5 Two students, P and Q, of equal mass climb to the top of a mountain. They both start their climb from the same vertical height.

Student P takes two hours to climb a shorter, steeper route. Student Q takes three hours to climb a longer, less steep route.

Which row of the table correctly describes the gain in gravitational potential energy and power developed by student P compared to student Q?

	Gain in gravitational potential energy	Power developed
☒ **A**	greater for P than Q	greater for P than Q
☒ **B**	greater for P than Q	less for P than Q
☒ **C**	same for P and Q	greater for P than Q
☒ **D**	same for P and Q	less for P than Q

(Total for Question 5 = 1 mark)

8 A student uses a wooden bat to hit a stationary ball of mass m.

As the bat hits the ball, the momentum of the bat decreases by Δp.
The ball then moves with velocity v.

The student then uses the bat to hit a stationary ball of mass $3m$.
The momentum of the bat decreases by $2\Delta p$.

Which of the following expressions gives the velocity of the ball of mass $3m$ after being hit?

☒ **A** $\frac{1}{6}v$

☒ **B** $\frac{2}{3}v$

☒ **C** $\frac{3}{2}v$

☒ **D** $6v$

(Total for Question 8 = 1 mark)

DO NOT WRITE IN THIS AREA

6 A lamp with an efficiency of 0.68 usefully transfers 120 J of energy.

Which of the following can be used to determine E, the energy supplied to the lamp?

☐ **A** $E = 0.68 \times 120 \times 100$

☐ **B** $E = 0.68 \times 120$

☐ **C** $E = \frac{120}{0.68} \times 100$

☐ **D** $E = \frac{120}{0.68}$

(Total for Question 6 = 1 mark)

9 Which of the following statements is **not** correct for a Newton's 3rd Law pair of forces?

☒ **A** The forces act in opposite directions.

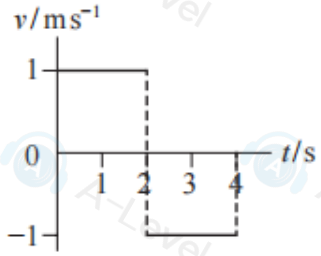
☒ **B** The forces act on the same body.

☒ **C** The forces are of the same type.

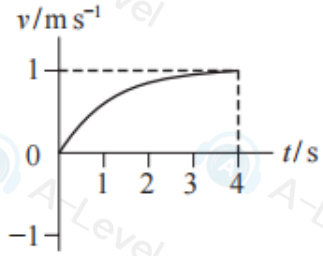
☒ **D** The forces have the same magnitude.

(Total for Question 9 = 1 mark)

5 Two objects P and Q are at the same position at time $t = 0$ s. The graphs show how the velocity v varies with time t for each object.



object P



object Q

Which of the following statements describes the positions of P and Q at $t = 4$ s?

☒ **A** P and Q are both at the initial position.

☒ **B** P and Q are the same distance from the initial position.

☒ **C** P is further from the initial position than Q.

☒ **D** Q is further from the initial position than P.

(Total for Question 5 = 1 mark)

DO NOT WRITE IN THIS AREA

3 An object is moving through a fluid.

Which row of the table states the conditions which must be met for Stokes' law to apply?

	Size of object	Shape of object	Type of flow
☒ **A**	any	any	turbulent
☒ **B**	any	spherical	turbulent
☒ **C**	small	spherical	laminar
☒ **D**	small	any	laminar

(Total for Question 3 = 1 mark)

6 Sea shells are the protective outer casing of some sea creatures. The shell is left behind when the creature dies and the shell is moved around on the seabed by the tides and waves.

Shells washed up on the beach are found to be as smooth as when the creature was alive.

This is because the material from which the shell is made is

☒ **A** hard.

☒ **B** stiff.

☒ **C** strong.

☒ **D** tough.

(Total for Question 6 = 1 mark)

6 A person stands on a moving staircase.

The moving staircase increases the gravitational potential energy of the person by 5000 J in a time of 42 s.

The efficiency of the moving staircase is 0.63

Which of the following expressions gives the power input to the moving staircase in watts?

☒ **A** $\frac{42}{5000 \times 0.63}$

☒ **B** $\frac{42 \times 0.63}{5000}$

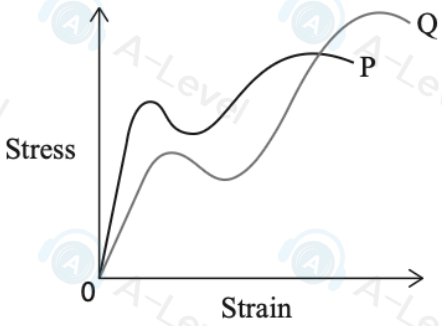
☒ **C** $\frac{5000}{42 \times 0.63}$

☒ **D** $\frac{5000 \times 0.63}{42}$

(Total for Question 6 = 1 mark)

9 A force is applied to stretch two wires, P and Q, until the wires break. Each wire is made of a different metal.

The stress-strain graph for each wire is shown.



Which of the following statements is correct?

☒ **A** P has a greater breaking stress than Q.

☒ **B** P has a greater breaking strain than Q.

☒ **C** P has a greater yield stress than Q.

☒ **D** P has a lower Young modulus than Q.

(Total for Question 9 = 1 mark)

3 Which of the following SI units can **only** be used with a scalar quantity?

A m

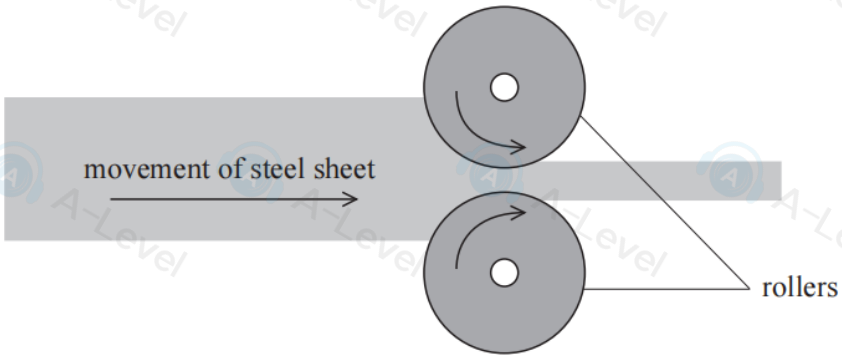
B s

C ms^{-1}

D ms^{-2}

(Total for Question 3 = 1 mark)

2 The thickness of a steel sheet is reduced by passing it between two rollers.



The thickness reduces because steel is

☒ **A** ductile.

☒ **B** hard.

☒ **C** malleable.

☒ **D** stiff.

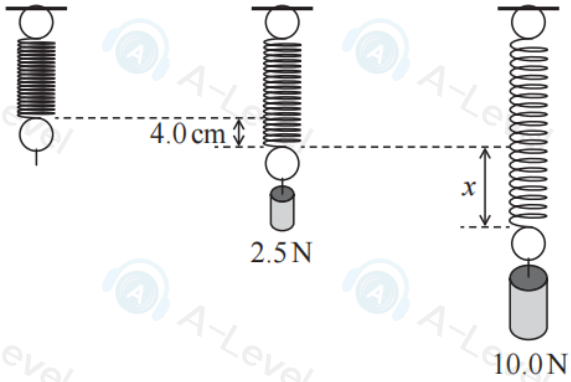
(Total for Question 2 = 1 mark)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

3 A spring is suspended from a bar. A load of 2.5 N is added to the free end of the spring and the spring extends by 4.0 cm.

The load is increased to 10.0 N and the spring extends by a further distance x.



What is the value of x?

☒ **A** 4.0 cm

☒ **B** 8.0 cm

☒ **C** 12.0 cm

☒ **D** 16.0 cm

(Total for Question 3 = 1 mark)

DO NOT WRITE IN THIS AREA

3 A block of mass m is placed on a bench and a horizontal force F is applied to the block. The block accelerates along the bench, travels a distance d in time t and reaches a velocity v.

The work done by the force F on the block is

☒ **A** Fd

☒ **B** Ft

☒ **C** Fv

☒ **D** mgd

(Total for Question 3 = 1 mark)

6 Which of the following expressions gives the work done stretching the spring from its original length p to length q?

- ☒ **A** $\frac{p \times R}{2}$
- ☒ **B** $\frac{(q - p) \times R}{2}$
- ☒ **C** $\frac{(q + p) \times R}{2}$
- ☒ **D** $(q - p) \times R$

(Total for Question 6 = 1 mark)

DO NOT WRITE IN THIS AREA

6 When a force F is applied to a spring of stiffness k, the extension of the spring is Δx.

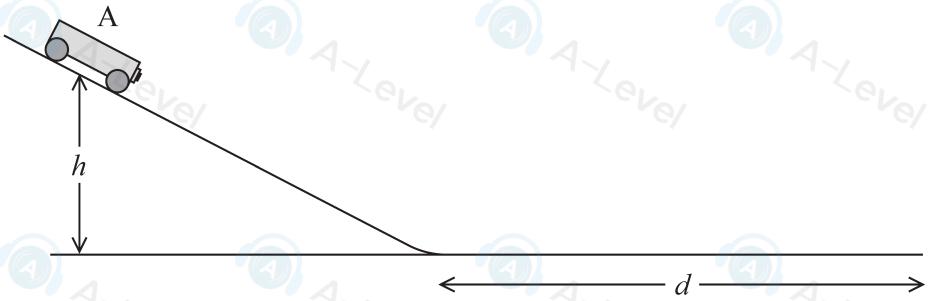
A force $2F$ is applied to a second spring of stiffness $3k$.

Which of the following expressions gives the extension of the second spring?

- ☒ **A** $\frac{2}{3}\Delta x$
- ☒ **B** $\frac{3}{2}\Delta x$
- ☒ **C** $\frac{1}{6}\Delta x$
- ☒ **D** $6\Delta x$

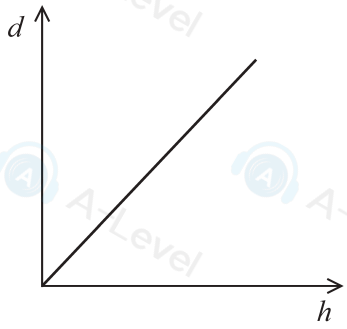
(Total for Question 6 = 1 mark)

12 A student set up the apparatus shown.



(a) When released from a height h, trolley A ran down the slope and then continued to move horizontally. On the horizontal part of the track a frictional force F brought the trolley to rest over a short distance d. The trolley has a mass m. The student measured d for a range of heights h.

The student plotted the following graph of d against h.



Derive an expression for the gradient of the graph, in terms of F, m and g.

(2)

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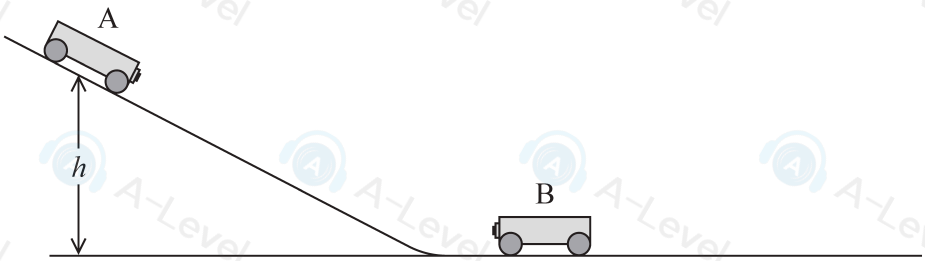
DO NOT WRITE IN THIS AREA

(b) In a second experiment, an identical trolley B was placed at rest at the bottom of the slope. When trolley A was released as before, it rolled down and collided with trolley B. After the collision the two trolleys joined together and moved off to the right with a velocity v.



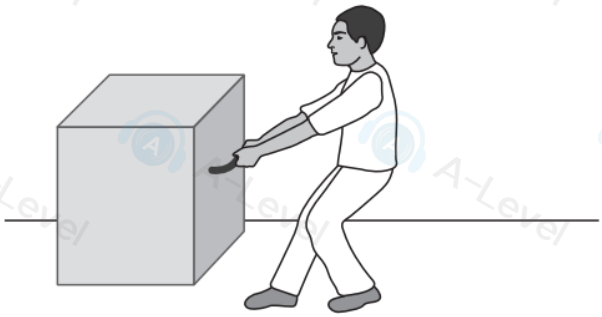
The student predicted that, provided friction was ignored, $v = \sqrt{\frac{gh}{2}}$.

Assess whether the student was correct.

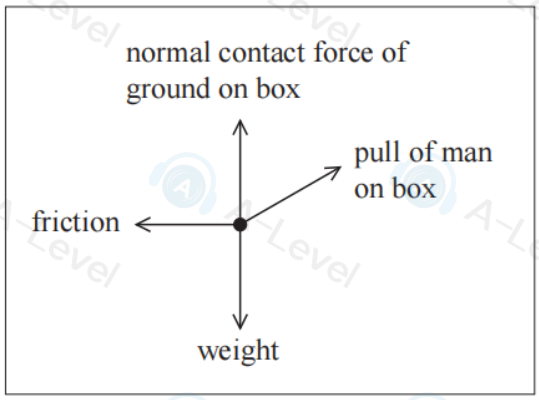
(4)

(Total for Question 12 = 6 marks)

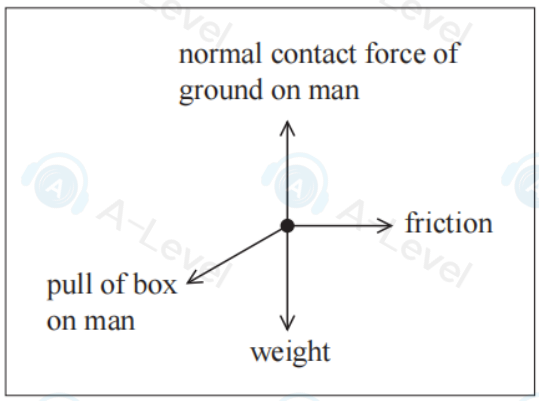
16 A man pulls a box towards him at a constant speed by pulling on a handle as shown.



The free-body force diagrams for the box and the man are shown.



free-body force diagram for the box



free-body force diagram for the man

(a) (i) Identify the pair of forces that have the same magnitude due to Newton's third law.

(1)

.....

.....

(ii) State one difference and one similarity, other than their magnitude, between these two forces.

(2)

Difference .....

Similarity .....

(b) The angle between the pull of the man on the box and the horizontal is 35°. The mass of the box is 85.0 kg.

(i) Show that the pull of the man on the box is about 400 N.

normal contact force of the ground on the box = 620 N

(4)

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(ii) The box moves at a constant speed towards the man.

Calculate the frictional force between the box and the ground.

(3)

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Frictional force between the box and the ground = ...

(iii) The man increases his pull on the box. The man and the box start to move together in the same direction with an acceleration of $0.200\,m\,s^{-2}$.

Calculate the frictional force between the ground and the man.

mass of man = 90.0 kg

(4)

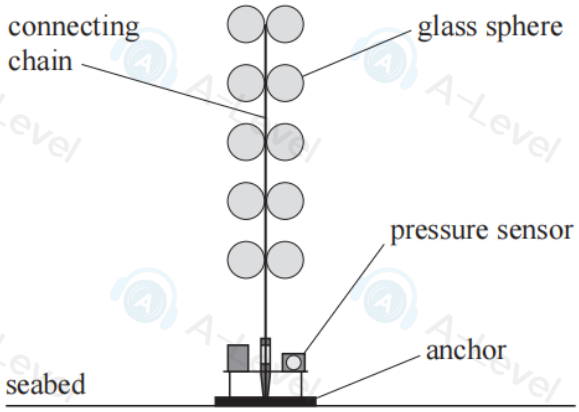
Frictional force between the ground and the man = ...

(Total for Question 16 = 14 marks)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN

19 An underwater system for detecting earthquakes is placed on the seabed. The system includes a pressure sensor and 10 glass spheres. The system is connected to a detachable anchor. Regular signals are sent, via satellite, to a central control station.



(a) The system and anchor are released just below the surface of the sea. They accelerate for a few seconds and then fall to the seabed at a constant velocity.

(i) Calculate the initial acceleration of the system and anchor.

(3)

total upthrust acting on the system and anchor = 2500 N
total mass of system and anchor = 470 kg

Initial acceleration = ...

(ii) Explain why, after a few seconds, the system and anchor fall to the seabed at a constant velocity.

(2)

(iii) Calculate the drag force acting on the system and anchor as they fall at a constant velocity.

(1)

Drag force = ...

(b) The system is re-floated every two years so that the batteries can be replaced. To re-float the system, the anchor is detached from the system and the glass spheres cause the system to rise to the surface of the water, leaving the anchor behind.

The total upthrust on the system due to the 10 glass spheres is 2500 N. It can be assumed that the upthrust on the rest of the system is negligible.

Calculate the diameter of one glass sphere.

(5)

density of sea water = 1030 kg m^{-3}

Diameter of one glass sphere = ...

(c) When selecting the material for the connecting chain, all the forces that act on the chain are considered.

(i) Explain why the connecting chain should be made of a high strength material.

(2)

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(ii) Suggest what causes an additional force on the connecting chain when the system is on the seabed.

(1)

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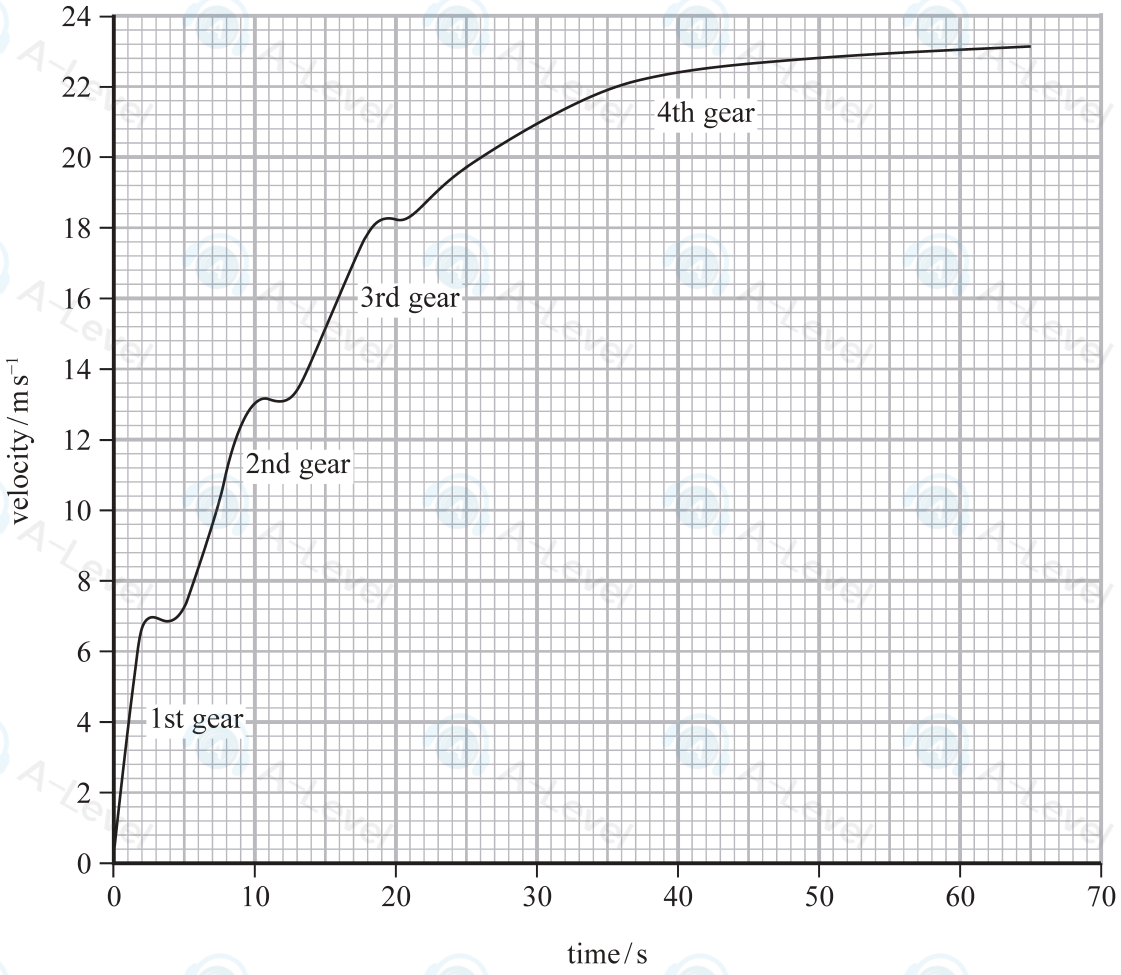
(Total for Question 19 = 14 marks)

17 The velocity-time graph for a car for the first part of a journey is shown.



(a) As the velocity of the car increased, the driver changed gear. Each change in gear produced a small decrease in velocity.

(i) State how the graph shows that in 3rd gear the car has a smaller acceleration than in 1st gear.

(1)

.....

.....

(ii) Determine the average acceleration when the car is accelerating in 2nd gear.

(2)

Average acceleration in 2nd gear = ...

(iii) The equation that links the power P of a car engine to the forward force F on the car and the velocity v of the car is

$$P = Fv$$

Comment on the magnitude of F when the car is in higher gears, assuming P remains constant.

(2)

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DO NOT WRITE IN THIS AREA

(b) The manufacturer of a different car gives the following information.

Gear	Maximum velocity / m s^{-1}	Maximum acceleration / m s^{-2}
1st	18	2.9
2nd	32	1.2
3rd	46	0.83
4th	74	0.72

(i) Calculate the minimum time taken for the car to accelerate from rest to 60 miles per hour. You may assume that the time taken to change gears is negligible.

1 mile = 1600 m

(4)

Time = ...

(ii) Explain why there will be a maximum speed at which the car can travel.

(3)

(Total for Question 17 = 12 marks)

TOTAL FOR SECTION B = 70 MARKS
TOTAL FOR PAPER = 80 MARKS

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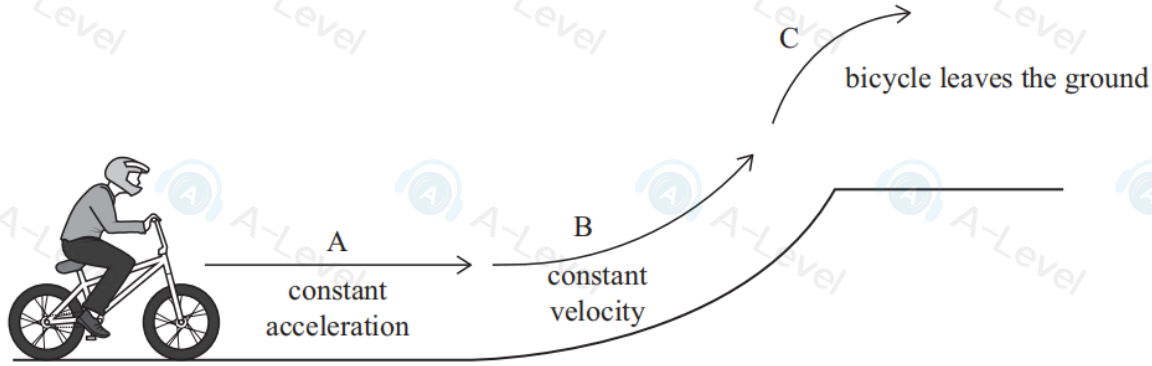
18 In the sport of bicycle motocross (BMX) a person rides a bicycle over small hills and ramps.

A person rides a bicycle to the top of a hill with enough speed for the bicycle to leave the ground.

The diagram shows three stages, A, B and C, of the motion of the bicycle.



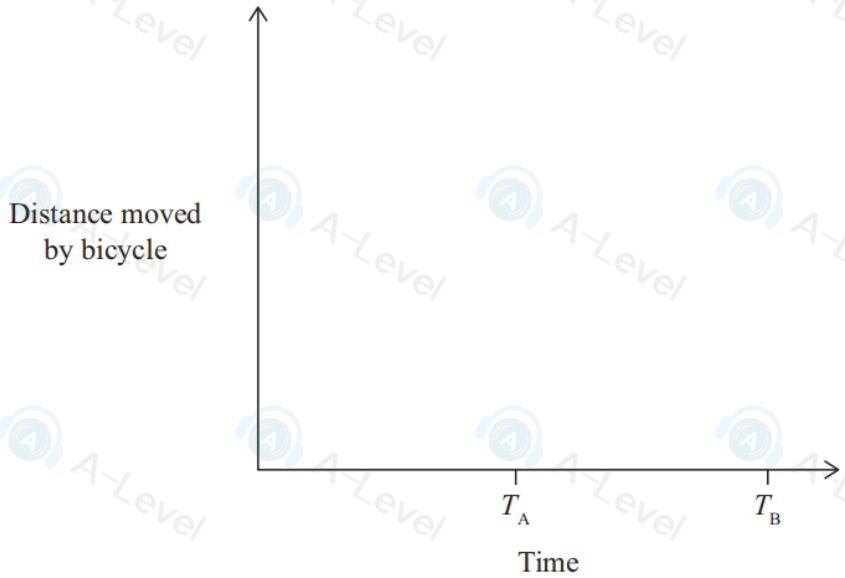
In stage A the bicycle moves with constant acceleration on a horizontal surface until time T_A.

In stage B the bicycle moves with constant velocity up a curved ramp until time T_B.

In stage C the bicycle leaves the ground.

(a) Complete the sketch graph for stages A and B.

(2)



*(b) Explain how the useful power output of the person varies through stages A, B and C.

You should consider energy changes during each stage.
Assume that air resistance is negligible.

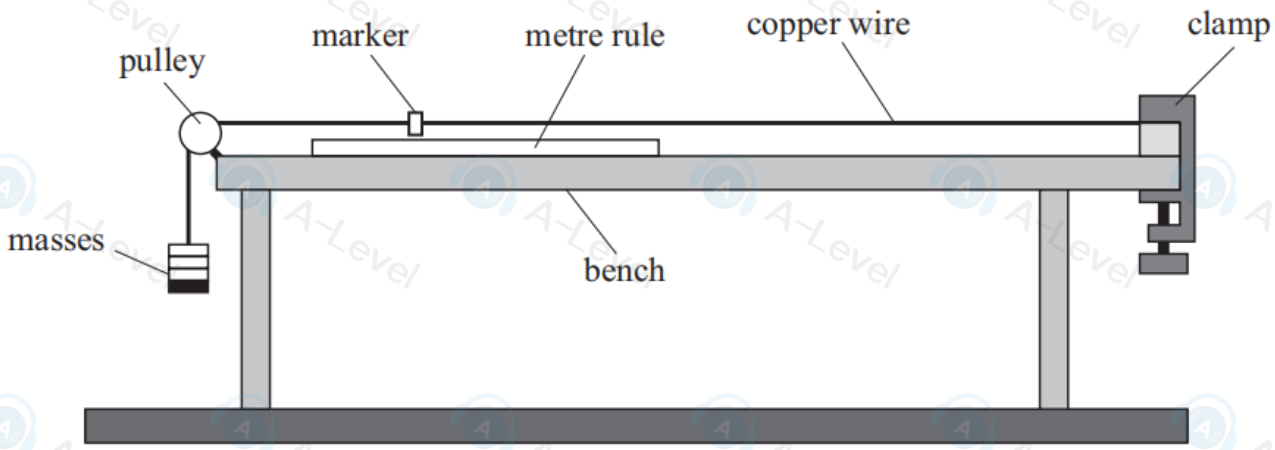
(6)

(Total for Question 18 = 8 marks)

16 A student carried out an experiment to determine the Young modulus of copper.

*(a) The student clamped one end of a copper wire to the bench. The wire passed over a pulley and masses were added to the other end of the wire.

A metre rule was fixed to the bench and a marker fixed to the wire, as shown.



The student measured the diameter of the copper wire.

Describe the other measurements that need to be made using this apparatus and how they will be used to determine the Young modulus of copper.

You should define the meanings of any symbols you use.

(6)

(b) Another student attaches a weight of 5.0 N to a copper wire of diameter 0.56 mm.

Calculate the extension of the wire.

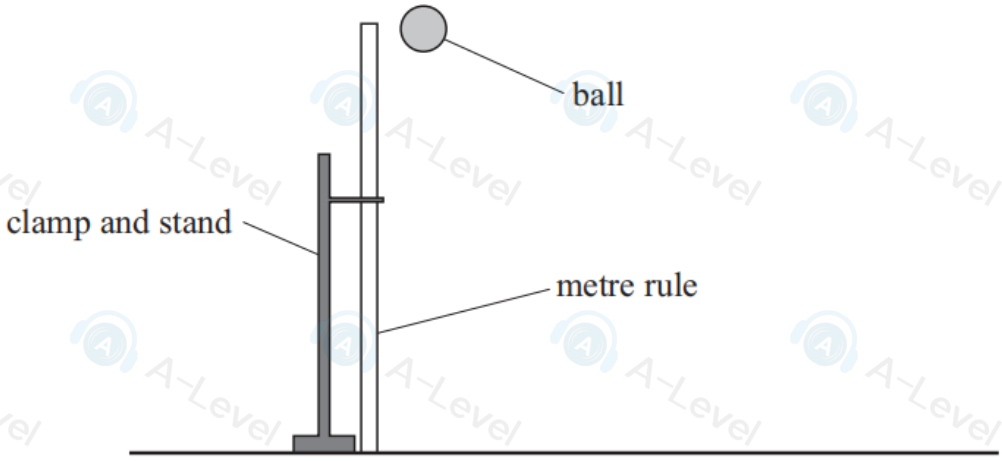
length of wire = 2.5 m
Young modulus of copper = 1.1×10^{11} Pa

(4)

Extension = ...

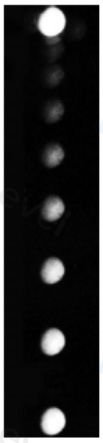
(Total for Question 16 = 10 marks)

14 A student clamped a metre rule so that it was vertical. She dropped a ball from rest near the top of the metre rule, as shown.



A strobe emits flashes of light. The time interval between flashes is constant.

The student photographed the falling ball using strobe lighting. The ball can be seen at different heights in the photograph, as shown.



(Source: © sciencephotos/Alamy Stock Photo)

For each flash of light, the student determined the distance fallen by the ball.

(a) She took one photograph using a strobe app on a mobile phone.
She took a second photograph using a laboratory strobe.

The time interval between flashes was the same for the strobe app and for the laboratory strobe. Each flash of light from the laboratory strobe has a smaller duration than each flash from the mobile phone.

Explain how the smaller duration of each flash from the laboratory strobe affected the uncertainty in the measurement of the distance fallen.

(2)

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(b) The student recorded the distances s fallen by the ball and corresponding values of the time t.

(i) Explain why a graph of s against t^2 gives a straight line.

(2)

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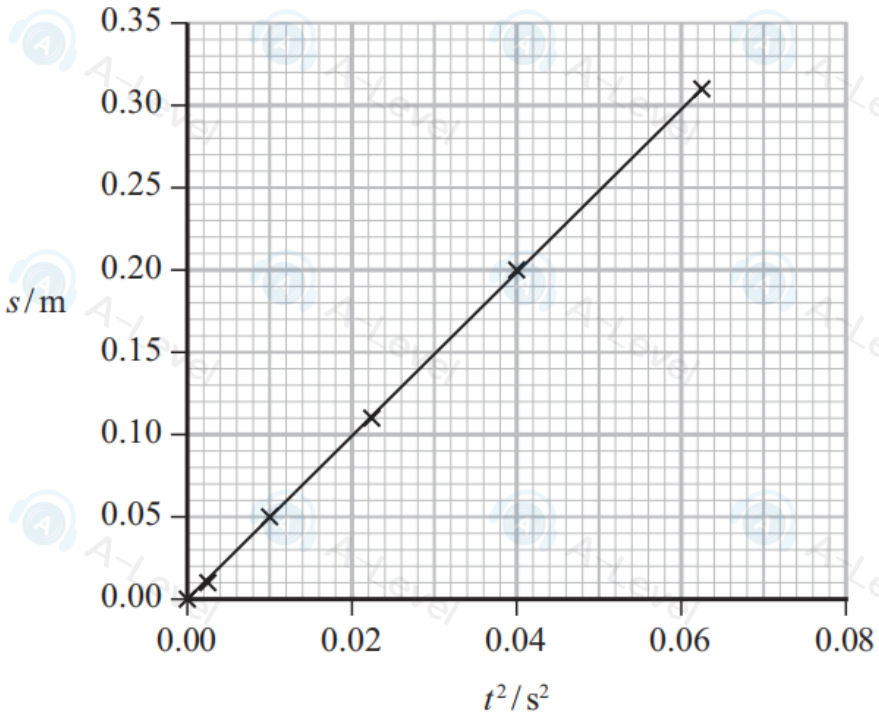
(ii) The student plotted a graph of s against t^2, as shown.



Determine the acceleration of free fall, g, using the student's graph.

(2)

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.....

g = ...

(Total for Question 14 = 6 marks)

13 A ball is dropped and reaches the ground after 0.42 s. The ball bounces and is caught at the same height from which it was dropped.

Draw, on the graph paper below, the velocity-time graph for the motion of the ball. You may assume that the time the collision with the ground takes and all frictional forces are negligible. Show your working in the space provided.

(5)

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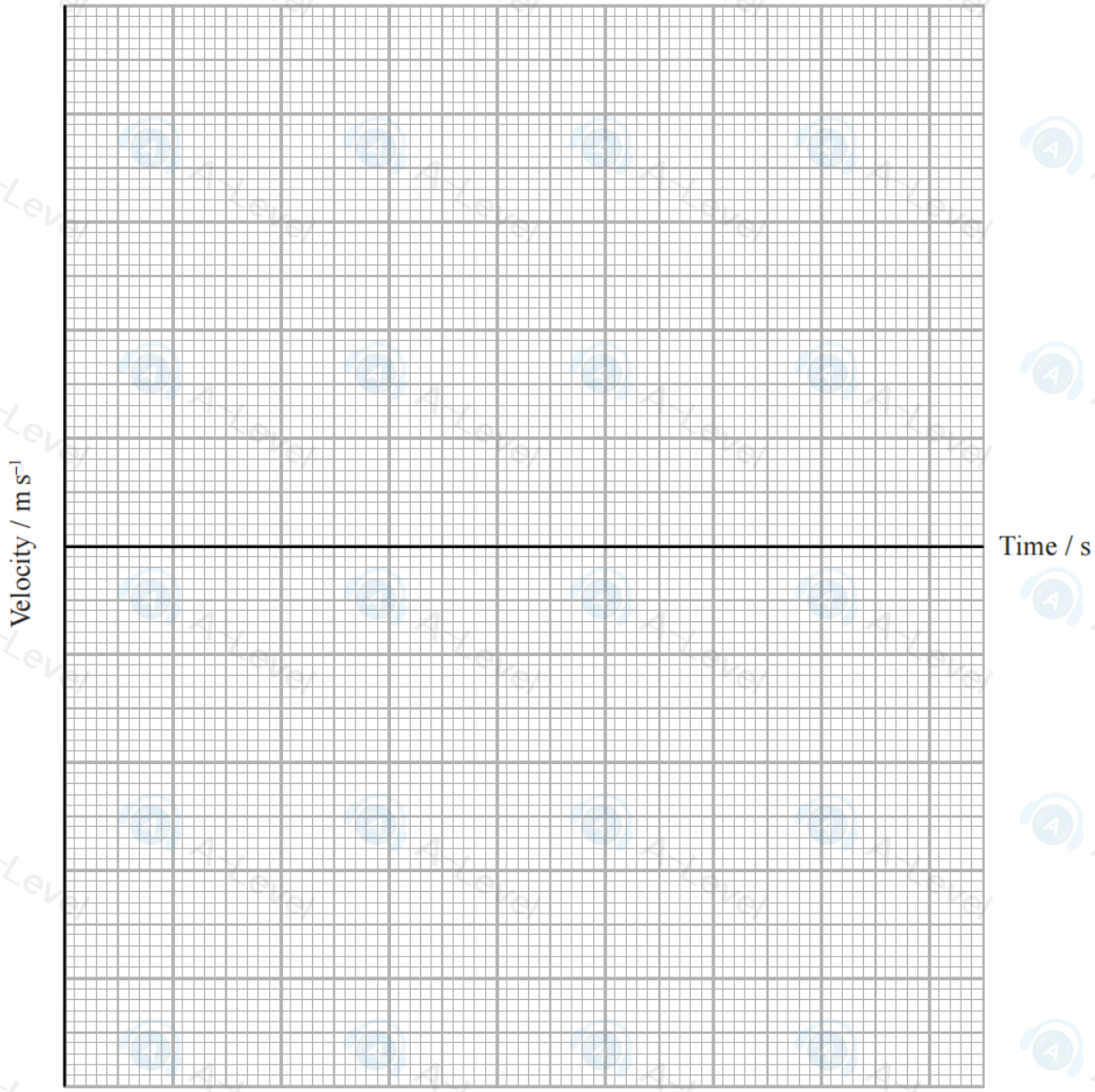
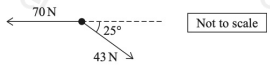


18 A small, remotely controlled submarine is used to explore the sea.

(a) The engine of the submarine produced a horizontal force of 70 N. The drag force on the submarine was 43 N at an angle of 25° to the horizontal, as shown.



Not to scale

Determine the resultant of these two forces on the submarine by drawing a scaled vector diagram in the space below.

(5)

Magnitude of resultant force = ...

Angle of resultant force to horizontal = ...

*(b) A crane on a ship can lift the submarine out of the sea, as shown.

(Source: adapted from © PJF Military Collection/Alamy Stock Photo)

The submarine is initially completely underwater and at rest just below the surface. A cable from the crane is attached to the submarine, so that the cable is vertical.

The crane pulls on the cable. The submarine moves vertically upwards at a constant speed until the whole submarine is out of the water.

Explain how the tension in the cable changes as the submarine moves from below the surface of the water to being completely out of the water.

You should assume the drag force on the submarine is negligible.

(6)

*(b) A crane on a ship can lift the submarine out of the sea, as shown.

crane
cable
submarine
DEEP DRONE

(Source: adapted from © PJF Military Collection/Alamy Stock Photo)

The submarine is initially completely underwater and at rest just below the surface. A cable from the crane is attached to the submarine, so that the cable is vertical.

The crane pulls on the cable. The submarine moves vertically upwards at a constant speed until the whole submarine is out of the water.

Explain how the tension in the cable changes as the submarine moves from below the surface of the water to being completely out of the water.

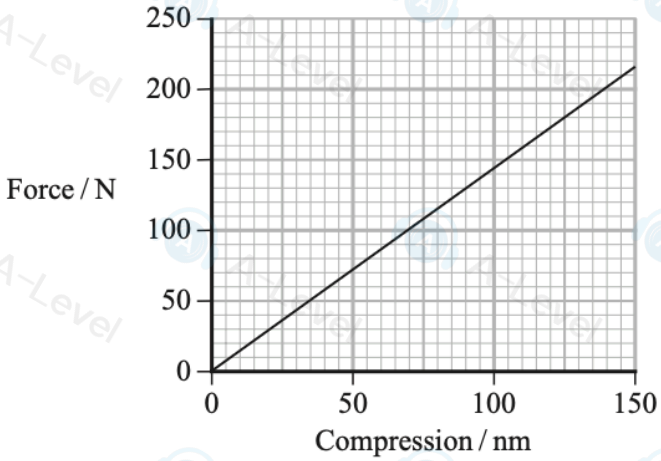
You should assume the drag force on the submarine is negligible.

(6)

15: A builder uses bricks to build a wall.

As the wall gets taller, the force on a brick at the bottom of the wall increases.

A force-compression graph for this brick is shown.



(a) Determine the increase in elastic strain energy in the brick as the force increases from 85 N to 140 N.

(3)

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Increase in elastic strain energy = ...

15: A builder uses bricks to build a wall.

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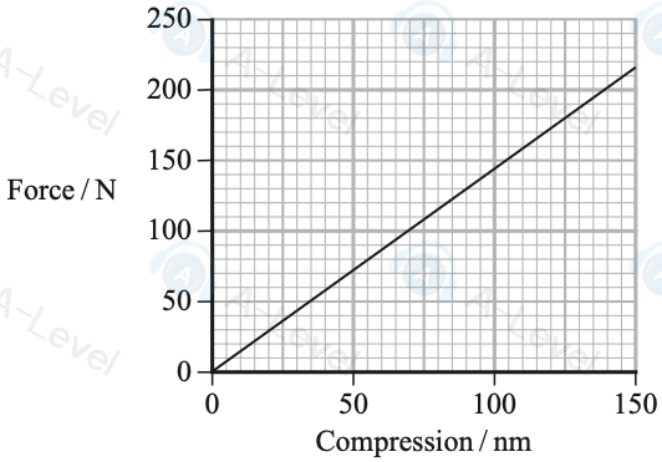

(a) Determine the increase in elastic strain energy in the brick as the force increases from 85 N to 140 N.

(3)

Increase in elastic strain energy = ...

(b) The brick undergoes elastic deformation.

State what is meant by elastic deformation.

(1)

(Total for Question 15 = 4 marks)