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EDEXCEL INTERNATIONAL GCSE PHYSICS: QUESTIONS BY TOPIC

## Forces and Motion (1)

### IGCSE Physics Topic 1

62 questions · 609 marks · Mark schemes included

*Pearson Edexcel International GCSE (9-1) Physics 4PH1, Papers 1P/1PR & 2P/2PR, 2019-2025*

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**HOW TO USE THIS BOOKLET**

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

| QUESTION                                                   | SOURCE                  | MARKS             | PAGE      |
|------------------------------------------------------------|-------------------------|-------------------|-----------|
| <b>1.1 UNITS, MEASUREMENTS AND PRACTICAL SKILLS</b>        |                         | 5 Qs · 44 marks   | <b>4</b>  |
| 1. <b>Q1</b>                                               | Paper 2PR June 2023     | 5                 | <b>5</b>  |
| 2. <b>Q7</b>                                               | Paper 1PR June 2019     | 7                 | <b>6</b>  |
| 3. <b>Q5</b>                                               | Paper 1P November 2021  | 7                 | <b>8</b>  |
| 4. <b>Q10</b>                                              | Paper 1P June 2023      | 10                | <b>10</b> |
| 5. <b>Q12</b> <i>also Topic 2</i>                          | Paper 1PR January 2021  | 15                | <b>12</b> |
| <b>1.2 SPEED, VELOCITY, ACCELERATION AND MOTION GRAPHS</b> |                         | 12 Qs · 114 marks | <b>16</b> |
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| <b>1.3 FORCES, NEWTON'S LAWS AND TERMINAL VELOCITY</b>     |                         | 8 Qs · 83 marks   | <b>41</b> |
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| <b>1.4 STOPPING DISTANCES</b>                              |                         | 5 Qs · 45 marks   | <b>59</b> |
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| QUESTION                                         | SOURCE                  | MARKS            | PAGE       |
|--------------------------------------------------|-------------------------|------------------|------------|
| 30. <b>Q1</b>                                    | Paper 1PR June 2025     | 5                | <b>68</b>  |
| <b>1.5 MOMENTUM</b>                              |                         | 9 Qs · 91 marks  | <b>70</b>  |
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| <b>1.6 MOMENTS AND CENTRE OF GRAVITY</b>         |                         | 10 Qs · 89 marks | <b>92</b>  |
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| <b>1.7 HOOKE'S LAW AND ELASTIC BEHAVIOUR</b>     |                         | 7 Qs · 73 marks  | <b>116</b> |
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| 56. <b>Q9</b>                                    | Paper 1PR June 2024     | 15               | <b>134</b> |
| <b>1.8 WORK DONE, ENERGY AND POWER IN MOTION</b> |                         | 6 Qs · 70 marks  | <b>138</b> |
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# QUESTIONS

62 questions · 609 marks · 8 sub-topics



## SUB-TOPIC 1.1

# UNITS, MEASUREMENTS AND PRACTICAL SKILLS

Sub-topic 1.1 · 5 questions · 44 marks · lowest tariff first



- 1 (a) The boxes show some physical quantities and their units.

Draw a straight line from each physical quantity to its correct unit.

One has been done for you.

(3)

| Physical quantity | Unit                                          |
|-------------------|-----------------------------------------------|
| velocity •        | • metre per second squared ( $\text{m/s}^2$ ) |
| force •           | • watt (W)                                    |
| power •           | • newton (N)                                  |
| moment •          | • metre per second ( $\text{m/s}$ )           |
| acceleration •    | • newton metre (Nm)                           |

- (b) Some physical quantities are scalars and other physical quantities are vectors.

- (i) State the difference between a scalar quantity and a vector quantity.

(1)

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- (ii) Give an example of a scalar quantity.

(1)

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**(Total for Question 1 = 5 marks)**





(b) Justify why the student should display their results as a bar chart.

(1)

**(Total for Question 7 = 7 marks)**



**5** A student uses a balance to measure the mass of an object.

This is the student's method.

- adjust the balance so that it displays a reading of zero
- place the object on the balance and record the reading

The student repeats this measurement several times.

(a) What is improved by adjusting the balance to give a reading of zero before the object is placed on it?

(1)

- ☐ **A** accuracy of the measurement
- ☐ **B** precision of the measurement
- ☐ **C** reliability of the measurement
- ☐ **D** validity of the measurement

(b) What is improved by repeating the measurement?

(1)

- ☐ **A** accuracy of the measurement
- ☐ **B** precision of the measurement
- ☐ **C** reliability of the measurement
- ☐ **D** validity of the measurement



(c) The student measures the mass of the object using six different balances.

The table shows the student's results.

| Mass in g |
|-----------|
| 18.96     |
| 19.01     |
| 19.05     |
| 18.98     |
| 19.34     |
| 19.04     |

(i) Draw a circle around the anomalous reading in the table.

(1)

(ii) Calculate the mean mass of the object.

(3)

mean mass = ..... g

(iii) State what other measurement the student would need to make to determine the density of the object.

(1)

(Total for Question 5 = 7 marks)



- 10** A student investigates how the time taken for a ball to roll down a slope changes with the distance from the bottom of the slope.

This is the student's method.

- place a ball on the slope 10 cm from the bottom of the slope
- release the ball and start a stopwatch
- stop the stopwatch when the ball arrives at the bottom of the slope
- record the time taken for the ball to roll down the slope
- repeat for different distances from the bottom of the slope

- (a) Complete the table by placing a tick (✓) to show which variables are the independent, dependent and control variables in this investigation.

(4)

|                    | Independent | Dependent | Control |
|--------------------|-------------|-----------|---------|
| Surface of slope   |             |           |         |
| Angle of slope     |             |           |         |
| Distance travelled |             |           |         |
| Time taken         |             |           |         |

- (b) The table shows the student's results.

| Distance travelled in cm | Time taken in s |
|--------------------------|-----------------|
| 10                       | 0.41            |
| 20                       | 0.58            |
| 30                       | 0.71            |
| 40                       | 0.82            |
| 50                       | 0.91            |

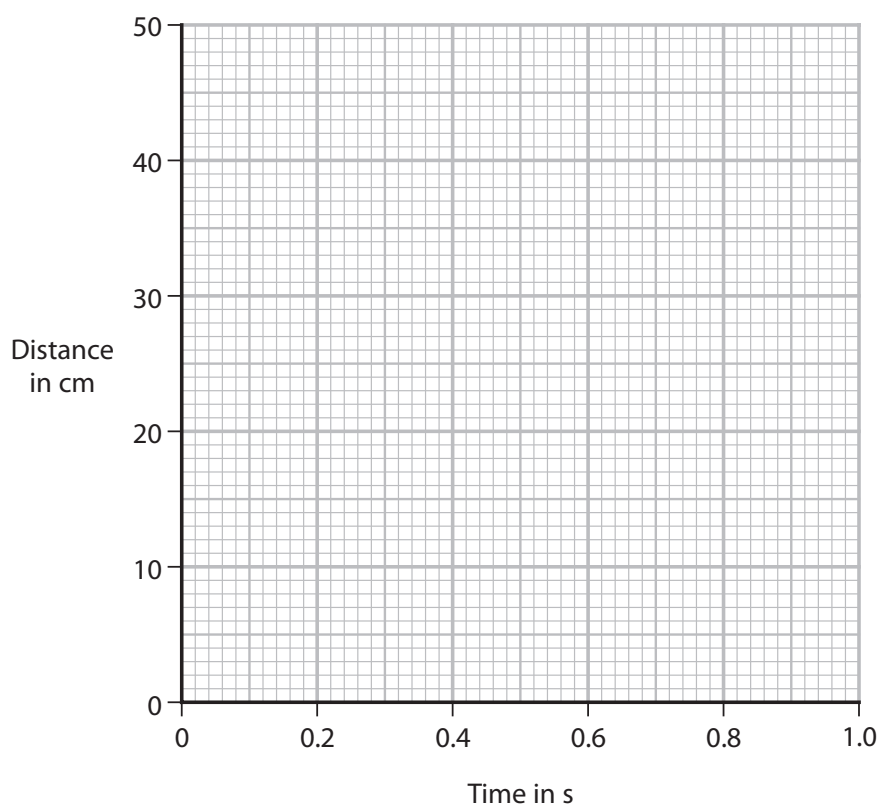
- (i) Plot the student's data on the grid.

(1)

- (ii) Draw a best fit curve.

(1)





(iii) The student concludes that the results obey this relationship

$$\text{distance} \div (\text{time}^2) = \text{constant}$$

Use the student's data to deduce whether the student's results support this conclusion.

(4)

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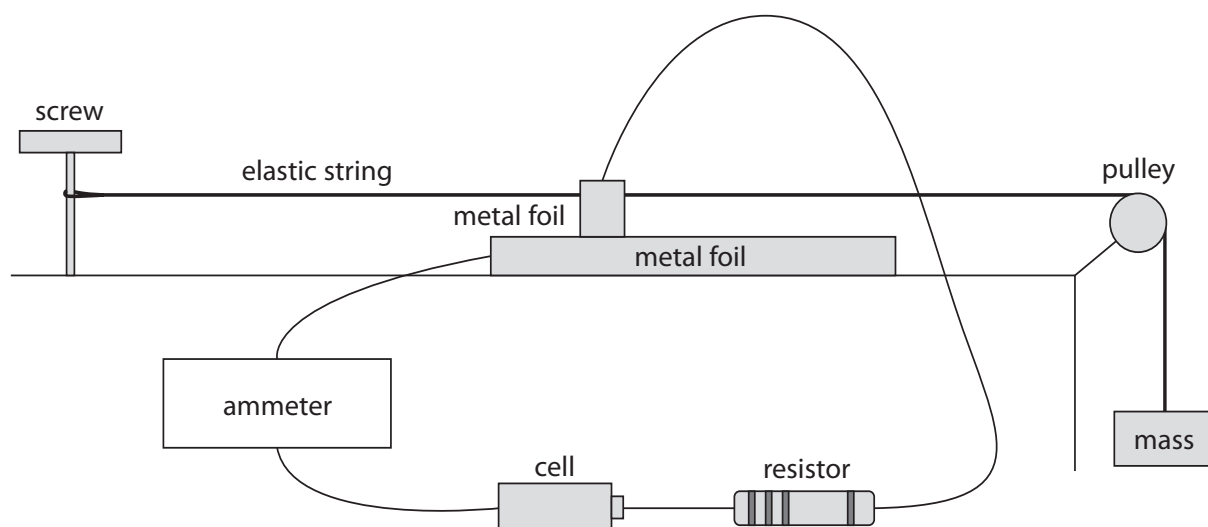
(Total for Question 10 = 10 marks)



**12** The diagram shows some apparatus used to find the mass of an object.

The two pieces of metal foil act as a variable resistor.

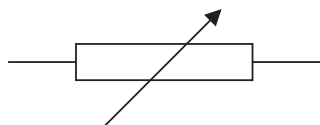
When more mass is added, the elastic string stretches and the small piece of metal foil moves to the right.



- (a) (i) Draw the circuit diagram for this electrical circuit.

The variable resistor has been drawn for you.

(4)



- (ii) Draw a voltmeter on the diagram to measure the voltage of the variable resistor.

(2)

- (b) Explain how the voltage across the variable resistor changes if more mass is added to the end of the elastic string.

(4)

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- (c) The student extends the investigation by keeping the mass constant and replacing the cell with a variable power supply.

The student measures the current in the circuit for different voltages.

These are the results.

| Voltage<br>in V | Current<br>in mA |
|-----------------|------------------|
| 0.0             | 0.0              |
| 2.0             | 4.0              |
| 4.0             | 7.0              |
| 6.0             | 11.0             |
| 8.0             | 14.0             |

- (i) State the independent variable in the student's investigation.

(1)

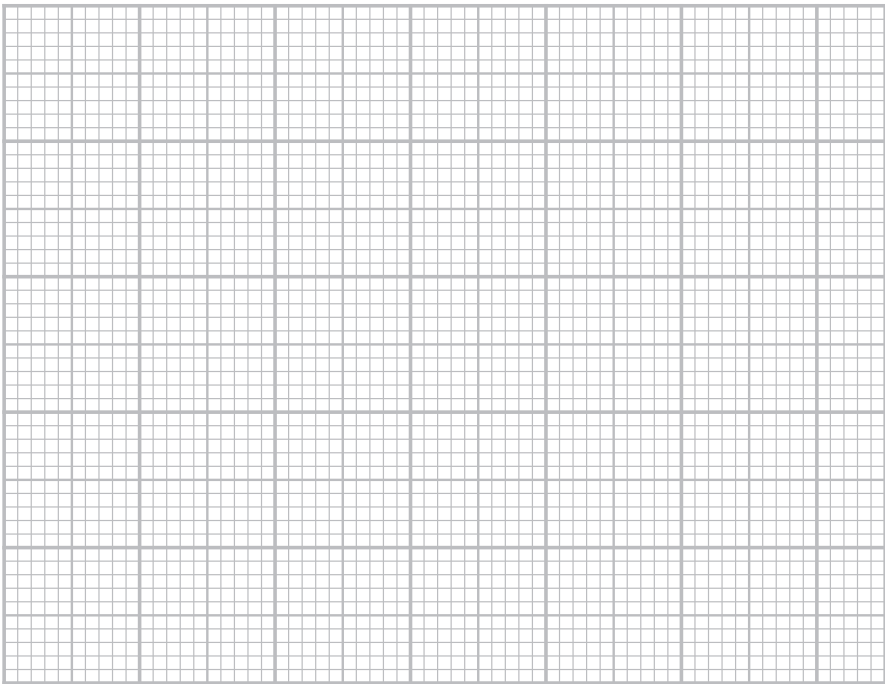
- 
- (ii) Plot the student's results on the grid.

(3)

- (iii) Draw a line of best fit.

(1)





(Total for Question 12 = 15 marks)



## SUB-TOPIC 1.2

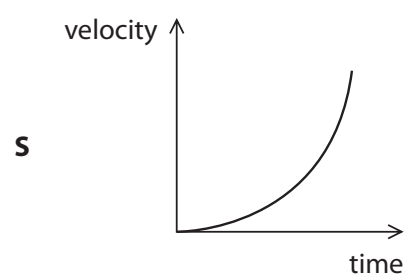
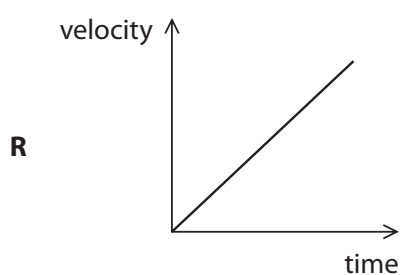
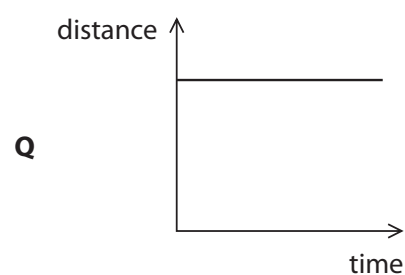
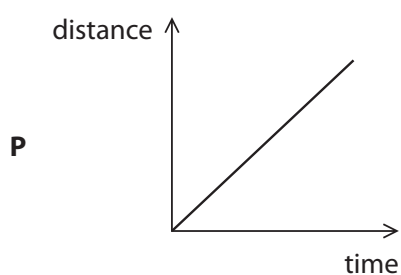
# SPEED, VELOCITY, ACCELERATION AND MOTION GRAPHS

Sub-topic 1.2 · 12 questions · 114 marks · lowest tariff first



1 The motion of an object can be represented using graphs.

(a) The graphs, P, Q, R and S, show different types of motion.



The table lists some types of motion.

Place one tick (✓) in each row of the table to show which graph represents which type of motion.

(4)

| Type of motion              | Graph |   |   |   |
|-----------------------------|-------|---|---|---|
|                             | P     | Q | R | S |
| constant acceleration       |       |   |   |   |
| increasing acceleration     |       |   |   |   |
| moving at constant velocity |       |   |   |   |
| stationary                  |       |   |   |   |

(b) State the feature of a velocity-time graph that can be used to determine the distance travelled by an object.

(1)

(Total for Question 1 = 5 marks)



**8** A car is moving along a road.

(a) The car has an initial velocity of  $26 \text{ m/s}$ .

The car then accelerates at  $1.2 \text{ m/s}^2$  until it reaches a velocity of  $35 \text{ m/s}$ .

(i) State the formula linking acceleration, change in velocity and time taken.

(1)

(ii) Calculate the time taken for the car to accelerate to  $35 \text{ m/s}$ .

(3)

time = ..... s



(b) A radar speed gun is used to measure the speed of the moving car.



© Petar An/Shutterstock

The radar speed gun emits radio waves towards the moving car.

The moving car reflects the radio waves back to a detector on the gun.

The detected radio waves have a different frequency from the emitted radio waves.

This change in frequency is used to measure the speed of the moving car.

Explain this change in frequency when the car is moving towards the radar speed gun.

(4)

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**(Total for Question 8 = 8 marks)**

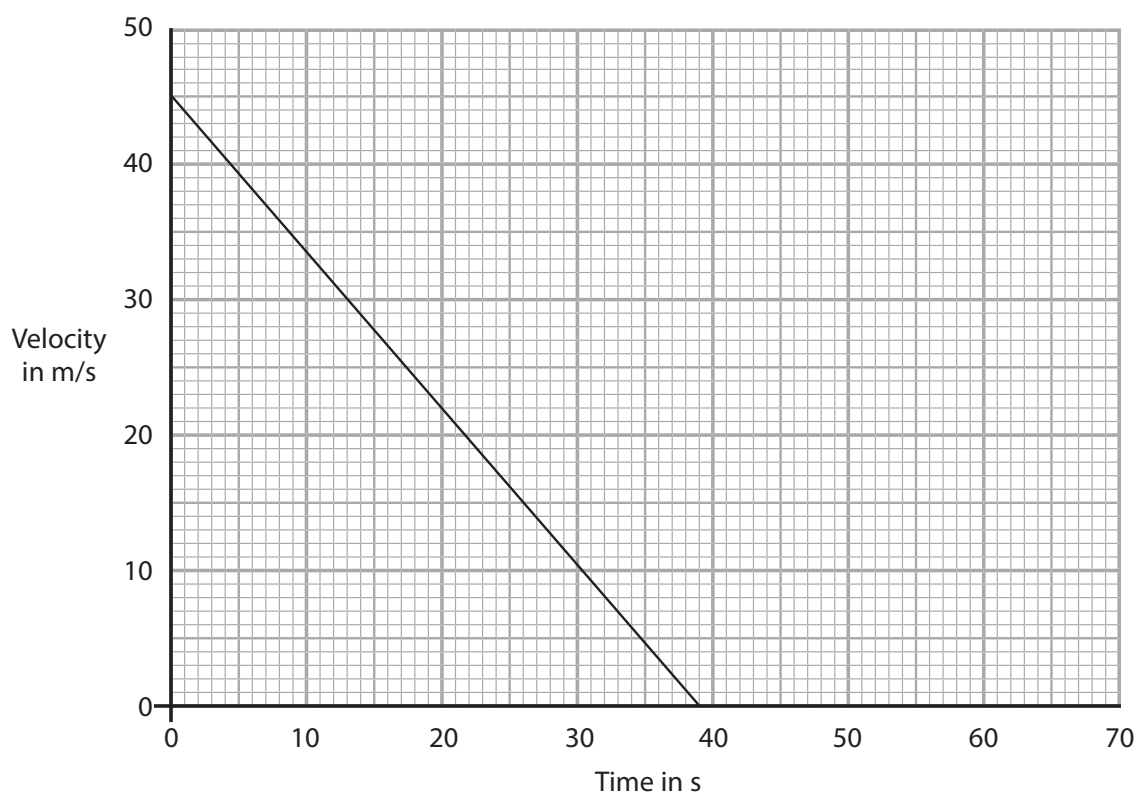
2 This question is about the movement of a train.

The diagram shows the train on a track.

The train starts braking at point P and stops moving at point Q.



The graph shows how the train's velocity changes with time as the train travels from P to Q.



(a) Calculate the acceleration of the train.

(3)

acceleration = .....  $\text{m/s}^2$

(b) Calculate the distance travelled by the train from P to Q.

(3)

distance = ..... m

(c) Draw a line on the graph to show how the train's velocity will change if its initial velocity is the same but the braking force is lower.

(2)

**(Total for Question 2 = 8 marks)**



**5** An aircraft travels along a runway.

(a) The aircraft starts from rest and has a constant acceleration of  $4.1 \text{ m/s}^2$ .

Calculate the distance required to reach take-off speed of  $75 \text{ m/s}$ .

(3)

distance = ..... m

(b) The aircraft takes off and reaches its maximum height above the ground.

At maximum height, the background radiation count rate is higher than on the ground.

(i) Explain what is meant by background radiation.

(2)

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(ii) Suggest why there is a limit to the number of hours that an airline pilot can fly at maximum height.

(3)

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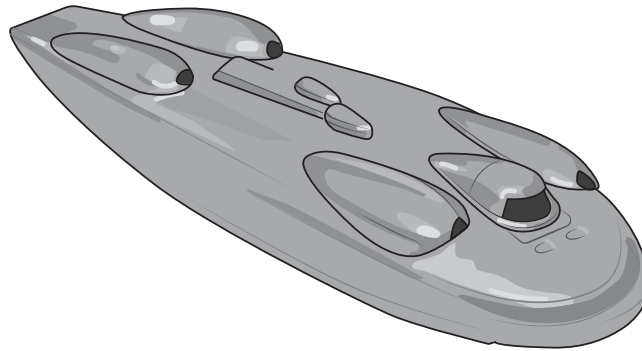
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**(Total for Question 5 = 8 marks)**



- 3** In 1947, the Railton Mobil Special was the first ground vehicle to achieve a speed of more than 400 miles per hour.



- (a) During a test, the vehicle travelled at a speed of 403 miles per hour.
- (i) Calculate a speed of 403 miles per hour in metres per second (m/s).  
[1 mile = 1600 m]

(2)

speed = ..... m/s

- (ii) During the test, the vehicle travelled past two markers.  
The markers were placed a known distance apart.

Describe how these markers could be used to determine the speed of the vehicle.

(3)

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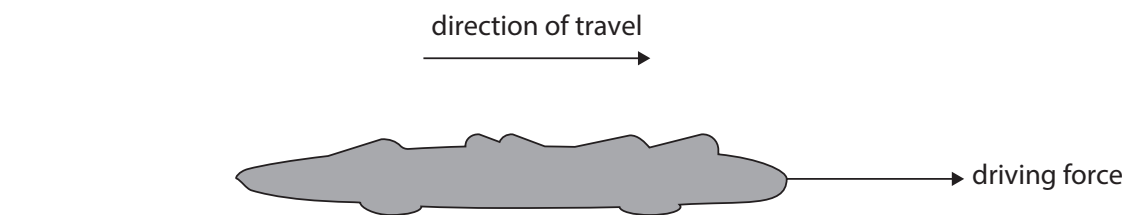
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(b) The diagram shows the vehicle travelling at a constant speed.



One of the horizontal forces acting on the vehicle has been drawn.

Complete the diagram by drawing a labelled arrow for the other horizontal force acting on the vehicle.

(3)

**(Total for Question 3 = 8 marks)**

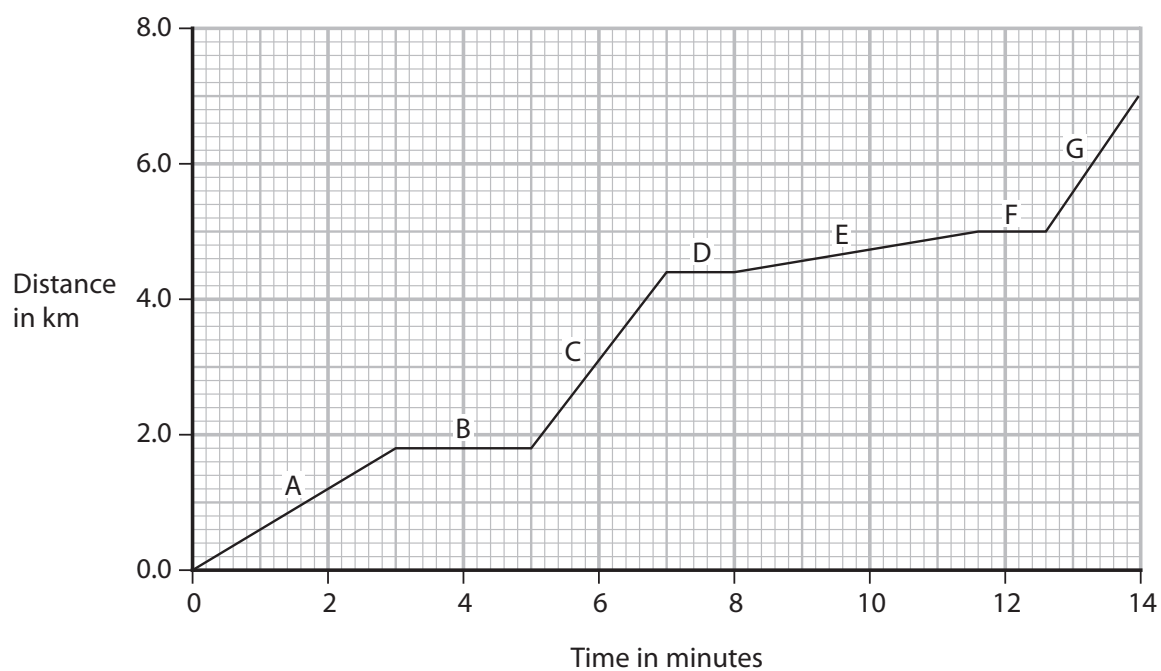
5 A bus transports passengers.



© Mikbiz/Shutterstock

(a) The bus stops at certain points in its journey to let passengers get on or off the bus.

The distance-time graph shows part of the bus journey, with sections labelled A to G.



(i) Give the letters of the sections where the bus is stationary.

(1)

(ii) Calculate the speed of the bus during section C of the journey.

Give your answer in m/s.

(4)

speed = ..... m/s

(iii) Explain what the graph shows about the speed of the bus in section E compared with the speed of the bus in section A.

(2)

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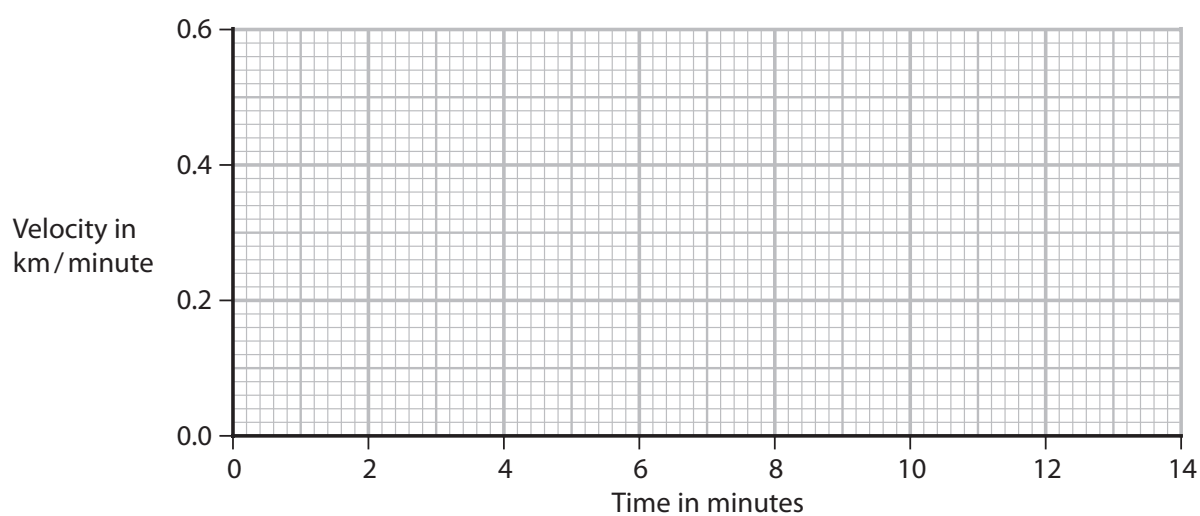
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(b) Another bus travels a distance of 7.0 km in a time of 14 minutes.

This bus travels at a constant velocity.

Complete the velocity-time graph to show the motion of this bus.

(2)



(Total for Question 5 = 9 marks)

- 2 (a) A speed camera is positioned at the side of a road.



© Darryl Sleath/Shutterstock

The camera measures the speed of a vehicle on the road to determine whether the vehicle is travelling too fast.

The camera takes two photographs of the vehicle 0.25 s apart.

The photographs are used to measure the distance travelled by the vehicle during this time.

- (i) State the formula linking average speed, distance moved and time taken.

(1)

- (ii) In the time between the two photographs, the car travels a distance of 6.5 m.

Calculate the average speed of the car.

(2)

average speed = ..... m/s

- (iii) The speed limit of the road is 80 kilometres per hour.

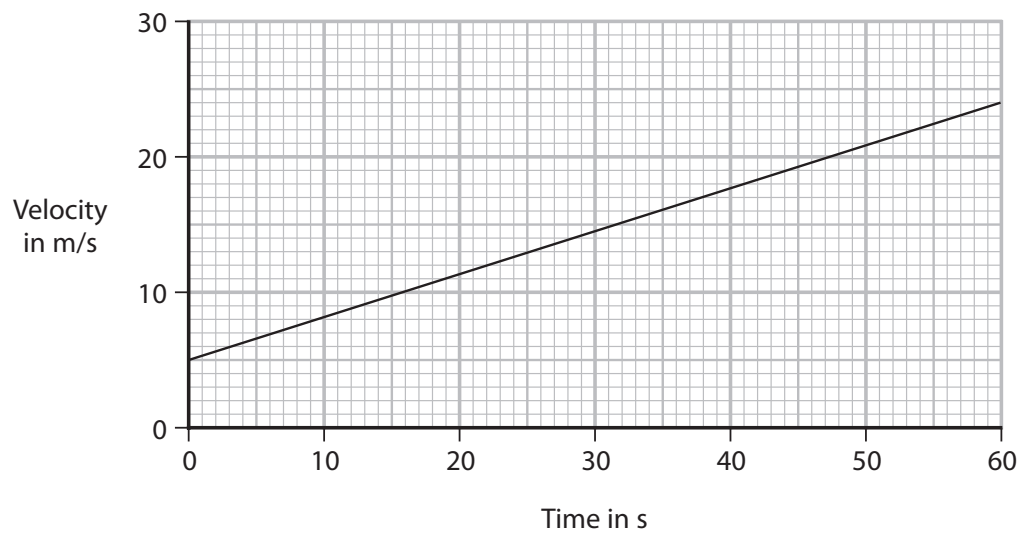
Determine whether the car is exceeding the speed limit.

(2)

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(b) The velocity-time graph shows how the velocity of a lorry changes with time.



(i) Explain how the graph shows that the lorry has a constant acceleration.

(2)

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(ii) State the formula linking acceleration, change in velocity and time taken.

(1)

(iii) Calculate the acceleration of the lorry.

(3)

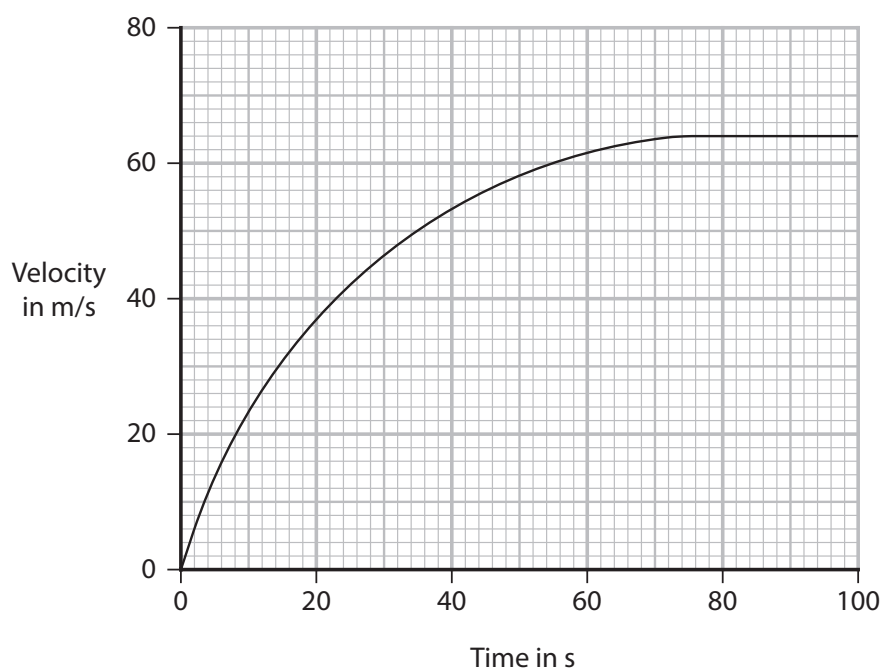
acceleration = .....  $\text{m/s}^2$

**(Total for Question 2 = 11 marks)**



- 12** A car accelerates with a constant driving force along a horizontal road and reaches its maximum speed.

This is the velocity-time graph for the car's journey.



- (a) By drawing a tangent to the curve, determine the acceleration of the car at a time of 20 s.

(4)

acceleration = ..... m/s<sup>2</sup>

(b) Determine the distance travelled by the car during the first 80 s of its journey. (5)

distance = ..... m

(c) Explain the motion of the car after 80 s. (3)

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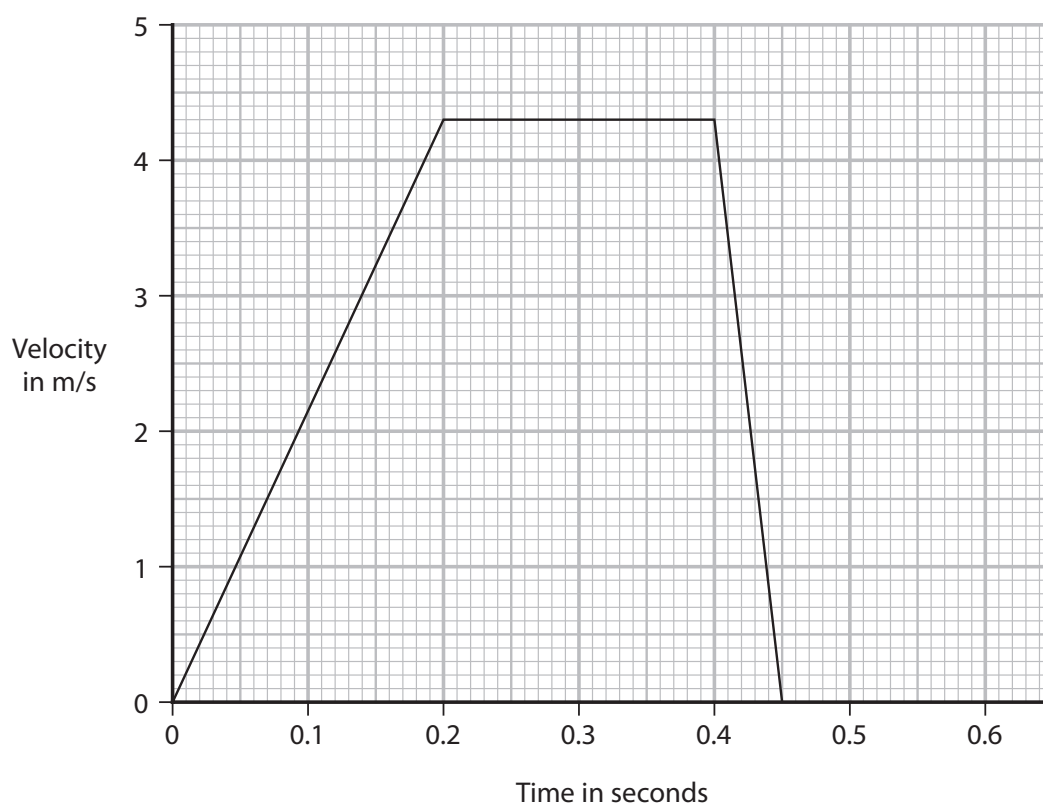
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(Total for Question 12 = 12 marks)

- 5 A student does an investigation to show how the velocity of a toy car changes when the car rolls down a ramp onto a table and hits a wooden block.

The graph shows how the velocity of the toy car changes with time.



- (a) Calculate the distance travelled by the car during the first 0.4 seconds.

(4)

distance = ..... m



(b) (i) Calculate the acceleration of the car between 0.40 s and 0.45 s.

(3)

acceleration = .....  $\text{m/s}^2$

(ii) State the formula linking resultant force, mass and acceleration.

(1)

(iii) The car has a mass of 0.13 kg.

Calculate the resultant force on the car as it slows down.

(2)

resultant force = ..... N

(c) A piece of soft material is fixed to the front of the toy car.

Explain how this will affect the gradient of the velocity-time graph after the car hits the block.

(3)

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**(Total for Question 5 = 13 marks)**



- 8 Diagram 1 shows two identical buzzers connected with springs.

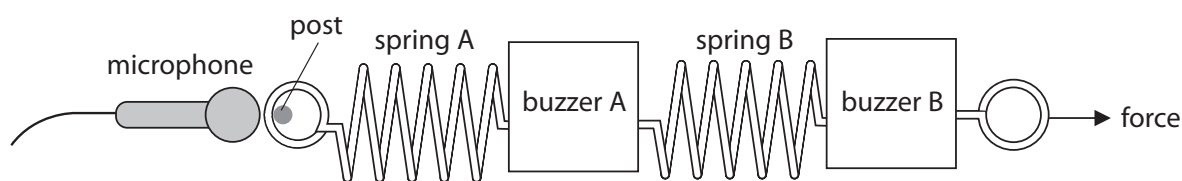


**Diagram 1**

Spring A is connected to a post.

A force acts on the apparatus for a short period of time, pulling both buzzers to the right.

During this time, buzzer A moves 2 cm and buzzer B moves 4 cm.

- (a) (i) Explain why buzzer B travels with twice the average speed of buzzer A.

(2)

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- (ii) A student connects the microphone to an oscilloscope to measure the frequency of sound from the two buzzers while the force acts on the arrangement.

Explain the difference in the measured frequencies of sound from buzzer A compared to buzzer B.

(3)

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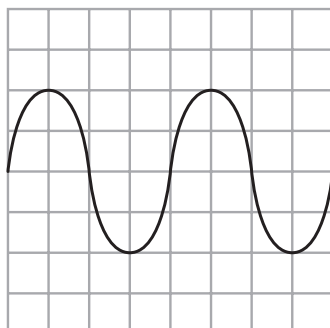
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(b) Diagram 2 shows an oscilloscope trace.

The trace represents the sound wave received by the microphone from buzzer A.



**Oscilloscope settings**

y direction: 1 square = 0.1 V

x direction: 1 square = 2 ms

**Diagram 2**

Measure the period of the sound waves from buzzer A.

Give your answer in standard form.

(3)

period = ..... s

(c) Diagram 3 shows two distant galaxies and the Earth.

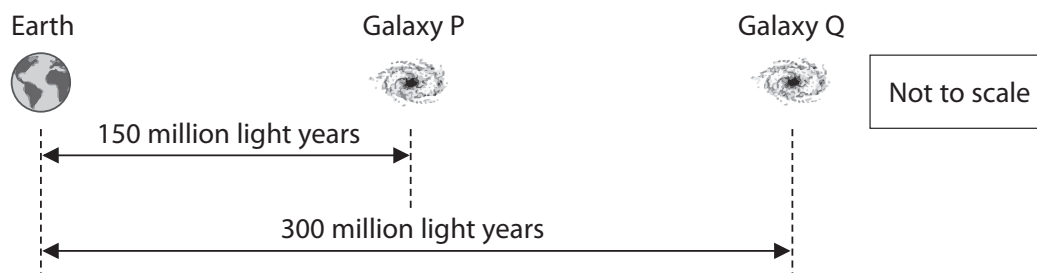


**Diagram 3**

Light emitted from a nearby star has a wavelength of 590 nm.

The light from an identical star in galaxy P arrives at the Earth.

The wavelength of the light from the star in galaxy P is 600 nm.

(i) Calculate the change in wavelength for light from the star in galaxy P.

(1)

change in wavelength = ..... nm



- 1 Ice hockey is a team sport played on ice. Players try to hit a disc called a puck into the other team's goal.



(Source: © Alexandr Grant/Shutterstock)

- (a) Diagram 1 shows a puck travelling across some smooth ice.

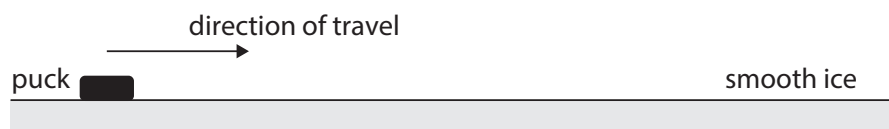


**Diagram 1**

- (i) State the formula linking average speed, distance moved and time taken.

(1)

- (ii) The puck travels at a constant speed of 2.8 m/s.

Calculate the distance moved by the puck in a time of 3.5 s.

(3)

distance moved = ..... m

(b) Diagram 2 shows a puck travelling across some rough ice.

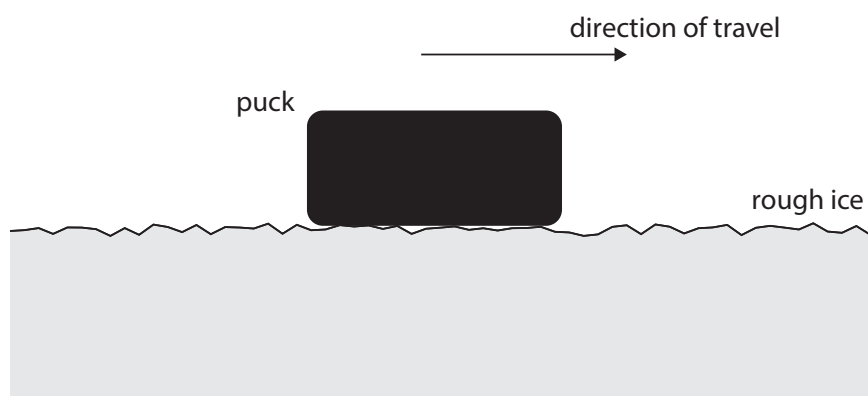


**Diagram 2**

The rough ice exerts a frictional force on the puck.

(i) Draw a labelled arrow on diagram 2 to show the force of friction acting on the puck.

(1)

(ii) Explain how the force of friction changes the velocity of the puck.

(2)

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**(Total for Question 1 = 7 marks)**

- 6 The photograph shows a rocket being launched at Cape Canaveral in the United States of America.



(Source: © Geopix / Alamy Stock Photo)

The table gives some information about the motion of the rocket during the first 5.0 seconds of its launch.

|                  |                     |
|------------------|---------------------|
| Initial velocity | 0.0 m/s             |
| Acceleration     | 13 m/s <sup>2</sup> |
| Time taken       | 5.0 s               |

(a) Calculate the final velocity of the rocket after 5.0 seconds.

Assume that the acceleration remains constant during this time.

(3)

final velocity = ..... m/s

(b) Calculate the distance the rocket travels during the 5.0 seconds.

Assume that the acceleration remains constant during this time.

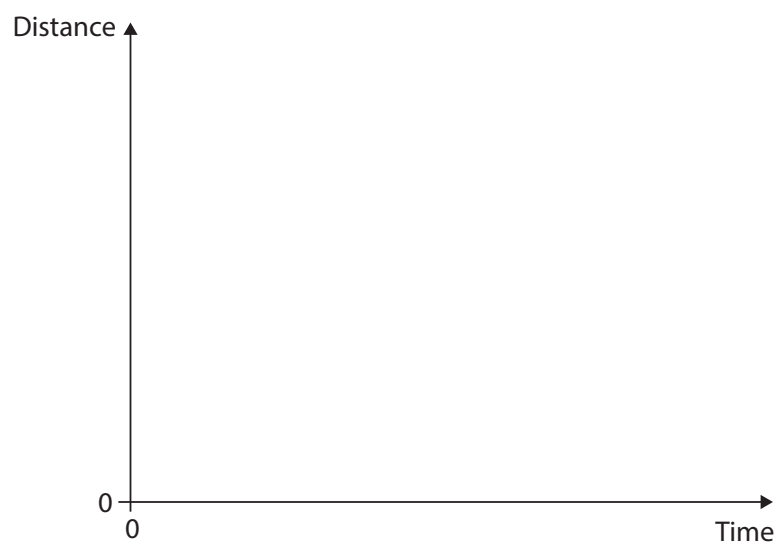
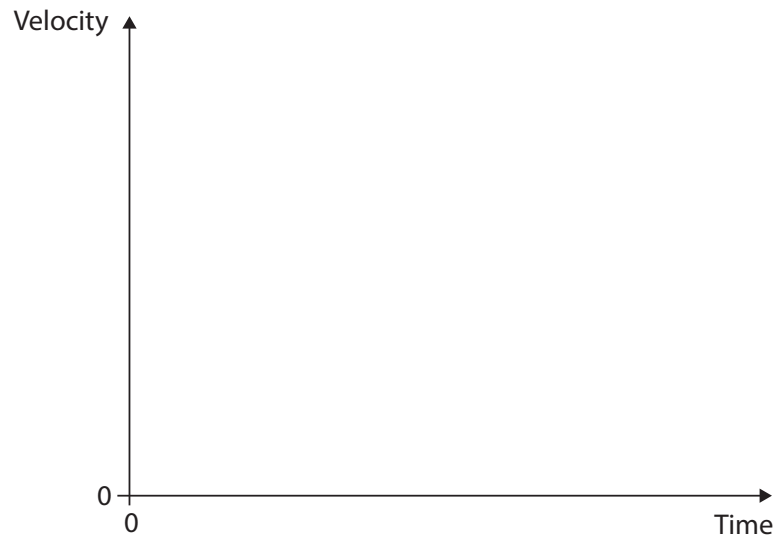
(3)

distance travelled = ..... m

- (c) Sketch a velocity-time graph and a distance-time graph showing how the motion of the rocket changes during the first 5.0 seconds of its launch.

You do not need to include values on the axes.

(4)



(Total for Question 6 = 10 marks)



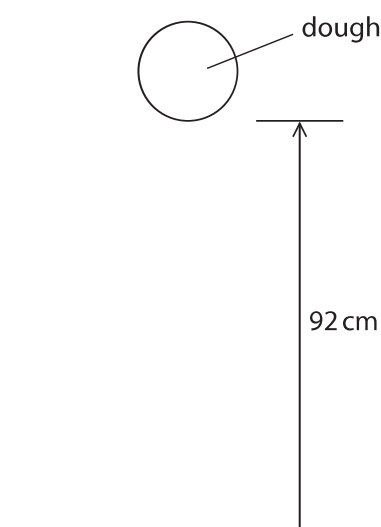
### SUB-TOPIC 1.3

## FORCES, NEWTON'S LAWS AND TERMINAL VELOCITY

Sub-topic 1.3 · 8 questions · 83 marks · lowest tariff first



- 12** (a) The diagram shows a ball of dough, of mass 580 g, held at a height of 92 cm above the floor.



Calculate the increase in gravitational potential energy (GPE) stored in the ball of dough when it is above the floor.

(3)

GPE = ..... J

(b) The ball of dough hits the floor and does not rebound.

Describe the energy transfers taking place from when the dough is dropped to after it has hit the floor.

You should refer to energy stores as well as transfers between energy stores at these stages.

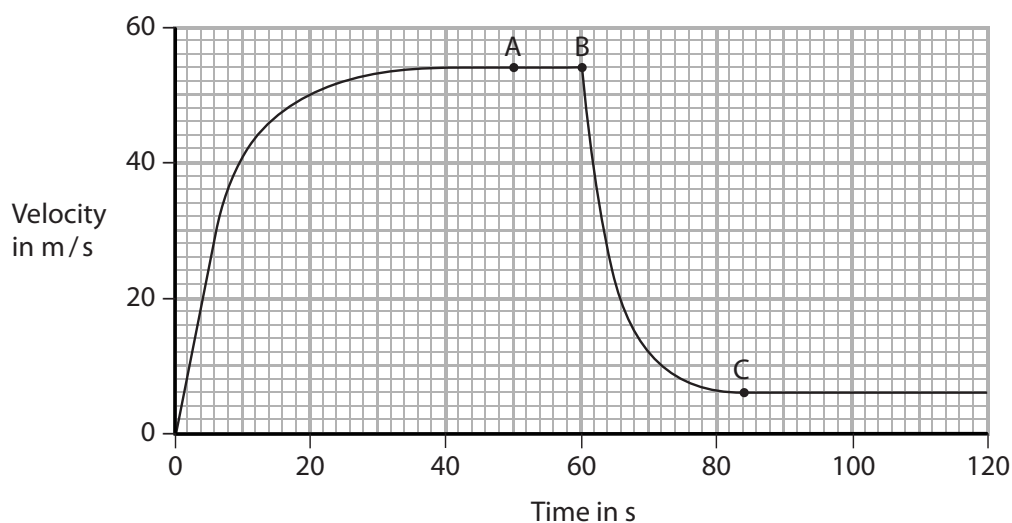
- before the dough is dropped
- just before the dough hits the floor
- after the dough has hit the floor

(4)

(Total for Question 12 = 7 marks)



8 The graph shows how the velocity of a parachute jumper changes with time.



(a) At point A, the parachute jumper is falling at terminal velocity and has not yet opened her parachute.

(i) Which statement is correct about the parachute jumper at point A?

(1)

- ☐ A acceleration and air resistance are equal
- ☐ B acceleration and velocity are equal
- ☐ C weight and acceleration are equal
- ☐ D weight and air resistance are equal

(ii) Which is the best estimate of the distance fallen by the parachute jumper from the start until point A?

(1)

- ☐ A 50 m
- ☐ B 1300 m
- ☐ C 2300 m
- ☐ D 2700 m

(b) The parachute jumper opens her parachute at point B.

Her velocity decreases until she reaches terminal velocity again at point C.

Explain this change in velocity.

(4)

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(c) After point C, the parachute jumper continues to fall at a constant velocity.

As she falls, energy is transferred from a gravitational store.

Which store is the energy transferred into?

(1)

- ☐ A chemical store
- ☐ B gravitational store
- ☐ C kinetic store
- ☐ D thermal store

(Total for Question 8 = 7 marks)



**5** A table tennis ball is a very light plastic ball filled with air.

(a) A student drops a table tennis ball from rest.

The ball falls 13 m to the ground.

Show that the final speed of the ball, just before it reaches the ground, should be about 16 m/s.

Assume that there is no air resistance.

(3)

(b) The student suggests that the ball will reach the ground with a speed that is less than 16 m/s because of air resistance.

Use ideas about forces to justify the student's suggestion.

(5)

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**(Total for Question 5 = 8 marks)**



- 9 The photograph shows a whale jumping out of the surface of the sea.



(Source: © Alexander Baumann/Shutterstock)

- (a) At the top of the jump, the whale's velocity is 0 m/s.

The whale falls 2.2 m from the top of the jump to the surface of the sea.

Calculate the velocity of the whale when it hits the surface of the sea.

(4)

velocity = ..... m/s

(b) A resultant force causes the whale to slow down when it hits the surface of the sea.

(i) Draw an arrow to show this resultant force.

(1)



(Source: © Eugenia Petrovskaya/Shutterstock)

(ii) The resultant force acting on the whale is 18 000 N.

The mass of the whale is 4100 kg.

Calculate the acceleration of the whale.

(3)

acceleration = ..... m/s<sup>2</sup>

**(Total for Question 9 = 8 marks)**

- 9 The driver of a racing car makes a pit stop during a race to change the tyres on the racing car.

The area where the tyres are changed is called the pit lane.



(Source: © Hafiz Johari/Shutterstock)

- (a) Before entering the pit lane, the speed of the car must decrease for safety reasons.

- (i) The mass of the racing car is 830 kg.

The maximum braking force is 41 000 N.

Show that the maximum deceleration of the racing car is approximately  $50 \text{ m/s}^2$ .

(3)

- (ii) The racing car is travelling at an initial speed of  $72 \text{ m/s}$ .

Calculate the minimum distance needed to decrease the speed of the racing car from  $72 \text{ m/s}$  to  $26 \text{ m/s}$ .

(3)

distance = ..... m

(b) The racing car slows down using its brakes.

The brakes work using friction.

The brakes become very hot when the racing car slows down.

Using ideas about energy, explain why the brakes become hot.

(3)

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(c) The tyres of the racing car also get very hot during a race.

A mechanic has to handle the hot tyres during the pit stop.

They wear protective gloves which have several layers of insulating materials.

Explain how the layers of insulating materials in the gloves reduce the risk of the mechanic burning their hands on the hot tyres.

(2)

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**(Total for Question 9 = 11 marks)**

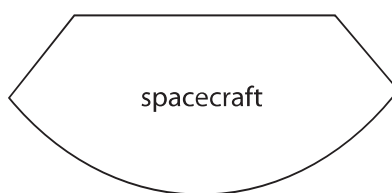


**8** Schiaparelli is a spacecraft that was sent to Mars in 2016.

(a) Schiaparelli slowed down as it fell vertically through the atmosphere of Mars.

- (i) Draw labelled arrows on the diagram to show the forces acting on Schiaparelli as it fell.

(3)



- (ii) Schiaparelli then opened a parachute to slow down.

Explain how the spacecraft reached a low terminal velocity after opening its parachute.

Use ideas about forces in your answer.

(4)

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- (b) The parachute was disconnected when Schiaparelli was at a height of 2.0 m from the surface of Mars and travelling at a speed of 0.45 m/s.

Calculate the speed of the spacecraft just before it hits the surface of Mars.  
[acceleration of free-fall on Mars =  $3.4 \text{ m/s}^2$ ]

(4)

speed = ..... m/s

- (c) Suggest why Mars has a lower gravitational field strength than Earth.

(1)

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**(Total for Question 8 = 12 marks)**



**10** (a) Diagram 1 shows a van accelerating along a horizontal road.

The horizontal forces acting on the van are shown.

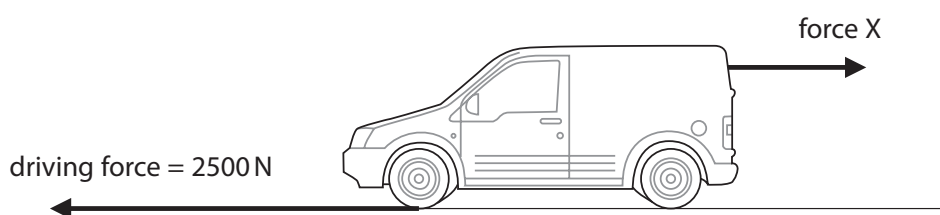


**Diagram 1**

(i) Force X opposes the motion of the van.

State the name of force X.

(1)

(ii) The resultant force acting on the van is 1500 N.

Calculate the magnitude of force X.

[assume X is the only horizontal force opposing the motion of the van]

(1)

force X = ..... N

(b) Diagram 2 shows the resultant force acting on the van when it brakes.

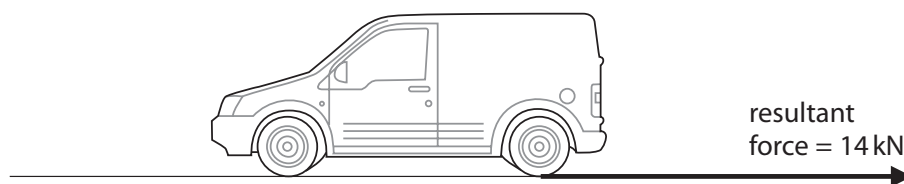


**Diagram 2**

(i) State the formula linking resultant force, mass and acceleration.

(1)

(ii) The mass of the van is 1900 kg.

Calculate the acceleration of the van when it brakes.

Give the unit.

(3)

acceleration = ..... unit .....

(iii) The van was travelling at an initial speed of 18 m/s before braking and coming to rest.

Calculate the distance travelled by the van while it is braking.

[assume that the acceleration remains constant]

(3)

distance travelled = ..... m

(iv) Describe two factors that would increase the braking distance.

(2)

1. ....

.....

2. ....

.....

(c) When the van is fully loaded its mass increases to 2500 kg.

Calculate the time taken to bring the fully loaded van to rest when it is travelling at an initial speed of 18 m/s.

[assume that the resultant force during braking remains at 14 kN]

(4)

time = ..... s

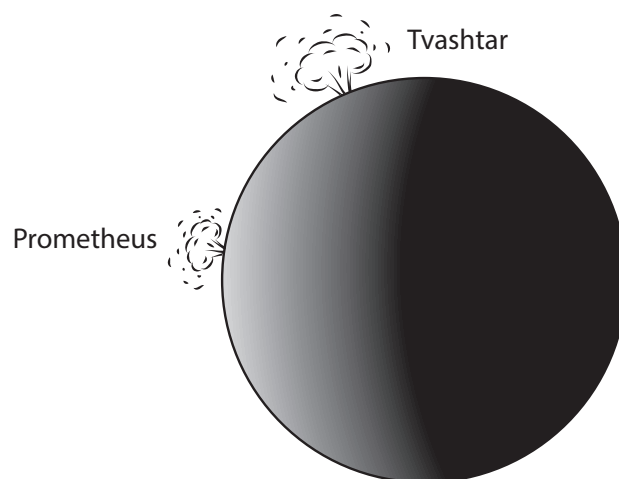
**(Total for Question 10 = 15 marks)**



7 This is a question about Io, a moon of Jupiter.

The diagram shows two jets of gas from volcanoes on Io.

One jet of gas is from the volcano Prometheus and the other is from the volcano Tvashtar.



(a) Gas particles in the Prometheus jet leave the surface of Io and move vertically upwards.

The particles reach their maximum height when their speed is zero.

Some particles in the Prometheus jet reach a maximum height of 92 km.

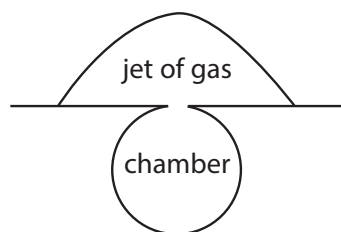
Calculate the initial speed of these particles as they leave the surface of Io.

[acceleration due to gravity on Io =  $1.8 \text{ m/s}^2$ ]

(3)

initial speed = ..... m/s

(b) Before the gas particles leave the surface of Io, they are trapped in a chamber.



(i) Explain how the gas particles exert a pressure on the walls of the chamber.

(3)

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(ii) The Tvashtar chamber has the same volume as the Prometheus chamber and contains the same number of molecules of the same type of gas.

The temperature of the gas in the Prometheus chamber is 1200 K.

The temperature of the gas in the Tvashtar chamber is 1600 K.

The pressure of the gas in the Prometheus chamber is 8.2 kPa.

Calculate the pressure of the gas in the Tvashtar chamber.

(3)

pressure = ..... kPa



(iii) Explain why the pressure inside the chambers increases when the temperature increases.

Use ideas about particles in your answer.

(3)

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(iv) Explain why the particles from the Tvashtar chamber reach a greater maximum height than the particles from the Prometheus chamber.

(3)

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**(Total for Question 7 = 15 marks)**



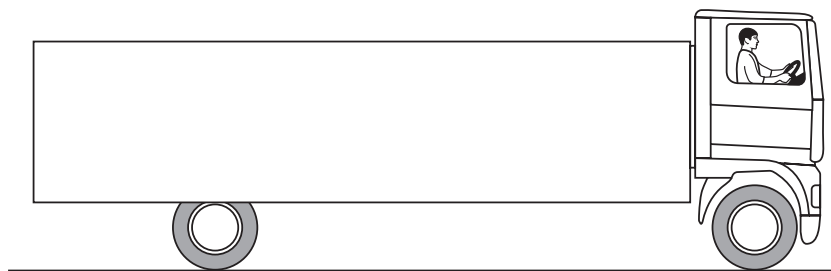
SUB-TOPIC 1.4

# STOPPING DISTANCES

Sub-topic 1.4 · 5 questions · 45 marks · lowest tariff first



3 The diagram shows a truck travelling along a horizontal road.



(a) The driver sees an obstacle in the road and then applies the brakes.

(i) Which of these factors affects thinking distance?

(1)

- ☐ A condition of the tyres
- ☐ B consumption of alcohol by the driver
- ☐ C mass of the vehicle
- ☐ D condition of the road

(ii) Which of these factors affects both thinking distance and braking distance?

(1)

- ☐ A condition of the brakes
- ☐ B condition of the road
- ☐ C mass of the vehicle
- ☐ D speed of the vehicle

(b) The truck experiences a braking force of 46 000 N.

(i) State the formula linking work done, force and distance moved.

(1)

(ii) The truck has 590 000 J of energy in its kinetic energy (KE) store before the driver applies the brakes.

The braking force does work on the truck to reduce the KE store of the truck to 0 J.

The braking distance is defined as the distance required for the KE store of the truck to reduce to 0 J when the brakes are applied.

Calculate the braking distance of the truck.

(3)

distance = ..... m

(c) The brakes increase in temperature when the truck is braking.

(i) State the name of the energy store that has increased for the brakes.

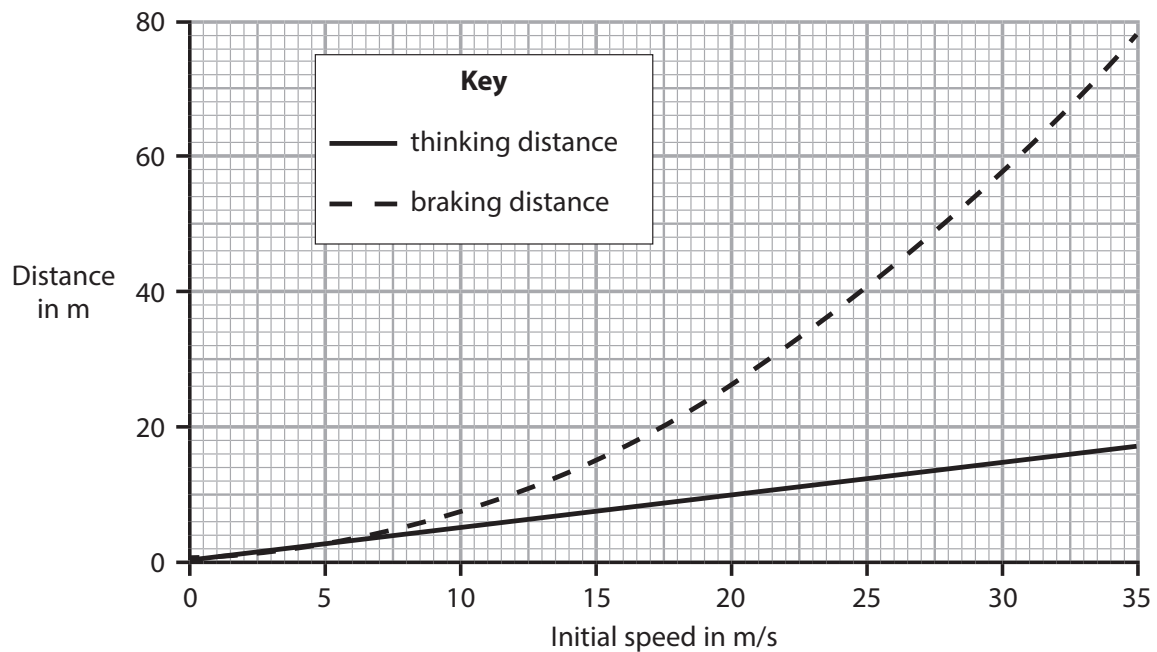
(1)

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(ii) State the method of energy transfer from the truck to the brakes.

(1)

.....  
(Total for Question 3 = 8 marks)

- 11 The graph shows how the thinking distance and braking distance of a car vary with its initial speed.



- (a) A car has an initial speed of 35 m/s.

The brakes are applied and the car comes to a complete stop in the braking distance shown by the graph.

Calculate the mean braking acceleration of the car.

(4)

braking acceleration = ..... m/s<sup>2</sup>

(b) Evaluate how the thinking distance and the braking distance vary for different values of initial speed.

Refer to information from the graph in your answer.

(5)

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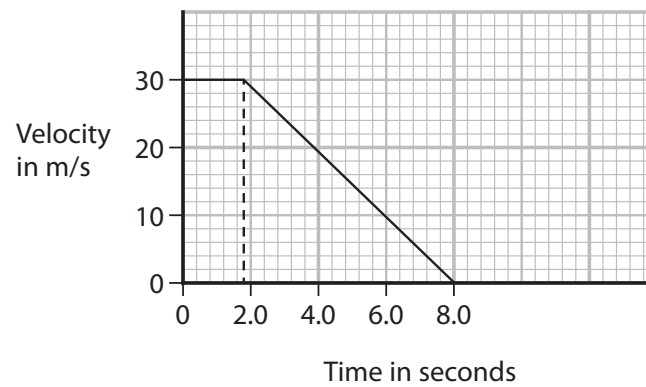
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(Total for Question 11 = 9 marks)



- 4 The diagram shows a velocity-time graph for a car from the time the driver sees an obstacle in the road until the car comes to rest.



- (a) (i) Calculate the acceleration of the car between 1.8 and 8.0 seconds.

(3)

acceleration = .....  $\text{m/s}^2$

- (ii) Calculate the braking distance of the car.

(3)

braking distance = ..... m



(iii) Explain the effect, if any, of increased driver tiredness on the thinking distance and on the braking distance of the car.

(4)

thinking distance.....

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.....

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braking distance.....

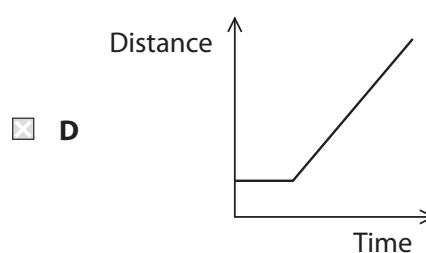
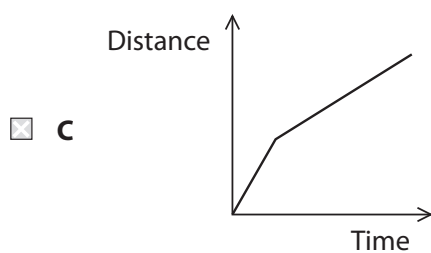
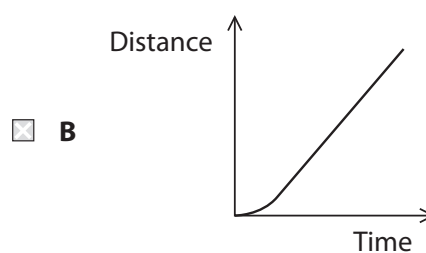
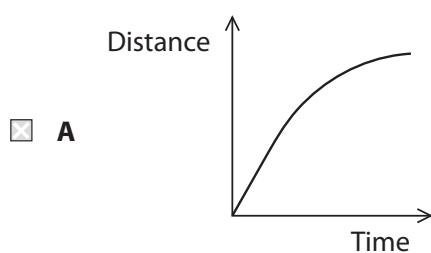
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(b) Which of these represents the distance-time graph for the car?

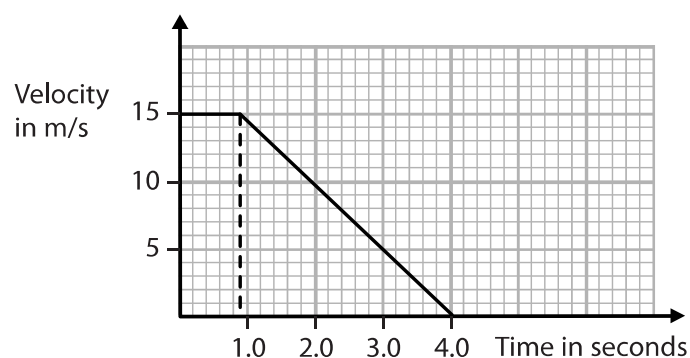
(1)



(Total for Question 4 = 11 marks)

- 4 A car driver sees a hazard on the road ahead.

The graph shows the velocity of the car from when the driver sees the hazard.



- (a) (i) Use the graph to determine the reaction time of the driver.

(1)

reaction time = ..... s

- (ii) Calculate the stopping distance of the car.

(4)

stopping distance = ..... m

- (iii) Calculate the acceleration of the car when the car is braking.

(3)

acceleration = .....  $\text{m/s}^2$



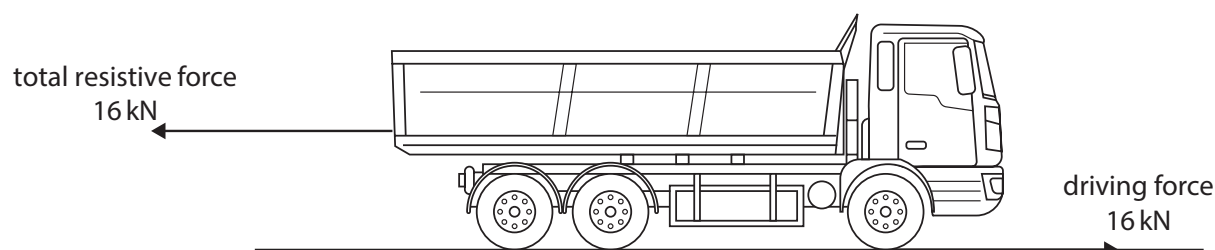
(b) The speed of the car affects the thinking distance and the braking distance.

Discuss other factors that affect the thinking distance and the braking distance of the car.

(4)

**(Total for Question 4 = 12 marks)**

1 The diagram shows a truck travelling along a horizontal road.



(a) The diagram shows the horizontal forces acting on the truck.

Give the resultant horizontal force acting on the truck.

(1)

resultant horizontal force = ..... kN

(b) The driver of the truck has to stop because a tree has fallen on the road.

(i) The thinking distance of the driver is 7 m.

The braking distance of the truck is 20 m.

Calculate the stopping distance of the truck.

(1)

stopping distance = ..... m

(ii) Give two factors that would affect the braking distance of the truck.

(2)

1 .....

.....

2 .....

.....

(iii) Which of these factors would **decrease** the driver's thinking distance?

(1)

- ☐ **A** the road is dry, rather than wet
- ☐ **B** the truck has old, worn tyres, rather than new tyres
- ☐ **C** the driver is tired
- ☐ **D** the truck is travelling at a lower speed

(Total for Question 1 = 5 marks)



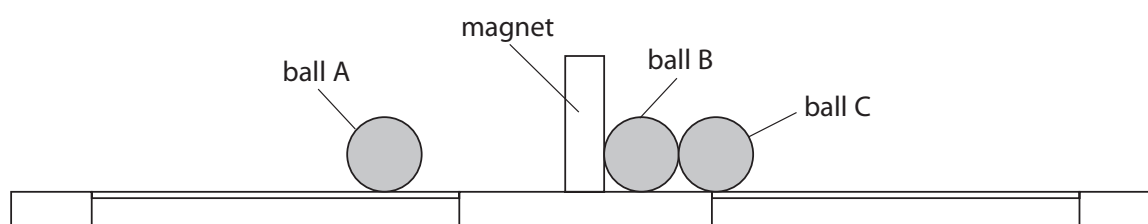
SUB-TOPIC 1.5

# MOMENTUM

Sub-topic 1.5 · 9 questions · 91 marks · lowest tariff first



7 The diagram shows a child's toy for accelerating steel balls.



This is how the toy works.

- the toy uses three identical steel balls, each with a mass of 4.1 g
- ball A moves towards the magnet
- ball B is in contact with the magnet
- balls B and C are initially at rest and are in contact with each other
- when ball A collides with the magnet, ball C moves away from the magnet

(a) Ball A moves towards the magnet with an initial velocity of 0.15 m/s.

Calculate the initial momentum of ball A.

(2)

initial momentum = ..... kg m/s

(b) Ball A is attracted to the magnet.

Explain how this attraction affects the momentum of ball A as it approaches the magnet.

(2)

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- (c) When ball A collides with the magnet, a force of 1.3 N is exerted on ball C for a time of 0.0025 s.

This causes ball C to move away from the magnet.

Calculate the change in velocity of ball C due to this force.

(3)

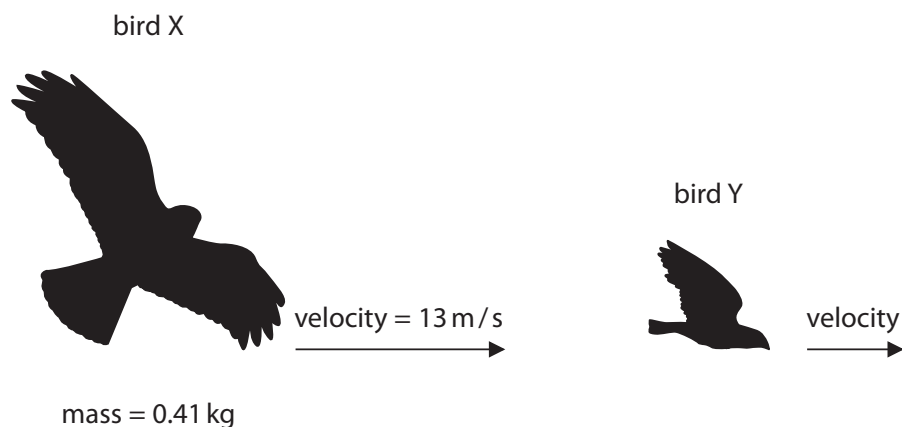
change in velocity = ..... m/s

**(Total for Question 7 = 7 marks)**



- 4 The diagram shows two birds, just before bird X catches the smaller bird Y.

Both birds are travelling horizontally at constant velocity.



- (a) Show that the momentum of bird X is about 5 kg m/s.

(2)

- (b) The momentum of bird Y just before it is caught is 0.15 kg m/s.

Calculate the total momentum of the birds just before bird X catches bird Y.

(1)

momentum = ..... kg m/s

- (c) State the total momentum of the birds just after bird X has caught bird Y.

(1)

momentum = ..... kg m/s

(d) Bird Y has a mass of 0.17 kg.

Calculate the velocity of the birds just after bird X has caught bird Y.

(3)

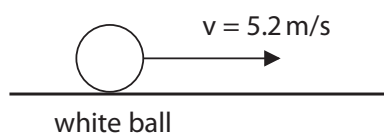
velocity = ..... m/s

**(Total for Question 4 = 7 marks)**



**7** A game is played on a table with balls of different colours.

(a) The diagram shows the white ball moving across a flat surface.



(i) State the formula linking momentum, mass and velocity.

(1)

(ii) The white ball has a mass of 170 g.

Calculate the momentum of the white ball.

(2)

momentum = ..... kg m/s

(b) The white ball collides with a stationary black ball.



(i) The black ball has a mass of 160 g.

After the collision, the black ball moves away from the white ball with a velocity of 5.0 m/s.

Calculate the velocity of the white ball after the collision.

(4)

velocity of white ball = ..... m/s

(ii) During the collision, the white ball exerts a force of 80 N on the black ball.

The direction of this force is to the right.

State the magnitude and direction of the force the black ball exerts on the white ball during the collision.

(2)

magnitude of force = ..... N

direction of force = .....

**(Total for Question 7 = 9 marks)**

3 This question is about momentum.

Diagram 1 shows a neutron approaching a uranium-235 nucleus.

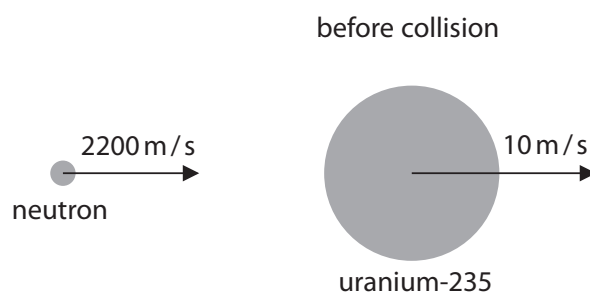


**Diagram 1**

(a) State the formula linking momentum, mass and velocity.

(1)

(b) Calculate the momentum of the neutron.

Give a unit with your answer.

[mass of neutron =  $1.67 \times 10^{-27}$  kg]

(3)

momentum = ..... unit .....

(c) State what is meant by the term **conservation of momentum**.

(1)

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- (d) Diagram 2 shows that when the neutron collides with the uranium-235 nucleus, they combine to give a uranium-236 nucleus.

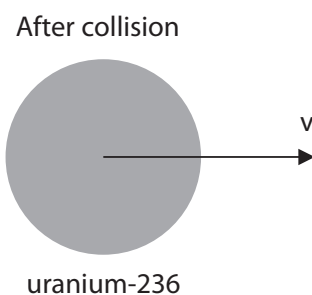


**Diagram 2**

Use conservation of momentum to calculate the velocity,  $v$ , of the uranium-236 nucleus.

[mass of uranium-235 nucleus =  $3.99 \times 10^{-25}$  kg]

[mass of uranium-236 nucleus =  $4.01 \times 10^{-25}$  kg]

(4)

$v = \dots\dots\dots$  m/s

**(Total for Question 3 = 9 marks)**

- 4 The photograph shows a dummy during a test of the safety features of a car in a collision.



(Source: © fStop Images GmbH/Alamy Stock Photo)

Before the collision, the dummy in the car is travelling at a velocity of  $14 \text{ m/s}$ .

The dummy has a momentum of  $1100 \text{ kg m/s}$ .

- (a) (i) State the formula linking momentum, mass and velocity.

(1)

- (ii) Show that the mass of the dummy is approximately  $80 \text{ kg}$ .

(3)

(b) The dummy is brought to rest during the collision by a mean force of 15 kN.

Calculate the time taken for the dummy to be brought to rest in the collision.

(3)

time taken = ..... s

(c) The car being tested is fitted with airbags.

Using ideas about momentum, explain how an airbag reduces the force experienced by the dummy in the collision.

(2)

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**(Total for Question 4 = 9 marks)**



**3** Curling is a sport played on ice.

A player slides stone A across the ice towards a scoring zone.

The ice reduces friction so that there is negligible friction when the stone is sliding.



© Corepics VOF/Shutterstock

(a) Stone A leaves the player's hand with a velocity of  $2.90 \text{ m/s}$ .

The mass of stone A is  $17 \text{ kg}$ .

(i) State the formula linking momentum, mass and velocity.

(1)

(ii) Show that the momentum of stone A is approximately  $50 \text{ kg m/s}$ .

(2)

(b) Stone A slides towards the scoring zone.

In the scoring zone, stone A collides with a stationary stone, B.



© Michael715/Shutterstock

(i) After the collision, both stones move in the same direction as the initial direction of stone A.

The velocity of stone A after the collision is  $0.40 \text{ m/s}$ .

Calculate the velocity of stone B after the collision.

[mass of stone B =  $19 \text{ kg}$ ]

(4)

velocity of stone B = .....  $\text{m/s}$

(ii) When the stones collided, they were in contact for a time of  $25 \text{ ms}$ .

Calculate the magnitude of the force stone A exerted on stone B in this collision.

(3)

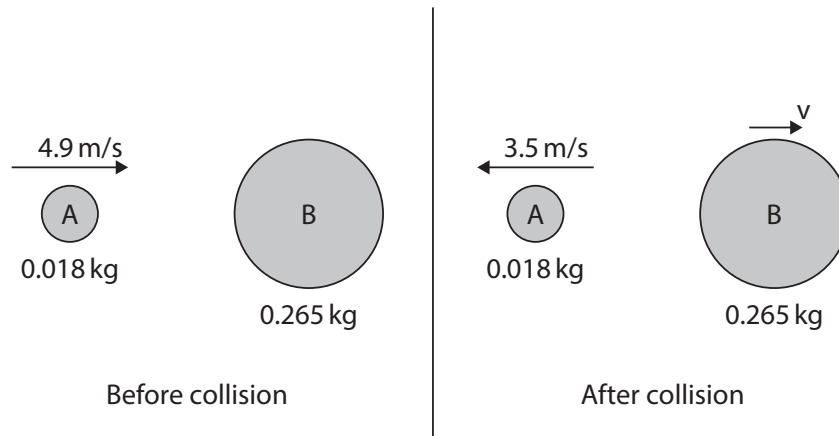
force = .....  $\text{N}$

**(Total for Question 3 = 10 marks)**

5 The diagram shows the collision between two balls, A and B.

The masses and velocities of both balls are shown before and after the collision.

Ball B is stationary before the collision.



(a) When the balls collide, ball B applies a force on ball A, which causes the velocity of ball A to change.

Ball A also applies a force on ball B during the collision.

Describe how the force applied on ball A compares with the force applied on ball B during the collision.

(2)

.....

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.....

(b) Calculate the momentum of ball A before the collision.

(2)

momentum of ball A before collision = .....  $\text{kg m/s}$

(c) Show that the velocity,  $v$ , of ball B after the collision is about  $0.6 \text{ m/s}$ .

(4)

(d) A collision is considered elastic if the total kinetic energy before the collision is equal to the total kinetic energy after the collision.

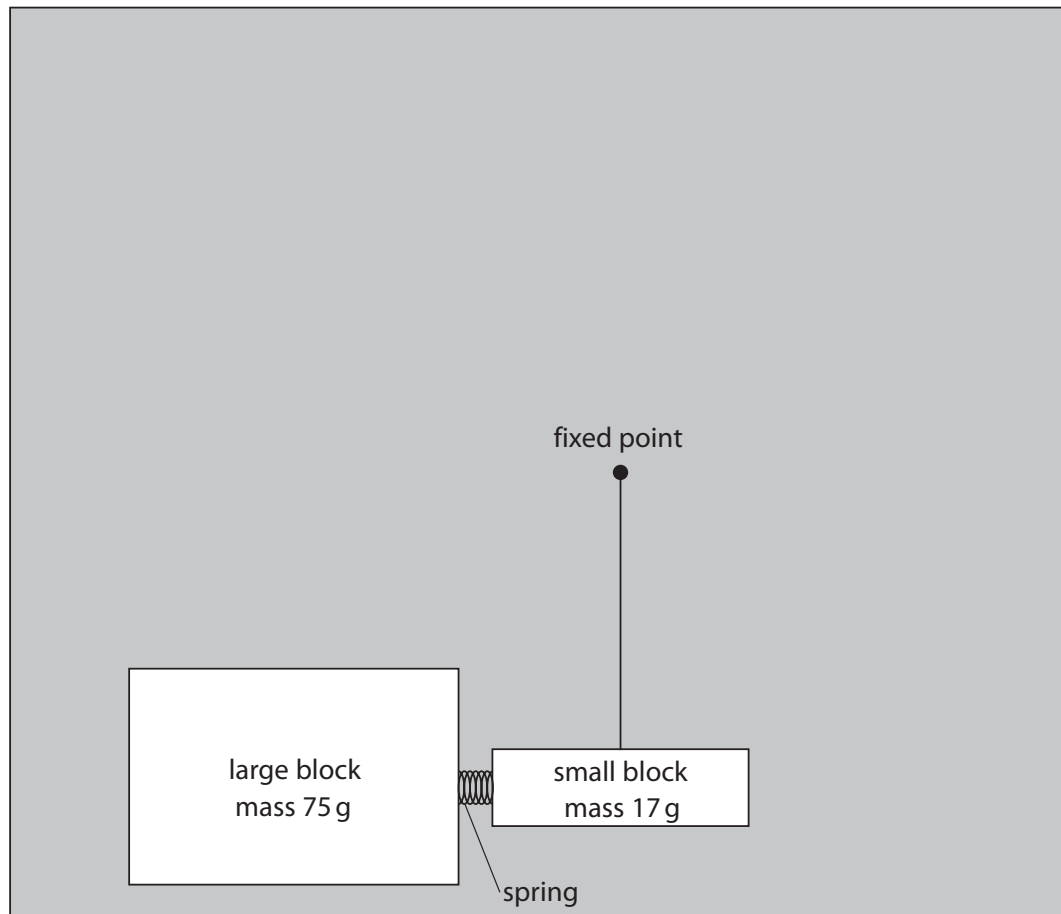
Using data from the diagram, deduce whether this collision is elastic.

(4)

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.....  
**(Total for Question 5 = 12 marks)**



- 7 The diagram shows two blocks at rest on a table, viewed from above.
- A spring is attached to the large block.
- The small block is attached by a piece of string to a fixed point on the table.
- A student pushes the two blocks together so that the spring is compressed.



- (a) The student releases the blocks.

The kinetic energy (KE) store of the small block is 0.29 J when the blocks are no longer in contact.

Show that the speed of the small block is about 6 m/s.

(3)

- (b) Using ideas about momentum, show that the speed of the large block is about 1 m/s after the blocks are no longer in contact.

(4)

- (c) The small block takes 0.11 s to reach 6 m/s.

Calculate the mean force exerted on the small block by the spring.

(3)

mean force = ..... N

**QUESTION 7 CONTINUES ON NEXT PAGE**



(d) The small block then moves around the fixed point on the table.

The block moves in a circular orbit of radius 17.6 cm at a constant orbital speed of 6 m/s.

The time period of the orbit can be found using the formula

$$\text{orbital speed} = \frac{2\pi \times \text{orbital radius}}{\text{time period}}$$

Calculate the time period of the orbit.

(3)

time period = ..... s

**(Total for Question 7 = 13 marks)**



5 A tennis ball is dropped from a height above the ground.

(a) Diagram 1 shows the tennis ball at the instant it is released.

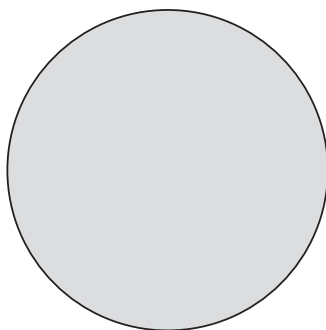


**Diagram 1**

On diagram 1, draw a labelled arrow to show the force acting on the tennis ball at the instant it is released.

(2)

(b) Diagram 2 shows the tennis ball at the instant it hits the ground.

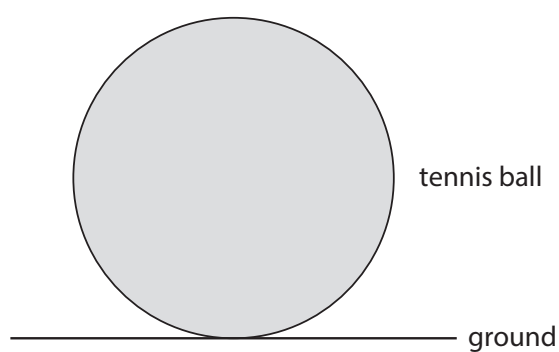


**Diagram 2**

Just before hitting the ground, the tennis ball is moving **downwards** at a velocity of 2.5 m/s.

Just after hitting the ground, the tennis ball is moving **upwards** at a speed of 1.9 m/s.

- (i) The mass of the tennis ball is 0.057 kg.

Calculate the change in momentum of the tennis ball when it hits the ground.

Give the unit.

(4)

change in momentum = ..... unit = .....

- (ii) The ball is in contact with the ground for a time of 6.0 ms.

Calculate the force exerted on the ball by the ground.

Give the direction of this force.

(3)

force = ..... N

direction = .....



- (c) The coefficient of restitution can be used to determine how high a ball will bounce. The higher the value of the coefficient of restitution, the higher the ball will bounce.

Diagram 3 shows a ball being dropped from a height ( $h_1$ ) above the ground.

The ball hits the ground and bounces.

At the top of its bounce, the ball reaches a height ( $h_2$ ) above the ground.

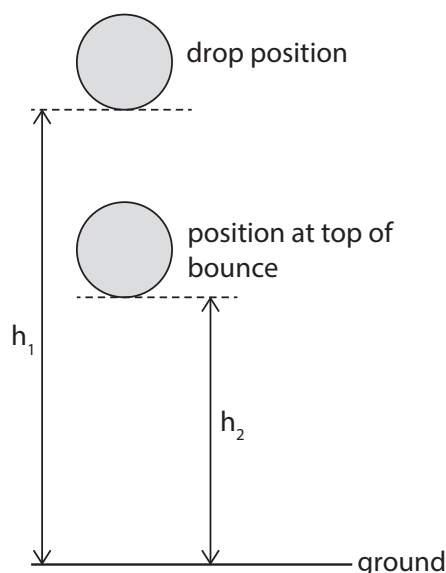


**Diagram 3**

The coefficient of restitution can be determined using the formula

$$\text{coefficient of restitution} = \sqrt{\frac{h_2}{h_1}}$$

A student decides to do an investigation to compare the coefficient of restitution for different types of ball.

Design a method for the student's investigation.

Your answer should include details of

- the variables in the investigation
- how to obtain accurate measurements
- how to obtain reliable results

You may add to diagram 3 or draw an additional diagram to help your answer.

(6)

**(Total for Question 5 = 15 marks)**

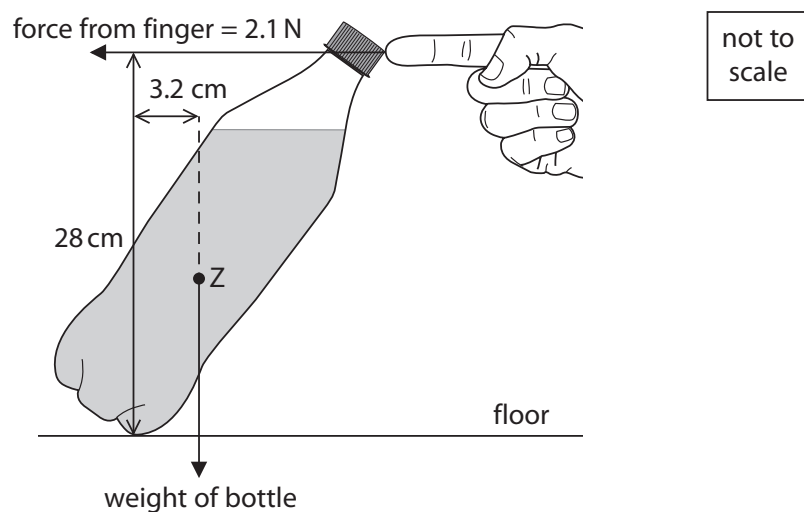
SUB-TOPIC 1.6

# MOMENTS AND CENTRE OF GRAVITY

Sub-topic 1.6 · 10 questions · 89 marks · lowest tariff first



- 8 The diagram shows a bottle supported by a finger.



- (a) State the name of point Z.

(1)

- (b) (i) State the formula linking moment, force and perpendicular distance from the pivot.

(1)

- (ii) The bottle does not move.

Calculate the weight of the bottle.

(4)

weight of bottle = ..... N

(Total for Question 8 = 6 marks)

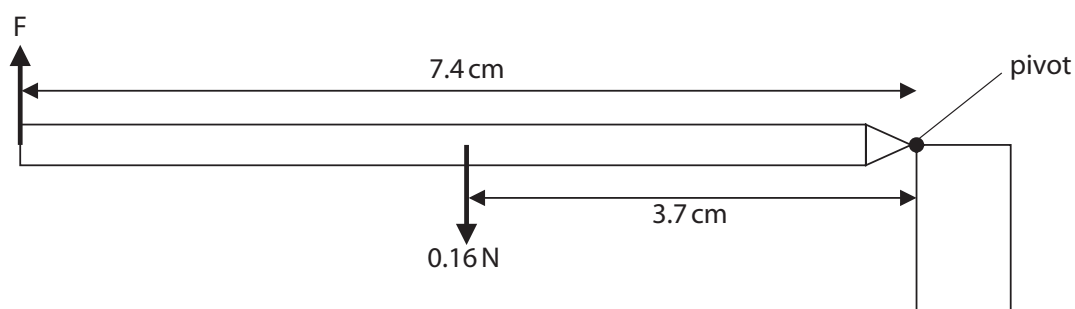
1 A pencil has a weight of 0.16 N.

(a) What is the mass of the pencil?

(1)

- ☐ A 1.6 g
- ☐ B 16 g
- ☐ C 160 g
- ☐ D 1600 g

(b) The diagram shows the pencil with one end resting on a small block.



A finger provides an upwards force,  $F$ , to keep the pencil horizontal.

(i) The weight of the pencil is 0.16 N.

Calculate the moment of the weight of the pencil about the pivot.

Use the formula

$$\text{moment} = \text{force} \times \text{perpendicular distance from the pivot}$$

(2)

moment = ..... N cm

(ii) State the moment of the force F.

(1)

moment = ..... N cm

(iii) Show that force F is 0.080 N.

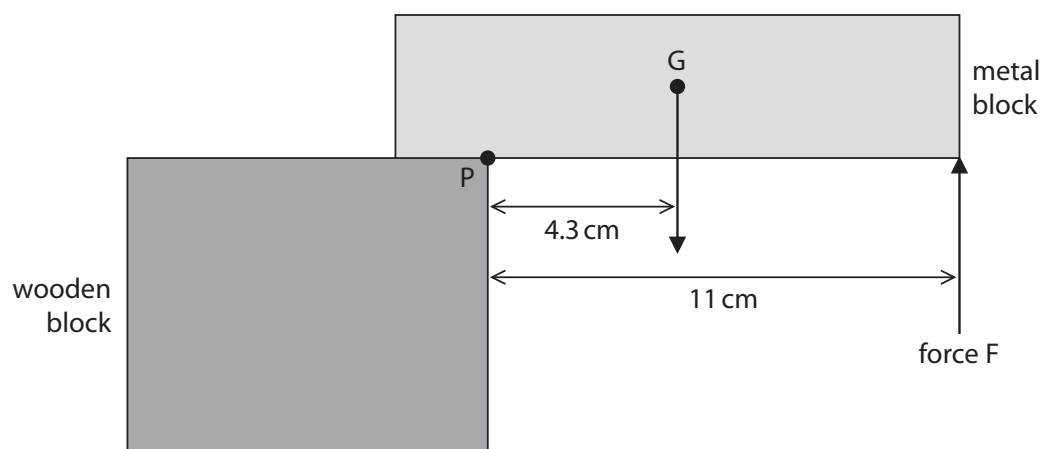
(2)

**(Total for Question 1 = 6 marks)**



- 2 The diagram shows a metal block on top of a wooden block.

The metal block is held stationary by force  $F$ .



- (a) (i) The weight of the metal block acts through point G.

Give the name of point G.

(1)

- (ii) Name a piece of apparatus that could be used to measure the weight of the metal block.

(1)

(b) (i) State the formula linking moment, force and perpendicular distance from the pivot.  
(1)

(ii) The weight of the metal block is 0.68 N.

Show that the moment of the weight of the metal block about point P is approximately 2.9 N cm.

(1)

(iii) Force F is applied to the metal block to stop it from moving.

Calculate the magnitude of force F.

(3)

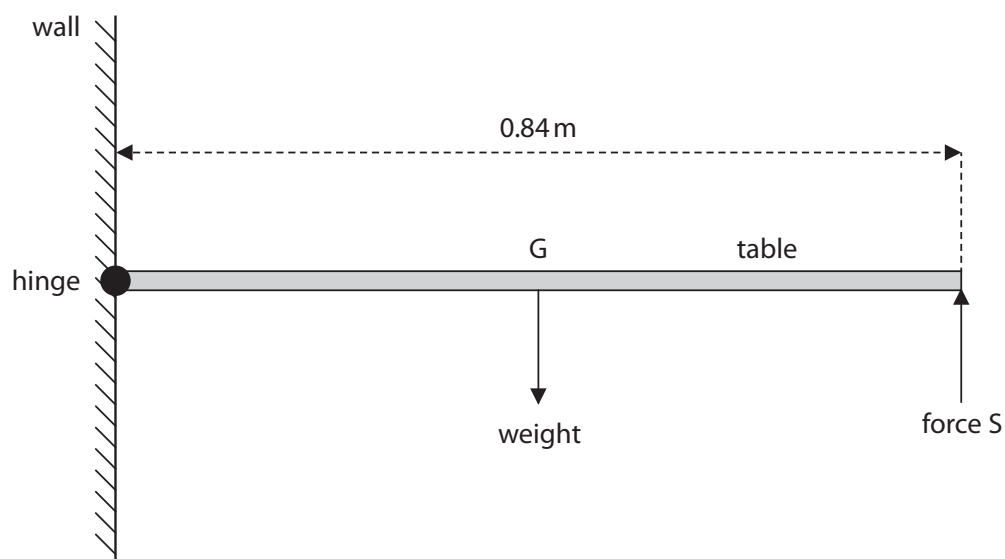
force F = ..... N

**(Total for Question 2 = 7 marks)**



2 This question is about a folding table.

The diagram shows some of the forces acting on the table.



(a) The weight of the table acts through point G.

State the name of point G.

(1)

(b) State the formula linking moment, force and perpendicular distance from the pivot.

(1)

(c) The moment of the weight force of the table about the hinge is 92 N m.

By using the principle of moments, calculate the force S that a person applies to keep the table in equilibrium.

(3)

force S = ..... N

(d) State Newton's third law.

(1)

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(e) State the magnitude and the direction of the force that the table applies to the person holding the table.

(2)

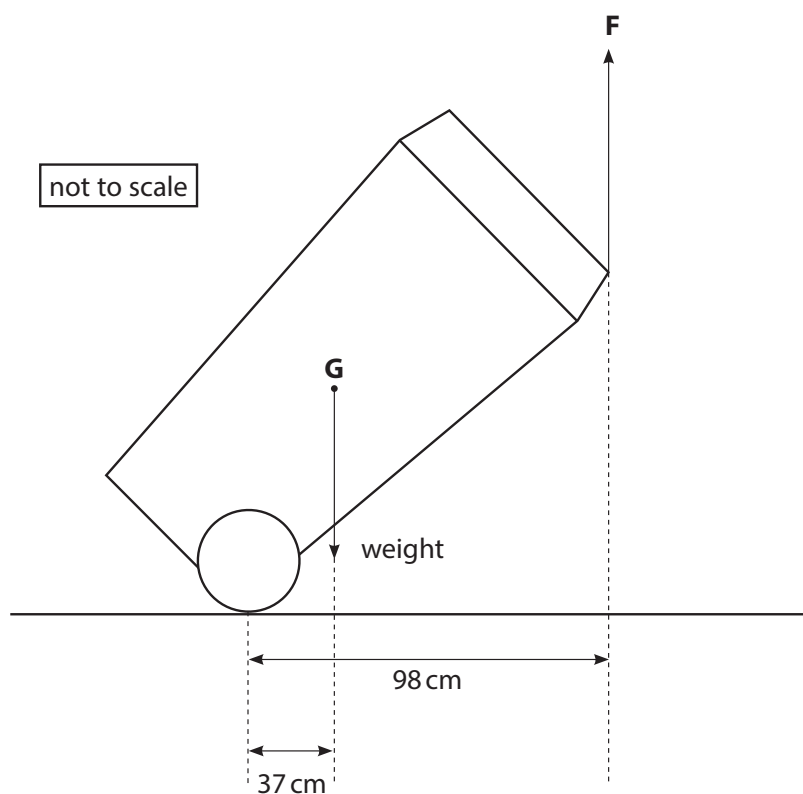
magnitude = ..... N

direction = .....

**(Total for Question 2 = 8 marks)**



- 3 The diagram shows some of the forces acting on a large rubbish bin on wheels.



- (a) The weight of the bin acts through point **G**.

Give the name of point **G**.

(1)

- (b) The mass of the bin is 23 kg.

- (i) What is the weight of the bin?

(1)

- ☐ **A** 23 kg
- ☐ **B** 230 kg
- ☐ **C** 230 N
- ☐ **D** 23 000 N

(ii) State the principle of moments.

(1)

(iii) A person applies force  $F$  to the bin to keep it stationary.

Calculate the magnitude of force  $F$ .

(4)

magnitude of force  $F = \dots\dots\dots$  N

(iv) State the magnitude and direction of the force applied to the person by the bin.

(2)

magnitude =  $\dots\dots\dots$  N

direction =  $\dots\dots\dots$

**(Total for Question 3 = 9 marks)**



**3** A builder needs to lift a large stone block.

(a) Diagram 1 shows the stone block.

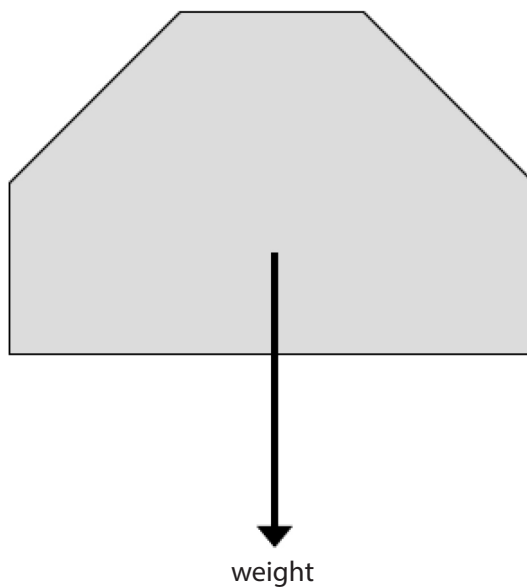


**Diagram 1**

(i) Draw an X on diagram 1 at the centre of gravity of the stone block.

(1)

(ii) State the formula linking weight, mass and gravitational field strength.

(1)

(iii) The mass of the stone block is 130 kg.

Calculate the weight of the stone block.

(2)

weight = ..... N

(b) The builder uses a wooden plank to lift the large stone block.

The plank is uniform and pivoted at its centre.

The builder pushes down on one end of the plank to lift the stone block.

Diagram 2 shows the plank when it is horizontal and stationary.

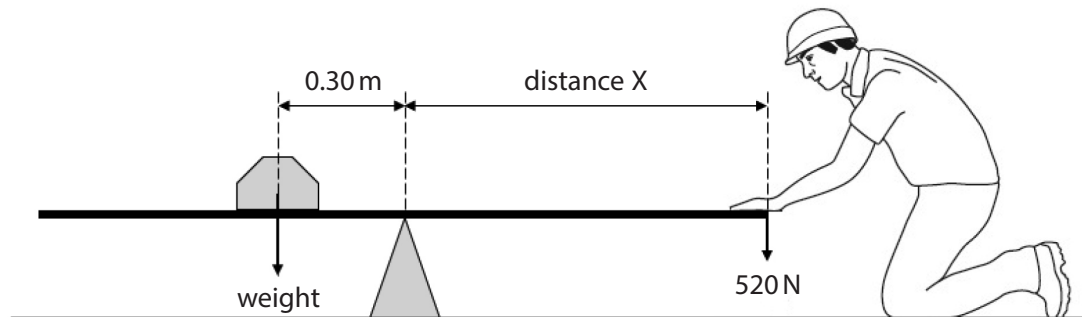


**Diagram 2**

(i) State the principle of moments.

(2)

.....

.....

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.....

(ii) The builder is pushing down with a force of 520 N to keep the plank horizontal.

Calculate distance X.

(3)

distance X = ..... m

(iii) Calculate the length of the plank.

(1)

length of plank = ..... m

**(Total for Question 3 = 10 marks)**

2 A wrench is used to turn a nut.

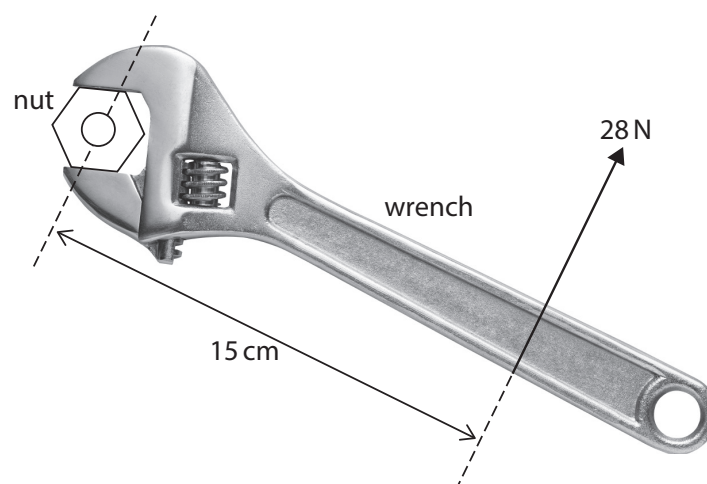


**Diagram 1**

(Source: <https://www.shutterstock.com/image-photo/adjustable-spanner-isolated-on-white-chrome-1794553030>)

(a) The force applied to the wrench is 28 N.

Calculate the moment applied by the wrench on the nut.

Give a suitable unit.

(3)

moment = ..... unit = .....

(b) State **two** changes that could be made to increase the size of the moment applied to the nut.

(2)

1 .....

.....

2 .....

.....

(c) Diagram 2 shows the wrench as it is turned through  $90^\circ$

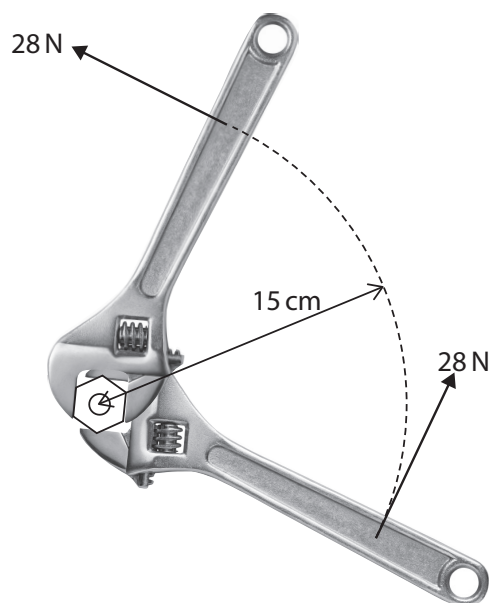


**Diagram 2**

(Source: <https://www.shutterstock.com/image-photo/adjustable-spanner-isolated-on-white-chrome-1794553030>)

- (i) The force is applied over a distance that is equal to a quarter of the circumference of a circle.

The circle has a radius of 15 cm.

Calculate the distance over which the force is applied.

[circumference of circle =  $2 \times \pi \times \text{radius}$ ]

(2)

distance = ..... cm

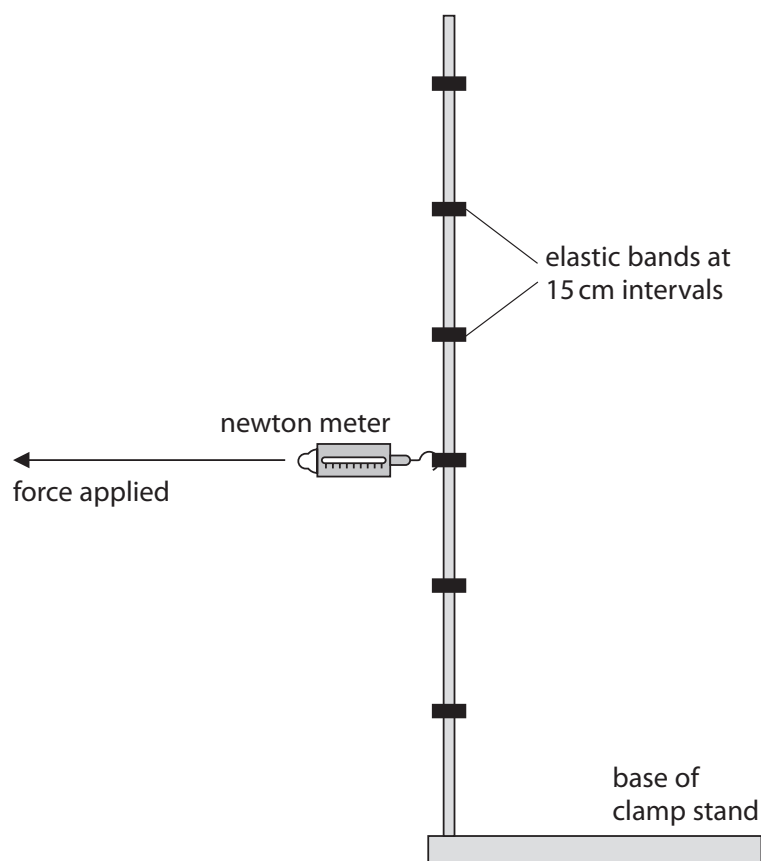
- (ii) Calculate the work done by the force as the wrench is turned through a quarter of the circumference of the circle.

(3)

work done = ..... J

**(Total for Question 2 = 10 marks)**

3 A student uses this apparatus to investigate moments.



This is the student's method.

- attach elastic bands at 15 cm intervals on a one metre tall clamp stand
- attach a newton meter to the highest elastic band and measure the horizontal force required to tilt the stand
- repeat the method at each 15 cm interval

(a) Name an instrument that the student should use to accurately measure the distances on the clamp stand.

(1)

(b) The table shows the student's results.

| Distance in cm | Force applied in N |
|----------------|--------------------|
| 15.0           | 10.0               |
| 30.0           | 5.6                |
| 45.0           |                    |
| 60.0           | 2.6                |
| 75.0           | 2.2                |
| 90.0           | 1.8                |

(i) The photograph shows the reading on the newton meter when the distance is 45.0 cm.



Use the photograph to determine the force required to tilt the stand when the distance is 45.0 cm.

(1)

force = ..... N

(ii) Give a reason why this newton meter is unsuitable for measuring the force for distances less than 15.0 cm.

(1)

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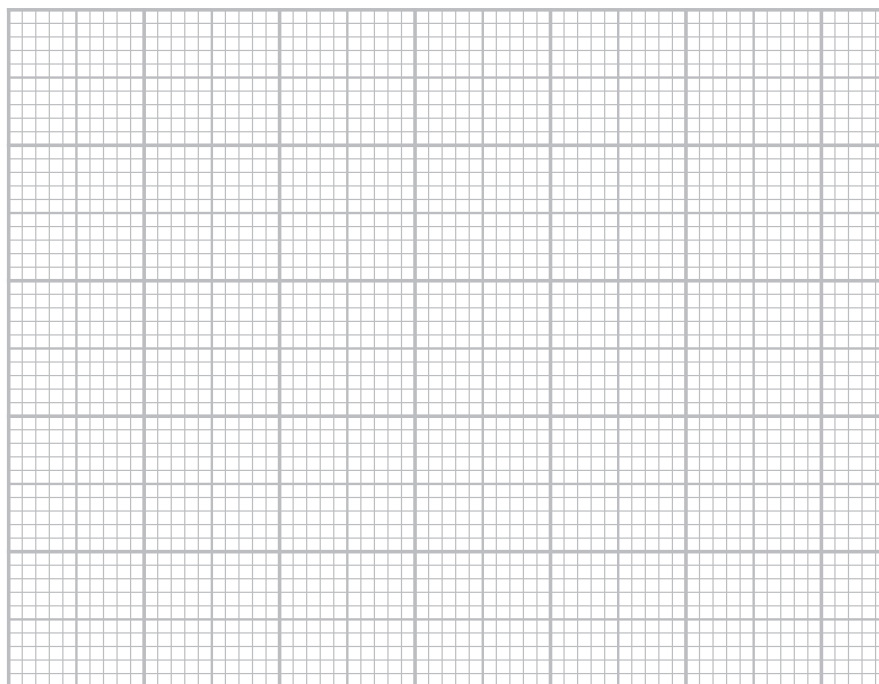
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(c) (i) Plot a graph of the student's results on the grid.

(3)

(ii) Draw the curve of best fit.

(1)



- (d) The student concludes that the moment required to tilt the clamp stand does not change when the distance is varied.

Use data from the table or the graph to evaluate the student's conclusion.

(4)

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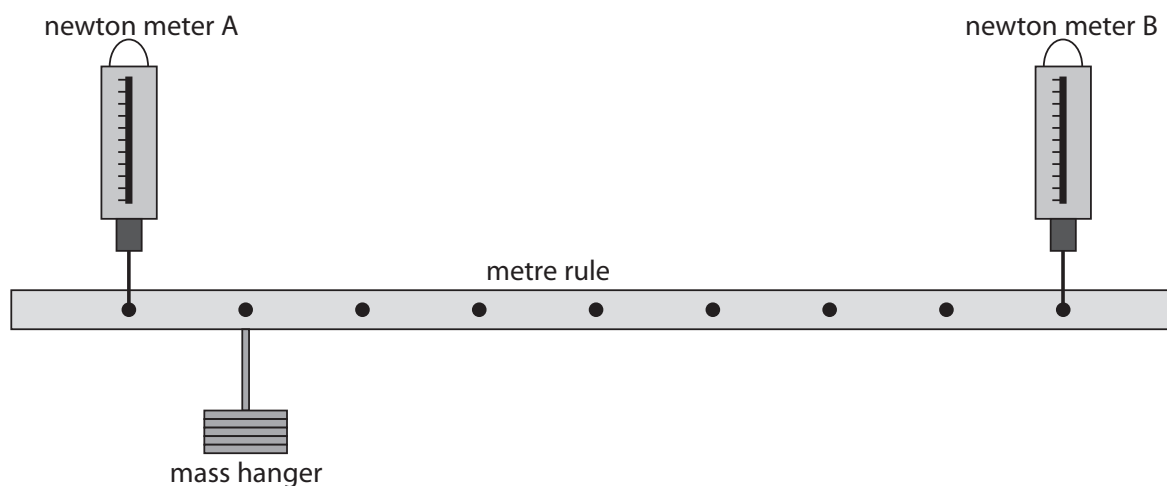
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(Total for Question 3 = 11 marks)



- 5 A student investigates how the support forces acting on a metre rule are affected by the position of a mass hanger.

He uses this apparatus.



This is the student's method.

- suspend a metre rule from its 10 cm and 90 cm marks using two newton meters
- place a mass hanger with a weight of 5 N at the 20 cm mark on the metre rule
- adjust the heights of the newton meters until the metre rule is horizontal
- record the readings on both newton meters

The student repeats the method, moving the mass hanger to a different position on the metre rule each time.

- (a) (i) State the independent variable in the student's investigation.

(1)

.....

- (ii) State two control variables in the student's investigation.

(2)

1 .....

2 .....

- (iii) Suggest how the student could improve the quality of his data.

(1)

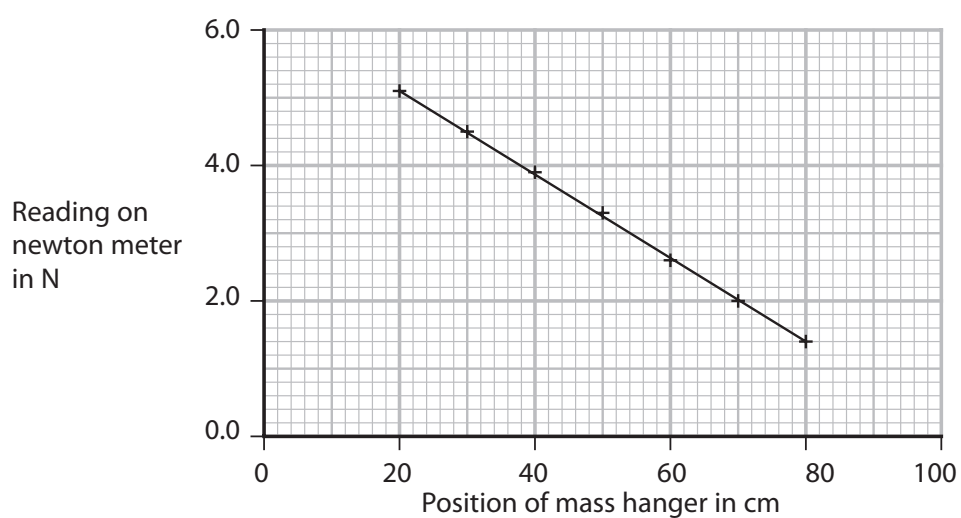
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(b) The table shows the student's results.

| Position of mass hanger in cm | Reading on newton meter A in N | Reading on newton meter B in N |
|-------------------------------|--------------------------------|--------------------------------|
| 20                            | 5.1                            | 1.4                            |
| 30                            | 4.5                            | 2.0                            |
| 40                            | 3.9                            | 2.6                            |
| 50                            | 3.3                            | 3.3                            |
| 60                            | 2.6                            | 3.9                            |
| 70                            | 2.0                            | 4.5                            |
| 80                            | 1.4                            | 5.1                            |

The graph shows the results for newton meter A.



(i) Plot the results for newton meter B.

(1)

(ii) Draw the line of best fit for newton meter B.

(1)



(iii) Describe the relationships shown by the graph.

(4)

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(c) Using ideas about moments, explain why the reading on newton meter A decreases as the mass hanger is moved towards newton meter B.

(3)

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**(Total for Question 5 = 13 marks)**

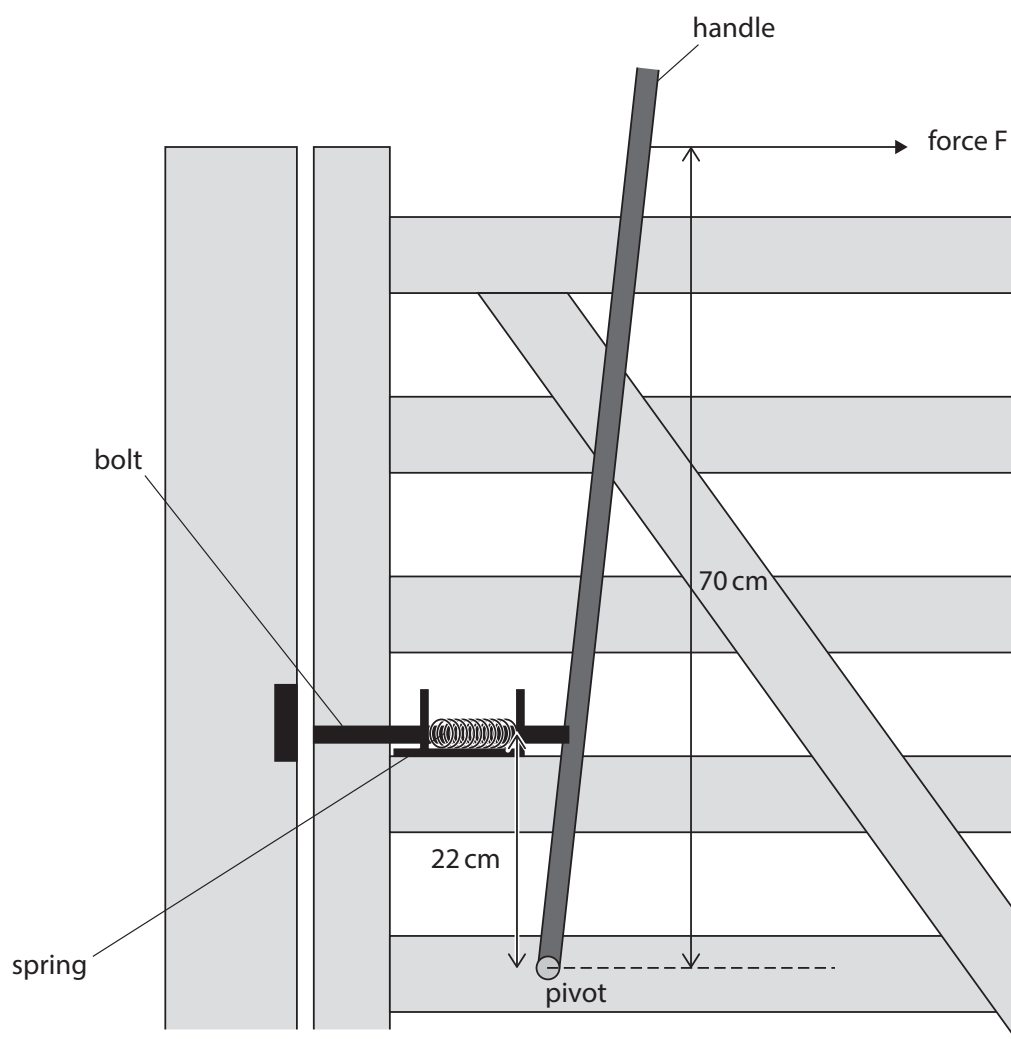


- 4 The photograph shows a mechanism that can be used to open a gate.



(Source: © Photimageon / Alamy Stock Photo)

The diagram shows the gate mechanism when the handle is being pulled to the right.



The bolt is connected to the handle. When the handle is pulled to the right, the bolt also moves to the right and the gate can be opened.

The spring is compressed when the bolt moves to the right. When the handle is released, the spring pushes the bolt back to its original position.

- (a) When the handle is pulled to the right, the spring applies a force on the handle to the left.

The vertical distance between the spring and the pivot point of the handle is 22 cm.

The force from the spring is 5.2 N.

- (i) Show that the force from the spring produces a moment of approximately 1 Nm.

(3)

- (ii) State what is meant by the term **principle of moments**.

(1)

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- (iii) Force  $F$  acts on the handle to keep the handle stationary so that the gate can be opened.

Force  $F$  acts at a vertical distance of 70 cm from the pivot point of the handle.

Calculate the magnitude of force  $F$ .

(3)

magnitude of force  $F =$  ..... N



(b) Give two changes to this gate mechanism that would make it easier to open the gate.

(2)

1 .....

.....

2 .....

.....

(Total for Question 4 = 9 marks)

SUB-TOPIC 1.7

# HOOKE'S LAW AND ELASTIC BEHAVIOUR

Sub-topic 1.7 · 7 questions · 73 marks · lowest tariff first

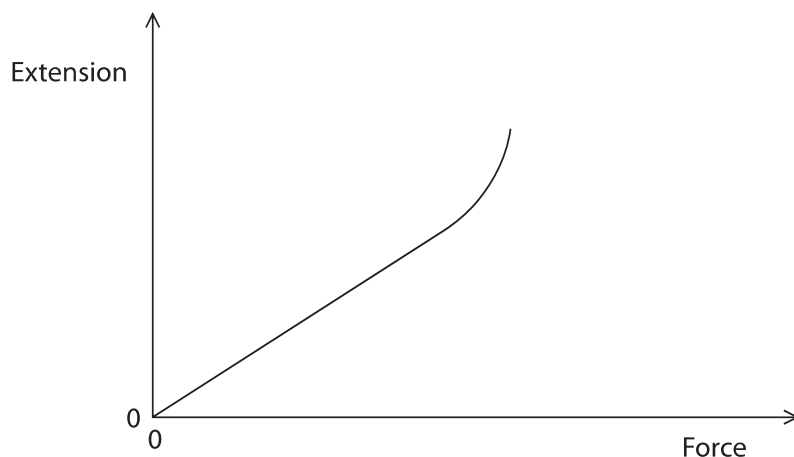


5 This question is about stretching a spring.

(a) The graph shows how the extension of a spring varies when a force is applied to the spring.

The line on the graph shows that the spring has been extended past its elastic limit.

The line has a straight section and a curved section.



(i) Draw a cross on the line to show the elastic limit of the spring.

(1)

(ii) Sketch another line to show how the extension will change when the force is decreased from its maximum value back to 0.

(2)

(b) (i) State which energy store of the spring increases when it is stretched. Assume the spring does not reach its elastic limit.

(1)

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(ii) How is this energy transferred to the spring?

(1)

- ☐ A electrically
- ☐ B by heating
- ☐ C mechanically
- ☐ D by radiation

(Total for Question 5 = 5 marks)

- 8 Diagram 1 shows a set of masses attached to a spring, which is suspended from a support.

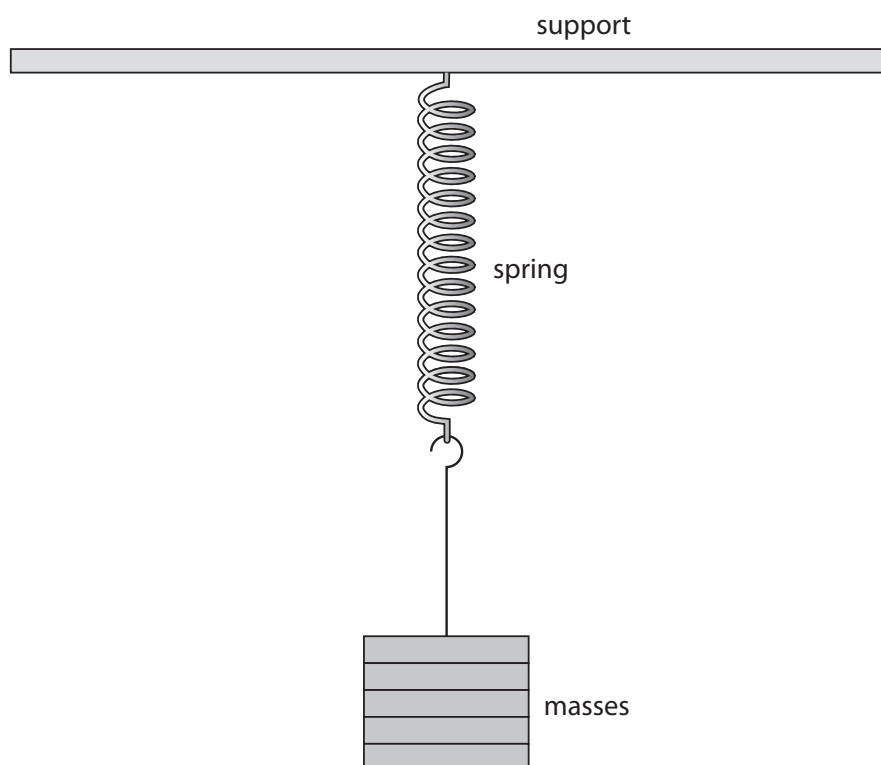


Diagram 1

- (a) After the masses are added, the length of the spring is 14.6 cm.

The student measures the extension of the spring as 11.5 cm.

- (i) Calculate the original length of the spring.

(1)

original length = ..... cm

- (ii) The student removes the masses and notices that the spring does **not** show elastic behaviour.

Predict a value for the new length of the spring after the masses have been removed.

(1)

new length of spring = ..... cm

(b) The student puts the masses back on the spring.

The student then pulls the masses down and releases them.

The masses vibrate up and down in a vertical direction, as shown in diagram 2.

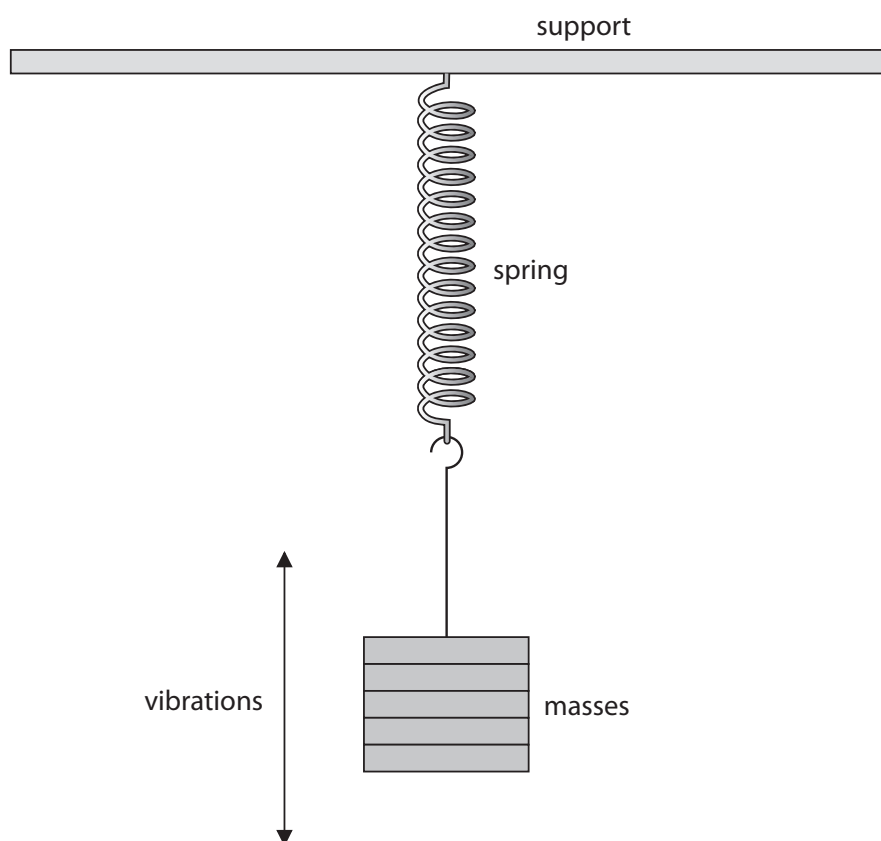
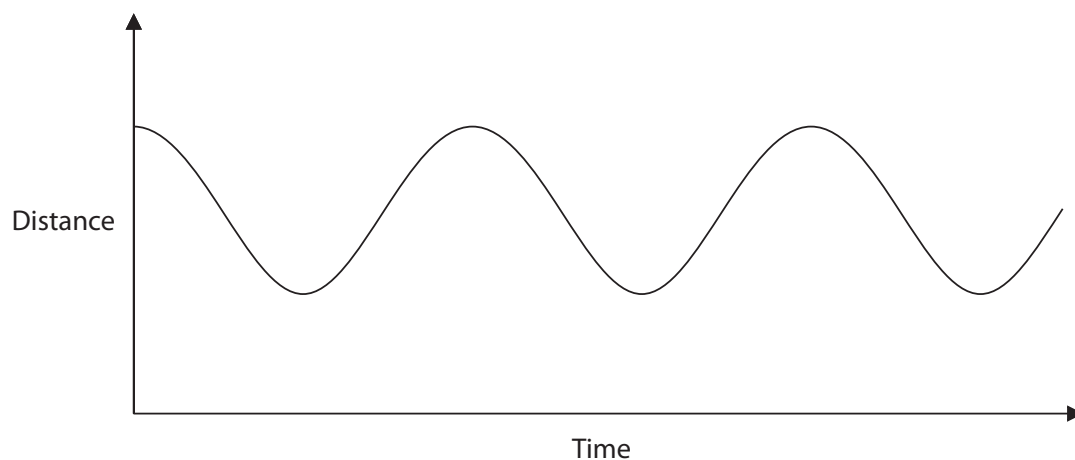


**Diagram 2**

The distance–time graph shows how the distance between the top of the masses and the support changes with time as the masses vibrate.



- (i) Explain how the gradient of the graph shows that the masses accelerate as they vibrate.

(3)

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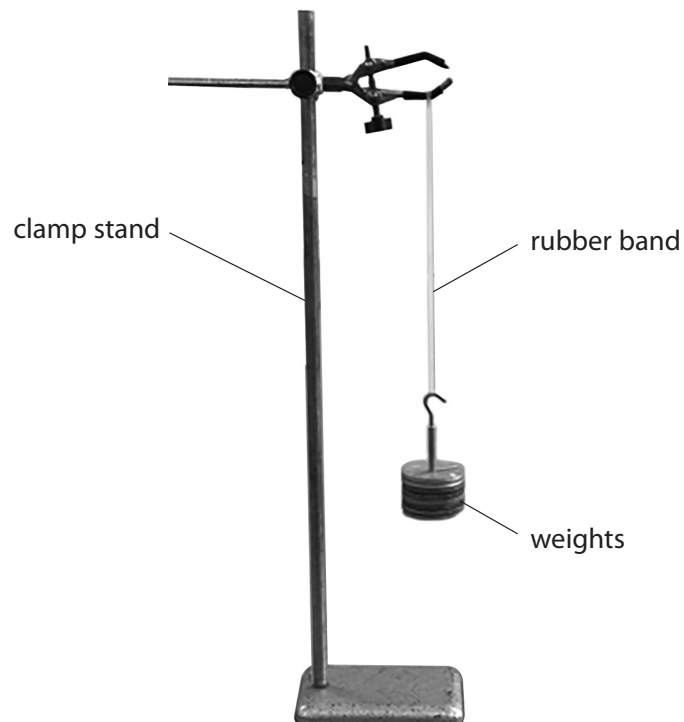
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- (ii) Add crosses (×) to the distance–time graph to show all the times when the masses are not moving.

(2)

**(Total for Question 8 = 7 marks)**

**10** A student uses this apparatus to investigate the stretching of a rubber band.



This is the student's method.

- attach the 12 cm long rubber band to a clamp stand
- hang a 1 N weight from the other end of the rubber band
- determine the extension of the rubber band

The student repeats this method, increasing the weight by 1 N each time until the weight is 10 N.

(a) Describe how the student could determine the extension of the rubber band.

(3)

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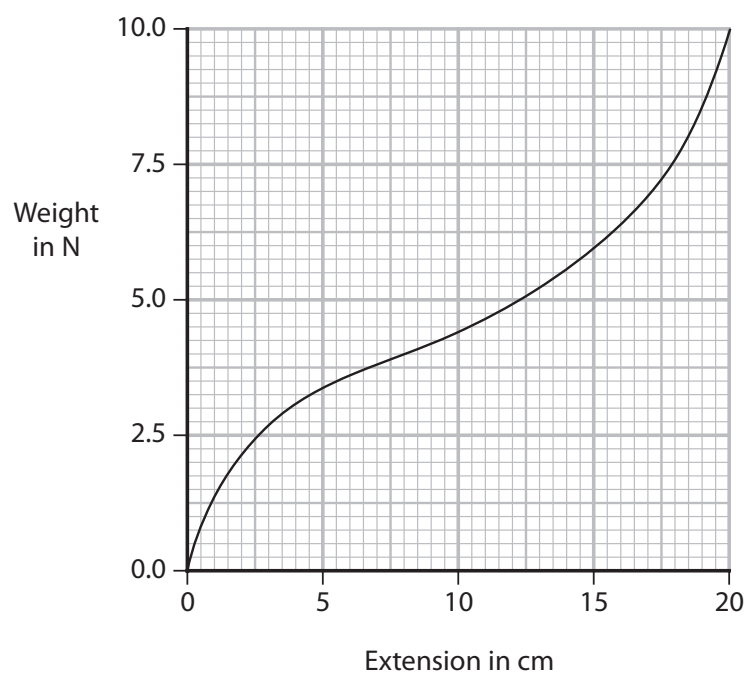
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(b) The graph shows the student's results.



(i) Explain how the graph shows that the rubber band does not obey Hooke's Law. (2)

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- (ii) The area under the curve on the graph is equal to the increase in the rubber band's elastic energy store.

Estimate the increase in the rubber band's elastic energy store when the rubber band has been extended by 20 cm.

(4)

increase = ..... J

**(Total for Question 10 = 9 marks)**



4 (a) (i) State Hooke's Law.

(2)

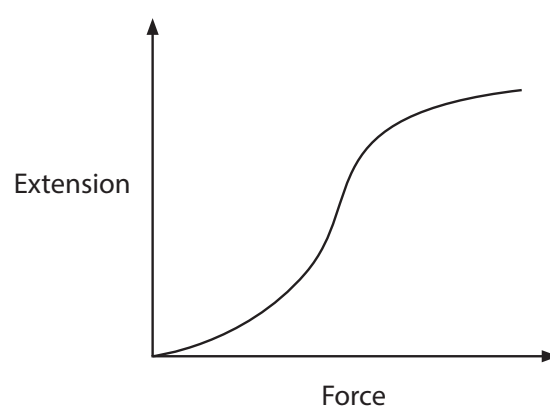
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(ii) The graph shows how the extension of a rubber band varies with the force applied.



Explain how the graph shows that the rubber band does not obey Hooke's Law. (2)

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(b) Diagram 1 shows a model aeroplane powered by a rubber band.

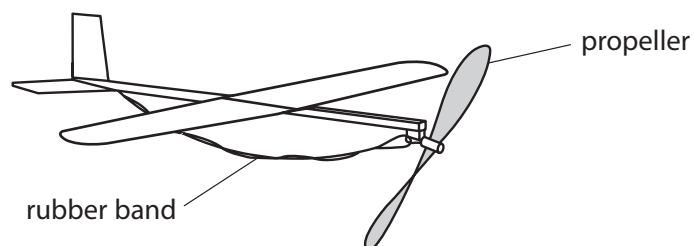


**Diagram 1**

A person rotates the propeller of the model aeroplane, which twists the rubber band.

He then releases the propeller and it spins.

Energy transfer occurs during this process.

The box lists words associated with energy.

|            |               |               |
|------------|---------------|---------------|
| kinetic    | gravitational | electrostatic |
| mechanical | elastic       | magnetic      |
| heating    | chemical      | radiation     |

Use words from the box to complete the passage.

(3)

The person does ..... work to twist the rubber band.

As the person twists the rubber band it extends, increasing the .....

energy store of the rubber band. When the rubber band is released it does mechanical work,

increasing the ..... energy store of the propeller.

(c) Diagram 2 shows the aeroplane flying horizontally to the right.

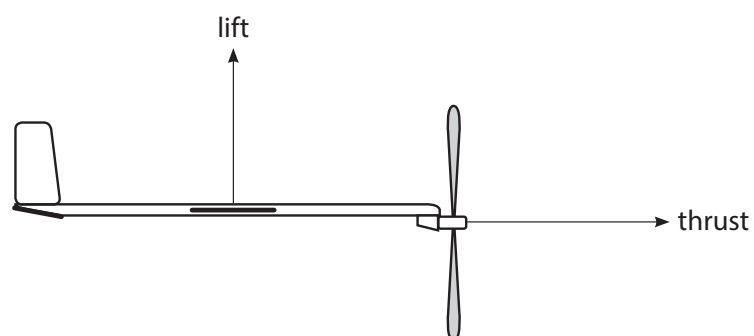


**Diagram 2**

The aeroplane flies at a constant speed.

Diagram 2 shows two forces acting on the aeroplane.

Draw labelled arrows on diagram 2 to show two more forces acting on the aeroplane.

(4)

**(Total for Question 4 = 11 marks)**

**5** (a) A metal spring obeys Hooke's law.

Sketch a graph to show that the spring obeys Hooke's law as it is stretched.

You should label both axes with appropriate physical quantities.

(3)



(b) Diagram 1 shows an object suspended from a support using a metal spring.

The object is initially at rest.

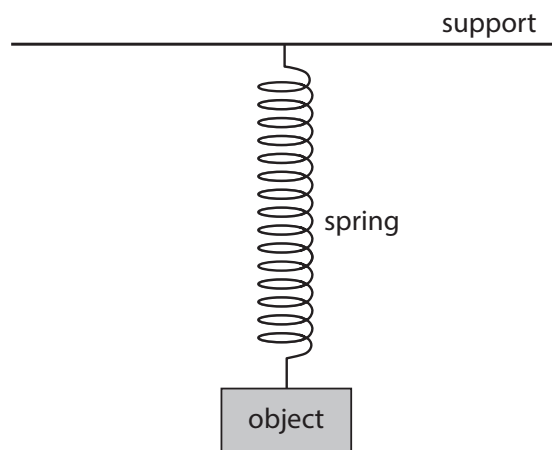


**Diagram 1**

(i) The object is pulled down and then released.

Diagram 2 shows the forces acting on the object at the instant it is released.

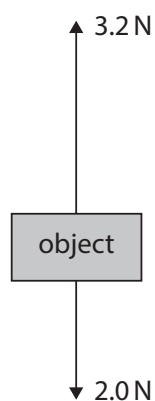


**Diagram 2**

Determine the magnitude and direction of the resultant force acting on the object.

(2)

magnitude of resultant force = ..... N

direction of resultant force = .....

- (ii) The object has a mass of 0.20 kg.

Calculate the acceleration of the object at the instant it is released.

(3)

acceleration = ..... m/s<sup>2</sup>

- (iii) Explain how the magnitude of the acceleration of the object changes, from the instant the object is released until the first time the object returns to its initial resting position.

You should refer to the forces acting on the object in your answer.

(3)

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**(Total for Question 5 = 11 marks)**



- 10** Diagram 1 shows the apparatus a student uses to investigate the bending of a wooden strip.

Part of the wooden strip is clamped to a table.

A load is fixed to the free end of the wooden strip, causing it to bend.

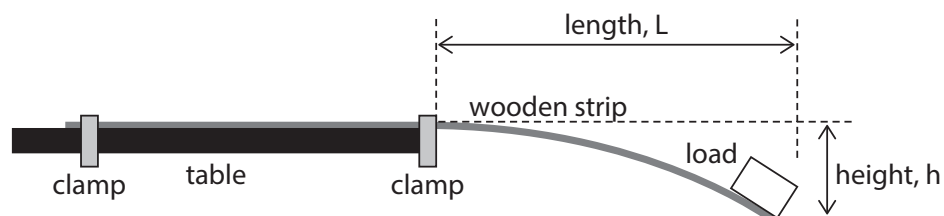


**Diagram 1**

The free end of the wooden strip is positioned a length,  $L$ , beyond the edge of the table, as shown in diagram 1.

The weight of the load causes the end of the wooden strip to move down through a height,  $h$ .

A student investigates how the length,  $L$ , affects the height,  $h$ .

- (a) The load has a mass of 250 g.

Calculate the weight of the load.

Use the formula

$$\text{weight} = \text{mass} \times \text{gravitational field strength, } g$$

(2)

weight = ..... N

(b) This is the student's method for the investigation.

- clamp the wooden strip so that  $L = 20\text{ cm}$
- fix the load to the end of the wooden strip, as shown in diagram 1
- measure the height,  $h$

The student repeats this method for different values of  $L$ .

(i) Give the independent and dependent variables in the investigation.

(2)

independent variable

dependent variable

(ii) Give two control variables in the investigation.

(2)

1 .....

2 .....

(iii) Suggest how the student could accurately measure the height,  $h$ .

(2)

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(c) The table shows the results of the investigation.

| Length (L) in cm | Height (h) in cm |
|------------------|------------------|
| 20               | 2                |
| 40               | 8                |
| 60               | 18               |
| 80               |                  |
| 100              | 53               |
| 120              | 71               |

(i) Diagram 2 shows the wooden strip when  $L = 80\text{ cm}$ .

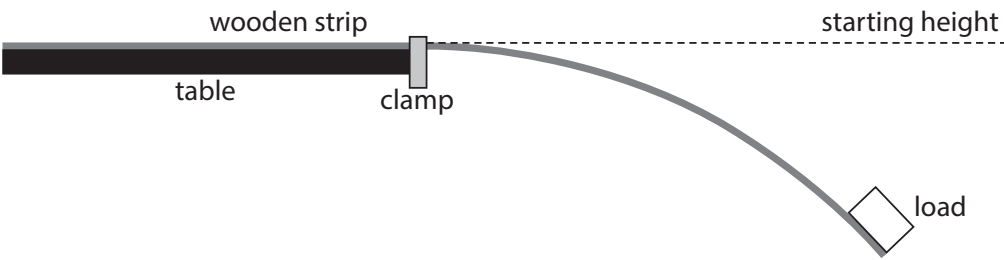


Diagram 2

Using diagram 2, determine the height,  $h$ , in the laboratory.  
[1 cm on the diagram = 10 cm in the laboratory]

(2)

height,  $h = \dots\dots\dots\text{ cm}$

(ii) Plot a graph of the student's results.

(2)

(iii) Draw the curve of best fit.

(1)

Height ( $h$ )  
in cm



Length ( $L$ ) in cm

(iv) The student concludes that  $h$  is directly proportional to  $L$ .

Evaluate the student's conclusion.

(2)

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**(Total for Question 10 = 15 marks)**

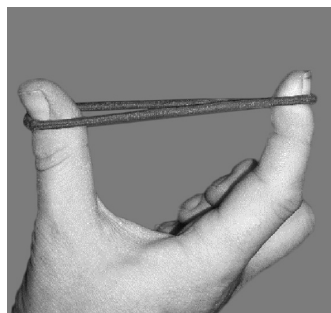


9 A student stretches a rubber band.

(a) The photographs show a rubber band before and after it has been stretched.



before



after

(i) State which energy store increases in the rubber band after it has been stretched.

(1)

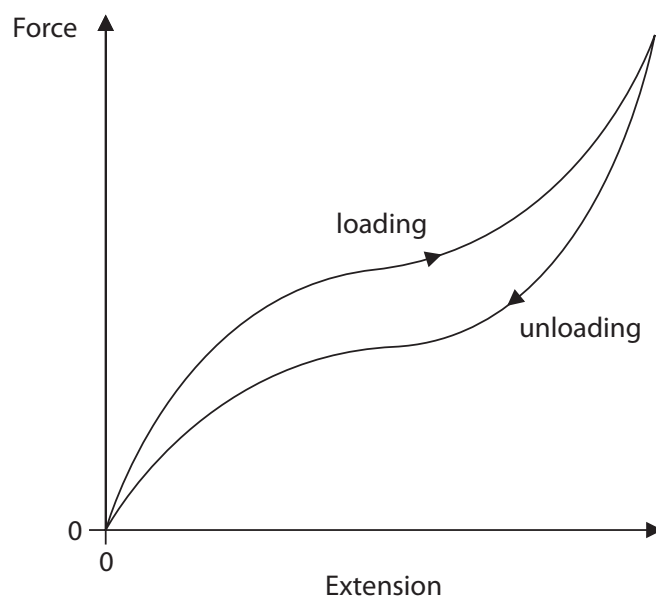
(ii) State the main method of energy transfer when the rubber band is stretched.

(1)

(iii) State the source of the energy transferred to the rubber band.

(1)

(b) The diagram shows a force-extension graph for a rubber band.



(i) State how the graph shows that the rubber band does not obey Hooke's law.

(1)

(ii) Explain how the graph shows that the rubber band is elastic.

(2)

(c) The student stretches the rubber band and then releases it. The band moves vertically upwards.

(i) The band travels with an initial speed of  $13 \text{ m/s}$ .

When the band reaches its maximum height above the student's hand, the band has a speed of  $0 \text{ m/s}$ .

Calculate the maximum height that the band reaches.

Give your answer to 2 significant figures.

[acceleration due to gravity =  $-10 \text{ m/s}^2$ ]

(4)

maximum height = ..... m





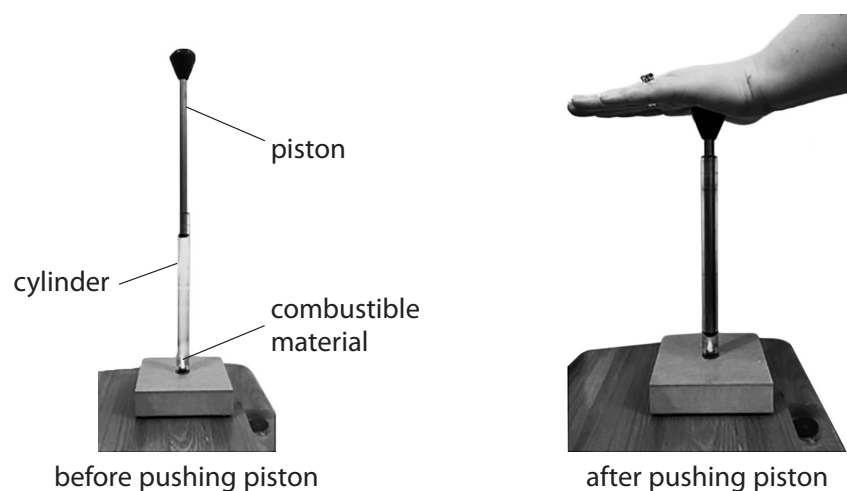
## SUB-TOPIC 1.8

# WORK DONE, ENERGY AND POWER IN MOTION

Sub-topic 1.8 · 6 questions · 70 marks · lowest tariff first



- 8 The photograph shows a device that can be used to ignite small pieces of combustible material. The device consists of a cylinder containing trapped air and a piston.



A small piece of combustible material is placed at the bottom of the cylinder.

When the piston is pushed quickly into the cylinder, the trapped air is compressed and heats up.

This increase in temperature is enough to ignite the combustible material.

- (a) The piston is quickly pushed down a distance of 145 mm.

The average force exerted on the piston is 4.2 N.

- (i) State the formula linking work done, force and distance moved in the direction of the force. (1)

- (ii) Calculate the work done on the trapped air when the piston is quickly pushed down. (2)

work done = ..... J

(iii) State the maximum amount of energy that could be transferred to the trapped air.

(1)

energy transferred = ..... J

(iv) Using ideas about molecules, explain why the trapped air heats up.

(2)

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(b) Suggest why the trapped air does not reach a high enough temperature to ignite the combustible material if the piston is slowly pushed into the cylinder.

(1)

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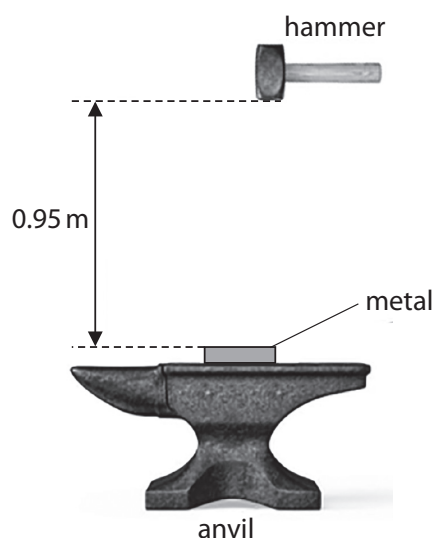
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**(Total for Question 8 = 7 marks)**



- 4 A metalworker uses a hammer of mass 1.8 kg to deform a piece of metal on an anvil.



- (a) (i) Calculate the increase in the hammer's gravitational potential energy (GPE) store when the hammer is raised through a height of 0.95 m above the metal.

[GPE gained = mass  $\times$  gravitational field strength  $\times$  height]

(2)

GPE increase = ..... J

- (ii) The metalworker moves the hammer down to strike the metal.

The hammer must have at least 21 J of energy in its kinetic energy (KE) store as it hits the metal to deform it.

Explain why the metalworker must do at least 4 J of mechanical work on the hammer to deform the metal.

(2)

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(b) (i) Calculate the velocity of the hammer just before it strikes the metal.

[KE of hammer = 21 J]

(4)

velocity = ..... m/s

(ii) When the hammer hits the metal, the hammer comes to rest without rebounding.

Calculate the mean (average) force needed to bring the hammer to rest in a time of 0.12 s.

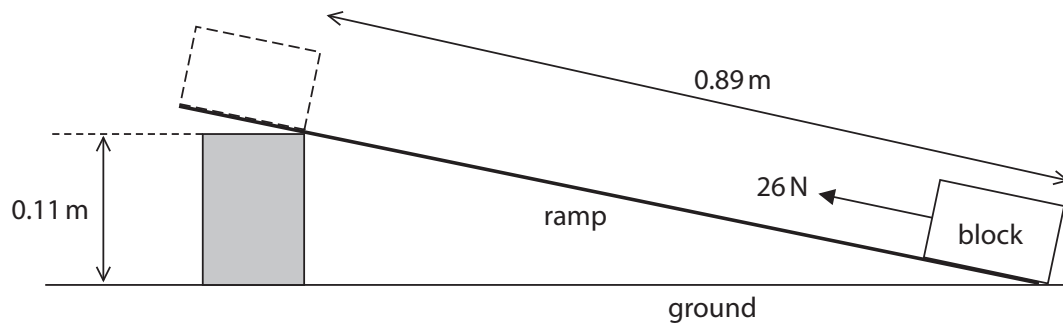
(2)

mean force = ..... N

**(Total for Question 4 = 10 marks)**



**11** A student uses this apparatus to investigate the force needed to pull a block along a ramp.



- (a) (i) State the formula linking work done, force and distance moved in the direction of the force.

(1)

- (ii) The student pulls the block 0.89 m along the ramp with a force of 26 N.

Show that the work done on the block by the 26 N force is about 23 J.

(2)

- (iii) The block has a mass of 1.3 kg and moves vertically upwards 0.11 m.

Calculate the increase in the gravitational potential energy (GPE) store of the block between the bottom and the top of the ramp.

(3)

increase in GPE = ..... J

(iv) Explain why the work done to move the block along the ramp is greater than the increase in the GPE store of the block.

(2)

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(b) The student suggests it is better to use a less steep ramp to raise the block through the same vertical height.

Discuss an advantage and a disadvantage of using a less steep ramp.

(4)

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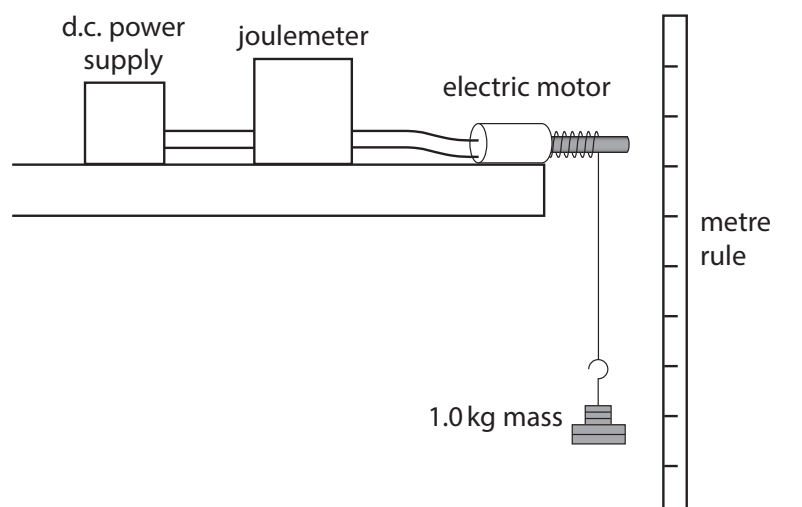
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**(Total for Question 11 = 12 marks)**



- 8 A student uses this apparatus to investigate how the efficiency of an electric motor varies with its input voltage.



This is the student's method.

- connect the electric motor to a d.c. power supply and a joulemeter
- attach a 1.0 kg mass to the electric motor using a length of string
- set the voltage of the power supply to 10V and switch on the power supply
- switch off the power supply when the mass has been lifted through a distance of 50 cm
- record the input energy to the motor from the joulemeter
- calculate the energy transferred to the gravitational store of the mass
- calculate the efficiency of the motor

The student repeats this process, setting the power supply to a different voltage each time.

- (a) State how the student could improve the reliability of her results.

(1)

.....

.....

- (b) Give two control variables for the investigation.

(2)

1 .....

2 .....

- (c) Show that the gravitational store of the 1.0 kg mass increases by 5.0 J when it is lifted through a distance of 50 cm.

(2)

- (d) The table shows the student's results.

| Power supply voltage in V | Joulemeter reading in J | Motor efficiency (%) |
|---------------------------|-------------------------|----------------------|
| 3.0                       | 99.4                    | 5.0                  |
| 3.5                       | 25.5                    | 19.6                 |
| 4.0                       | 16.5                    | 30.3                 |
| 5.0                       | 13.5                    | 37.0                 |
| 6.0                       | 12.6                    | 39.7                 |
| 8.0                       | 12.8                    | 39.1                 |
| 10.0                      | 12.7                    |                      |

- (i) Calculate the motor efficiency when the power supply is set to a voltage of 10 V.

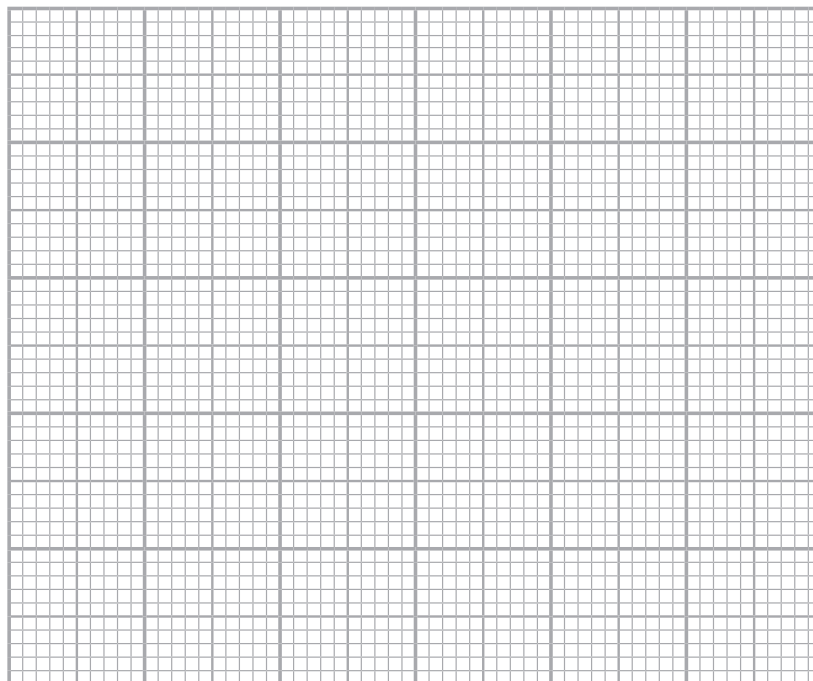
(3)

efficiency = ..... %



- (ii) Plot a graph of the motor efficiency on the y-axis against the power supply voltage on the x-axis.

(3)



- (iii) Draw a curve of best fit.

(2)

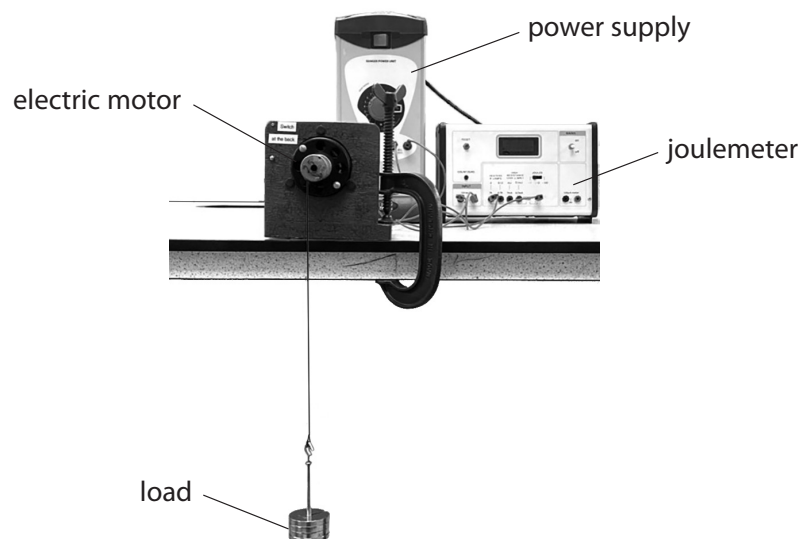
- (iv) Using the graph, determine the minimum power supply voltage that will allow the electric motor to operate at maximum efficiency.

(1)

power supply voltage = ..... V

**(Total for Question 8 = 14 marks)**

- 3 A model electric motor is used to lift a load through a vertical height.



- (a) The load has a mass of 400 g and gains 3.2 J of energy in its gravitational store when lifted.

- (i) State the formula linking gravitational potential energy, mass, gravitational field strength ( $g$ ) and height.

(1)

- (ii) Calculate the height the load is lifted.

(3)

height = ..... m

- (iii) State the amount of useful work done on the load by the motor when the load is lifted through this height.

(1)

work done = ..... J

- (b) The load is lifted at a constant speed.

Diagram 1 shows the lifting force acting on the load as it is lifted.

Draw a labelled arrow on diagram 1 to show the other force acting on the load.

Ignore the effects of air resistance.

(2)

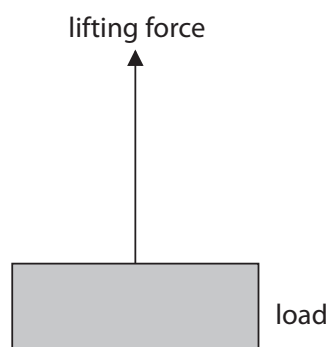


**Diagram 1**

- (c) A joulemeter measures the amount of energy transferred electrically to the motor as the motor lifts the load.

The joulemeter displays a reading of 11.0 J when the load has gained 3.2 J of energy in its gravitational store.

- (i) Calculate the efficiency of the motor.

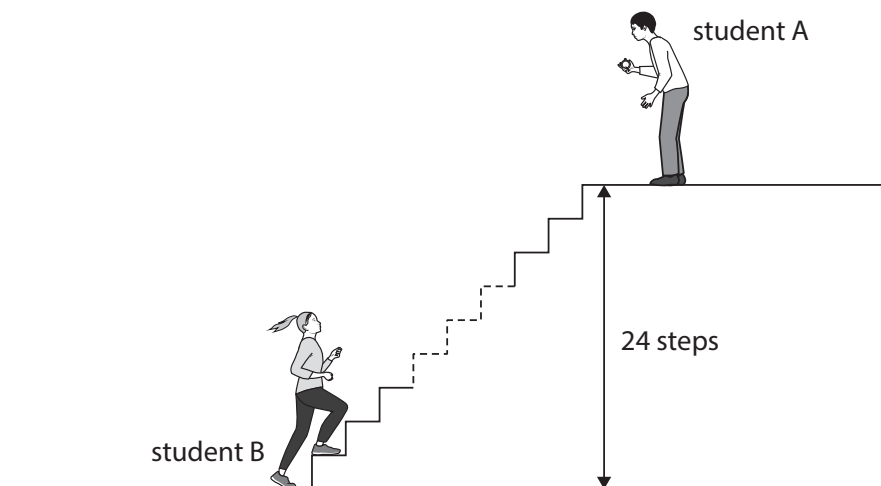
(3)

efficiency = .....



- 6 Two students do an experiment to determine their power when running up a set of steps.

The diagram shows how they set up their experiment. Not all of the steps are shown in the diagram.



This is the students' method.

- student A stands with a stopwatch at the top of the steps
- student A starts timing on the stopwatch and shouts "go" at the same time
- student B begins to run up the steps when she hears student A shout
- student A stops timing when student B reaches the top of the steps

The students repeat their method two more times.

- (a) Give a reason why the times recorded may not be accurate.

(1)

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.....

(b) There are 24 steps in total and each step has a height of 19 cm.

(i) Student B has a mass of 67 kg.

Show that student B gains about 3000 J of energy in her gravitational store when she runs up the set of steps.

(3)

(ii) The table shows the times recorded for student B.

| Time in s |
|-----------|
| 4.28      |
| 4.95      |
| 4.65      |

Calculate the mean time from this data.

Give your answer to three significant figures.

(2)

mean time = ..... s

(iii) Calculate the mean power of student B transferring energy to her gravitational store as she runs up the steps.

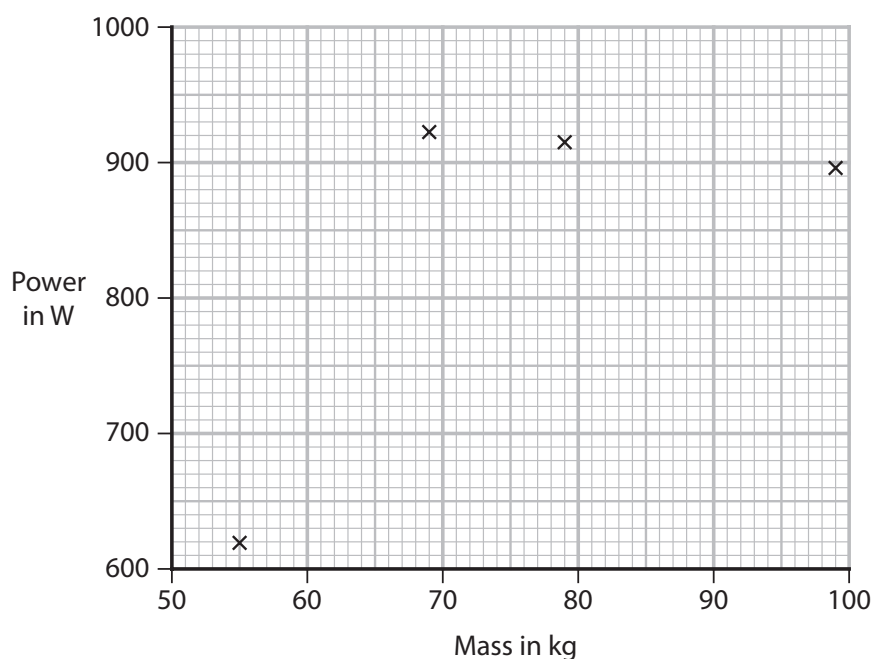
(2)

mean power = ..... W



- (c) The students extend their investigation by calculating the power for students of different masses running up the steps.

The graph shows their results.



The students conclude that the greater the mass of the person, the greater the power of the person when running up the steps.

Comment on the students' conclusion.

(4)

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(Total for Question 6 = 12 marks)



# MARK SCHEMES

official mark schemes



| Question number | Answer                                                 | Notes                                                                                                                                                                                                                           | Marks |
|-----------------|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1 (a)           | <p>Physical quantity</p> <p>Unit</p>                   | <p>ignore line drawn from force as already given</p> <p>3 marks if all correct<br/>2 marks if 2 correct<br/>1 mark for any 1 correct</p> <p>ignore line if more than one physical quantity or unit are linked to each other</p> | 3     |
| (b) (i)         | idea that vectors have a direction but scalars do not; | allow idea that <b>only</b> vectors have a direction                                                                                                                                                                            | 1     |
| (ii)            | any correct scalar;                                    | e.g. speed, distance, length, mass, time, temperature, energy, power etc.                                                                                                                                                       | 1     |

Total for Question 1 = 5 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 7 (a)           | <p><b>measuring equipment:</b></p> <p>MP1. ruler / tape measure;<br/>MP2. stopclock / stopwatch;</p> <p><b>variables:</b></p> <p>MP3. surface material is the independent variable;<br/>MP4. (average) speed is the dependent variable;<br/>MP5. any one control variable from;</p> <ul style="list-style-type: none"> <li>size / mass / material / area / weight of block</li> <li>height/angle/gradient of ramp</li> <li>initial force given to block</li> </ul> <p>• distance travelled down the ramp</p> <p><b>determining average speed:</b></p> <p>MP6. use of (average) speed = distance travelled / time</p> | <p>allow if clearly included in diagram</p> <p>condone 'timer'</p> <p>accept use of light gates if connected to timing device e.g. computer/datalogger</p> <p>accept 'camera' if subsequent method describes 'freeze-frame' / timestamp technique</p> <p>allow time as the dependent variable<br/>allow 'keep constant' for 'control variable'</p> <p>allow 'push' given to block<br/>allow <b>initial</b> speed or velocity</p> <p>allow same starting point and finishing point</p> <p>accept use of light gate if description includes length of card/block and time of transit</p> | 6     |
| (b)             | (bar chart because) surface material is a {categorical / discontinuous / non-continuous} variable;                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | condone surface material being a discrete variable                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1     |

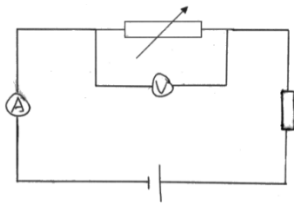
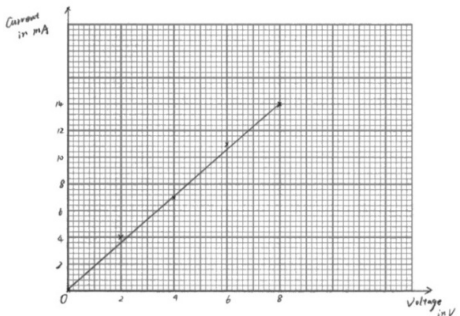
Total for Question 7 =7 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                               | Notes                                                                                                                                                                                                                         | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | A (accuracy of the measurement);<br><br>B is incorrect because removing a zero error does not allow the measurement to be made to more decimal places<br>C is incorrect because removing a zero error does not allow the repeatability to be assessed<br>D is incorrect because removing a zero error does nothing to improve the control of other variables that may affect the measurement of mass                 |                                                                                                                                                                                                                               | 1     |
| (b)             | C (reliability of the measurement);<br><br>A is incorrect because repeating a measurement does not make the measurement closer to the true value<br>B is incorrect because repeating a measurement does not allow the measurement to be made to more decimal places<br>D is incorrect because repeating a measurement does nothing to improve the control of other variables that may affect the measurement of mass |                                                                                                                                                                                                                               | 1     |
| (c) (i)         | 19.34 reading circled;                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                               | 1     |
| (ii)            | anomalous reading excluded from calculation;<br>mean mass evaluated;<br><br>final answer expressed to 2 decimal places;<br><br>e.g.<br>(mean =) $[18.96 + 19.01 + 19.05 + 18.98 + 19.04] \div 5$<br>(mean =) 19.008<br>(mean mass =) 19.01 (g)                                                                                                                                                                       | allow ecf from (i)<br>allow ecf if anomalous reading included<br>allow ecf if anomalous reading included<br><br><br>if anomalous reading included, allow final 2 marking points only<br>19.06 = 2 marks<br>19.063... = 1 mark | 3     |
| (iii)           | volume;                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                               | 1     |

Total for Question 5 = 7 marks

| Question number    | Answer                                                                                                                                                                                                                                                                                                                                                                         | Notes                                                                                                                                                                                                                                                                                                                                                                                                 | Marks          |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------|----------|------------------|------|-------|----|----------------|-------|----|------|--------------------|----|------|-------|------------|------|-------|---|-------------------------------------------|---|
| 10 (a)             | one mark for each correct row;;;;<br><table><tr><td></td><td>Independent</td><td>Dependent</td><td>Control</td></tr><tr><td>Surface of slope</td><td></td><td></td><td>✓</td></tr><tr><td>Angle of slope</td><td></td><td></td><td>✓</td></tr><tr><td>Distance travelled</td><td>✓</td><td></td><td></td></tr><tr><td>Time taken</td><td></td><td>✓</td><td></td></tr></table> |                                                                                                                                                                                                                                                                                                                                                                                                       | Independent    | Dependent | Control  | Surface of slope |      |       | ✓  | Angle of slope |       |    | ✓    | Distance travelled | ✓  |      |       | Time taken |      | ✓     |   | reject mark for row if more than one tick | 4 |
|                    | Independent                                                                                                                                                                                                                                                                                                                                                                    | Dependent                                                                                                                                                                                                                                                                                                                                                                                             | Control        |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| Surface of slope   |                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                       | ✓              |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| Angle of slope     |                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                       | ✓              |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| Distance travelled | ✓                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                       |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| Time taken         |                                                                                                                                                                                                                                                                                                                                                                                | ✓                                                                                                                                                                                                                                                                                                                                                                                                     |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| (b) (i)            | all points correct;<br>                                                                                                                                                                                                                                                                                                                                                        | within ½ small square                                                                                                                                                                                                                                                                                                                                                                                 | 1              |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| (ii)               | curve goes through all points;                                                                                                                                                                                                                                                                                                                                                 | judge by eye<br>ignore curve before first data point                                                                                                                                                                                                                                                                                                                                                  | 1              |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| (iii)              | constant correctly calculated for one row of table;<br>constant correctly calculated for another row of table;<br><br>statement/expression comparing constants;<br><br>consistent conclusion about relationship based on comparison of constants;                                                                                                                              | <table><tr><th>Distance in cm</th><th>Time in s</th><th>Constant</th></tr><tr><td>10</td><td>0.41</td><td>59.49</td></tr><tr><td>20</td><td>0.58</td><td>59.45</td></tr><tr><td>30</td><td>0.71</td><td>59.51</td></tr><tr><td>40</td><td>0.82</td><td>59.49</td></tr><tr><td>50</td><td>0.91</td><td>60.38</td></tr></table><br>allow even if comparison suggests the constants are not equal<br>DOP | Distance in cm | Time in s | Constant | 10               | 0.41 | 59.49 | 20 | 0.58           | 59.45 | 30 | 0.71 | 59.51              | 40 | 0.82 | 59.49 | 50         | 0.91 | 60.38 | 4 |                                           |   |
| Distance in cm     | Time in s                                                                                                                                                                                                                                                                                                                                                                      | Constant                                                                                                                                                                                                                                                                                                                                                                                              |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| 10                 | 0.41                                                                                                                                                                                                                                                                                                                                                                           | 59.49                                                                                                                                                                                                                                                                                                                                                                                                 |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| 20                 | 0.58                                                                                                                                                                                                                                                                                                                                                                           | 59.45                                                                                                                                                                                                                                                                                                                                                                                                 |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| 30                 | 0.71                                                                                                                                                                                                                                                                                                                                                                           | 59.51                                                                                                                                                                                                                                                                                                                                                                                                 |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| 40                 | 0.82                                                                                                                                                                                                                                                                                                                                                                           | 59.49                                                                                                                                                                                                                                                                                                                                                                                                 |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |
| 50                 | 0.91                                                                                                                                                                                                                                                                                                                                                                           | 60.38                                                                                                                                                                                                                                                                                                                                                                                                 |                |           |          |                  |      |       |    |                |       |    |      |                    |    |      |       |            |      |       |   |                                           |   |

Total for Question 10 = 10 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                   | Notes                                                                 | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-------|
| 12 (a) (i)      | correct symbol for resistor;<br>correct symbol for cell;<br>correct symbol for ammeter;<br>circuit is complete series circuit;                                                                                                                                                                                           | reject extra components<br>allow ECF for<br>missing/incorrect symbols | 4     |
|                 |                                                                                                                                                                                                                                         |                                                                       |       |
| (ii)            | voltmeter symbol is correct and in parallel with any component;<br>voltmeter is in parallel with variable resistor;                                                                                                                                                                                                      |                                                                       | 2     |
| (b)             | any FOUR from:<br>stretchy resistor increases in resistance (when mass increased);<br>total resistance increases;<br>$I = V/R$ ;<br><br>current in circuit less;<br>voltage across fixed resistor decreases;<br>so voltage across stretchy resistor increases;<br>as total voltage is constant/voltage of cell constant; | reject $V=IR$ or $I=V/R$ with assumption of constant current          | 4     |
| (c) (i)         | voltage;                                                                                                                                                                                                                                                                                                                 | allow 'V'                                                             | 1     |
| (ii)            | suitable linear scale chosen (>50% of grid used);<br>axes labelled with quantities and unit;<br><u>all</u> plotting correct to nearest half square;                                                                                                                                                                      | ignore orientation                                                    | 3     |
|                 |                                                                                                                                                                                                                                       |                                                                       |       |
| (iii)           | correct best fit line judged by eye;                                                                                                                                                                                                                                                                                     |                                                                       | 1     |

(Total for Question 12 = 15 marks)

| Question number             | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Notes          | Marks |   |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-------|---|--|--|---|---|---|---|-----------------------|--|--|---|--|-------------------------|--|--|--|---|-----------------------------|---|--|--|--|------------|--|---|--|--|--|---|
| 1 (a)                       | <p>one mark for each correct row;;;;</p> <table><tr><th rowspan="2">Type of motion</th><th colspan="4">Graph</th></tr><tr><th>P</th><th>Q</th><th>R</th><th>S</th></tr><tr><td>constant acceleration</td><td></td><td></td><td>✓</td><td></td></tr><tr><td>increasing acceleration</td><td></td><td></td><td></td><td>✓</td></tr><tr><td>moving at constant velocity</td><td>✓</td><td></td><td></td><td></td></tr><tr><td>stationary</td><td></td><td>✓</td><td></td><td></td></tr></table> <p>reject mark for row if more than one tick seen</p> | Type of motion | Graph |   |  |  | P | Q | R | S | constant acceleration |  |  | ✓ |  | increasing acceleration |  |  |  | ✓ | moving at constant velocity | ✓ |  |  |  | stationary |  | ✓ |  |  |  | 4 |
| Type of motion              | Graph                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                |       |   |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
|                             | P                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Q              | R     | S |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
| constant acceleration       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                | ✓     |   |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
| increasing acceleration     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                |       | ✓ |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
| moving at constant velocity | ✓                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                |       |   |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
| stationary                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | ✓              |       |   |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |
| (b)                         | area (under the line) / eq;                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                | 1     |   |  |  |   |   |   |   |                       |  |  |   |  |                         |  |  |  |   |                             |   |  |  |  |            |  |   |  |  |  |   |

Total for Question 1 = 5 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                  | Notes                                                                                                                     | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-------|
| 8 (a) (i)       | acceleration = change in velocity / time;                                                                                                                                                                                                                                                               | allow rearrangements and standard symbols<br>e.g. $a = v \cdot u / t$ ,<br>$a = \Delta v / t$ , $a = \Delta v / \Delta t$ | 1     |
| (ii)            | substitution;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$1.2 = (35 - 26) / t$<br>$t = 9 / 1.2$<br>(t =) 7.5 (s)                                                                                                                                                                                   |                                                                                                                           | 3     |
| (b)             | any four from:<br>MP1. frequency increases;<br><br>MP2. due to Doppler effect;<br><br>MP3. idea that car behaves as the source of the (reflected) waves;<br><br>MP4. (reflected) wavefronts closer together;<br><br>MP5. (reflected) wavelength decreased;<br><br>MP6. speed (of waves) stays constant; | allow “waves become bunched up”<br><br><br>allow quotation of<br>$v = f \times \lambda$                                   | 4     |

Total for Question 8 = 8 marks



| Question number | Answer                                                                                                                                                                                                                                                     | Notes                                                                                                                                                                        | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2 (a)           | any attempt at gradient/reference to correct formula;<br>substitution of values from graph;<br>evaluation;<br><br>e.g.<br>acceleration = change in velocity/time taken<br>acceleration = $(-)/45 / 39$<br>acceleration = $(-)/1.2 \text{ (m/s}^2\text{)}$  | check graph for evidence of working<br><br>ignore minus sign<br><br><br>allow 1.1-1.2 (m/s <sup>2</sup> )                                                                    | 3     |
| (b)             | any attempt at or reference to an area;<br><br>correct attempt = $\frac{1}{2} \times 45 \times 39$ ;<br><br>correct evaluation;<br><br>e.g.<br>distance travelled = area under graph<br>distance = $\frac{1}{2} \times 45 \times 39$<br>distance = 880 (m) | allow alternative method using $v^2 = u^2 + 2as$ with answer from (a)<br>allow ECF of incorrect velocity or time reading if also used in (a)<br><br><br>allow 878, 877.5 (m) | 3     |
| (c)             | line showing decreasing velocity from same initial velocity as existing line;<br>line drawn is less steep than existing line throughout;                                                                                                                   |                                                                                                                                                                              | 2     |

Total for Question 2 = 8 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                           | Notes                                                                                                                                                                  | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | <p>substitution into <math>v^2 = u^2 + 2as</math>;<br/> rearrangement;<br/> evaluation;</p> <p>e.g.<br/> <math>75^2 = (0^2 +) 2 \times 4.1 \times s</math><br/> <math>s = 5625 / 8.2</math><br/> <math>(s =) 690 \text{ (m)}</math></p>                                                                                          | <p>allow alternative method of finding the time taken and then using <b>average</b> speed = distance/time</p> <p>1371-1372 = 2 marks</p> <p>allow 686, 685.9756...</p> | 3     |
| (b) (i)         | <p>any two from:<br/> MP1. idea of radiation that is always present / present everywhere;<br/> MP2. idea of no 'obvious' source;<br/> MP3. any valid source of background radiation given e.g. radon/rocks/cosmic rays/medical or military activity/the Sun etc.;</p>                                                            |                                                                                                                                                                        | 2     |
| (ii)            | <p>any three from:<br/> MP1. idea that excessive exposure time can be harmful/increases risk;<br/> MP2. idea that dosage is higher (at maximum height);<br/> MP3. idea that increased risk of cancer;<br/> MP4. idea that there is less atmosphere to absorb cosmic radiation;<br/> MP5. cosmic rays/radiation is increased;</p> | allow cell mutation for cancer                                                                                                                                         | 3     |

(Total for Question 5 = 8 marks)

| Question number | Answer                                                                                                                                                 | Notes                                                                                                         | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-------|
| 3 (a) (i)       | $\times 1600$ seen in working OR $\div 3600$ seen in working;<br>speed = 179 (m/s);                                                                    | allow $\div 60^2$<br>allow any answer that would round to 179<br>condone 180<br>NB $1600 \times 403 = 644800$ | 2     |
| (ii)            | idea of measuring time taken (to travel between markers);<br><br>use of appropriate instrument to measure time;<br><br>use of speed = distance / time; | <br><br>allow stopwatch, timer, (stop)clock, light gates<br>condone any subject of equation.                  | 3     |
| (b)             | length of arrow equal to given arrow;<br><br>arrow drawn horizontally to the left;<br><br>arrow labelled "air resistance";                             | ignore vertical arrows<br><br>judge by eye<br><br>allow drag, friction<br>ignore wind resistance              | 3     |

Total for Question 3 = 8 marks

| Question number | Answer                                                                                                                                                                                                                                                                                     | Notes                                                                                                                                                                                           | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a) (i)       | B, D, F;                                                                                                                                                                                                                                                                                   | all required for the mark<br>reject if additional<br>sections listed                                                                                                                            | 1     |
| (ii)            | use of speed = distance / time;<br><br>correctly read time or distance from graph;<br>conversion from minutes to seconds or km to m;<br>correct evaluation;<br><br>e.g.<br>$v = s / t$<br>distance = 2.6 km or time = 2 minutes<br>distance = 2600 m or time = 120 s<br>( $v =$ ) 22 (m/s) | seen anywhere<br>allow symbols<br>allow attempt to find<br>gradient of line<br><br><br><br><br>allow $s = d / t$<br><br>allow 21.7, 21.6... (m/s)<br>0.0216..., 1300 = 3 marks<br>1.3 = 2 marks | 4     |
| (iii)           | idea that speed of bus is greater in section A;<br>(because) line is steeper / gradient is larger / eq;                                                                                                                                                                                    |                                                                                                                                                                                                 | 2     |
| (b)             | single horizontal line drawn;<br><br>horizontal line drawn at 0.5 km/minute for some<br>period of time in journey;                                                                                                                                                                         | judge by eye<br>line must extend the<br>entire length of the time<br>axis                                                                                                                       | 2     |

Total for Question 5 = 9 marks

| Question number | Answer                                                                                                                                                                                                                                                                                  | Notes                                                                                                                                            | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2 (a) (i)       | (average) speed = distance (moved) / time (taken);                                                                                                                                                                                                                                      | allow standard symbols and rearrangements e.g. $v = s / t$<br>allow s for speed, d for distance                                                  | 1     |
| (ii)            | substitution;<br>evaluation;<br><br>e.g.<br>(speed =) $6.5 / 0.25$<br>(speed =) 26 (m/s)                                                                                                                                                                                                |                                                                                                                                                  | 2     |
| (iii)           | correct conversion of EITHER m to km OR s to h;<br>full conversion from m/s to km/h AND consistent conclusion;;<br><br>e.g.<br>$26 \text{ (m/s)} = 0.026 \text{ (km/s)}$ OR $26 \text{ (m/s)} = 93600 \text{ (m/h)}$<br>$94 \text{ (km/h)} \Rightarrow$ too fast                        | allow ECF from (ii)<br>allow ECF from (ii)<br>allow conversion of km/h to m/s e.g. $80 \text{ km/h} = 22.2 \text{ m/s}$<br><br>allow 93.6 (km/h) | 2     |
| (b) (i)         | acceleration is the gradient (of the graph);<br>graph has a constant gradient;                                                                                                                                                                                                          | allow line on graph is straight                                                                                                                  | 2     |
| (ii)            | acceleration = change in velocity / time;                                                                                                                                                                                                                                               | allow standard symbols and rearrangements e.g.<br>$a = (v-u) / t$ , $a = \Delta v / t$                                                           | 1     |
| (iii)           | correct reading of either two velocity values or time interval taken from graph;<br>correct substitution into formula;<br>evaluation;<br><br>e.g.<br>$u = 5 \text{ (m/s)}$ , $v = 24 \text{ (m/s)}$ OR $t = 60 \text{ (s)}$<br>(a =) $24-5 / 60$<br>(a =) $0.32 \text{ (m/s}^2\text{)}$ | allow attempt at gradient calculation<br><br>allow $(v - u =) 19$ seen<br><br>allow range of 0.30-0.32                                           | 3     |

Total for Question 2 = 11 marks

| Question number | Answer                                                                                                                                                                                                         | Notes                                                                                                                                                                                                                                                             | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 12 (a)          | appropriate attempt to draw tangent at 20s on the graph;<br>acceleration = gradient;<br><br>acceleration in the range 1.00-1.20 ( $\text{m/s}^2$ );<br>acceleration in the range 1.05-1.15 ( $\text{m/s}^2$ ); | allow if seen explicitly or from a clear attempt to calculate a gradient<br>scores 3 marks total<br>scores 4 marks total                                                                                                                                          | 4     |
| (b)             | distance = area under line;<br><br>suitable method used;<br><br>distance in the range = 3200-4200 (m);<br>distance in the range = 3500-4000 (m);<br>distance in the range = 3700-3800 (m);                     | seen explicitly or implied by working allow <ul style="list-style-type: none"> <li>• use of trapeziums</li> <li>• rectangles and triangles</li> <li>• counting squares estimation</li> </ul> scores 3 marks total<br>scores 4 marks total<br>scores 5 marks total | 5     |
| (c)             | speed/velocity is constant;<br><br>idea that driving force of car = air resistance;<br><br>resultant force is zero;                                                                                            | allow terminal velocity<br><br>allow forces are balanced<br>allow acceleration is zero                                                                                                                                                                            | 3     |

Total for Question 12 = 12 marks

| Question number | Answer                                                                                                                                                                                                                | Notes                                                                                                                                                             | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | any attempt at finding the area/ "area = distance" stated;<br>area of triangle = $\frac{1}{2} \times 4.3 \times 0.2$ (= 0.43 m);<br><br>area of rectangle = $4.3 \times 0.2$ (= 0.86 m);<br><br>distance = 1.29 (m) ; | accept area of trapezium = $\frac{1}{2} \times 4.3 \times (0.2 + 0.4)$ for MP2 and MP3.<br>count squares;<br>area of 1 square = 0.001 (m);<br>distance = 1.29 (m) | 4     |
| (b) (i)         | idea that acceleration = gradient;<br>gradient = $(-)/4.3 / 0.05$ ;<br>acceleration = $(-)/86$ (m/s <sup>2</sup> );                                                                                                   | -1 for POT error                                                                                                                                                  | 3     |
| (ii)            | (resultant) force = mass x acceleration / $F = ma$                                                                                                                                                                    |                                                                                                                                                                   | 1     |
| (iii)           | substitution;<br>evaluation;<br><br>eg<br>$F = 0.13 \times 86$<br>$F = 11$ (N)                                                                                                                                        | allow ECF from (i)<br><br>ignore sign<br>11.18, 11.2                                                                                                              | 2     |
| (c)             | increases time of collision;<br>any reference to shallower gradient on graph;<br>so acceleration will be smaller (in magnitude);                                                                                      |                                                                                                                                                                   | 3     |

(Total for Question 5 = 13 marks)

| Question number | Answer                                                                                                                                                                                                                                                                        | Notes                                                                                                                                                                                                                                                                           | Marks |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 8 (a)           | (i) buzzer B travels <b>twice</b> the distance;<br><br>in the same time (period) OR<br>(average) speed = distance/time taken;                                                                                                                                                 | ignore quoting distances since given in question                                                                                                                                                                                                                                | 2     |
|                 | (ii) any three from:<br>MP1. frequency decreases;<br><br>MP2. due to Doppler effect;<br>MP3. idea of increased wavelength;<br><br>MP4. idea that <b>decrease</b> in frequency of buzzer B is twice that of buzzer A;                                                          | allow for either / both buzzer(s)<br>reject if one frequency said to be increased<br><br>allow idea of waves behind buzzers being more spread out<br>reject if one wavelength said to be decreased<br>allow frequency of buzzer B being lower than frequency of buzzer A / OR A | 3     |
| (b)             | determination of number of squares for one period;<br>correct use of oscilloscope settings;<br>evaluation in standard form;<br><br>e.g.<br>period = 4 squares<br>(period = 4) $\times$ 0.002<br>(period =) $8 \times 10^{-3}$ (s)                                             | seen anywhere in working<br><br>award 2 marks for answers of $4 \times 10^{-3}$ , $16 \times 10^{-3}$ (s)                                                                                                                                                                       | 3     |
| (c)             | (i) 10 (nm);                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                 | 1     |
|                 | (ii) idea the speed of Q is double the speed of P;                                                                                                                                                                                                                            | allow greater speed                                                                                                                                                                                                                                                             | 1     |
|                 | (iii) 20 (nm);                                                                                                                                                                                                                                                                | allow ecf from (c)(i)                                                                                                                                                                                                                                                           | 1     |
|                 | (iv) any four from:<br>MP1. further / faster galaxy (Q) shows greater red shift;<br>MP2. further galaxy (Q) is travelling faster;<br>MP3. (which suggests) universe is expanding;<br>MP4. idea that at an earlier point in time;<br><br>MP5. the universe was a single point; | allow use of phrases such as “originated” / eq.                                                                                                                                                                                                                                 | 4     |

Total for Question 8 = 15 marks



| Question number | Answer                                                                                                                                                                                                                | Notes                                                                                                                                                                    | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1 (a)           | (i) (average) speed = distance (travelled) / time (taken);                                                                                                                                                            | allow standard symbols and rearrangements e.g. $s = vt$<br>allow d, D, s, S for distance<br>allow s, S, v, V for speed                                                   | 1     |
|                 | (ii) substitution;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$2.8 = \text{distance} / 3.5$<br>$\text{distance} = 2.8 \times 3.5$ OR $\text{distance} = \text{speed} \times \text{time}$<br>(distance =) 9.8 (m) |                                                                                                                                                                          | 3     |
| (b)             | (i) horizontal arrow drawn acting to the left;                                                                                                                                                                        | label not needed for the mark but reject contradictory arrows<br>ignore starting position and length of arrow                                                            | 1     |
|                 | (ii) speed / velocity will decrease;<br><br>(resultant) force is in the opposite direction to the velocity;                                                                                                           | allow puck slows down, decelerates<br>ignore kinetic energy / KE decreases<br><br>allow "it" for force<br>allow alternatives to velocity e.g. speed, motion, travel etc. | 2     |

Total for Question 1 = 7 marks

| Question number | Answer                                                                                                                                                                                 | Notes                                                                                                                                                                                                                                | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 6 (a)           | substitution into $a = v-u/t$ ;<br><br>rearrangement;<br><br>evaluation;<br><br><br><br><br>e.g.<br><br>$13 = v (-0) / 5.0$<br><br>$v = 13 \times 5.0$<br><br>$(v =) 65 \text{ (m/s)}$ | allow in either order<br><br>ignore sign<br>-1 for POT error<br><br><br><br><br><br><br><br>correct answer without working scores all marks                                                                                          | 3     |
| (b)             | substitution into $v^2 = u^2 + 2as$ ;<br><br>rearrangement;<br><br>evaluation;<br>e.g.<br>$65^2 = (0^2) + 2 \times 13 \times s$<br>$s = 65^2 / 26$<br>$(s =) 160 \text{ (m)}$          | allow ecf from (a)<br>allow use of ' $s = \frac{1}{2} v t$ '<br><br>allow in either order<br><br>ignore sign<br>-1 for POT error<br>allow 162, 163, 162.5 (m)<br><br><br><br><br><br>correct answer without working scores all marks | 3     |

|     |                                                                                                                                                                                                                                                                                            |  |   |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|
| (c) | <p><b>for velocity-time graph</b></p> <p>straight line drawn;</p> <p>line starts at origin and has positive gradient throughout;</p> <p><b>for distance-time graph</b></p> <p>line starts at origin and has positive gradient throughout;</p> <p>gradient of line increases over time;</p> |  | 4 |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|

Total for Question 6 = 10 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Notes                                                                                                                                                                                                                                                                 | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 12 (a)          | <p>substitution into <math>GPE = \text{mass} \times g \times \text{height}</math>;</p> <p>at least one quantity correctly converted to SI units;<br/>correct evaluation;</p> <p>e.g.<br/> <math>GPE = 0.580 \times 10 \times 0.92</math><br/> mass = 0.580 (kg) OR height = 0.92 (m)<br/> (GPE =) 5.3 (J)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <p>allow substitution with no unit conversions<br/>allow <math>g = 9.8, 9.81</math></p> <p>allow 5.2, 5.34, 5.336, 5.23...</p>                                                                                                                                        | 3     |
| (b)             | <p>any four from:</p> <p>MP1. mention of energy being transferred <u>mechanically</u> at any stage in the response;</p> <p>MP2. (before it is dropped) dough initially has energy in its gravitational store (and no energy in its kinetic store);</p> <p>MP3. (just before it hits the floor) energy is in the dough's kinetic store (and less energy in its gravitational store);</p> <p>MP4. (as the dough falls / after the dough has hit the floor) the thermal store <b>of the air / floor / surroundings</b> has increased;</p> <p>MP5. (after the dough has hit the floor) the thermal/elastic store <b>of the dough</b> has increased (and the kinetic store of the dough is zero);</p> <p>MP6. energy has been transferred to the surroundings (mechanically and) by radiation;</p> | <p>condone the ball initially having GPE</p> <p>condone energy transferred to KE</p> <p>condone energy transferred to heat energy of the surroundings<br/>ignore references to sound energy</p> <p>condone energy transferred to elastic/heat energy of the dough</p> | 4     |

Total for Question 12 = 7 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                              | Notes                                                                                                                                                                                                                                                                                                                       | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 8 (a) (i)       | D – (weight and air resistance are equal);<br>A, B and C cannot be correct because accelerations, forces and velocities are not the same SI quantities.                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                             | 1     |
| (ii)            | C – (2300 m);<br>A cannot be correct because each large square represents 200 m and the area is larger than one large square.<br>B cannot be correct because the area is larger than 6.5 large squares<br>D cannot be correct because the area is lower than 12.5 large squares                                                                                     |                                                                                                                                                                                                                                                                                                                             | 1     |
| (b)             | any four from:<br><br>MP1. air resistance increases (greatly) when parachute is opened;<br>MP2. idea that air resistance is greater than the weight;<br><br>MP3. (therefore) deceleration / upwards acceleration;<br><br>MP4. idea that air resistance decreases with speed;<br>MP5. resultant force (eventually) becomes zero;<br><br>MP6. constant speed achieved | allow “drag” for air resistance throughout<br>allow “upwards force”<br><br>allow upwards force is bigger than downwards force<br>allow idea of upwards resultant force<br>ignore “velocity decreases”<br><br>allow “forces are balanced again”<br>allow air resistance = weight<br>allow idea that there is no acceleration | 4     |
| (c)             | D – (thermal store);<br>A cannot be correct as there is no mechanism for this transfer<br>B cannot be correct as the gravitational store is decreasing<br>C cannot be correct as the jumper is at constant velocity                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                             | 1     |

Total for Question 8 = 7 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                         | Notes                                                                                                                             | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | substitution into given equation $v^2 = u^2 + (2 \times a \times s)$ ;<br>evaluation of $v^2$ ;<br>evaluation of $v$ to 3sf or more i.e. 16.1 (m/s);<br><br>e.g.<br>$v^2 = u^2 + (2 \times a \times s)$<br>$v^2 = 0^2 + (2 \times 10 \times 13)$<br>$v^2 = 260$<br>$v = \sqrt{260} = 16.1 \text{ (m/s)}$                       | accept $mgh = 1/2mv^2$<br><br>accept use of<br>$g = 9.8(1) \text{ m/s}^2$ giving<br>$v = 16.0, 15.97$ etc.                        | 3     |
| (b)             | any FIVE from:<br><br>MP1 ball has weight;<br><br>MP2 ball accelerates;<br><br>MP3 drag increases (while accelerating);<br><br>MP4 resultant force decreases;<br><br>MP5 (so) acceleration decreases;<br><br>MP6 drag = weight / resultant = 0 / forces balanced;<br><br>MP7 terminal velocity/constant speed /acceleration=0; | allow 'has gravitational force'<br>REJECT 'has gravity'<br><br>REJECT 'balls slows down'<br><br>allow 'air resistance' for 'drag' | 5     |

Total for Question 5 = 8 marks

| Question number | Answer                                                                                                                                                                                                                                                                    | Notes                                                                                                                                                                                                                                                                        | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 9 (a)           | <p>use of <math>v^2 = u^2 + 2as</math>;</p> <p>substitution;</p> <p>rearrangement;</p> <p>evaluation;</p> <p>e.g.</p> <p><math>v^2 = u^2 + 2as</math></p> <p><math>v^2 = (0) + 2 \times 10 \times 2.2</math></p> <p><math>v = \sqrt{44}</math></p> <p>(v =) 6.6 (m/s)</p> | <p>seen anywhere in working</p> <p>allow use of <math>g=9.8, 9.81</math></p> <p>allow alternative method using <math>mgh = \frac{1}{2}mv^2</math></p> <p>final answer of 44 (m/s) is 2 marks only</p> <p>allow 6.63...(m/s), 6.56...(m/s)</p> <p>6.5 scores 3 marks only</p> | 4     |
| (b) (i)         | vertical arrow drawn upwards;                                                                                                                                                                                                                                             | ignore labels                                                                                                                                                                                                                                                                | 1     |
| (ii)            | <p>substitution into <math>F = ma</math>;</p> <p>rearrangement;</p> <p>evaluation;</p> <p>e.g.</p> <p><math>18\,000 = 4100 \times a</math></p> <p><math>a = 18\,000 / 4100</math></p> <p>(a =) 4.4 (m/s<sup>2</sup>)</p>                                                  | <p>reject if more than one arrow drawn unless resultant force is clearly labelled</p> <p>-1 for POT error</p> <p>allow 4.39...(m/s<sup>2</sup>)</p>                                                                                                                          | 3     |

Total for Question 9 = 8 marks

| Question number | Answer                                                                                                                                                                                                                                                                                              | Notes                                                                                                                                                                                                                                        | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 9 (a) (i)       | recall of (unbalanced) force = mass × acceleration;<br><br>substitution and rearrangement;<br>evaluation to 2 s.f. or more;<br><br>e.g.<br>$F = m \times a$<br>$a = 41000 / 830$<br>$a = 49 \text{ (m/s}^2\text{)}$                                                                                 | allow symbols<br>can be implied from<br>valid substitution of<br>data<br><br><br>allow 49.39...                                                                                                                                              | 3     |
| (ii)            | substitution into $v^2 = u^2 + 2as$ ;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$26^2 = 72^2 + 2 \times (-50) \times s$<br>(distance =) $5184 - 676 / 100$<br>(distance =) 45 (m)                                                                                                             | allow ecf from (i)<br><br><br><br>expect answers in range<br>45-46 (m)<br>reject $72 - 26 = 46$<br>(wrong physics)<br>accept 46 if unqualified                                                                                               | 3     |
| (b)             | kinetic energy (store) of car decreases;<br><br>thermal energy (store) of brake(s) increases;<br><br>energy transferred mechanically;                                                                                                                                                               | kinetic energy/ KE of<br>car<br>transforms to<br>{heat/thermal} energy<br>of brakes<br>due to work done by<br>{friction / brakes}<br><br>NB only award from<br>either the answer<br>column or notes<br>column, not from a mix<br>of the two. | 3     |
| (c)             | any two from:<br>MP1. idea that insulating materials are poor<br>conductors;<br>MP2. layers trap air;<br>MP3. air itself is a poor conductor/(good)<br>insulator<br>MP4. (energy transfer due to / rate of)<br>conduction reduces;<br>MP5. idea increased thickness reduces (rate of)<br>conduction | condone idea of<br>stopping conduction                                                                                                                                                                                                       | 2     |

Total for Question 9 = 11 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                          | Notes                                                                                                                                                                                                                                                                                                                                                                                                         | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 8 (a) (i)       | <p>downward force arrow labelled "weight";</p> <p>upward force arrow labelled "drag" / "air resistance";</p> <p>upward force larger than downward force by eye;</p>                                                                                                                                                                                                             | <p>ignore starting position of arrows and any horizontal arrows</p> <p>allow "gravitational force", "gravitational pull", "force of gravity"</p> <p>reject "gravity"</p> <p>allow "friction"</p> <p>ignore "upthrust"</p>                                                                                                                                                                                     | 3     |
| (ii)            | <p>any four from:</p> <p>MP1. air resistance increases (greatly) when parachute is opened;</p> <p>MP2. idea that air resistance is greater than weight;</p> <p>MP3. (therefore) resultant force is upwards;</p> <p>MP4. idea that as speed decreases, air resistance decreases;</p> <p>MP5. resultant force (eventually) becomes zero;</p> <p>MP6. constant speed achieved;</p> | <p>allow "drag" for air resistance throughout</p> <p>condone "gravity" for weight throughout</p> <p>allow "upwards force" for air resistance</p> <p>allow upward force is bigger than downward force</p> <p>allow deceleration / upwards acceleration</p> <p>ignore "it slows down"</p> <p>allow forces are balanced/equal</p> <p>air resistance = weight</p> <p>allow idea that there is no acceleration</p> | 4     |

|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                        |   |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| (b) | <p>attempted use of <math>v^2 = u^2 + (2 \times a \times s)</math>;</p> <p>correct substitution;<br/>rearrangement of formula / evaluation of <math>v^2</math>;<br/>evaluation of <math>v</math>;</p> <p>e.g.<br/><math>v^2 = u^2 + (2 \times a \times s)</math>;<br/><math>v^2 = 0.45^2 + (2 \times 3.4 \times 2.0)</math>;<br/><math>v = \sqrt{0.45^2 + (2 \times 3.4 \times 2.0)}</math> OR <math>v^2 = 13.8</math><br/>(<math>v =</math>) 3.7 (m/s)</p> | <p>accept answers in terms of<br/>GPE lost = KE gained,<br/>whatever candidate<br/>chooses for mass<br/>can be implied from<br/>calculation<br/>reject if contradicted by<br/>another irrelevant formula<br/>and no further working<br/>seen</p> <p>allow if 13.8 seen</p> <p>allow 3.72, 3.715...</p> | 4 |
| (c) | <p>any one from:<br/>MP1. Mars has a smaller mass;<br/>MP2. Mars has a lower density;<br/>MP3. Mars has a smaller (iron rich) core;</p>                                                                                                                                                                                                                                                                                                                     | <p>allow RA<br/>allow Mars is less massive</p>                                                                                                                                                                                                                                                         | 1 |

**Total for Question 8 = 12 marks**

| Question number | Answer                                                                                                                                                                                                                                                                               | Notes                                                                                                                                                                                                                      | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 10 (a) (i)      | friction / air resistance / drag;                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                            | 1     |
| (ii)            | 1000 (N);                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                            | 1     |
| (b) (i)         | (resultant) force = mass × acceleration;                                                                                                                                                                                                                                             | allow rearrangements and standard symbols<br>e.g. $a = F/m$                                                                                                                                                                | 1     |
| (ii)            | substitution AND rearrangement;<br>evaluation;<br>unit;<br><br>e.g.<br>(a =) $(-14000 / 1900)$<br>(a =) $(-7.4)$<br><br>$m/s^2$                                                                                                                                                      | -1 for POT error<br>mark independently<br><br>Condone 7.4, 7.36842..., etc.<br><br>accept $m s^{-2}$<br>ignore N/kg                                                                                                        | 3     |
| (iii)           | substitution into $v^2 = u^2 + 2as$ ;<br><br>rearrangement;<br>evaluation;<br><br>e.g.<br>$0 = 18^2 + (2 \times -7.4 \times s)$<br>(s =) $324 / (2 \times 7.4)$<br>(s =) 22 (m)                                                                                                      | allow ecf from (b)(ii)<br>no mark for equation alone as given<br><br>-1 if negative sign given with answer<br><br>allow answer in range 21.8-22.0 from rounding differences<br>allow time to stop of 2.4... (s) for 1 mark | 3     |
| (iv)            | any two <b>described</b> factors from:<br><br>MP1. increased mass (of van);<br>MP2. increased speed (of van);<br>MP3. idea of less friction on the road e.g. road being wet / icy etc;<br>MP4. idea of worn vehicle parts e.g. tyres / brakes etc.;<br>MP5. van travelling downhill; | ignore condition of driver<br><br>allow weight for mass<br><br>allow KE for speed                                                                                                                                          | 2     |

|     |                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                   |   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| (c) | <p>calculation of new acceleration (5.6);</p> <p>substitution into <math>a = (v - u) / t</math>;</p> <p>rearrangement;</p> <p>evaluation;</p> <p>e.g.</p> <p>new acceleration = 5.6 (m/s<sup>2</sup>)</p> <p><math>5.6 = 18 / t</math></p> <p><math>(t =) 18/5.6</math></p> <p><math>(t =) 3.2</math> (s)</p> | <p>-1 if POT error</p> <p>allow ecf from acceleration value</p> <p>allow use of previously calculated acceleration</p> <p>award full marks for momentum method i.e. recall of <math>F = (mv - mu)/t</math>;</p> <p>substitution;</p> <p>rearrangement;</p> <p>evaluation;</p> <p>allow 3.214...</p> <p>ignore negative</p> <p>reject <math>25000/14000 \times 18</math> (i.e. mass <math>\times 10 \times</math> speed/force) which gives 32.</p> | 4 |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

Total for Question 10 = 15 marks



| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                 | Notes                                                                                                                                                                                                                                            | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 7 (a)           | substitution into $v^2 = u^2 + 2as$ ;<br>rearrangement;<br>evaluation;<br>e.g.<br>$0^2 = u^2 + (2 \times -1.8 \times 92\,000)$<br>$u = \sqrt{3.6 \times 92\,000}$<br>(initial speed =) 580 (m/s)                                                                                                                                                                                                       | allow answers in terms of conservation of energy for full marks<br>ignore units<br>condone poor handling of minus signs<br>allow 575.(499...) (m/s)<br>answer of 331 200 gains 2 marks<br>POT error on distance will give 18.2 (m/s) for 2 marks | 3     |
| (b) (i)         | particles collide with walls;<br>(collisions result in) force on walls;<br>force over area gives pressure;                                                                                                                                                                                                                                                                                             | ignore collisions between particles<br>allow momentum arguments<br>allow $p = F / A$                                                                                                                                                             | 3     |
| (ii)            | substitution into $p_1/T_1 = p_2/T_2$ ;<br>rearrangement;<br>evaluation;<br>e.g.<br>$8.2/1200 = p_2/1600$<br>$p_2 = (1600 \times 8.2/1200)$<br>$(p_2 =) 11$ (kPa)                                                                                                                                                                                                                                      | allow pressure in kPa or Pa<br>allow 10.9... (kPa)                                                                                                                                                                                               | 3     |
| (iii)           | any three from:<br>particles have more kinetic energy;<br>particles collide with walls more <b>frequently</b> ;<br>idea that particles collide with walls with more force / 'harder';<br>(average) force increases;                                                                                                                                                                                    | allow particles move faster/eq.                                                                                                                                                                                                                  | 3     |
| (iv)            | any three from:<br>MP1. idea that higher pressure means higher speed;<br>MP2. Tvashtar particles have more (initial) KE;<br>MP3. particles from both chambers experience the same deceleration;<br>MP4. (higher speed with same deceleration) takes longer to reach 0 m/s;<br>MP5. relevant quantitative argument based on motion formulae;<br>MP6. Tvashtar particles have more GPE (at max. height); | allow Tvashtar particles have higher speed / RA<br>allow Tvashtar particles take longer to reach max. height / RA                                                                                                                                | 3     |

Total for Question 7 = 15 marks



| Question number | Answer                                                                                                                                                                                                                                                                | Notes                                                                                                                  | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-------|
| 3 (a)           | (i) B - consumption of alcohol by the driver;<br><br>A is incorrect because condition of tyres only affects braking distance<br>C is incorrect because mass of vehicle only affects braking distance<br>D is incorrect because wet road only affects braking distance |                                                                                                                        | 1     |
|                 | (ii) D - speed of the vehicle;<br><br>A is incorrect because condition of brakes only affects braking distance<br>B is incorrect because condition of road only affects braking distance<br>C is incorrect because mass of vehicle only affects braking distance      |                                                                                                                        | 1     |
| (b)             | (i) work done = force × distance;                                                                                                                                                                                                                                     | allow correct rearrangements<br>allow standard symbols<br>i.e. W/E/WD for work done, F/f for force, d/D/s for distance | 1     |
|                 | (ii) substitution;<br><br>rearrangement;<br>evaluation;<br><br>e.g.<br>$590000 = 46000 \times \text{distance}$<br>$d = 590000/46000$<br>$d = 13 \text{ (m)}$                                                                                                          | allow subs and re-arrange in either order<br><br><br><br><br><br>allow 12.8 (m), 12.83 (m) etc                         | 3     |
| (c)             | (i) thermal;                                                                                                                                                                                                                                                          |                                                                                                                        | 1     |
|                 | (ii) mechanic(ally);                                                                                                                                                                                                                                                  |                                                                                                                        | 1     |

Total for Question 3 = 8 marks



| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Notes                                                                                                                                                                                                                                                                                                                                                                                                                              | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 11 (a)          | <p>value of braking distance correctly read from graph;<br/>substitution into <math>v^2 = u^2 + 2as</math>;<br/>rearrangement;<br/>evaluation;</p> <p>e.g.<br/>braking distance = 78 m<br/> <math>0 = 35^2 + (2 \times a \times 78)</math><br/> <math>(a =) (-) 35^2 / (2 \times 78)</math><br/> <math>(a =) (-) 7.9 \text{ (m/s}^2\text{)}</math></p>                                                                                                                                                                                                                                                                                  | <p>allow 77-79 m<br/>allow ecf incorrect distance</p> <p>allow 7.75... - 7.95...(m/s<sup>2</sup>)</p>                                                                                                                                                                                                                                                                                                                              | 4     |
| (b)             | <p>any five from:</p> <p>MP1. thinking distance OR braking distance increases as (initial) speed increases;<br/> MP2. braking distance increases by a greater amount than thinking distance for the same increase in (initial) speed;<br/> MP3. thinking distance is (directly) proportional to (initial) speed;<br/> MP4. braking distance has a non-linear relationship with (initial) speed;<br/> MP5. idea that braking distance is proportional to (initial) speed squared;<br/> MP6. suitable use of data to justify thinking distance relationship;<br/> MP7. suitable use of data to justify braking distance relationship;</p> | <p>e.g. gradient of braking distance graph larger than gradient for thinking distance</p> <p>e.g. when initial speed doubles, the braking distance is four times greater / eq.<br/> e.g. reading off thinking distance for two values of initial speed and showing they increase by the same factor<br/> e.g. reading off braking distance for two values of initial speed and showing they do not increase by the same factor</p> | 5     |

Total for Question 11 = 9 marks



| Question number | Answer                                                                                                                                                                                                                                     | Notes                                                                                                                                                                            | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a) (i)       | use of acceleration = change in velocity / time;<br><br>substitution;<br>evaluation;<br><br>e.g.<br>acceleration = change in velocity / time<br>acceleration = $(-30) / 6.2$<br>(acceleration =) $(-4.8 \text{ (m/s}^2\text{)})$           | seen anywhere in working<br>allow clear indication that acceleration is gradient<br><br>ignore minus sign<br><br><br>allow<br>$(-4.8 \text{ to } (-)5.0 \text{ (m/s}^2\text{)})$ | 3     |
| (ii)            | clear indication that distance is area under line;<br>understanding braking distance is area of triangle section only;<br>evaluation;<br><br>e.g.<br>distance = area<br>distance = $0.5 \times 30 \times 6.2$<br>(distance =) 93 (m)       | 54 (m) = 1 mark<br>147 (m) = 2 marks<br><br><br>accept alternative method using ecf answer from (a)(i) and $v^2 = u^2 + 2as$ giving 93.75 (m)                                    | 3     |
| (iii)           | thinking distance:<br>increase in thinking distance;<br>(due to) increased reaction time;<br><br>braking distance:<br>no effect on braking distance;<br>(due to) no effect on braking time / braking force;                                | <br><br><br><br><br><br>allow idea that braking distance does not depend on human factors                                                                                        | 4     |
| (b)             | A;<br><br>B is incorrect because it does not show deceleration<br>C is incorrect because the distance cannot change abruptly and the car is moving throughout<br>D is incorrect because the first portion shows that the car is not moving |                                                                                                                                                                                  | 1     |

Total for Question 4 = 11 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                           | Notes                                                                                                                                                                                                                                                                                                                                                                                                  | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a) (i)       | 0.9 (s);                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                        | 1     |
| (ii)            | distance = area (under line);<br><br>thinking distance (rectangle) = 13.5(m) OR<br>braking distance (triangle) = 23.25(m)<br>correctly determined;<br><br>attempt at calculating area of a trapezium /<br>adding values for areas of rectangle and<br>triangle;<br><br>(stopping distance =) 37 (m);                                                                             | allow ECF from incorrect time<br>found in (a)(i)<br>can be implied from calculation,<br>explicit statement or working on<br>graph itself<br><br>allow 36.75, 36.7, 36.8                                                                                                                                                                                                                                | 4     |
| (iii)           | acceleration formula seen in working;<br><br>correct substitution into acceleration<br>formula;<br>evaluation of acceleration;<br><br>e.g.<br>(acceleration =) change in velocity ÷ time<br><br>(acceleration =) $(-15 / 3.1)$<br>(acceleration =) $-4.8 \text{ (m/s}^2\text{)}$                                                                                                 | can be implied from substitution<br>of data<br>allow ECF from incorrect time<br>found in (a)(i)<br>reject if given as a positive value<br><br>allow $(a =) v - u \div t$<br>allow acceleration is gradient<br>condone change in speed ÷ time<br><br>allow any answer that rounds to<br>$-4.8$<br>allow deceleration = $4.8 \text{ (m/s}^2\text{)}$                                                     | 3     |
| (b)             | max. two factors linked to thinking distance:<br><br>MP1. tiredness (of driver);<br>MP2. age (of driver);<br>MP3. alcohol or drug consumption;<br>MP4. distraction (of driver);<br><br>max. two factors linked to braking distance:<br>MP5. mass / weight of car;<br><br>MP6. condition of brakes;<br>MP7. condition of road;<br>MP8. condition of tyres;<br>MP9. slope of road; | allow 'reaction time' if no other<br>thinking distance mark achieved<br>ignore factors affecting visibility<br><br>e.g. caffeine, medicine etc.<br>e.g. using a mobile phone etc.<br><br>ignore bald "the weather"<br>allow however expressed e.g.<br>more people, less luggage etc.<br><br>e.g. icy road, wet road<br>e.g. how much grip left / eq<br>e.g. whether the car is going up<br>or downhill | 4     |

Total for Question 4 = 12 marks

| Question number | Answer                                                                                                                                                                                                                                                                 | Notes                                                                                                                                   | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1 (a)           | 0 (kN);                                                                                                                                                                                                                                                                |                                                                                                                                         | 1     |
| (b) (i)         | (stopping distance = $7 + 20 =$ ) 27 (m);                                                                                                                                                                                                                              |                                                                                                                                         | 1     |
| (ii)            | any two from:<br><br>MP1. speed of truck;<br>MP2. mass or weight of truck;<br>MP3. condition of brakes/eq;<br>MP4. condition of tyres/eq;<br>MP5. condition of road/eq;<br>MP6. braking uphill / downhill;<br>MP7. how hard the brake pedal is pressed;                | allow wet/icy roads eq.<br><br>reference to factors that affect thinking distance, e.g. alcohol, tiredness etc. limits score 1 mark max | 2     |
| (iii)           | <b>D (the truck is travelling at a lower speed);</b><br><br>A is incorrect because this would affect the braking distance<br><br>B is incorrect because this would affect the braking distance<br><br>C is incorrect because this would increase the thinking distance |                                                                                                                                         | 1     |

Total for Question 1 = 5 marks

| Question number | Answer                                                                                                                                                                                 | Notes                                                                                                                           | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-------|
| 7 (a)           | substitution into momentum = mass $\times$ velocity;<br>evaluation;<br><br>e.g.<br>$p = 0.0041 \times 0.15$<br>(p =) 0.00062 (kgm/s)                                                   | allow use of standard symbols e.g. $p = m \times v$<br>-1 for POT error<br><br>allow decimal or standard form<br>allow 0.000615 | 2     |
| (b)             | velocity of ball increases;<br>momentum increases;                                                                                                                                     | allow ball speeds up                                                                                                            | 2     |
| (c)             | substitution into $F = (mv - mu) / t$ ;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$1.3 = 0.0041 \times v - 0 / 0.0025$<br>(v =) $1.3 \times 0.0025 / 0.0041$<br>(v =) 0.79 (m/s) | -1 for POT error<br><br>allow 0.79268...                                                                                        | 3     |

Total for Question 7 = 7 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                    | Notes                                                                                                                                                                                                                              | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a)           | $0.41 \times 13$ ;<br>5.3(3);                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                    | 2     |
| (b)             | 5.15 / 5.45 / 5.48 / 5.5;                                                                                                                                                                                                                                                                                 | allow ecf from (a)                                                                                                                                                                                                                 | 1     |
| (c)             | same as candidate's answer to (b)<br>i.e. 5.48 (kg m/s);                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                    | 1     |
| (d)             | total mass = 0.58 (kg);<br>substitution of candidate's answer to part (c);<br><br>rearrangement and correct evaluation;<br><br><br><br><br><br><br>correct answer: 9.4 (m/s)<br><br>e.g. total momentum = 5.48 kg m/s<br>total mass = 0.58 kg<br>velocity = $5.48 \div 0.58$<br>velocity = 9.448... (m/s) | accept re-calculation of total momentum 'from first principles'<br><br>acceptable values for the velocity here are 8.88..., 9.40..., 9.448..., 9.48... or ecf from (c)<br><br>allow full credit for correct answer with no working | 3     |

Total for question 4: 7 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                             | Notes                                                                                                                                                                                                                           | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 7 (a) (i)       | momentum = mass $\times$ velocity;                                                                                                                                                                                                                                                                                                                                 | allow rearrangements and standard symbols<br>e.g. $m = p / v$<br>reject $m$ for momentum                                                                                                                                        | 1     |
| (ii)            | substitution;<br>evaluation;<br><br>e.g.<br>( $p =$ ) $0.170 \times 5.2$<br>( $p =$ ) $0.88 \text{ (kgm/s)}$                                                                                                                                                                                                                                                       | -1 if POT error<br><br>allow $0.884 \text{ (kgm/s)}$                                                                                                                                                                            | 2     |
| (b) (i)         | momentum of black ball calculated;<br>conservation of momentum used correctly;<br><br>final momentum of white ball calculated;<br>evaluation of final velocity of white ball;<br><br>e.g.<br>$p_{\text{black}} = 0.80 \text{ (kgm/s)}$<br>$0.88 = p_{\text{white}} + 0.80$<br>$p_{\text{white}} = 0.08 \text{ (kgm/s)}$<br>$v_{\text{white}} = 0.47 \text{ (m/s)}$ | ignore units<br>stated or implied from calculation<br>allow ecf from (a)<br>ignore units<br><br>allow $800 \text{ (gm/s)}$<br><br>allow $80 \text{ (gm/s)}$<br>allow $0.5, 0.4705\dots$<br>$0.49$ for use of $0.884$ from a(ii) | 4     |
| (ii)            | $80 \text{ (N)}$ ;<br>(to the) left;                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                 | 2     |

Total for Question 7 = 9 marks



| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                 | Notes                                                                                                                                      | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3 (a)           | momentum = mass $\times$ velocity;                                                                                                                                                                                                                                                                                                                                                                                                     | allow standard symbols and rearrangements e.g.<br>$p = m \times v$<br>reject M, m for momentum                                             | 1     |
| (b)             | substitution;<br>evaluation;<br>unit;<br><br>e.g.<br>$p = 1.67 \times 10^{-27} \times 2200$<br>(p =) $3.7 \times 10^{-24}$<br>kg m/s                                                                                                                                                                                                                                                                                                   | allow $3.6(74) \times 10^{-24}$<br>allow $3.7 \times 10^{-21}$ g<br>m/s for 3 marks                                                        | 3     |
| (c)             | (total) momentum before (collision) =<br>(total) momentum after (collision);                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                            | 1     |
| (d)             | evaluation of momentum of U-235 before collision;<br>addition of neutron momentum;<br>rearrangement to give velocity of U-236;<br><br>correct evaluation;<br><br>e.g.<br>$p_{U-235} = (3.99 \times 10^{-25} \times 10 =) 3.99 \times 10^{-24}$<br>$p_{U-236} = 3.99 \times 10^{-24} + 3.7 \times 10^{-24}$<br>$v_{U-236} = \text{momentum} / \text{mass} = 7.664 \times 10^{-24} / 4.01 \times 10^{-25}$<br>( $v_{U-236} =$ ) 19 (m/s) | allow ecf from (b)<br>seen or implied by working<br><br>not adding neutron momentum gives<br>9.95 m/s = 2 marks<br><br>allow 19.1... (m/s) | 4     |

Total for Question 3 = 9 marks

| Question number | Answer                                                                                                                                                          | Notes                                                                                                                                                                                   | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a) (i)       | momentum = mass $\times$ velocity;                                                                                                                              | all standard symbols and rearrangements<br>e.g. $m = p / v$<br>ignore m, M for momentum                                                                                                 | 1     |
| (ii)            | substitution;<br>rearrangement;<br>evaluation to 2 or more s.f.;<br><br>e.g.<br>$1100 = \text{mass} \times 14$<br>$\text{mass} = 1100 / 14$<br>(mass =) 79 (kg) | answer of 78 (kg) gets 2 marks only<br><br>allow 78.6, 78.57...<br>condone 78.5                                                                                                         | 3     |
| (b)             | substitution into $F = \Delta p / t$ ;<br><br>rearrangement;<br>evaluation;<br><br>e.g. $15000 = 1100 / t$<br>$t = 1100 / 15000$<br>(t =) 0.073 (s)             | ignore not converting kN to N<br>allow use of<br>$\Delta p = (80 \times 14 =) 1120$<br><br>-1 for POT error<br><br>allow 0.07, 0.0733..., 0.075, 0.0746...                              | 3     |
| (c)             | idea that airbag increases the (collision) time;<br>reduces the <b>rate of</b> change of momentum;                                                              | condone slows down <b>change of</b> momentum<br><br>allow reduces acceleration<br><br>allow use of equation AND statement that change in momentum is constant (which reduces the force) | 2     |

Total for Question 4 = 9 marks



| Question number | Answer                                                                                                                                                                                                                                                                                                                                            | Notes                                                                                                                                                                                                                                                                                                                                                                 | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3 (a) (i)       | momentum = mass $\times$ velocity;                                                                                                                                                                                                                                                                                                                | allow standard symbols and rearrangements<br>e.g. $p = m \times v$<br>reject use of $m$ for momentum                                                                                                                                                                                                                                                                  | 1     |
|                 | (ii) substitution;<br>evaluation to 2 or 3 s.f.;<br><br>e.g.<br>( $p =$ ) $17 \times 2.9$<br>( $p =$ ) $49 \text{ (kg m/s)}$                                                                                                                                                                                                                      | allow $49.3 \text{ (kg m/s)}$                                                                                                                                                                                                                                                                                                                                         | 2     |
| (b) (i)         | use of conservation of momentum;<br><br>momentum of stone A after collision calculated;<br>momentum of stone B after collision calculated;<br>evaluation of velocity of stone B;<br><br>e.g.<br>momentum before = momentum after<br>$p_A = (17 \times 0.4 =) 6.8$<br>$p_B = (50 - 6.8 =) 43.2$<br><br>( $v_B = 43.2 / 19 =$ ) $2.3 \text{ (m/s)}$ | seen written explicitly or implied by working<br><br>allow, for 1 mark only, “(total) momentum before = (total) momentum after” if no other marks scored.<br><br>allow $42.5$ , $42.2$ from non-rounded values for (a)<br>allow $2.27\dots \text{ (m/s)}$<br>allow $2.22\dots$ , $2.23\dots$                                                                          | 4     |
|                 | (ii) conversion of ms to s;<br><br>substitution into $F = \Delta p / t$ ;<br><br>evaluation of force;<br><br>e.g.<br>$t = 0.025 \text{ s}$<br>$F = 43.2 / 0.025$<br>( $F =$ ) $1700 \text{ (N)}$                                                                                                                                                  | allow $\div 1000 / 0.025$ seen anywhere in working<br>no mark for formula alone as given in paper<br>2 marks max. for POT error e.g. $1.7 \text{ (N)}$<br><br>allow ecf from (b)(i)<br>allow answers in the range $1688$ - $1728$<br>accept, in full, responses including use of ‘ $F = ma$ ’ provided correct values for $u$ , $v$ and $\Delta t$ to calculate $a$ . | 3     |

Total for Question 3 = 10 marks



| Question number | Answer                                                                                                                                                                                                                                                                                      | Notes                                                                                                                                                                                                              | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | both forces are the same size/magnitude/equal;<br>forces are in opposite <b>directions</b> ;                                                                                                                                                                                                | ignore same force<br>allow one (force) is left<br>and the other (force) is right<br>“forces are equal and opposite” / “every action has an equal and opposite reaction”<br>scores 1 mark if no other marks awarded | 2     |
| (b)             | substitution into $p = m \times v$ ;<br>evaluation;<br><br>e.g.<br>(momentum =) $0.018 \times 4.9$<br>(momentum =) $0.088 \text{ (kg m/s)}$                                                                                                                                                 | -1 for POT error from incorrectly converting kg to g<br><br>allow 0.09, 0.0882 (kg m/s)                                                                                                                            | 2     |
| (c)             | use of conservation of momentum;<br><br>setting up equation to be solved;<br>rearrangement;<br>evaluation to 2 or more significant figures;<br><br>e.g.<br>momentum is conserved<br>$0.088 = 0.018 \times -3.5 + 0.265 \times v$<br>$v = [0.088 + 0.063]/0.265$<br>$v = 0.57 \text{ (m/s)}$ | seen explicitly or implied from working<br>allow ecf from (b)<br><br>ignore 0.6 as given in question<br>answer of 0.095... scores 3 marks<br><br>allow any answer rounding to 0.57                                 | 4     |
| (d)             | use of $KE = \frac{1}{2} \times m \times v^2$ ;<br><br>evaluation of KE before collision;<br><br>evaluation of KE after collision;<br><br>comparison with correct conclusion that collision is not elastic/inelastic;                                                                       | seen explicitly or implied from working<br>allow 0.2, 0.22, 0.216, 0.216... (J)<br>allow 0.15-0.16 (J) OR 0.110 AND 0.043 seen in working<br>DOP<br>allow ecf from KE calculations                                 | 4     |

Total for Question 5 = 12 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Notes                                                                                                                                                                                                                                                                                                                                                                               | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 7 (a)           | <p>correct substitution <math>KE = \frac{1}{2} (\text{mass}) \times (\text{speed})^2</math>;</p> <p>re-arrangement to give <math>v</math>;</p> <p>evaluation to show 5.8(4...) (m/s);</p> <p>e.g. <math>KE = \frac{1}{2} m v^2</math><br/> <math>0.29 = 0.5 \times 0.017 \times v^2</math><br/> <math>v^2 = 0.29 \div (0.5 \times 0.017) = 34.1176471\dots</math><br/> <math>v = \sqrt{34.1176471} = 5.8(4\dots) \text{ (m/s)}</math></p>                                 | <p>allow use of standard symbols e.g. <math>KE = \frac{1}{2} m v^2</math></p> <p>allow mass = 17 at this point</p>                                                                                                                                                                                                                                                                  | 3     |
| (b)             | <p>idea of conservation of momentum;</p> <p>idea that momentum before release was zero;</p> <p>evidence of re-arrangement;</p> <p>evaluation of large block speed giving 1.3 m/s;</p> <p>e.g. momentum of small block = <math>17 \times 6 = 102 \text{ g m/s}</math><br/> therefore momentum of large block = <math>102 \text{ g m/s}</math><br/> momentum = mass <math>\times</math> velocity = <math>75 v</math><br/> so <math>v = 102/75 = 1.36 \text{ m/s}</math></p> | <p>however expressed</p> <p>allow idea that momenta of two blocks is equal in magnitude</p> <p>allow 1.4 if <math>v_{\text{small}} = 6 \text{ m/s}</math><br/> ignore mass unit provided<br/> both masses consistent</p> <p><math>v=1.31</math> if <math>v_{\text{small}} = 5.8 \text{ m/s}</math><br/> <math>v=1.32</math> if <math>v_{\text{small}} = 5.84 \text{ m/s}</math></p> | 4     |
| (c)             | <p>substitution into given equation;</p> <p>idea of initial momentum = 0;</p> <p>evaluation;</p> <p>correct answer = 0.93 (N)</p> <p>e.g. force = change in momentum <math>\div</math> time taken<br/> force = <math>((0.017 \times 6) - 0) \div 0.11</math><br/> force = <math>0.102 \div 0.11</math><br/> force = <math>0.9272\dots \text{ (N)}</math></p>                                                                                                              | <p>allow use of init velocity = 0</p>                                                                                                                                                                                                                                                                                                                                               | 3     |
| (d)             | <p>substitution and re-arrangement of given equation;</p> <p>conversion of 17.6 cm to 0.176 m;</p> <p>evaluation;</p> <p>correct answer = 0.18(41...) (s)</p> <p>e.g. orbital speed = <math>(2\pi \times \text{orbital radius}) \div \text{time period}</math><br/> <math>6 = (2\pi \times 0.176) \div T</math><br/> <math>T = (2\pi \times 0.176) \div 6</math><br/> <math>T = 0.1843\dots \text{ (s)}</math></p>                                                        | <p>accept 0.2 (s)</p> <p>accept use of <math>v=5.84\dots \text{ (m/s)}</math></p> <p>-1 POT error</p> <p>0.092.. (s) for using 17.6 cm as a diameter scores 2 marks</p>                                                                                                                                                                                                             | 3     |

Total for Question 7: 13 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                               | Notes                                                                                                                                                                                                                                                                                                                                                        | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | <p>arrow drawn vertically downwards such that its line of action passes through the centre of the ball;</p> <p>arrow labelled “weight”;</p>                                                                                                                                                                                                          | <p>ignore any additional arrows</p> <p>judge by eye</p> <p>ignore starting position of arrow</p> <p>allow force due to gravity, gravitational force</p> <p>ignore gravity</p>                                                                                                                                                                                | 2     |
| (b) (i)         | <p>initial momentum calculated;</p> <p>final momentum calculated;</p> <p>evaluation of change in momentum;</p> <p>consistent unit;</p> <p>e.g.<br/>(initial momentum = <math>0.057 \times 2.5 =</math>) 0.14</p> <p>(final momentum = <math>0.057 \times 1.9 =</math>) 0.11</p> <p>(change in momentum = <math>0.14 + 0.11 =</math>) 0.25 kg m/s</p> | <p>ignore any minus signs</p> <p>allow if calculated in kg m/s or g m/s</p> <p>change in momentum of 0.034(2) scores first two marks</p> <p>allow 0.142, 0.143, 0.1425</p> <p>allow 0.108, 0.1083</p> <p>allow 0.251, 0.2508</p> <p>allow Ns</p> <p>allow g m/s only if consistent with values</p>                                                           | 4     |
| (ii)            | <p>substitution into given formula;</p> <p>evaluation;</p> <p>direction of force = upwards;</p> <p>e.g.<br/>(force =) <math>0.25 / 0.0060</math></p> <p>(force =) 42 (N)</p> <p>direction = upwards</p>                                                                                                                                              | <p>allow ecf from (i)</p> <p>ignore units</p> <p>allow upwards arrow</p> <p>ignore north</p> <p>allow 41-42 (N)</p>                                                                                                                                                                                                                                          | 3     |
| (c)             | <p>any <b>two</b> marks max. from:</p> <p>MP1. independent variable is type of ball;</p> <p>MP2. dependent variable is height of bounce;</p> <p>MP3. any named control variable;</p> <p>any <b>two</b> marks max. from:</p> <p>MP4. ensure distances are measured vertically;</p> <p>MP5. use of set square;</p> <p>MP6. measure at eye level;</p>   | <p>related to variables</p> <p>allow material of ball</p> <p>allow coefficient of restitution</p> <p>e.g. drop height, surface used, temperature of ball, released from rest</p> <p>related to accuracy</p> <p>allow ruler/tape measure perpendicular to ground</p> <p>can be awarded from well-drawn diagram</p> <p>ignore unqualified “avoid parallax”</p> | 6     |

|  |                                                                                                                                                                                                                |                                                                                                                                |  |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|--|
|  | <p>MP7. use of (slow motion) camera to measure height;</p> <p>any <b>two</b> marks max. from:</p> <p>MP8. repeats taken for each ball;</p> <p>MP9. identify anomalies;</p> <p>MP10. calculate mean values;</p> | <p>ignore use of light gates</p> <p>related to reliability</p> <p>allow repeat investigation</p> <p>allow average for mean</p> |  |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|--|

Total for Question 5 = 15 marks

| Question number | Answer                                                                                                                                                                                                                                          | Notes                                                                                                                                                  | Marks |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 8 (a)           | Centre of gravity;                                                                                                                                                                                                                              | Accept 'Centre of Mass'                                                                                                                                | 1     |
| (b) (i)         | Moment = force x (perpendicular) distance;                                                                                                                                                                                                      | Condone $M = f \times d$                                                                                                                               | 1     |
| (ii)            | Any correct moment;<br>i.e. $2.1 \times 0.28$ or $W \times 0.032$<br><br>Evidence of use of principle of moments;<br>i.e. $2.1 \times 28 = W \times 3.2$<br><br>Re-arrangement ; i.e. $W = 2.1 \times 28 / 3.2$<br><br>Evaluation; $W = 18$ (N) | Allow calculation performed in cm<br><br><br><br><br><br>Accept unrounded 18.375, 18.4 N.<br><br>Condone for 1 mark statement of principle of moments. | 4     |

| Question number | Answer                                                                                                                                                           | Notes                                                                                                                                                                                                                                         | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 1 (a)           | B - 16 g;<br><br>A cannot be correct as g on Earth is not 100<br>C cannot be correct as g on Earth is not 1<br>D cannot be correct as g on Earth is not 0.1      |                                                                                                                                                                                                                                               | 1     |
| (b) (i)         | substitution into given formula;<br>correct evaluation;<br><br>correct answer: 0.59(2) (N cm)<br><br>e.g.<br>moment = $0.16 \times 3.7$<br>moment = 0.592 (N cm) | ignore units here<br>accept 0.00592 Nm (i.e. unit on answer line changed)<br>condone 1sf answer<br><br>accept 0.00592 Nm (i.e. unit on answer line changed)<br>-1 POT error otherwise                                                         | 2     |
| (ii)            | 0.59(2) (N cm);                                                                                                                                                  | ECF candidate's answer from (i)                                                                                                                                                                                                               | 1     |
| (iii)           | substitution;<br><br>re-arrangement and evaluation;<br><br>e.g.<br>$0.592 = F \times 7.4$<br>$F = 0.592 \div 7.4 = 0.08(0)$                                      | ECF candidate's answer from (ii) for substitution only<br><br>ignore reverse argument<br>accept $0.16 \times 3.7$ for 0.59(2)<br><br>$0.592 / 7.4 = 0.080$<br>or $0.59 / 7.4 = 0.0797...$<br>or $0.6 / 7.4 = 0.08108...$<br>all score 2 marks | 2     |

Total for question 1: 6 marks

| Question number | Answer                                                                                                                                                      | Notes                                                                                                                       | Marks |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|-------|
| 2 (a) (i)       | centre of gravity / centre of mass;                                                                                                                         | allow centre of weight                                                                                                      | 1     |
| (ii)            | balance / newtonmeter;                                                                                                                                      | allow <u>newton</u> scales<br>ignore scales                                                                                 | 1     |
| (b) (i)         | moment = force × (perpendicular) distance;                                                                                                                  | allow standard symbols and rearrangements e.g.<br>moment = $F \times d$<br>ignore m for moment                              | 1     |
| (ii)            | substitution;<br><br>e.g.<br>$0.68 \times 4.3 (= 2.924 \text{ N cm})$                                                                                       |                                                                                                                             | 1     |
| (iii)           | idea that anti-clockwise moment = clockwise moment;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$2.9 = F \times 11$<br>$F = 2.9 / 11$<br>(F =) 0.26 (N) | stated or implied by working<br><br>allow ECF from (ii)<br><br>allow 0.2636...-<br>0.2658...<br>allow 0.27<br>condone 0.263 | 3     |

(Total for Question 2 = 6 marks)

| Question number | Answer                                                                                                                           | Notes                                                                                                                             | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------|
| 2 (a)           | centre of gravity;                                                                                                               | accept centre of mass                                                                                                             | 1     |
| (b)             | moment = force $\times$ (perpendicular) distance;                                                                                | allow standard symbols and rearrangements<br>e.g. $M = F \times d$<br>allow d, s, x for distance                                  | 1     |
| (c)             | substitution;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$92 = F_s \times 0.84$<br>$F_s = 92 / 0.84$<br>( $F_s =$ ) 110 (N) | -1 for POT error<br>2 marks max. if incorrect distance used<br>e.g. 0.42 m giving answer of 219 (N)<br><br>allow 109.5, 109.52... | 3     |
| (d)             | idea that every force has an equal and opposite reaction;                                                                        | however expressed<br>allow “action” for force                                                                                     | 1     |
| (e)             | same value as (c);<br><br>down;                                                                                                  | allow ecf from (c)<br>expected answer is 110 (N)                                                                                  | 2     |

Total for Question 2 = 8 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                 | Notes                                                                                     | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------|
| 3 (a)           | centre of gravity;                                                                                                                                                                                                                                                                                                     | allow centre of mass                                                                      | 1     |
| (b) (i)         | C (230 N);<br><br>A is not correct as this is the mass of the bin;<br>B is not correct as this has the incorrect unit for force;<br>D is not correct as the mass has been converted to grams before being multiplied by g.                                                                                             |                                                                                           | 1     |
| (ii)            | (in equilibrium) sum of clockwise moments = sum of anticlockwise moments;                                                                                                                                                                                                                                              | condone 'clockwise moment = anticlockwise moment'                                         | 1     |
| (iii)           | calculation of moment of weight or expression for moment of F;<br>equating moments;<br>rearrangement for F;<br>correct evaluation of F;<br><br>e.g. moment of F = $0.98 \times F$<br>moment of weight = $230 \times 0.37$<br>$230 \times 0.37 = 0.98 \times F$<br>$F = 230 \times 0.37 / 0.98$<br>$F = 87 \text{ (N)}$ | ignore POT for this MP<br><br><br><br><br><br><br><br><br><br>allow 86.8, 86.84, 86.83... | 4     |
| (iv)            | Magnitude=candidate's answer for (iii);<br>direction: down(wards);                                                                                                                                                                                                                                                     | expect 87 N                                                                               | 2     |

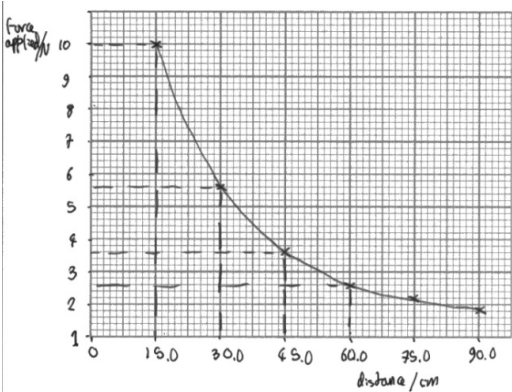
Total for Question 3 = 9 marks

| Question number | Answer                                                                                                                                                                                                                     | Notes                                                                                                                | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|-------|
| 3 (a)           | (i) X drawn at the base of the weight arrow;                                                                                                                                                                               | judge by eye                                                                                                         | 1     |
|                 | (ii) weight = mass $\times$ gravitational field strength;                                                                                                                                                                  | allow standard symbols and rearrangements<br>e.g. $W = m \times g$<br>ignore 'gravity' for $g$                       | 1     |
|                 | (iii) substitution;<br>evaluation;<br><br>e.g.<br>(W =) $130 \times 10$<br>(W =) 1300 (N)                                                                                                                                  | -1 for POT error only e.g.<br>from incorrectly converting kg to g<br><br>allow $g = 9.8, 9.81$<br>allow 1274, 1275.3 | 2     |
| (b)             | (i) in equilibrium / when balanced;<br>(sum of) clockwise moment(s) = (sum of) anti-clockwise moment(s);                                                                                                                   | allow idea that net moment is zero                                                                                   | 2     |
|                 | (ii) correct expression for either moment;<br>correct use of principle of moments;<br>evaluation of distance X;<br><br>e.g.<br>$1300 \times 0.30$ OR $520 \times X$<br>$1300 \times 0.30 = 520 \times X$<br>$X = 0.75$ (m) | allow ecf from (a)(iii)                                                                                              | 3     |
|                 | (iii) (length of plank =) 1.5 (m);                                                                                                                                                                                         | allow ecf from (b)(ii)                                                                                               | 1     |

Total for Question 3 = 10 marks

| Question number | Answer                                                             | Notes                                                                                                                                   | Marks |
|-----------------|--------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2 (a)           | substitution into moment = force $\times$ distance;                | accept dimensionally correct substitution                                                                                               | 3     |
|                 | evaluation;                                                        | -1 for POT error                                                                                                                        |       |
|                 | matching unit;                                                     | condone case error                                                                                                                      |       |
|                 | e.g.                                                               |                                                                                                                                         |       |
|                 | moment = $28 \times 0.15$                                          | allow $28 \times 15$                                                                                                                    |       |
|                 | (moment =) 4.2 N m                                                 | allow 420 N cm                                                                                                                          |       |
|                 |                                                                    |                                                                                                                                         |       |
|                 |                                                                    |                                                                                                                                         |       |
| (b)             | apply a larger force / eq;                                         | allow pivot for nut                                                                                                                     | 2     |
|                 | apply force further from nut / eq;                                 | allow use a longer wrench<br>condone bigger wrench                                                                                      |       |
|                 |                                                                    |                                                                                                                                         |       |
|                 |                                                                    |                                                                                                                                         |       |
| (c) (i)         | circumference of circle calculated;                                |                                                                                                                                         | 2     |
|                 | divided by 4 to find distance;                                     | answer evaluated as a decimal only<br>ecf candidate's circumference                                                                     |       |
|                 | e.g.                                                               | $22/7$ for $\pi$ gives 94.3                                                                                                             |       |
|                 | (circumference = $2\pi r = 2 \times \pi \times 15$ ) = 94(.2) (cm) |                                                                                                                                         |       |
|                 | (distance = $94 / 4$ =) 24 (cm)                                    | allow anything that would round to 24 (cm)<br>condone 23.5 (cm)                                                                         |       |
|                 |                                                                    |                                                                                                                                         |       |
| (ii)            | conversion of cm to m;                                             | allow ecf from (i) seen explicitly or implied by working                                                                                | 3     |
|                 | substitution;                                                      |                                                                                                                                         |       |
|                 | evaluation;                                                        | answer evaluated as a decimal only<br>-1 for POT error                                                                                  |       |
|                 | e.g.                                                               |                                                                                                                                         |       |
|                 | work done = force $\times$ distance                                |                                                                                                                                         |       |
|                 | work done = $28 \times 0.24$<br>(work done =) 6.7 (J)              | allow any answer that rounds to 6.6 (J) or 6.7 (J)<br><br>using 0.94 for the distance gives an answer that rounds to 26 (J) ecf 3 marks |       |

Total for Question 2 = 10 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                                       | Notes                                                                                                                                                                            | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3 (a)           | (metre) rule(r)/(metal) tape measure;                                                                                                                                                                                                                                                                                                                                                                        | allow<br>(Vernier) caliper(s)                                                                                                                                                    | 1     |
| (b) (i)         | 3.6;                                                                                                                                                                                                                                                                                                                                                                                                         | allow 3.7                                                                                                                                                                        | 1     |
| (ii)            | idea that the reading would be larger than the range of the instrument;                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                  | 1     |
| (c) (i)         | suitable linear scale chosen (>50% of grid used);<br>axes labelled with quantities and units;<br>plotting correct to nearest half square;<br>                                                                                                                                                                              | ignore plotting of 45cm point                                                                                                                                                    | 3     |
| (ii)            | line (curve) of best fit acceptable;                                                                                                                                                                                                                                                                                                                                                                         | allow ECF from plotting<br>i.e. smooth curve with<br>points evenly<br>distributed about it                                                                                       | 1     |
| (d)             | any four from:<br><br>MP1. as distance increases, <b>force</b> decreases;<br>MP2. (because) moment = force x distance;<br>MP3. any one calculated moment value from results table or graph;<br>MP4. a second calculated moment value from results table or graph;<br>MP5. evidence shows moments are not all the same;<br>MP6. (but) no pattern in the data (so could be attributed to experimental errors); | no mark for simply<br>'student is right/wrong'<br><br><br><br>allow evidence shows<br>moments are similar<br>allow consistent<br>conclusion i.e. variation<br>isn't large enough | 4     |

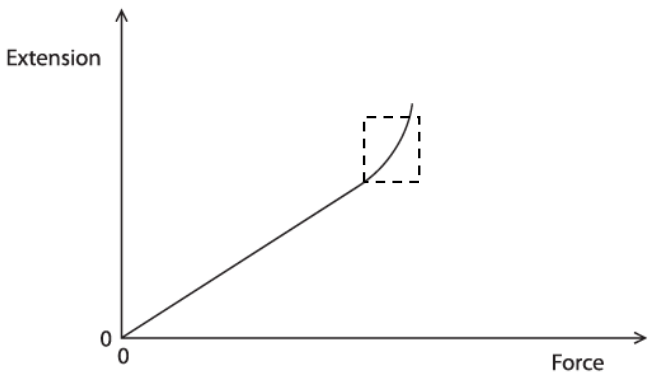
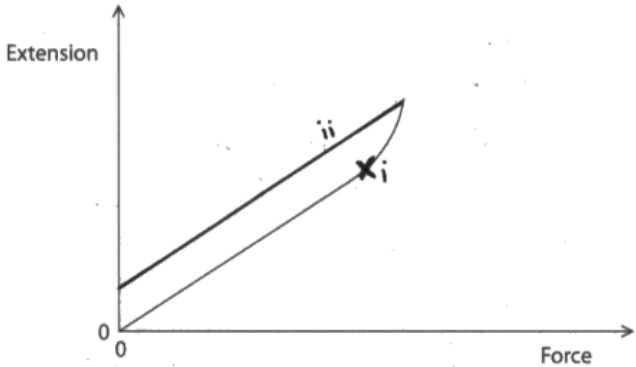
Total for Question 3 = 11 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                                                                 | Notes                                                                                      | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------|
| 5 (a) (i)       | position of the mass hanger;                                                                                                                                                                                                                                                                                                                                                           | allow distance of mass hanger/eq<br>reject unqualified "distance"                          | 1     |
|                 | (ii) any two from:<br><br>MP1. weight or mass of metre rule<br>MP2. weight or mass of mass hanger;<br>MP3. positions of newton meter(s);                                                                                                                                                                                                                                               | ignore "same equipment"                                                                    | 2     |
|                 | (iii) any one from:<br>• take repeats and find mean;<br>• extend the range of the results;<br>• measure more intermediate positions;<br>• repeat to {identify/remove} anomalies;<br>• plot a graph to spot anomalies;                                                                                                                                                                  |                                                                                            | 1     |
| (b) (i)         | all data plotted to within half a small square;                                                                                                                                                                                                                                                                                                                                        |                                                                                            | 1     |
|                 | (ii) straight line passing through all points;                                                                                                                                                                                                                                                                                                                                         | allow straight line with points evenly distributed either side if plotting error in (i)    | 1     |
|                 | (iii) any four from:<br>MP1. as position of mass hanger increases, reading on newton meter A decreases;<br>MP2. as position of mass hanger increases, reading on newton meter B increases;<br><br>MP3. relationship(s) are linear;<br>MP4. idea that newton meter readings are the same when the position is 50cm;<br>MP5. idea that the sum of the newton meter readings is constant; | accept "as A decreases, B increases" for MP1 & MP2<br>ignore references to proportionality | 4     |
| (c)             | any three from:<br>MP1. idea that clockwise moment equals anti-clockwise moment;<br><br>MP2. distance of mass hanger from newton meter B decreases;<br><br>MP3. (therefore) anti-clockwise moment of mass hanger weight (about B) decreases;<br>MP4. clockwise moment (of newton meter A reading) decreases (thereby decreasing reading);                                              | allow idea that moments must balance<br>allow distance from newton meter A increases       | 3     |

Total for Question 5 = 13 marks

| Question number | Answer                                                                                                                                                                                                                                            | Notes                                                                                                                                                                                                                 | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a) (i)       | <p>use of moment = force <math>\times</math> distance;<br/>substitution;<br/>evaluation to 2 s.f. or more;</p> <p>e.g.<br/>moment = force <math>\times</math> distance<br/>moment = <math>5.2 \times (0.)22</math><br/>moment = 1.14(4) (N m)</p> | <p>may be implied by substitution<br/>ignore units<br/>i.e. answer of 1.14(4) (N m) or 114(.4) N cm is acceptable</p> <p>RA scores one mark max<br/>i.e. attempt to find force or distance from a moment of 1 N m</p> | 3     |
| (ii)            | idea that (sum of) clockwise moment(s) = (sum of) anti-clockwise moment(s);                                                                                                                                                                       |                                                                                                                                                                                                                       | 1     |
| (iii)           | <p>substitution into principle of moments;<br/>rearrangement;<br/>evaluation;</p> <p>e.g.<br/><math>F \times (0.)70 = 1.14</math><br/><math>F = 1.14 \div (0.)70</math><br/>(F =) 1.63 (N)</p>                                                    | <p>allow ECF from (i)<br/>ignore units</p> <p>allow any answer that rounds to 1.4 (N) by using 1 N m as the moment or rounds to 1.6 by using 1.14(4) N m as the moment</p>                                            | 3     |
| (b)             | <p>any two from:</p> <p>MP1. longer handle/eq;<br/>MP2. weaker spring/eq;</p> <p>MP3. spring closer to pivot point/eq;<br/>MP4. lubricate pivot or lubricate spring /eq;</p>                                                                      | <p>ignore changes to force applied</p> <p>accept 'lower spring constant'</p> <p>allow bolt for spring</p> <p>ignore unqualified 'longer coil', 'more coils', 'longer spring', 'less coils' etc</p>                    | 2     |

Total for Question 4 = 9 marks

| Question number | Answer                                                                                                                                                                                                                                                                                          | Notes                                                             | Marks |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|-------|
| 5 (a) (i)       | cross drawn on line in region shown;<br>                                                                                                                                                                       | cross cannot be drawn at the extreme upper end of the curved line | 1     |
| (ii)            | any line drawn above and starting at the end of the original that shows a reduction in extension as the force is decreased;<br>line drawn is straight and returns to the extension axis above the origin;<br> | DOP<br>judge straightness by eye                                  | 2     |
| (b) (i)         | elastic (potential);                                                                                                                                                                                                                                                                            |                                                                   | 1     |
| (ii)            | C (mechanically);<br><br>A is incorrect because there is no electrical circuit<br>B is incorrect because there is no temperature difference<br>D is incorrect because transfers by radiation do not involve forces                                                                              |                                                                   | 1     |

Total for Question 5 = 5 marks

| Question number |     |      | Answer                                                                                                                         | Notes                                                                                                                                                  | Marks |
|-----------------|-----|------|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 8               | (a) | (i)  | 3.1 (cm);                                                                                                                      |                                                                                                                                                        | 1     |
|                 |     | (ii) | any value above candidate's answer for (a)(i) up to and including 14.6cm;                                                      |                                                                                                                                                        | 1     |
|                 | (b) | (i)  | idea that speed is the gradient/slope of the graph;<br><br>gradient is not constant;<br><br>(therefore) speed is not constant; | e.g. "it's a curve"/"it's not a straight line"<br><br>allow description of how the speed is varying e.g. zero at turning points, maximum when steepest | 3     |
|                 |     | (ii) | any cross drawn at a peak/trough on the curve;<br><br>crosses drawn at all three peaks and all three troughs;                  | reject if contradicted by a cross drawn in an incorrect place by eye                                                                                   | 2     |

Total for Question 8 = 7 marks



| Question number | Answer                                                                                                                                                  | Notes                                                                                                                                                                                       | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a)           | (i) idea that extension is (directly) proportional to force or load;<br>up to limit of proportionality;                                                 | condone 'mass' for force<br><br>allow up to elastic limit                                                                                                                                   | 2     |
|                 | (ii) line is not straight / eq;<br>so, force and extension cannot be (directly) proportional;                                                           | allow line is curved                                                                                                                                                                        | 2     |
| (b)             | mechanical;<br>elastic;<br>kinetic / gravitational;                                                                                                     | allow elastic potential<br>allow gravitational potential                                                                                                                                    | 3     |
| (c)             | drag force drawn horizontally left;<br><br>drag force = thrust force;<br><br>weight force drawn vertically downwards;<br><br>weight force = lift force; | judge by eye<br>allow air resistance, friction<br>judge by eye<br>ignore force labels<br>judge by eye<br>allow gravitational force<br>ignore gravity<br>judge by eye<br>ignore force labels | 4     |

Total for Question 4 = 11 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                           | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 5 (a)           | <p>axes labelled “extension”/“elongation” and “load”/“force”/“weight”;</p> <p>straight line of positive gradient drawn throughout;</p> <p>line passes through origin;</p>                                                                                                                                        | <p>ignore units</p> <p>allow “distance/length stretched” for extension</p> <p>ignore orientation of axes</p> <p>judge by eye</p> <p>condone curve at end of line if clear indication that Hooke’s law does not apply for that part of the line e.g. “limit of proportionality” marked at end of straight section</p> <p>ignore “elastic limit”</p> <p>allow full marks for axes labelled “length” and “load”/“force”/“weight” if line intersects length axis above zero</p> | 3     |
| (b) (i)         | <p>magnitude = 1.2 (N);</p> <p>direction = up(wards);</p>                                                                                                                                                                                                                                                        | <p>allow arrow pointing up</p> <p>ignore unqualified “north”</p>                                                                                                                                                                                                                                                                                                                                                                                                            | 2     |
| (ii)            | <p>substitution into <math>F = m \times a</math>;</p> <p>rearrangement;</p> <p>evaluation;</p> <p>e.g.</p> <p><math>1.2 = 0.20 \times a</math></p> <p><math>a = 1.2 / 0.20</math></p> <p>(a =) 6.0 (m/s<sup>2</sup>)</p>                                                                                         | <p>allow ecf from (i)</p> <p>-1 for POT error</p> <p>allow 6 (m/s<sup>2</sup>)</p>                                                                                                                                                                                                                                                                                                                                                                                          | 3     |
| (iii)           | <p>acceleration decreases (to zero);</p> <p>with any two from:</p> <ul style="list-style-type: none"> <li>spring extension decreases;</li> <li>force from spring / elastic force / upwards force decreases;</li> <li>weight (of object) stays the same;</li> <li>resultant force decreases (to zero);</li> </ul> | <p>ignore decelerates</p> <p>allow spring becomes less stretched</p> <p>ignore other irrelevant forces e.g. upthrust, air resistance etc.</p> <p>allow forces are balanced if clear that this only applies when the mass is at its initial resting position</p>                                                                                                                                                                                                             | 3     |

Total for Question 5 = 11 marks

| Question number | Answer                                                                                                                                                                                                                                                                                              | Notes                                                                                                                                                                                                   | Marks |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 10 (a)          | substitution into formula;<br>evaluation;<br><br>e.g.<br>weight = $250 (\div 1000) \times 10$<br>(weight =) 2.5 (N)                                                                                                                                                                                 | ignore units<br>-1 for clear POT error in units of mass<br><br>allow use of $g = 9.8, 9.81$<br>allow 2.45, 2.4525                                                                                       | 2     |
| (b) (i)         | independent variable = length (extending beyond table);<br><br>dependent variable = height;                                                                                                                                                                                                         | allow L/l<br>condone length of wood(en strip)<br><br>allow H/h                                                                                                                                          | 2     |
| (ii)            | any two from: <ul style="list-style-type: none"> <li>mass/weight of load;</li> <li>position of load (on wooden strip);</li> <li>thickness of wood(en strip);</li> <li>material/type of wood(en strip);</li> </ul>                                                                                   | ignore "same load" on its own<br><br>allow "same wood(en strip)" in the absence of either of these marks                                                                                                | 2     |
| (iii)           | any two from: <p>MP1. use of (metre) rule;</p> <p>MP2. fixed in place at end of wooden strip;</p> <p>MP3. 0 on rule placed at original height of wooden strip;</p> <p>MP4. method to ensure measurement is vertical e.g. using a plumb line, set square etc.;</p> <p>MP5. measure at eye level;</p> | allow tape measure<br>condone metre stick<br><br>allow alternative valid methods e.g. distance measured up from the ground with and without load<br><br>ignore unqualified references to parallax error | 2     |

| (c)   | (i)                                                                                                                                                  | correct measurement from diagram = 3.1 (cm);<br>use of scale factor gives 31 (cm);                                                                                                                                                          | allow between 3(.0) and 3.2 (cm)<br>allow $\times 10$ seen in working<br><br>answer between 30 and 32 (cm)<br>scores both marks                                                                                                                                                                                                                            | 2                |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
|-------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|------------------|----|---|----|---|----|----|----|----|-----|----|-----|----|---|
|       | (ii)                                                                                                                                                 | suitable linear scale chosen (>50% of grid used);<br>plotting correct to nearest half square;                                                                                                                                               | allow use of false origin<br>allow ecf from (i)<br>reject if non-linear scale used<br><table><tr><th>Length (L) in cm</th><th>Height (h) in cm</th></tr><tr><td>20</td><td>2</td></tr><tr><td>40</td><td>8</td></tr><tr><td>60</td><td>18</td></tr><tr><td>80</td><td>31</td></tr><tr><td>100</td><td>53</td></tr><tr><td>120</td><td>71</td></tr></table> | Length (L) in cm | Height (h) in cm | 20 | 2 | 40 | 8 | 60 | 18 | 80 | 31 | 100 | 53 | 120 | 71 | 2 |
|       | Length (L) in cm                                                                                                                                     | Height (h) in cm                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
|       | 20                                                                                                                                                   | 2                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| 40    | 8                                                                                                                                                    |                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| 60    | 18                                                                                                                                                   |                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| 80    | 31                                                                                                                                                   |                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| 100   | 53                                                                                                                                                   |                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| 120   | 71                                                                                                                                                   |                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                            |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| (iii) | acceptable curve of best fit drawn for data<br>between 20cm and 120cm;                                                                               | i.e. smooth curve with points<br>distributed equally either side<br><br>all points should be at least 1<br>small square from curve unless<br>there is a plotting error in (ii) or<br>a measurement error in (i), in<br>which case apply ecf | 1                                                                                                                                                                                                                                                                                                                                                          |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |
| (iv)  | idea that proportionality requires a straight line<br>(through the origin);<br><br>(graph does not show this so)<br>conclusion/student is incorrect; | allow idea that relationship is not<br>linear / gradient is not constant<br>allow idea that h/L should be<br>constant<br>DOP<br><br>score 0 marks if any indication<br>that the response is proportional<br>or directly proportional        | 2                                                                                                                                                                                                                                                                                                                                                          |                  |                  |    |   |    |   |    |    |    |    |     |    |     |    |   |

Total for Question 10 = 15 marks

| Question number | Answer                                                                                                                                                                                                                                                                                                                                      | Notes                                                                                                                                                           | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 9 (a)           | (i) elastic (potential) / EPE;                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                 | 1     |
|                 | (ii) mechanically/mechanical (working);                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                 | 1     |
|                 | (iii) the person/the hand/the fingers;                                                                                                                                                                                                                                                                                                      | allow chemical (energy of the student)                                                                                                                          | 1     |
| (b)             | (i) curve/variable gradient/not linear;                                                                                                                                                                                                                                                                                                     | accept 'unloading and loading are different'<br>ignore reference to proportionality                                                                             | 1     |
|                 | (ii) line returns to {origin/start/(0,0)/no extension};<br><br>when the force is removed/ unloaded;                                                                                                                                                                                                                                         | ignore reference to shape<br>allow returns to original length<br>condone 'when unloading'                                                                       | 2     |
| (c)             | (i) substitution into given equation " $v^2 = u^2 + 2as$ ";<br><br>re-arrangement;<br>evaluation;<br>answer to 2 sig figs;<br><br>e.g.<br>$0^2 = (13)^2 + (2 \times -10 \times s)$<br>height = 169 / 20<br>(height =) 8.45 (m)<br>(height =) 8.5 (m)                                                                                        | ignore sign<br>accept $mgh = \frac{1}{2} m v^2$<br><br>independent mark                                                                                         | 4     |
|                 | (ii) any five from:<br><br>MP1. band has weight;<br><br>MP2. no drag at highest point;<br><br>MP3. resultant force is downwards;<br><br>MP4. band accelerates;<br><br>MP5. (once band is moving) there is drag<br>MP6. drag increases (while accelerating);<br><br>MP7. resultant force decreases;<br><br>MP8. (so) acceleration decreases; | allow 'has gravitational force'<br>ignore 'has gravity'<br>allow 'air resistance' for 'drag'<br><br>allow 'speed increases'<br><br>MP6 automatically scores MP5 | 5     |

Total for Question 9 = 15 marks

| Question number | Answer                                                                                                                                                                                                                                         | Notes                                                                                      | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------|
| 8 (a) (i)       | work (done) = force $\times$ distance (moved in direction of force);                                                                                                                                                                           | accept correct symbols and rearrangements<br>e.g. $W = F \times s$<br>allow d for distance | 1     |
| (ii)            | substitution;<br>evaluation;<br><br>e.g.<br>(W =) $4.2 \times 0.145$<br>(W =) 0.61 (J)                                                                                                                                                         | -1 for POT error<br><br>allow 0.609 (J)<br><br>609 (J) gains 1 mark                        | 2     |
| (iii)           | same answer as (ii);                                                                                                                                                                                                                           |                                                                                            | 1     |
| (iv)            | kinetic energy (store) of molecules increases;<br><br>(temperature increases) because temperature is proportional to (mean) KE (of molecules);                                                                                                 | allow molecules move faster / eq                                                           | 2     |
| (b)             | any one from:<br>MP1. idea that (more) energy would be transferred / lost to the surroundings (for slow compressions);<br>MP2. <b>piston</b> would have less KE (to transfer);<br>MP3. less force on <b>piston</b> (so less work done on gas); | allow less work done on air                                                                | 1     |

Total for Question 8 = 7 marks

| Question number | Answer                                                                                                                                                                                                                                                           | Notes                                                                                                                        | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|-------|
| 4 (a) (i)       | substitution;<br>evaluation;<br><br>e.g.<br>(GPE =) $1.8 \times 10 \times 0.95$<br>(GPE =) 17 (J)                                                                                                                                                                | allow $g = 9.8, 9.81$<br><br>allow 16.8, 16.7..., 17.1... (J)                                                                | 2     |
| (a) (ii)        | idea that KE (gained) is greater than GPE (lost);<br>idea KE gained = GPE lost + work done;<br>e.g. $17 + 4 = 21$ OR $21 - 17 = 4$                                                                                                                               |                                                                                                                              | 2     |
| (b) (i)         | use of $KE = \frac{1}{2} \times \text{mass} \times \text{speed}^2$ ;<br><br>substitution;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$KE = \frac{1}{2} \times m \times v^2$<br>$21 = 0.5 \times 1.8 \times v^2$<br>$v = \sqrt{(21/0.9)}$<br>(v =) 4.8 (m/s) | allow standard symbols<br>can be implied from<br>working<br><br><br>allow 4.83, 4.83... (m/s)                                | 4     |
| (ii)            | substitution into $F = mv - mu / t$ ;<br>evaluation;<br><br>e.g.<br>$F = (1.8 \times 4.8) / 0.12$<br>(F =) 72 (N)                                                                                                                                                | allow ecf from (b)(i)<br><br>allow alternative<br>method using<br>$a = (v-u)/t$ and $F = ma$<br><br>allow 72.5, 72.45... (N) | 2     |

Total for Question 4 = 10 marks

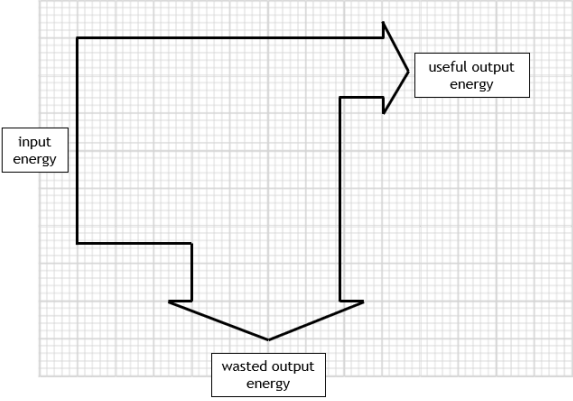
| Question number | Answer                                                                                                                                                                                                                                                                   | Notes                                                                                                                                           | Marks |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 11 (a) (i)      | work done = force $\times$ distance (travelled);                                                                                                                                                                                                                         | allow accepted symbols                                                                                                                          | 1     |
| (ii)            | substitution;<br>evaluation;<br>e.g.<br>work done = $0.89 \times 26$<br>work done = 23.1(4 J)                                                                                                                                                                            |                                                                                                                                                 | 2     |
| (iii)           | evidence of recall of formula $GPE = mgh$ ;<br>substitution;<br>evaluation;<br>e.g.<br>$GPE = mgh$<br>$GPE = 1.3 \times 10 \times 0.11$<br>$GPE = 1.4(3 J)$                                                                                                              | allow $g = 9.8(1) (N/kg)$                                                                                                                       | 3     |
| (iv)            | any TWO from:<br>any reference to friction/air resistance;<br>energy transferred to the surroundings (by mechanical work);<br><br>block not necessarily at constant speed;                                                                                               | -1 for POT error providing use of $g$ seen<br><br>allow 'heat/thermal energy transferred to air/ramp by friction for 2 marks                    | 2     |
| (b)             | any TWO from:<br>lower force required;<br>to prevent block from slipping down required / to move block;<br><br>any TWO from:<br>longer distance required (with a lower force);<br>more inefficient;<br><br>greater proportion of energy transferred to the surroundings; | allow 'to overcome friction'<br><br>allow 'easier to move block' for 2 marks<br><br>Allow idea of more work required (for same increase in GPE) | 4     |

(Total for Question 11 = 12 marks)

| Question number | Answer                                                                                                                                                                                            | Notes                                                                        | Marks |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------|
| 8 (a)           | take repeats and find the mean;                                                                                                                                                                   | allow 'average' for 'mean'                                                   | 1     |
| (b)             | any two from:<br>MP1. mass (being lifted);<br>MP2. height (lifted) / distance;<br>MP3. power supply / circuit being used;<br>MP4. temperature (of motor);                                         | ignore 'same motor'<br>condone weight                                        | 2     |
| (c)             | conversion of cm to m;<br>substitution into $GPE = \text{mass} \times g \times \text{height}$ ;<br><br>e.g.<br>$50 \text{ cm} = 0.5 \text{ m}$<br>$GPE = 1 \times 10 \times 0.5 (= 5 \text{ J})$  | allow 0.5 seen anywhere<br>allow use of $g = 9.8(1) \text{ (m/s}^2\text{)}$  | 2     |
| (d) (i)         | efficiency formula seen;<br>substitution;<br>evaluation;<br><br>e.g.<br>efficiency = useful energy output / total energy input<br>efficiency = $5 / 12.7 (\times 100\%)$<br>efficiency = 39.4 (%) | ignore s.f.<br><br>allow 39, 39.37...<br>reject unsupported incorrect answer | 3     |
| (ii)            | suitable linear scale chosen (>50% of grid used);<br>axes labelled with quantities and unit;<br>all plotting correct to nearest half square;                                                      | ignore orientation<br><br>ignore plotting at 10V                             | 3     |
| (iii)           | acceptable curve of best fit drawn up to a voltage of 6V;<br><br>straight horizontal line of best fit drawn from 6V onwards;                                                                      | i.e. curved line with even distribution of points either side<br>by eye      | 2     |
| (iv)            | correctly read voltage from graph consistent with candidate's curve of best fit;                                                                                                                  | allow range 5.4V - 6.6V<br><br>allow ecf from (iii)                          | 1     |

Total for Question 8 = 14 marks

| Question number | Answer                                                                                                                                                                                                                                 | Notes                                                                                                                                                                                                                                                           | Marks |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 3 (a) (i)       | GPE = mass $\times$ g $\times$ height;                                                                                                                                                                                                 | allow standard symbols and rearrangements e.g.<br>$h = \text{GPE} / m \times g$<br>ignore 'gravity' for g                                                                                                                                                       | 1     |
|                 | (ii) substitution;<br>rearrangement;<br>evaluation;<br><br>e.g.<br>$3.2 = 0.40 \times 10 \times h$<br>$h = 3.2 / 0.40 \times 10$<br>(h =) 0.80 (m)                                                                                     | in either order<br>-1 for POT error due to not converting g to kg but not if due to physics error such as missing g<br><br>accept use of $g = 9.8(1)$<br>accept 1sf answer i.e. 0.8 (m)<br><br>0.815 or 0.816 or 0.82 if g used is 9.8(1) and then rounded      | 3     |
|                 | (iii) 3.2 (J);                                                                                                                                                                                                                         | this answer only                                                                                                                                                                                                                                                | 1     |
| (b)             | downward arrow labelled "weight"/"W"/"mg";<br><br>vertically downward arrow drawn equal in length to lifting force arrow;                                                                                                              | ignore starting position of arrow<br>ignore 'gravity/g/gravitational field strength'<br>allow 'gravitational force'<br>reject if both gravity force and weight force shown<br><br>mark independently by eye<br>reject any other labelled arrows for second mark | 2     |
| (c) (i)         | recall of efficiency formula;<br><br>substitution;<br>evaluation;<br><br>e.g.<br>efficiency = $\frac{\text{useful energy output}}{\text{total energy output}}$<br>efficiency = $3.2 / 11.0 (\times 100\%)$<br>efficiency = 0.29 or 29% | may be implied from substitution<br><br><br><br><br><br>allow 0.29, 0.2909..., 29%, 29.09...%<br>29 without % is PoT 2 marks                                                                                                                                    | 3     |
|                 | (ii) idea that energy must be conserved;<br><br>demonstration that $7.8 + 3.2 = 11(.0)$ ;                                                                                                                                              | comparison in words e.g.<br>total = useful + wasted /eq<br>allow $11(.0) - 3.2 = 7.8$                                                                                                                                                                           | 2     |

|       |                                                                                                                                                                                                                                               |                                                                                                         |   |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|---|
| (iii) | <p>only one additional arrow drawn pointing to the right;<br/>labelled “useful output (energy)”</p> <p>width of arrow drawn = 8 small squares;<br/>e.g.</p>  | <p>allow “gravitational (potential energy)”, “GPE” etc.<br/>reject reference to power</p> <p>by eye</p> | 3 |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|---|

Total for question 3 = 15 marks

| Question number | Answer                                                                                                                                                                                                                                                           | Notes                                                                                                                                                                                 | Marks |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 6 (a)           | idea that reaction time is an issue / eq;                                                                                                                                                                                                                        | allow student (A) starts/stops stopwatch early/late<br>allow student (B) starts running early/late<br>ignore human error, comments relating to time for sound to travel               | 1     |
| (b) (i)         | selection of $GPE = mgh$ ;<br>substitution;<br><br>evaluation to more than 2s.f.;<br><br>e.g.<br>$GPE = mgh$<br>$GPE = 67 \times 10 \times 24 \times 0.19$<br>$GPE = 3055.2 \text{ (J)}$                                                                         | condone omitting factor of 24 for this mark only<br>allow use of $g = 9.8$ , 9.81<br>ignore POT errors from not converting cm to m<br><br>allow 3055, 3060, 3100, 2994, 2997.1... (J) | 3     |
| (ii)            | evaluation of mean;<br>rounded to 3s.f.;<br><br>e.g.<br>mean time = $(4.28 + 4.95 + 4.65) / 3 = 4.626...$<br>mean time = 4.63 (s)                                                                                                                                | independent mark                                                                                                                                                                      | 2     |
| (iii)           | substitution into $P = E/t$ ;<br>evaluation;<br><br>e.g.<br>power = $3055.2 / 4.63$<br>power = 660 (W)                                                                                                                                                           | allow ecf from (i) and (ii)<br><br>allow 646 - 671 (W)                                                                                                                                | 2     |
| (c)             | any four from:<br><br>MP1. not enough data points to make a valid conclusion;<br><br>MP2. idea of testing a greater range of masses;<br><br>MP3. idea of testing masses in between values;<br><br>MP4. idea that there is a general (weak) positive correlation; | ignore students are correct / incorrect<br>allow idea that more students/readings are needed<br><br>allow power increases with mass for the first two data points                     | 4     |

|  |                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                     |  |
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|  | <p>MP5. idea that one of the data points could be anomalous;</p> <p>MP6. if first data point considered anomalous then there is a (weak) negative correlation;</p> <p>MP7. idea that final three data points suggest that power could be independent of mass;</p> <p>MP8. person with greatest mass does not have the greatest power;</p> | <p>allow any named data point</p> <p>allow power decreases with increasing mass ignoring the first data point</p> <p>allow final three data points have approximately same power</p> <p>allow statement that 69kg person has the greatest power</p> |  |
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Total for Question 6 = 12 marks