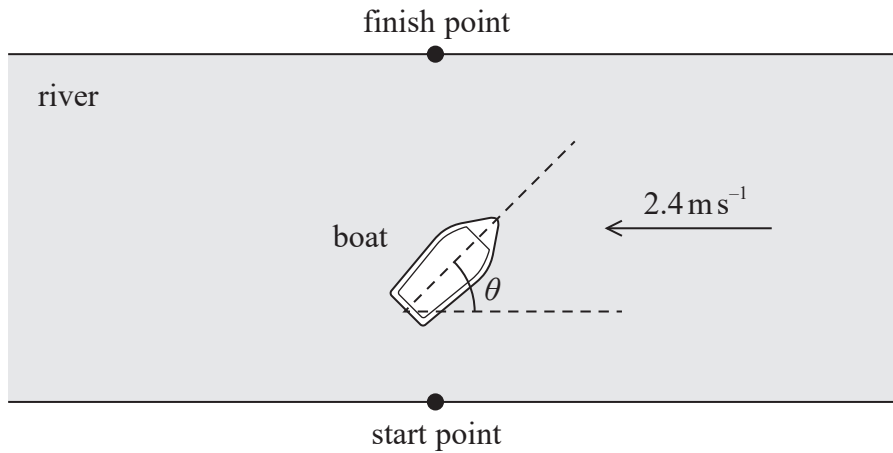
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- 12 A boat crosses a river, to a point on the bank directly opposite the starting point as shown. The velocity of the water in the river is 2.4 m s^{-1} .

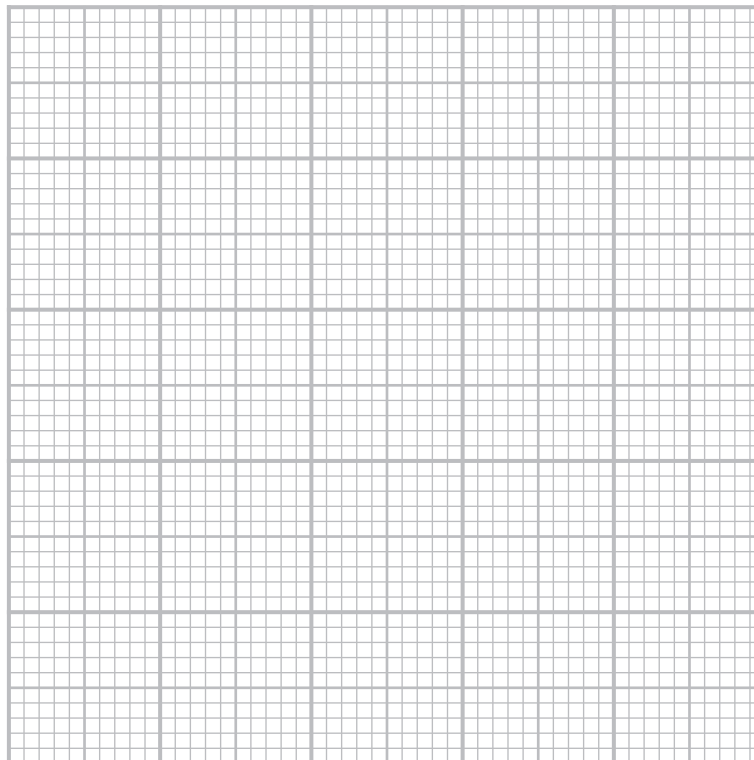


- (a) The boat is steered at an angle θ to the velocity of the water in the river in order to travel in a straight line across to the finish point.

The speed of the boat relative to the water is 4.3 m s^{-1} .

Determine the value of θ by drawing a scaled vector diagram.

(3)



$\theta = \dots\dots\dots$

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- (b) The boat repeats the crossing, at the same speed, when the velocity of the water in the river is greater.

Explain how the time taken for the crossing will change.

(3)

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(Total for Question 12 = 6 marks)

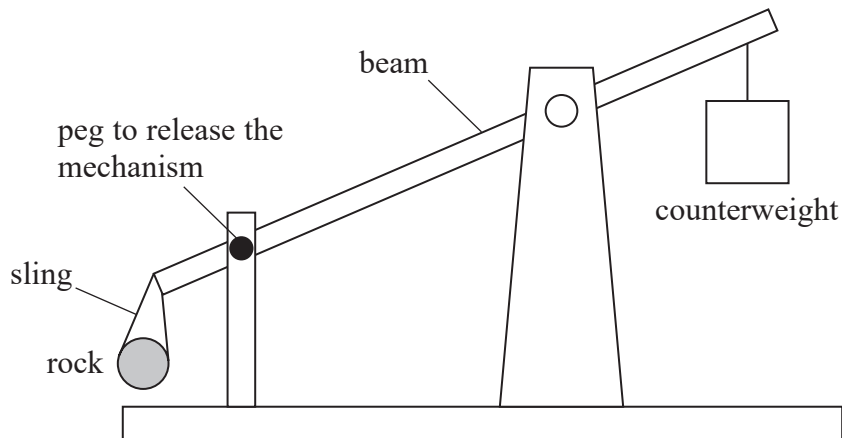
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- 13 A trebuchet is a medieval catapult designed to project a rock over large distances. A simplified diagram of a trebuchet is shown.



The rock is held in a sling. When the peg is removed the counterweight falls and the rock is projected through the air.

- (a) A student assumes that all the gravitational potential energy transferred from the counterweight is transferred to the kinetic energy of the rock.

Give two reasons why this is not correct.

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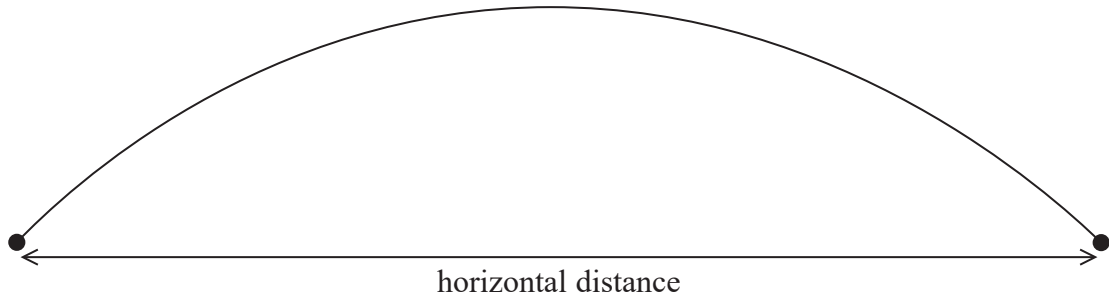
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(b) The rock was projected with a velocity of 41.5 m s^{-1} at an angle of 30° to the horizontal. The diagram shows the flight of the rock after it has left the trebuchet.



The rock rises to a maximum height and then falls back to the same height as its release height.

Calculate the horizontal distance travelled by the rock in this time.

(4)

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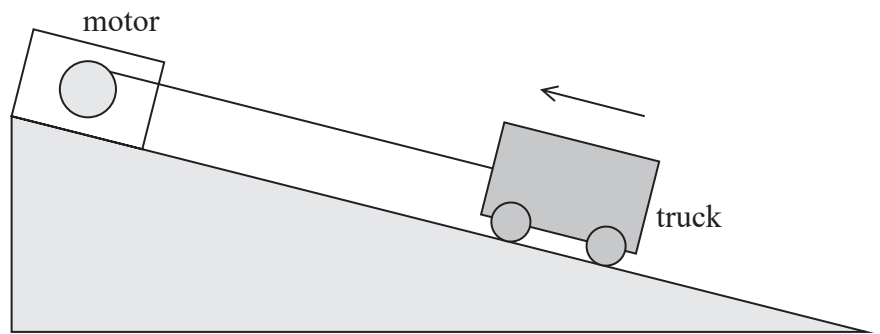
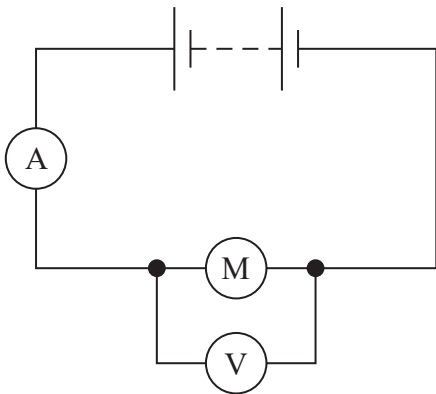
Horizontal distance =

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15 An electric motor is used to pull a truck up a slope at a constant speed.

The electric motor circuit includes a battery with no internal resistance, an ammeter and a very high resistance digital voltmeter as shown.



- (a) The truck moves through a vertical height of 0.20 m in 15 s. The current in the motor is 8.1 mA and the potential difference across the motor is 12 V.

mass of truck = 550 g

Calculate the efficiency of the motor.

(4)

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Efficiency =

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(b) The digital voltmeter is replaced with an analogue voltmeter with much less resistance.

Deduce how this will affect the efficiency of the motor circuit.

(4)

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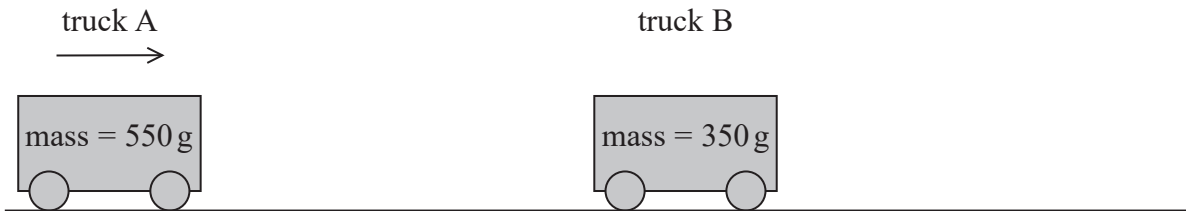
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- (c) The string pulling the truck was cut. The truck (A) travelled down the slope onto a horizontal surface and collided with a second truck (B), which was stationary, as shown.



The velocity of truck A just before the collision was 5.4 m s^{-1} and just after the collision was 2.1 m s^{-1} .

Determine the velocity of truck B after the collision.

(3)

Velocity of truck B =

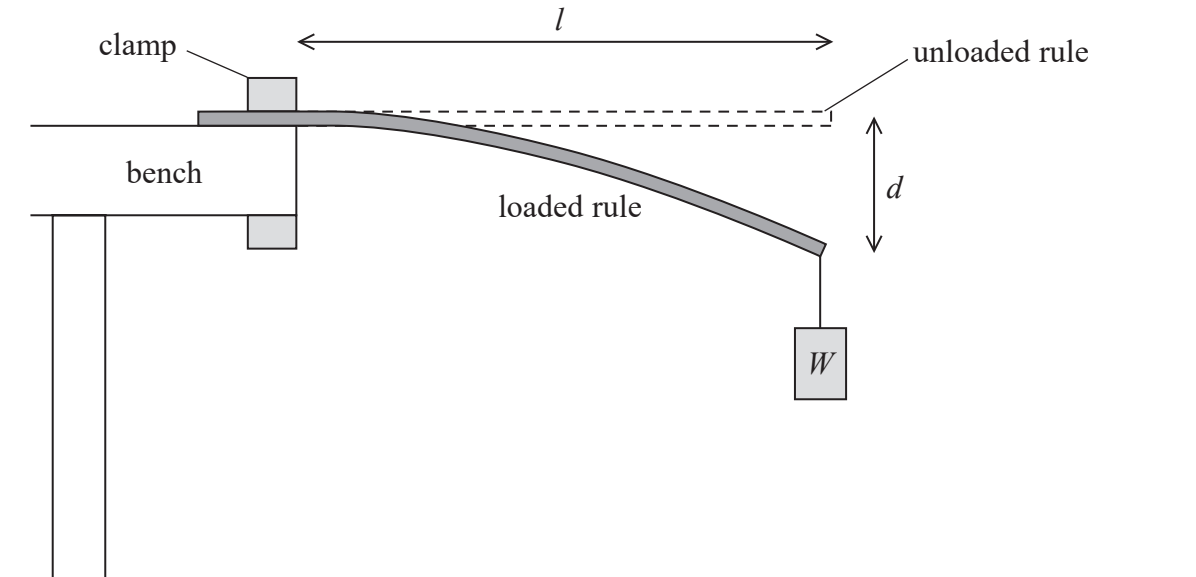
(Total for Question 15 = 11 marks)



SECTION B

Answer ALL questions in the spaces provided.

- 17 The diagram shows a wooden metre rule which is clamped horizontally to a bench. The other end of the rule is loaded with a weight W . The length l of the metre rule between the clamp and W can be varied. The loaded end of the rule is displaced through a vertical distance d as shown.



A student investigated how d varied with l .

- (a) Describe how the student should use set squares and a second metre rule to determine d . You may add to the diagram.

(2)

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- (b) The student used the following equation for the relationship between the deflection d and the length l .

$$d = \frac{4Wl^3}{Ebt^3}$$

E is the Young modulus of the wood, b is the width of the rule and t is the thickness of the rule.

- (i) The student measured t several times and calculated its mean value \bar{t} .

t / mm				\bar{t} / mm
6.25	6.27	6.29	6.24	6.26

Calculate the percentage uncertainty in the thickness of the rule.

(2)

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Percentage uncertainty =

- (ii) The student's results are shown in the table.

l / m	d / mm	
0.300	6	
0.400	18	
0.500	39	
0.600	68	
0.700	107	
0.800	166	

Plot a graph of d on the y -axis against l^3 on the x -axis on the grid opposite. Use the additional column of the table for your processed data.

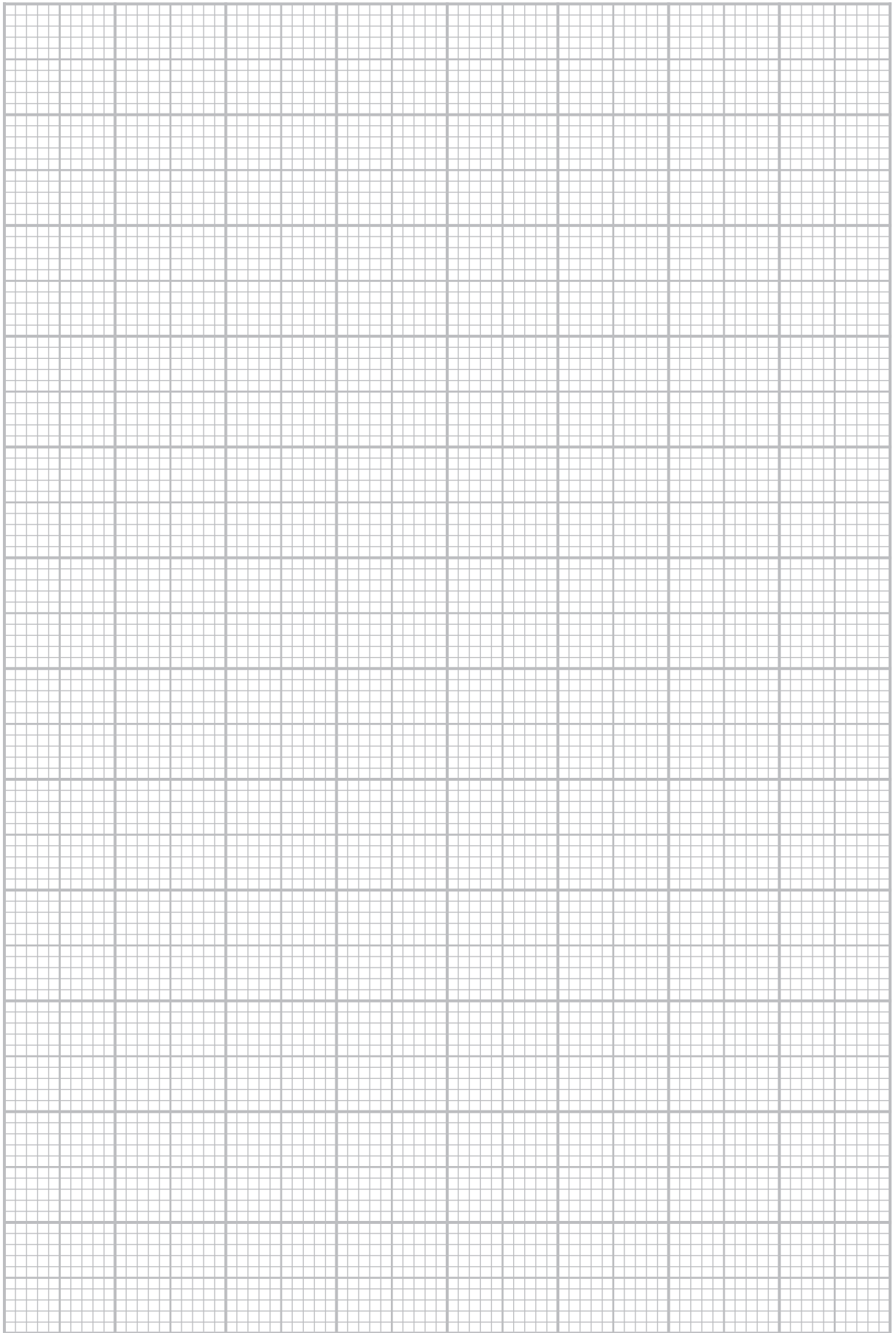
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P 6 9 4 4 0 R A 0 2 5 3 2

(iii) The table gives the value of E for several types of wood.

Wood type	E / GPa
Pine	6.9
Douglas fir	9.7
Spruce	11.1
Birch	13.9

Deduce the type of wood from which the rule was made.

$$W = 5.6 \text{ N}$$

$$b = 3.02 \text{ cm}$$

$$t = 6.26 \text{ mm}$$

(5)

(Total for Question 17 = 14 marks)

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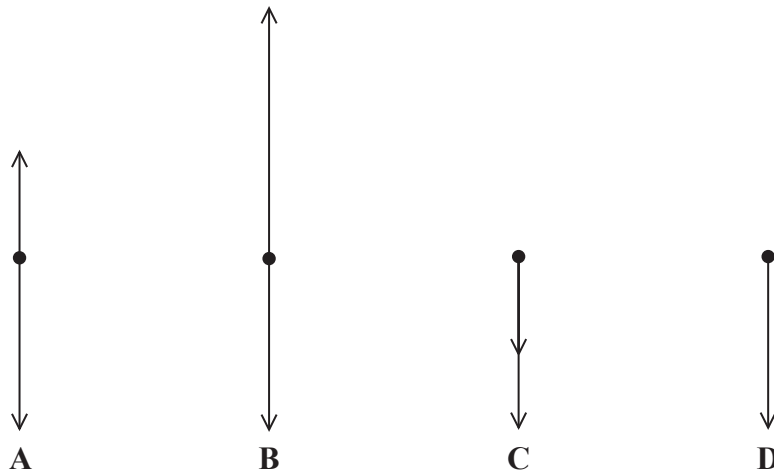
SECTION A

Answer ALL questions.

All multiple choice questions must be answered with a cross in the box ☒ for the correct answer from A to D. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

- 1 A student throws a ball vertically upwards.

Which of the following shows a free-body force diagram for the ball immediately after it leaves the student's hand?



- A
- B
- C
- D

(Total for Question 1 = 1 mark)

- 2 Which row of the table contains only scalar quantities?

- A
- B
- C
- D

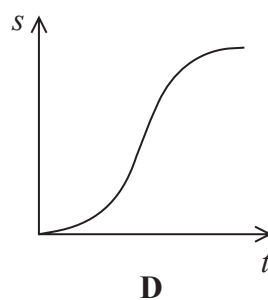
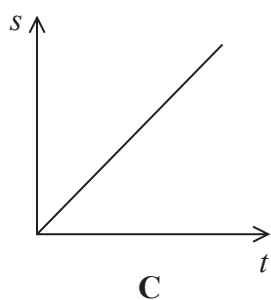
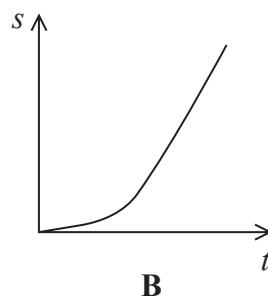
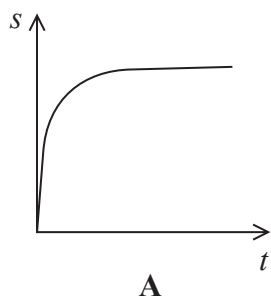
speed	displacement	current
energy	mass	momentum
power	time	work done
acceleration	work done	temperature

(Total for Question 2 = 1 mark)



3 A ball falls from rest through glycerine and reaches terminal velocity.

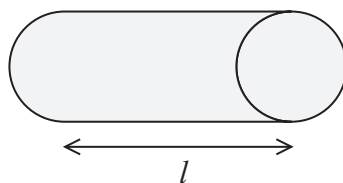
Which of the following graphs shows how displacement s varies with time t for the ball?



- A
- B
- C
- D

(Total for Question 3 = 1 mark)

4 A piece of conducting putty is shaped into a cylinder of uniform cross-sectional area, as shown. The length of the cylinder is l . The resistance between the two ends is $8.0\ \Omega$.



The piece of putty is then rolled out until the length is $2l$.

Which of the following is now the value of the resistance between the two ends?

- A $2.0\ \Omega$
- B $4.0\ \Omega$
- C $16.0\ \Omega$
- D $32.0\ \Omega$

(Total for Question 4 = 1 mark)



- 5 A car is travelling at a constant speed in a straight line along a horizontal road.

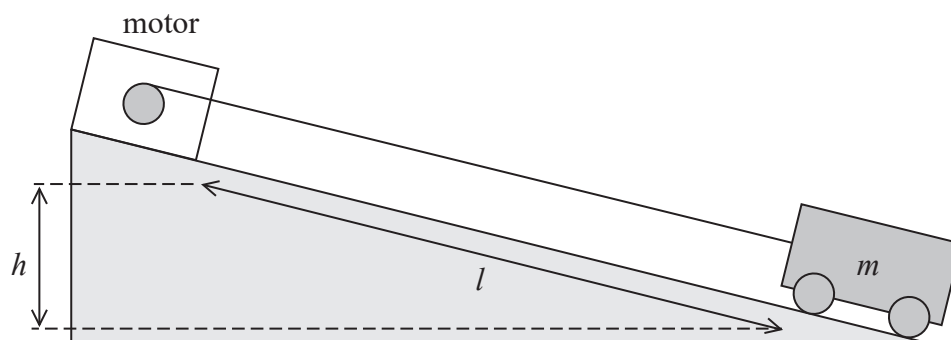
Which row of the table gives a Newton's third law pair of forces?

	Force 1	Force 2
<input type="checkbox"/> A	normal force of car on road	friction between wheels and road
<input type="checkbox"/> B	normal force of car on road	normal force of road on car
<input type="checkbox"/> C	weight of car	normal force of car on road
<input type="checkbox"/> D	weight of car	normal force of road on car

(Total for Question 5 = 1 mark)

- 6 The diagram shows an electric motor pulling a truck of mass m along a slope. The truck moves through a vertical height h and a distance l along the slope, during a time t .

There is a potential difference V across the motor and a current I in the motor.



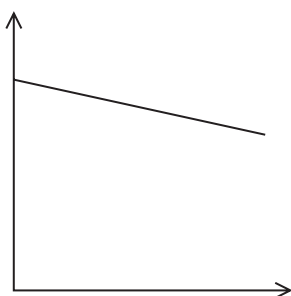
Which of the following expressions gives the efficiency of the motor?

- A $\frac{VIt}{mgl}$
- B $\frac{VIt}{mgh}$
- C $\frac{mgl}{VIt}$
- D $\frac{mgh}{VIt}$

(Total for Question 6 = 1 mark)



- 7 A student investigated the e.m.f. and internal resistance of a battery. The student produced the following sketch graph.



Which row of the table gives the quantities plotted?

	y-axis	x-axis
<input type="checkbox"/> A	e.m.f.	circuit resistance
<input type="checkbox"/> B	e.m.f.	current
<input type="checkbox"/> C	terminal potential difference	circuit resistance
<input type="checkbox"/> D	terminal potential difference	current

(Total for Question 7 = 1 mark)

- 8 A ball is thrown vertically upwards at a velocity of 6.0 m s^{-1} .

Which of the following gives the maximum height, in m, reached by the ball?

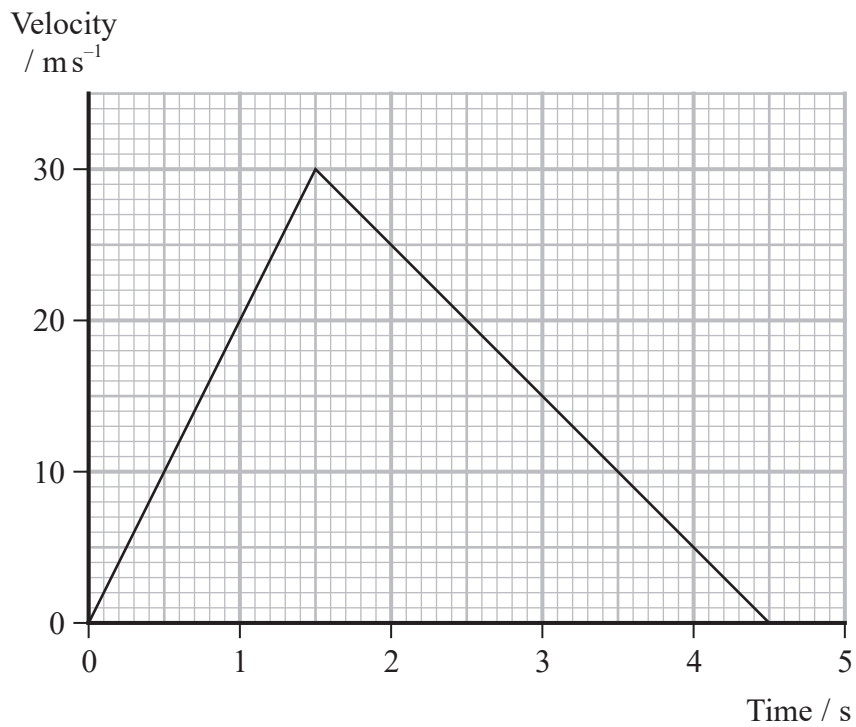
- A $\frac{6.0^2}{2 \times 9.81}$
- B $\frac{6.0^2}{2 \times (-9.81)}$
- C $\frac{6.0}{2 \times 9.81}$
- D $\frac{6.0}{2 \times (-9.81)}$

(Total for Question 8 = 1 mark)



10 A model rocket accelerates vertically upwards then decelerates due to gravity until it reaches a maximum height.

(a) A velocity-time graph for the rocket until it reaches maximum height is shown.



Show that the rocket reaches a maximum height of about 68 m.

(2)

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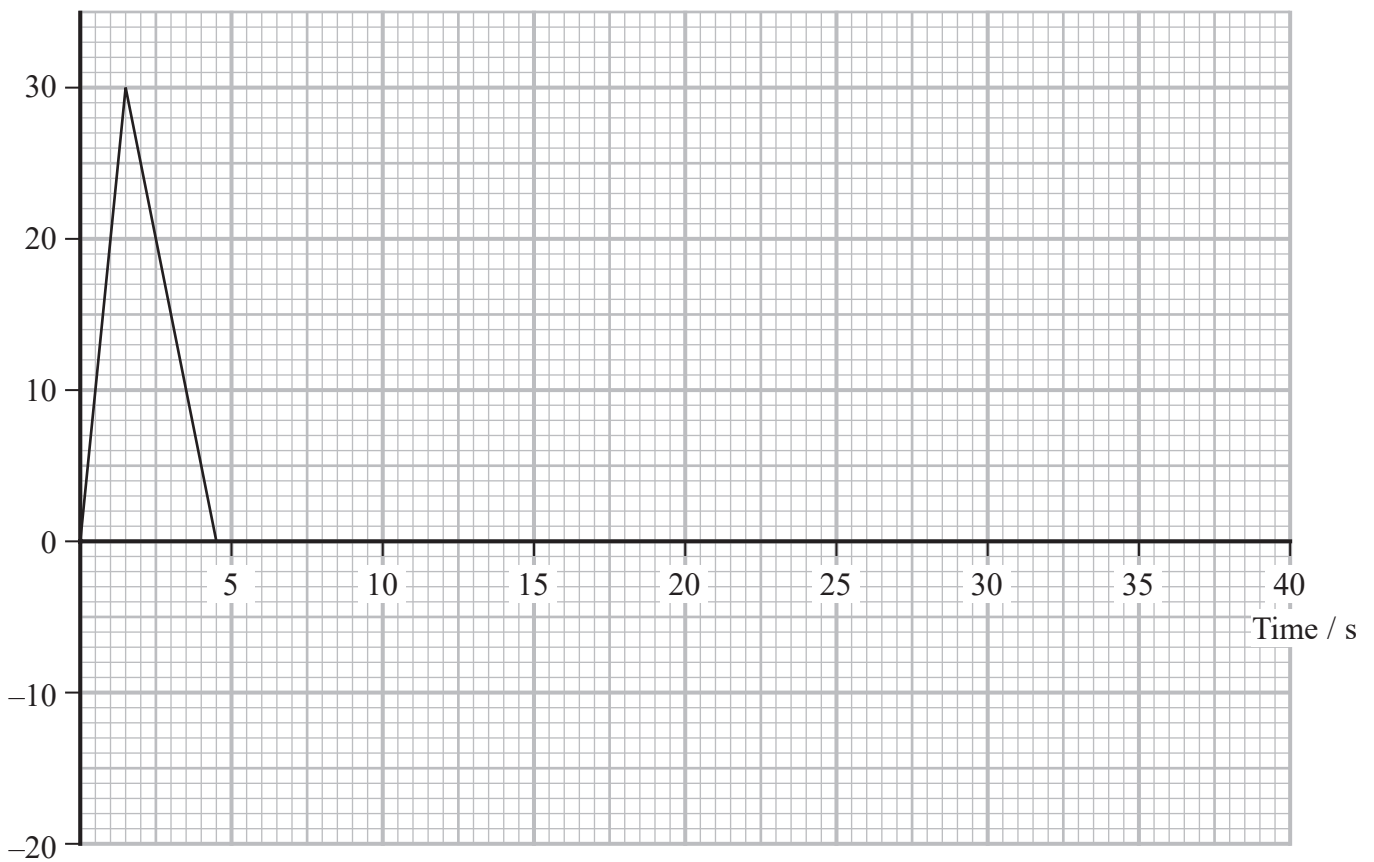


- (b) When the rocket reaches the maximum height of 68 m, a parachute opens. Almost instantly, the rocket reaches a terminal velocity of 2.0 ms^{-1} .

Complete the velocity-time graph below for the motion of the rocket until it reaches the ground.

(2)

Velocity
/ ms^{-1}



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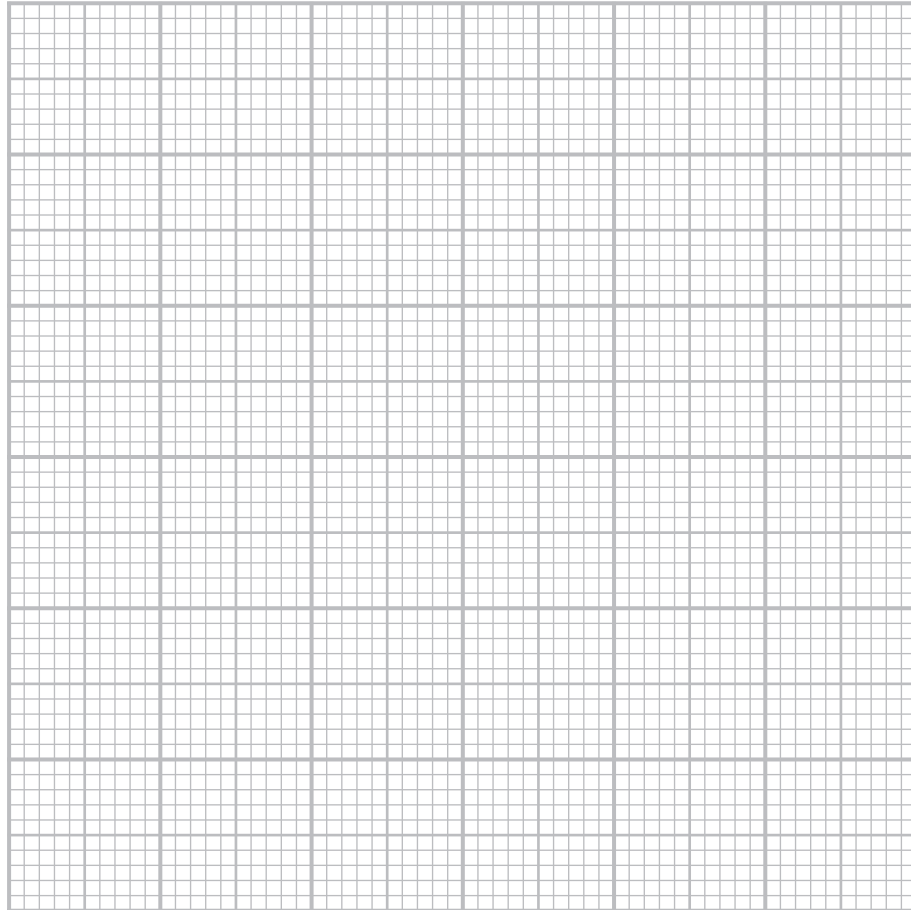
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- (c) The rocket is fired upwards a second time when the wind is blowing. The rocket falls with a vertical velocity of 2.0 m s^{-1} and a horizontal velocity of 1.5 m s^{-1} .

Determine the velocity of the rocket by drawing a scaled vector diagram.

(4)



Magnitude of velocity = m s^{-1}

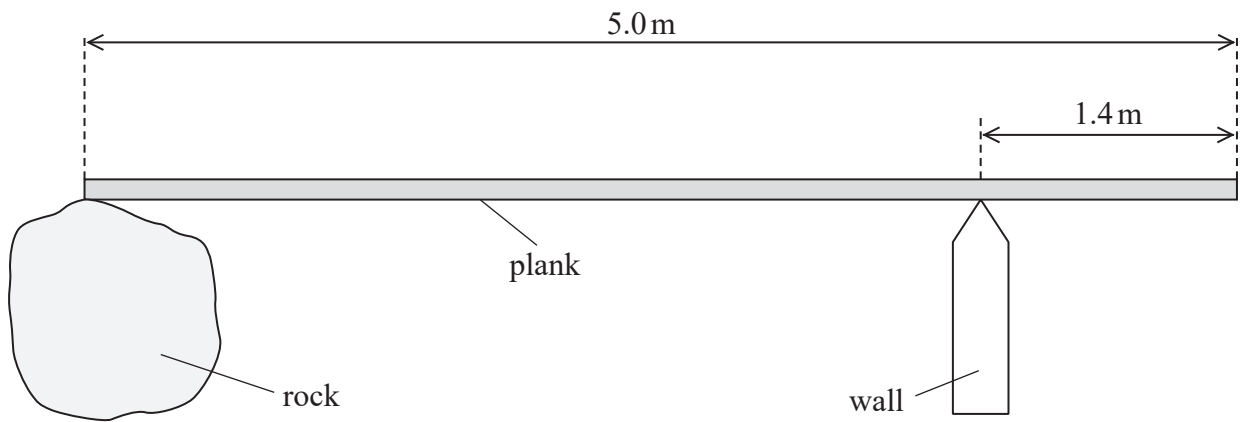
Angle to the horizontal of velocity = $^{\circ}$

(Total for Question 10 = 8 marks)



13 Some students used a plank to make a bridge to cross a stream. The plank rested on a rock and a wall as shown.

Assume the plank is uniform.



(a) (i) Show that the weight of the plank is about 250 N.

mass of plank = 25 kg

(1)

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(ii) Determine the force exerted by the wall on the plank.

(3)

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Force exerted by wall on plank =

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(b) A student of weight 550 N states that the plank will tip if she walks from the rock to the other end of the plank.

Justify the student's statement.

(3)

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(Total for Question 13 = 7 marks)

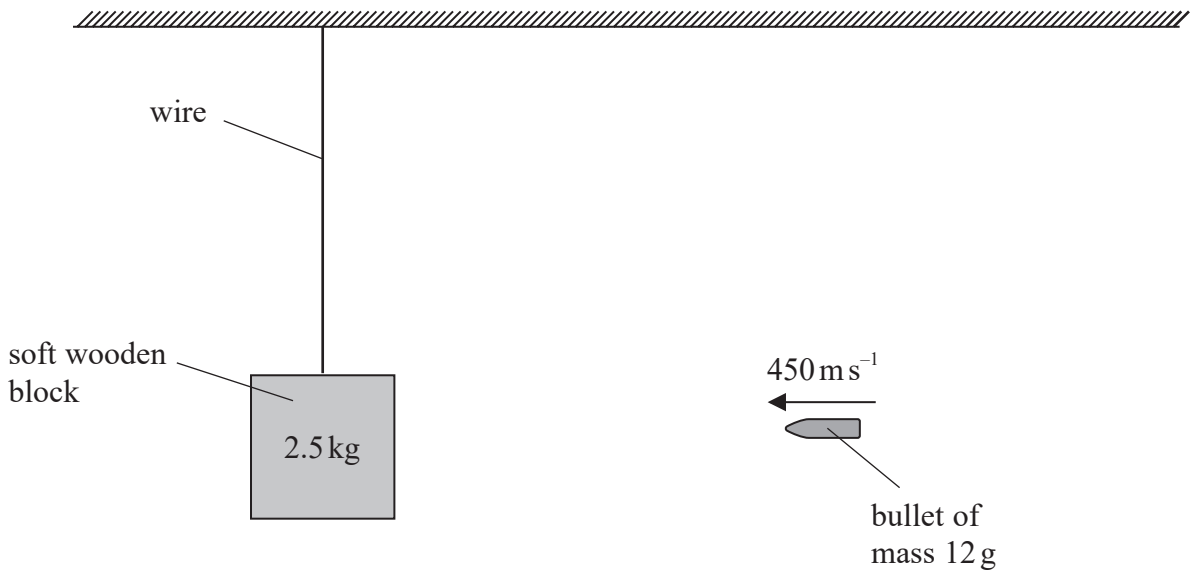
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15 A bullet of mass 12 g moved at a speed of 450 m s^{-1} . The bullet hit a soft wooden block of mass 2.5 kg which was attached to a wire, as shown. The bullet became stuck in the wooden block which swung upwards.



(a) (i) Show that the momentum of the bullet is about 5 kg m s^{-1} . (2)

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(ii) Determine the maximum change in vertical height of the wooden block. (3)

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Maximum change in vertical height =

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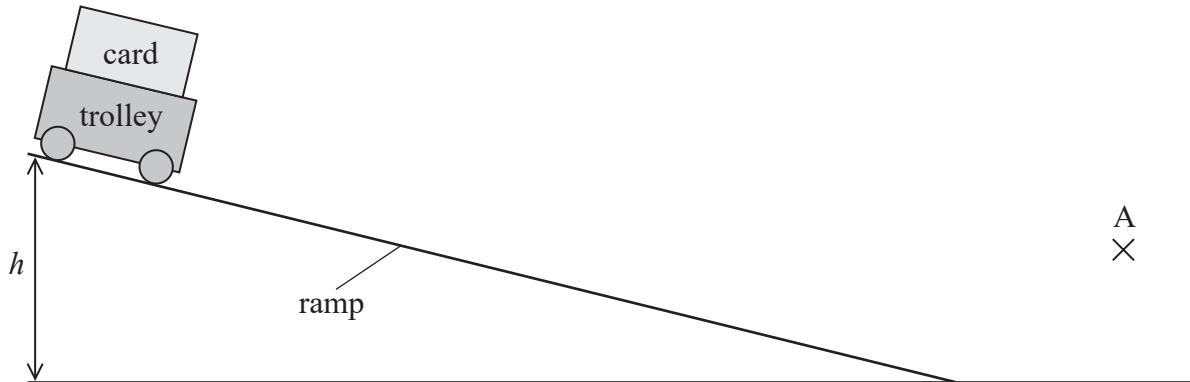
SECTION B

Answer ALL questions in the spaces provided.

16 A student released a trolley from the top of a ramp of length of about 1.5 m, as shown.

The student investigated how the speed v of the trolley at the bottom of the ramp varied as the height h of the ramp was increased.

The student placed a light gate connected to a data logger at position A to measure v as the card passed through the light gate.



(a) Describe how the student could measure h accurately.

(2)

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P 7 1 9 2 8 A 0 2 1 3 2

(b) The student derived the following equation for the motion of the trolley

$$h = \frac{v^2}{2g}$$

where g is the acceleration due to gravity.

(i) Explain why plotting a graph of h against v^2 will produce a straight line.

(2)

(ii) The student varied h and measured corresponding values of v . The results are recorded below.

h / cm	$v / \text{m s}^{-1}$	
10.8	1.38	
18.9	1.98	
28.7	2.45	
40.3	2.86	
49.8	3.22	
58.7	3.46	

Plot a graph of h on the y -axis against v^2 on the x -axis on the grid opposite. Use the additional column in the table for your processed data.

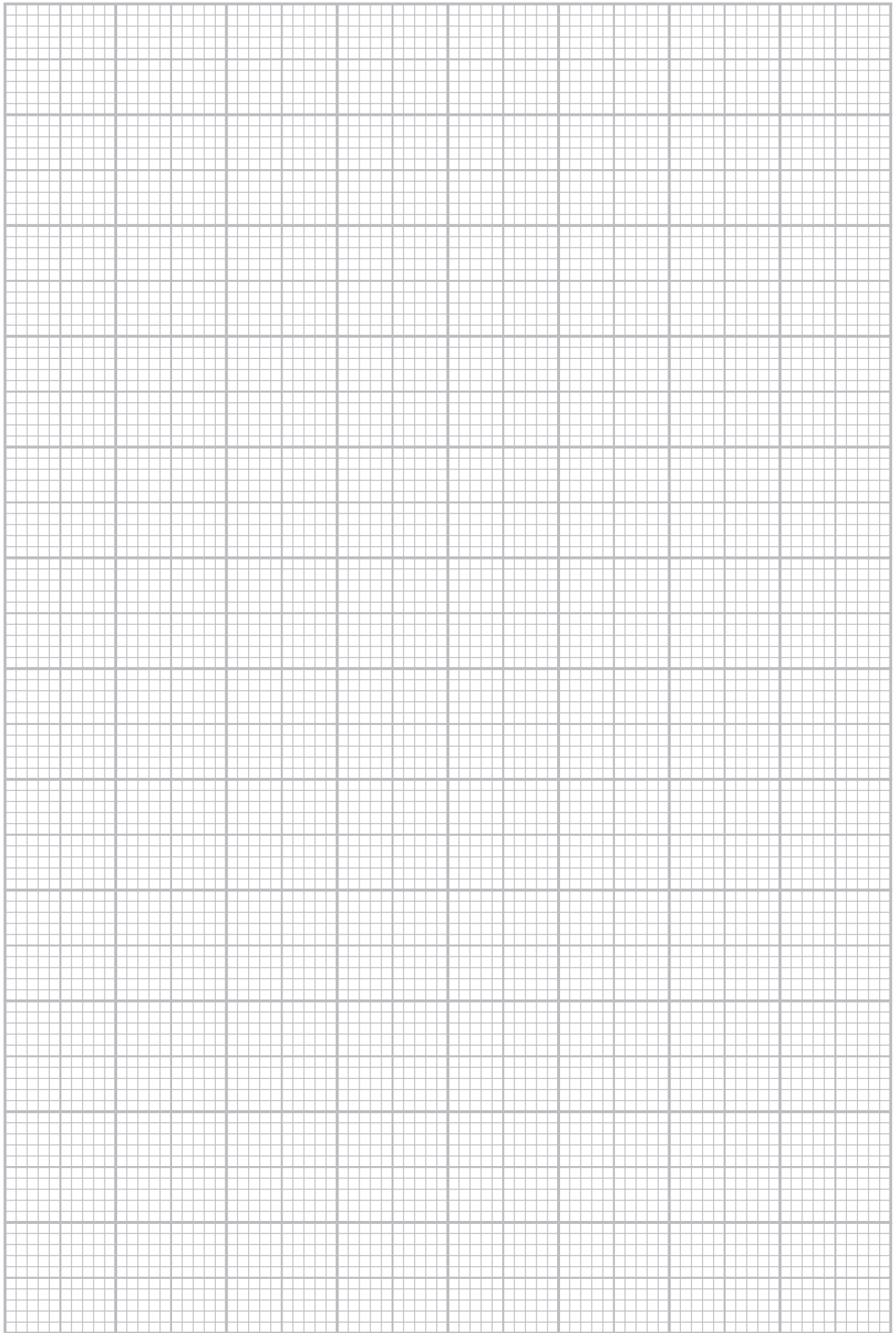
(5)



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P 7 1 9 2 8 A 0 2 3 3 2

(iii) The student used her results to plot a graph and determine a value for g .

She concluded that her value was consistent with the value of g given on the data sheet at the back of this paper.

Comment on the student's conclusion.

(3)

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(Total for Question 16 = 12 marks)

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17 An empty lift is positioned at the first floor of a building. It is suspended by 6 identical steel cables of length 50 m.

(a) Calculate the extension of each lift cable.

cross-sectional area of a cable = $3.1 \times 10^{-4} \text{ m}^2$
 Young modulus of steel = 200 GPa
 weight of lift = 12 kN

(3)

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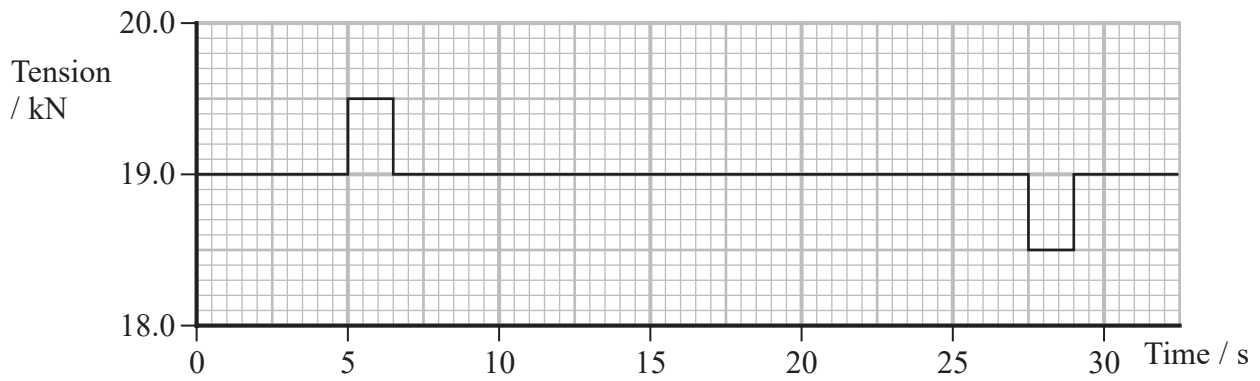
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Extension =

(b) Ten people enter the lift. After 5 seconds the lift starts to move upwards and stops at the top floor of the building.

The graph shows the total tension force in the cables during this time.



(i) Calculate the total mass of the people in the lift.

weight of lift = 12 kN

(3)

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Mass of people =

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(ii) Explain the motion of the lift between 5 s and 29 s.

(3)

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(c) When the lift is empty, a technician removes one of the cables for maintenance.

Assess how removing one cable would affect the extension of the remaining cables.

(3)

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(Total for Question 17 = 12 marks)

TOTAL FOR SECTION B = 24 MARKS
TOTAL FOR PAPER = 80 MARKS

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