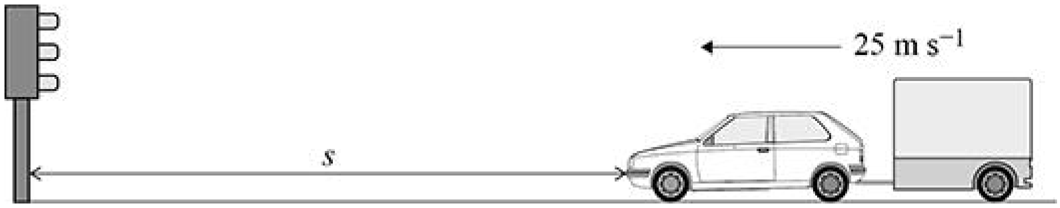
Q1.

In this question, assume that all forces are coplanar.

(a) **Figure 1** shows a car and trailer moving at 25 m s^{-1} at a distance s from traffic lights.

Figure 1



The driver applies the brakes so that the car and trailer stop at the lights.

The car and trailer undergo a constant deceleration of 2.8 m s^{-2}.

Calculate s.

s = ______________________ m

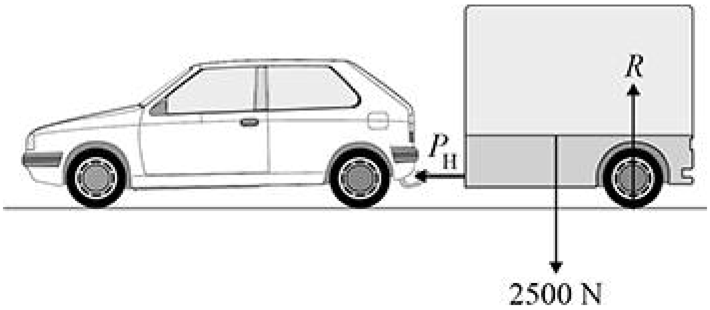
(2)

The car and trailer accelerate from rest along a horizontal road.

Figure 2 shows:

- that the car exerts a horizontal force P_H on the trailer
- that the trailer has a weight of 2500 N
- the reaction force R on the wheels of the trailer.

Figure 2



(b) Initially, there are no resistive forces and the trailer accelerates at 1.5 m s^{-2}.

Calculate the initial value of P_H.

P_H = ____________________ N

(2)

Air resistance D acts on the trailer when it is moving. D increases as the velocity v of the trailer increases.

Figure 3 shows how D varies with v.

Figure 3

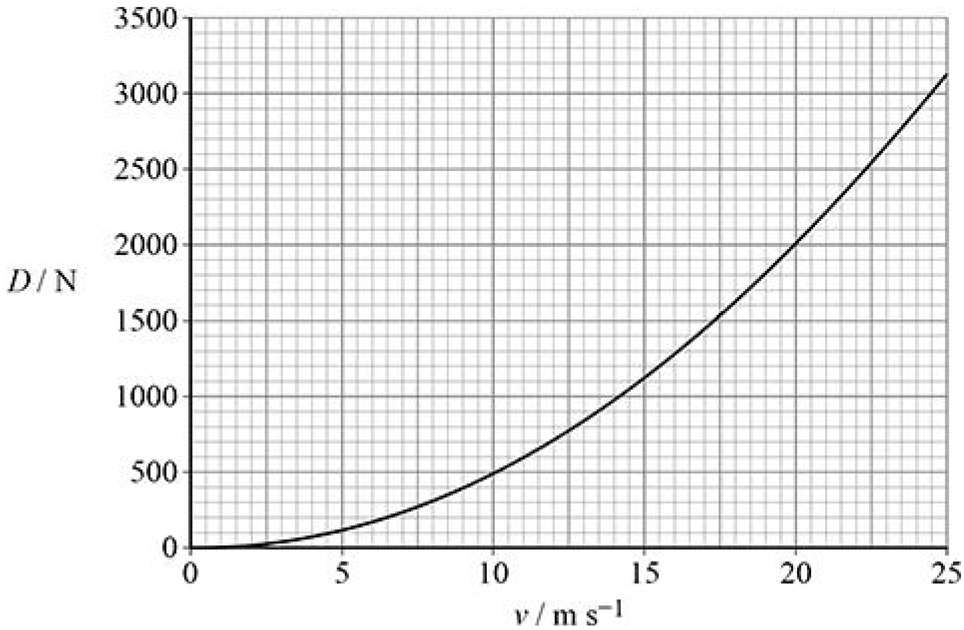
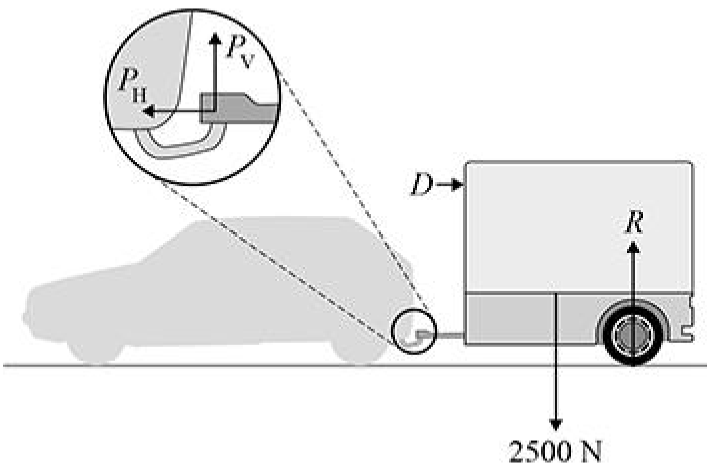


Figure 4 shows the forces acting on the trailer when it is travelling at a constant horizontal velocity.
The car exerts a vertical force P_V and a horizontal force P_H on the trailer when it is travelling at a constant horizontal velocity v_1.
An enlarged view of P_V and P_H is also shown in **Figure 4**.

Figure 4



The horizontal force P_H is now greater than the value calculated in part (b).

(c) The vertical force P_V is 762 N.
The resultant of P_H and P_V is 912 N.

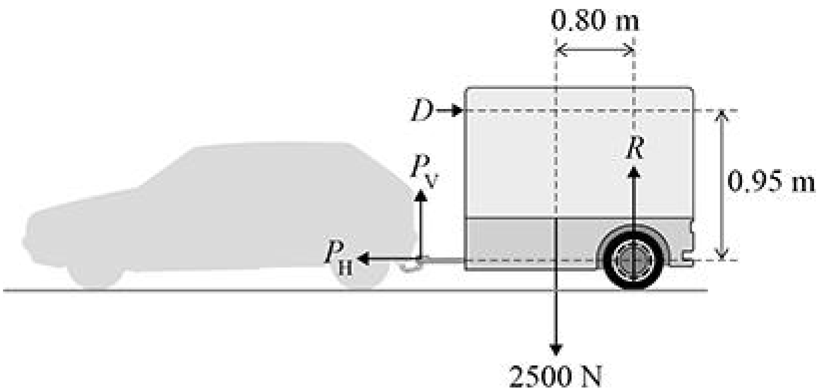
Determine v_1.

v_1 = ____________________ m s^{-1}

(3)

D can be considered to act at the position shown in **Figure 5**. For some of the forces, the distances of their lines of action from the centre of the trailer's wheel have been included.

Figure 5



(d) Explain why P_H has no moment about the centre of the trailer's wheel in **Figure 5**.

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(1)

(e) When the car and trailer travel with velocity v_2, P_V is zero.

Determine v_2.

v_2 = ____________________ m s^{-1}

(3)

(f) The air resistance D acting on the trailer increases as the velocity v of the trailer increases.

Explain this increase in D with reference to the momentum of the air displaced by the trailer.
You should also refer to appropriate Newton's laws of motion.

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(3)

(g) The car has a maximum power output of 95 kW.

The maximum velocity of the car and trailer is 25 $m\ s^{-1}$.
At this velocity, the force D on the trailer is 3100 N.

The car exerts a horizontal force P_H on the trailer and the trailer exerts an equal and opposite force of magnitude P_H on the car.
Assume that air resistance and P_H are the only resistive forces acting on the car.

Calculate the air resistance acting on the car when it is travelling at a constant velocity of 25 $m\ s^{-1}$.

air resistance on car = ____________________ N

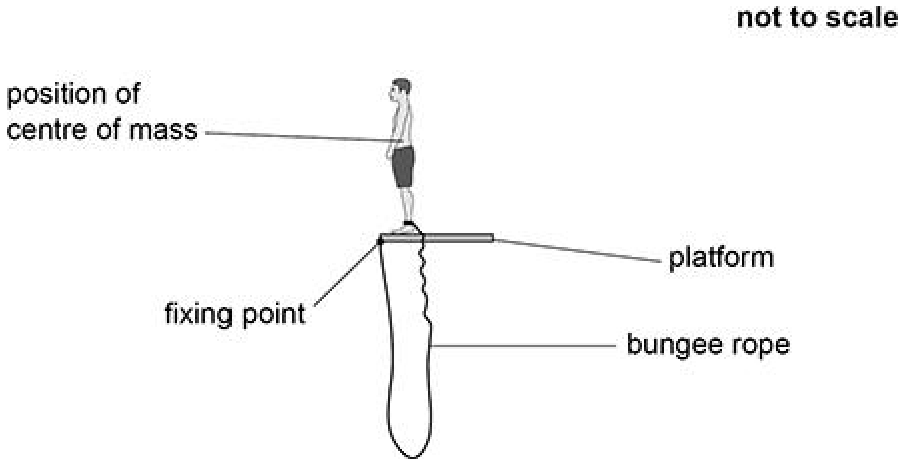
(3)

(Total 17 marks)

Q2.

Figure 1 shows a boy of mass m standing on a platform about to perform a bungee jump. He steps off the platform and falls vertically. The tension in the rope increases as it stretches. The boy decelerates to rest at the lowest point of the jump.
Assume that air resistance is negligible throughout this question.

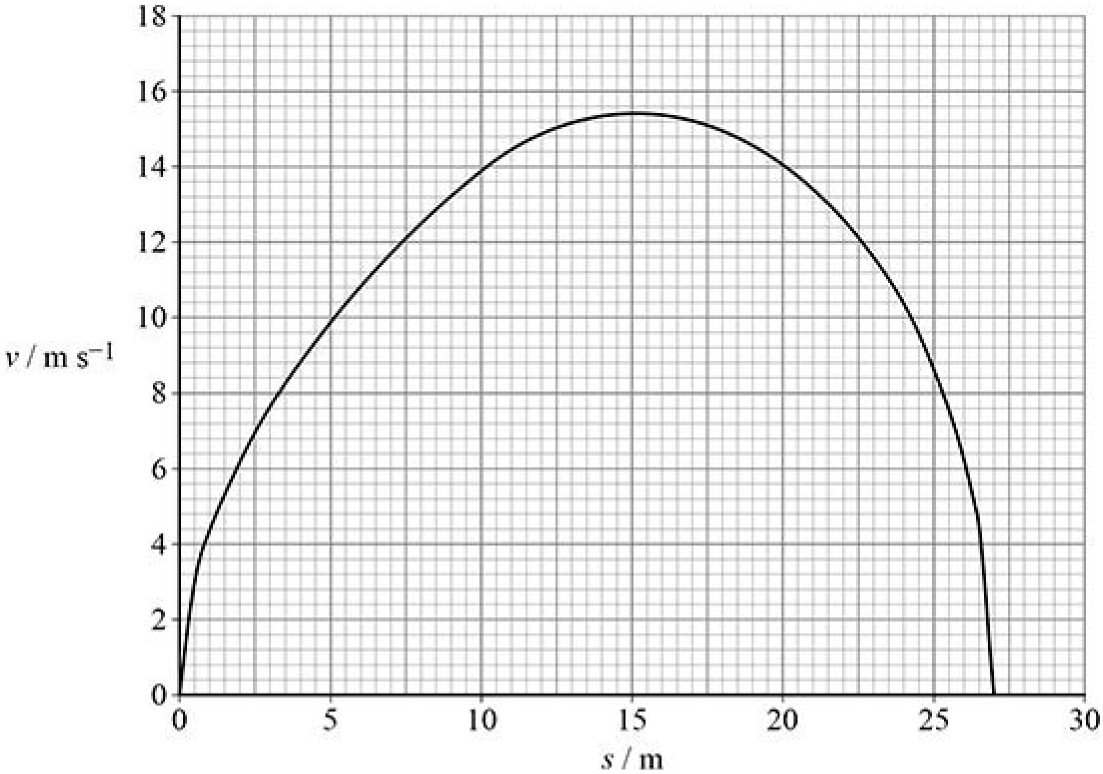
Figure 1



During the jump, s is the vertical displacement moved by the boy's centre of mass. The lowest point of the jump occurs when s is 27 m.

Figure 2 shows the variation of his velocity v with s during the jump.

Figure 2



(a) The boy experiences freefall when he steps off the platform.

During which part of the jump does the boy's acceleration begin to decrease?

Tick (✓) **one** box.

between s = 0 and s = 7.5 m	☐
between s = 7.5 m and s = 15 m	☐
between s = 15 m and s = 22.5 m	☐
between s = 22.5 m and s = 27 m	☐

(1)

(b) When the boy's centre of mass has moved through a distance s of 15.0 m the change in his gravitational potential energy is 9.56 kJ.

Calculate the mass m of the boy.

m = ____________________ kg

(2)

The bungee rope has a stiffness k of 110 N m^{-1} and obeys Hooke's law.

(c) The maximum kinetic energy of the boy is 7.71 kJ.

Calculate, by considering the energy transfers, the extension ΔL of the bungee rope when the kinetic energy of the boy is at a maximum.

ΔL = ____________________ m

(3)

(d) Deduce the tension in the rope when the kinetic energy of the boy is at a maximum.
Give a reason to support your answer.

tension = ____________________ N

reason ____

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(2)

The original rope is replaced with a second rope and the boy repeats the jump.

The table below contains information about the original rope and the second rope. Both ropes obey Hooke's law.

	Young modulus	**Cross-sectional area**	**Unstretched length**
original rope	E	A	L
second rope	1.2E	A	1.2L

The Young modulus is given by:

$$\text{Young modulus} = \frac{\text{stiffness} \times \text{unstretched length}}{\text{cross-sectional area}}$$

(e) Show that each rope has the same stiffness.

(1)

(f) Deduce whether the boy's maximum velocity is increased when using the second rope.

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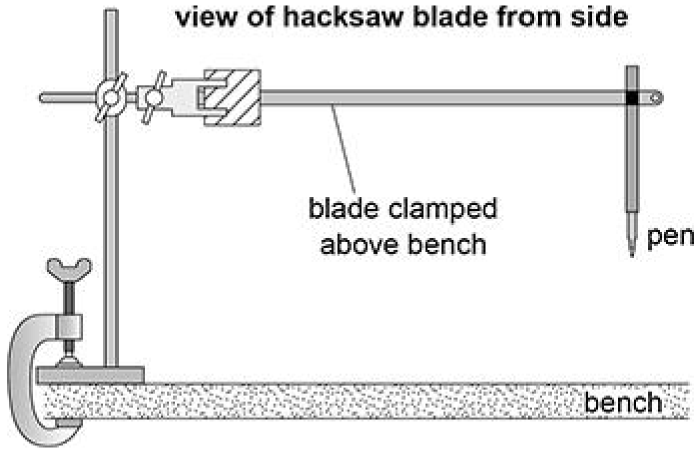
(3)
(Total 12 marks)

Q3.

A hacksaw blade is a thin flexible strip of metal.
Figure 1 shows a blade clamped between two blocks above a horizontal bench.
A pen is attached to the free end of the blade.

Figure 1



The free end of the blade is displaced and released.
The blade oscillates in a horizontal plane as shown in **Figure 2**.

Figure 2

The time for each oscillation is T.

(a) The table below shows repeated measurements of $60T$.

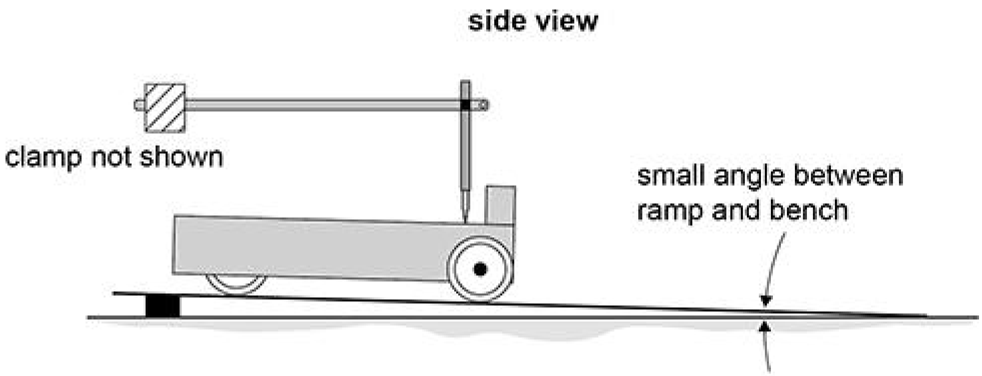
Measurements of $60T$ / s			
25.20	25.05	24.97	25.10

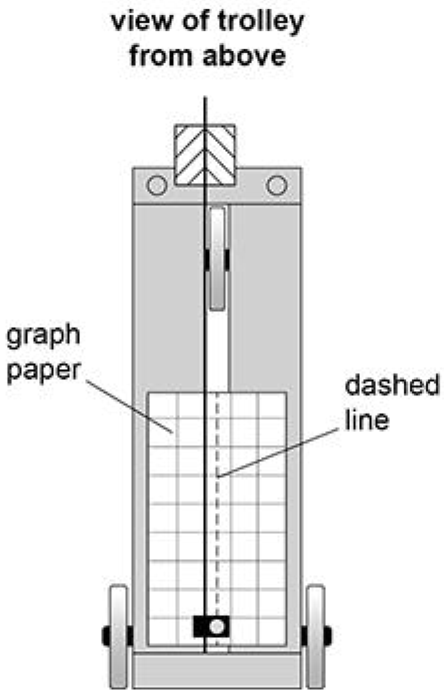
Show that T is about 0.42 s.

(1)

Figure 3 shows a trolley placed on a ramp that is inclined at a small angle to the bench.
A piece of graph paper is fixed to the upper surface of the trolley.
The blade and pen are positioned so that the tip of the pen rests on the graph paper.
The dashed line shows the rest position of the pen.

Figure 3





The free end of the blade is displaced as shown in **Figure 4a**.
The blade and the trolley are then both released at the same moment.
The blade oscillates horizontally.
The pen remains in contact with the graph paper as the trolley moves.

Figures 4b and **4c** show the trolley as it moves down the ramp with uniform acceleration.

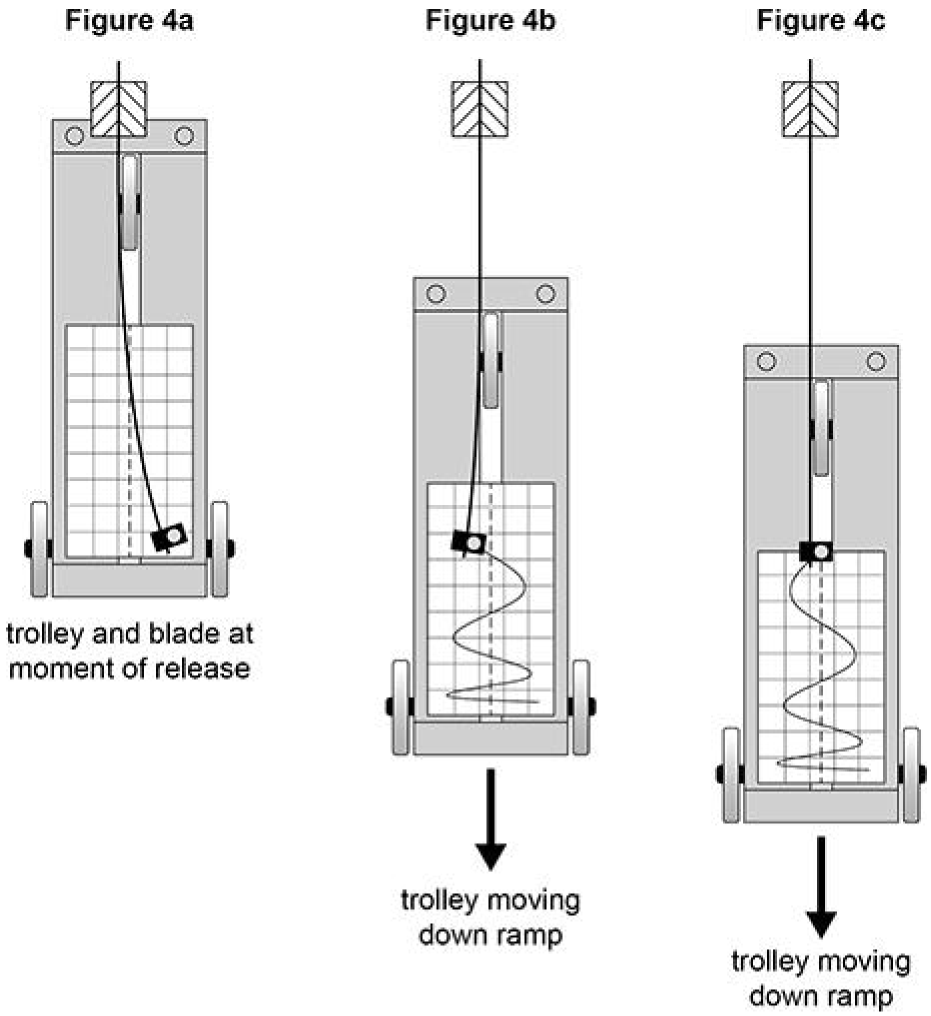
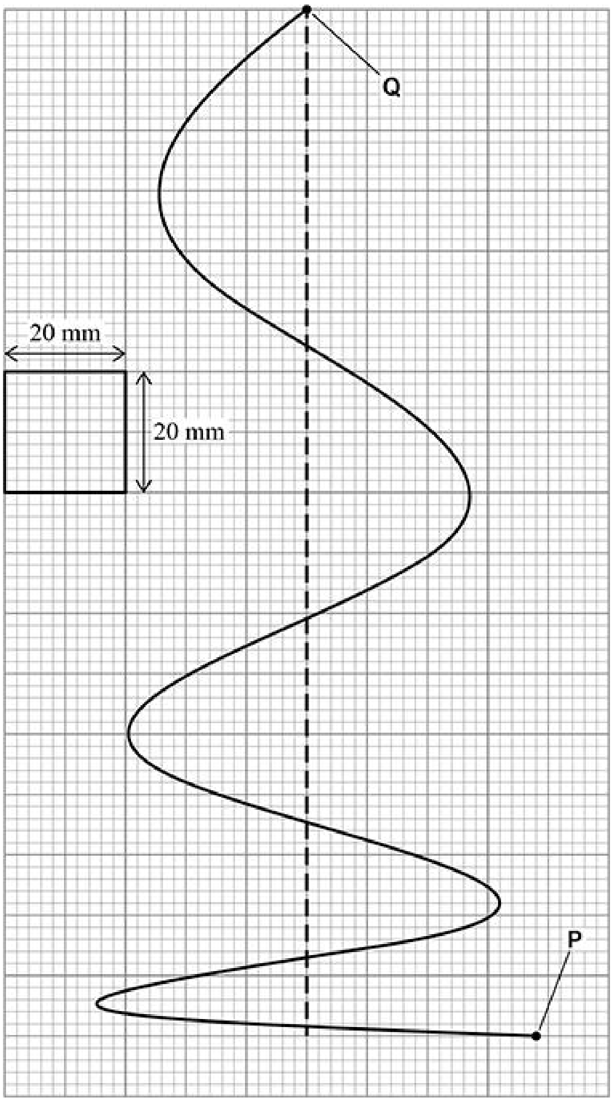


Figure 5 shows the graph paper.
Points **P** and **Q** mark the start and end of the continuous line drawn by the pen after the trolley is released.

Figure 5



T_{PQ} is the time for the pen to draw the line from **P** to **Q**.
s is the displacement of the trolley during T_{PQ}.

(b) Determine T_{PQ}.
Assume that the time for each full oscillation of the blade is 0.42 s.

T_{PQ} = ______________________ s

(2)

(c) Determine s.
The scale of the graph paper is shown on **Figure 5**.

s = ____________________ m

(1)

(d) Determine the acceleration a of the trolley.

a = ____________________ m s^{-2}

(2)

(e) A teacher suggests that the absolute uncertainty in s is ±2 mm.

Explain why this is a valid suggestion.

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(2)

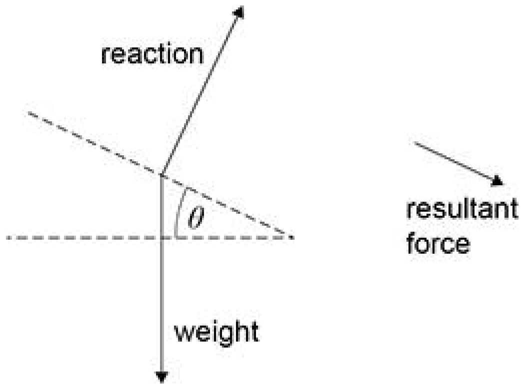
(f) The percentage uncertainty in T_{PQ} is 0.46%.
Determine the percentage uncertainty in your result for a.

percentage uncertainty = ____________________ %

(2)

(g) **Figure 6** is a diagram drawn by a student to explain why the trolley accelerates.
The diagram is incomplete because the student has ignored the friction forces involved.

Figure 6



Using **Figure 6** it can be shown that:

$$g = \frac{a}{\sin\theta}$$

where a is the acceleration of the trolley.

The student determines g using this equation.

State and explain how the student's value of g compares with 9.81 m s^{-2}.

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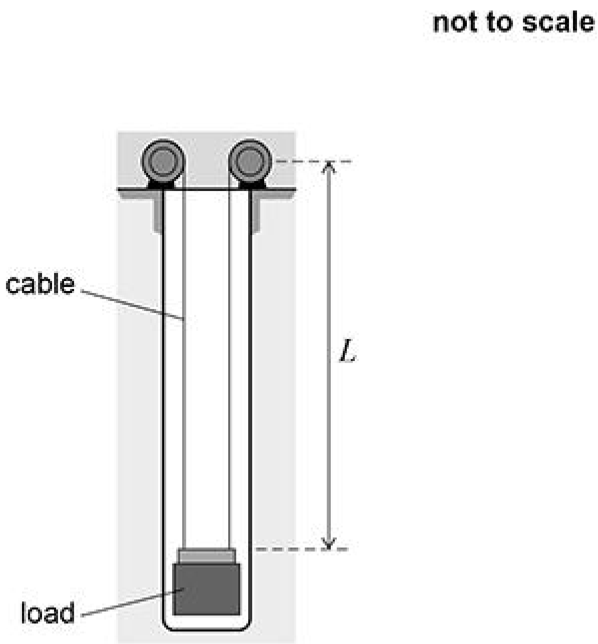
(2)

(Total 12 marks)

Q4.

Figure 1 shows an energy storage system. The system uses a load suspended from two long steel cables in a vertical tunnel. Energy is stored when the load is raised. Electricity is generated when the load falls.

Figure 1



When the load is at its lowest point, each cable has a vertical length L.
The total mass of the two vertical cables is 3.7×10^4 kg.
Each cable has a cross-sectional area of 9.6×10^{-3} m^2.

(a) Calculate L.

density of steel = 7.4×10^3 kg m^{-3}

L = ____________________ m

(2)

(b) The load is accelerated from its lowest point. The mass of the load is 2.8×10^5 kg.

The maximum tension in each cable is 1.6×10^6 N during the acceleration.

Calculate the initial acceleration of the load.

initial acceleration = ____________________ $m\ s^{-2}$

(4)

(c) For safety, the breaking stress of each steel cable must be at least three times the maximum stress produced during the initial acceleration.

breaking stress for steel = 890 MPa

Deduce whether this system operates safely.

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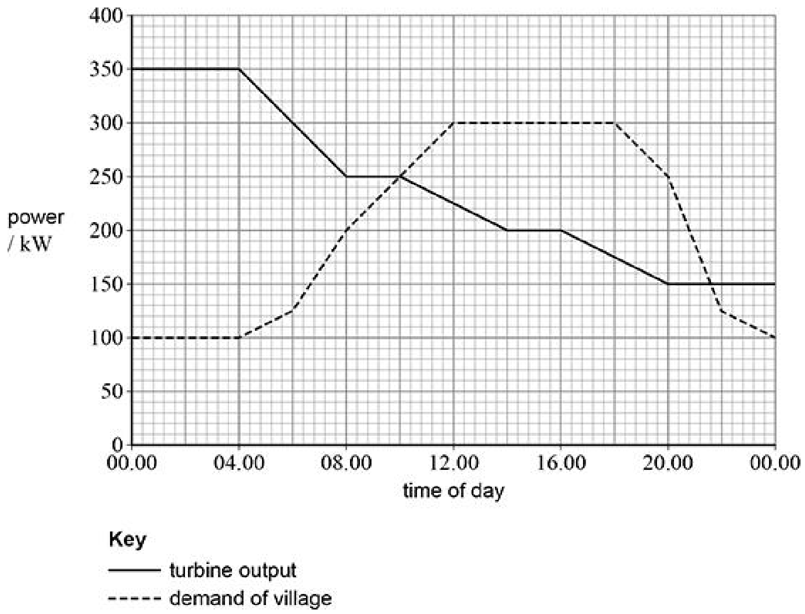
(2)

(d) A village combines the storage system with a wind turbine to provide energy.
Figure 2 shows how the output power of the wind turbine varies with time during one particular day.
The power demand of the village is also shown.

Figure 2



When the power demand is greater than the output power of the wind turbine, the load in the storage system descends and generates electricity to match the demand.
When the load has fully descended and the storage system is empty, electrical power is provided by the National Grid.

The efficiency of the energy transfer from the storage system to the village is 85%. The maximum energy stored by the storage system is 760 MJ.

Deduce whether the storage system and the wind turbine can together provide all the electrical energy needed by the village from 10.00 until 14.00.

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(4)
(Total 12 marks)

Q5.

The deuterium–tritium (D–T) reaction is a nuclear reaction between two isotopes of hydrogen.
The D–T reaction is

$$ {}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + n $$

The energy from this reaction is transferred to the kinetic energy of the helium nucleus and the kinetic energy of the neutron.
Assume that the kinetic energies of the hydrogen nuclei are zero just before the reaction occurs.

(a) Show that the kinetic energy of the neutron represents approximately 80% of the total energy transferred.

(2)

(b) The combined kinetic energy of the helium nucleus and the neutron is 2.82 $\times 10^{-12}$ J.

Calculate the initial speed of the neutron.

initial speed = ____________________ $m\ s^{-1}$

(2)

(Total 4 marks)

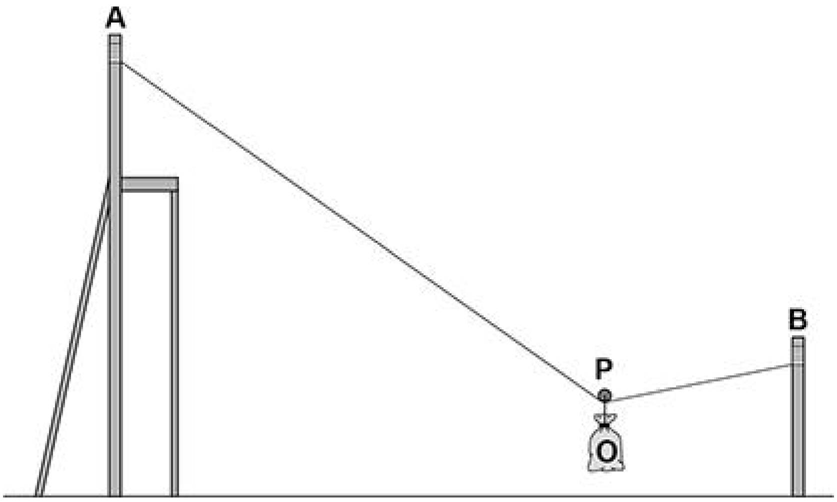
Q6.

A cable system is to be used to transfer supplies across a river. A model of the proposed system is built in order to test its performance.

The model consists of a cable attached to two vertical posts **A** and **B**, as shown in **Figure 1**.
A pulley **P** of negligible mass is attached to the cable.

In this question the length of the cable does not change and the weight of the cable can be ignored.

Figure 1

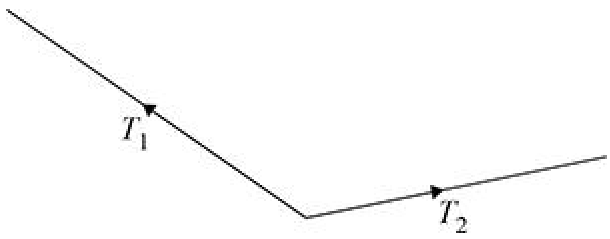


An object **O** is attached to **P**. In one test, **O** and **P** are at rest in the position shown in **Figure 1**.
The weight of **O** is 350 N.

(a) **Figure 2** is a force diagram drawn to scale. It represents the magnitudes and directions of the tensions T_1 and T_2 in the cable when **O** is at rest in the position shown in **Figure 1**. At this position, resistive forces are zero.

Complete the force diagram.
Go on to determine, using your diagram, the magnitudes of T_1 and T_2.

Figure 2



T_1 = ____________________ N

T_2 = ____________________ N

(4)

(b) In a second test, pulley **P** with **O** attached is released from **A**.
P and **O** move along the cable to **B**.
The change in height of the centre of mass of **O** between **A** and **B** is 4.5 m.
The distance travelled along the cable is 18 m.
The speed of **O** when it reaches **B** is 6.5 m s^{-1}.
Calculate the average resistive force on **O** and **P** as they move from **A** to **B**.

average resistive force = ____________________ N

(5)

(c) **O** contains a fragile item packed in suitable material.

Explain how the material can prevent damage to the fragile item when **O** stops suddenly at **B**.

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(3)

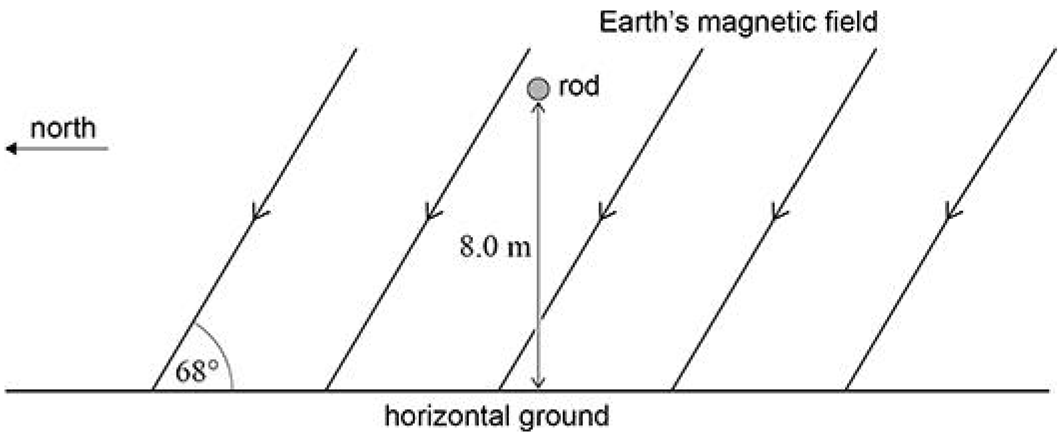
(Total 12 marks)

Q7.

A conducting rod is held horizontally in an east–west direction.
The magnetic flux density of the Earth's magnetic field is 4.9×10^{-5} T and is directed at an angle of 68° to the ground.

(a) **Figure 1** shows the arrangement. The rod has a length of 2.0 m.

Figure 1



The rod is released and falls 8.0 m to the ground. It remains in a horizontal east–west direction as it falls.

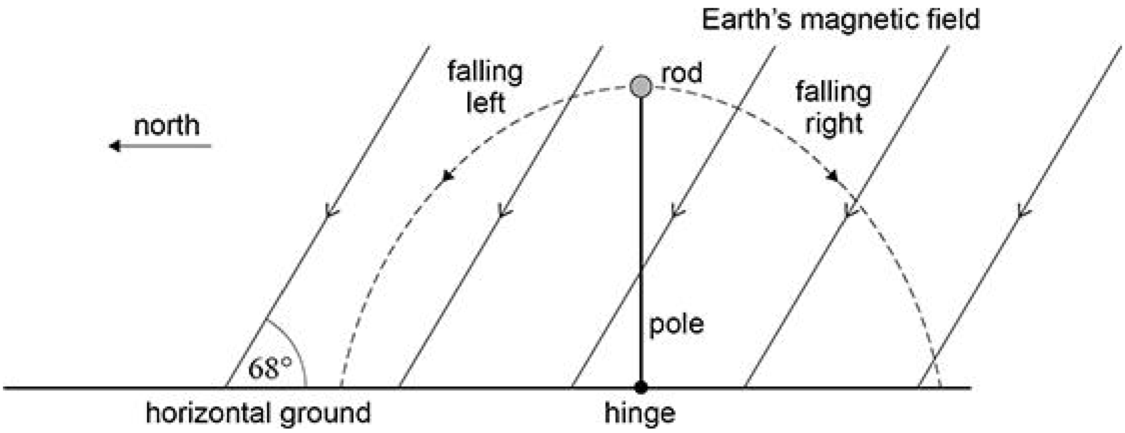
Determine the average emf across the rod during its fall to the ground.
Assume that air resistance is negligible.

average emf = ____________________ V

(3)

(b) The rod is returned to its original position. It is now supported by a non-conducting pole that is hinged on the ground as shown in **Figure 2**. The pole is initially vertical and is then released. The rod and pole can fall to the ground to the left or to the right.

Figure 2



During each fall there are changes in the magnitude and direction of the induced emf. These changes differ depending on whether the rod falls to the left or to the right.

Explain any changes in the magnitude and direction of the induced emf as the rod falls:

- to the left
- to the right.

left ____

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right ____

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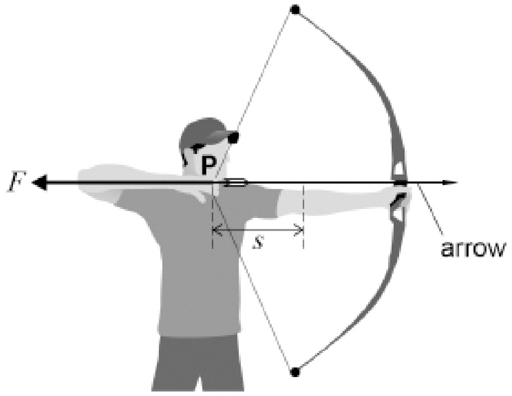
(4)
(Total 7 marks)

Q8.

Figure 1 shows an archer using a bow in a competition.

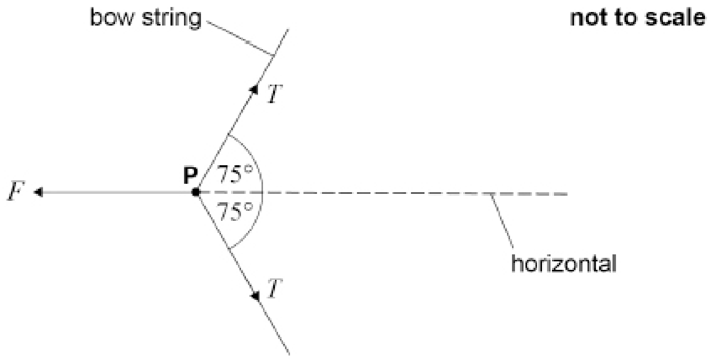
Figure 1



The archer exerts a force F to pull point **P** on the string back through a distance s.

(a) **Figure 2** is a simplified diagram of the bow string showing the forces acting on **P**.
The tension in the string is T and the string makes an angle of 75° to the horizontal.

Figure 2



In **Figure 2**, F is 160 N and **P** is in equilibrium.

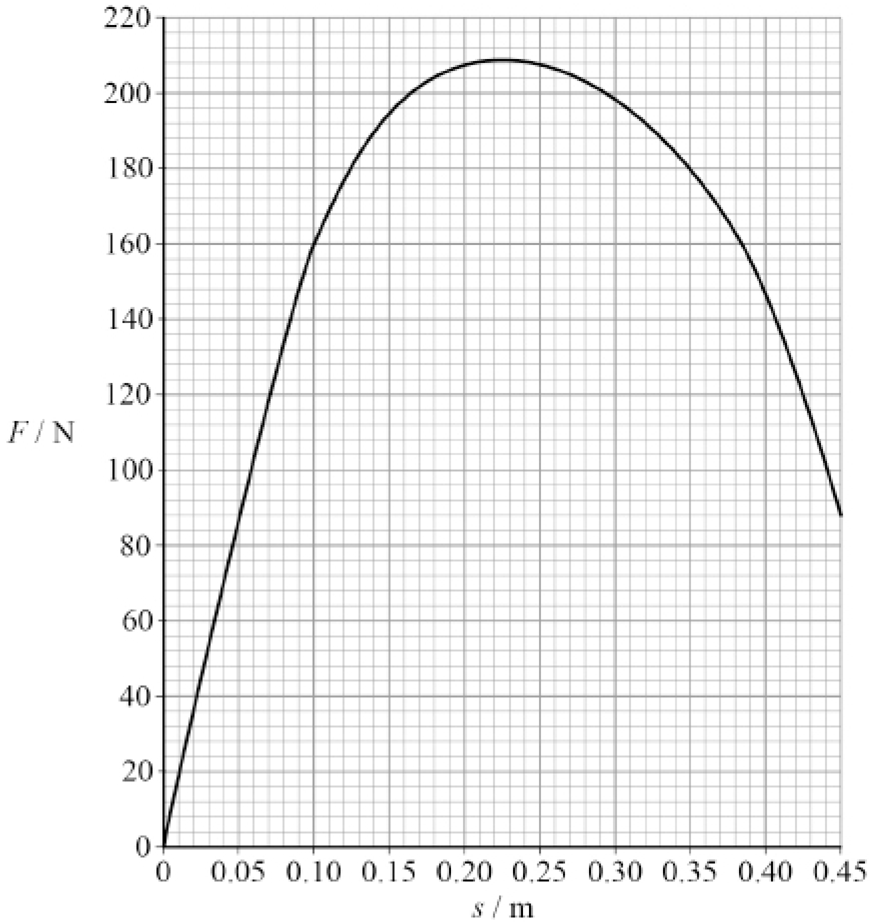
Calculate T.

T = ____________________ N

(2)

The bow is designed so that F varies with s as shown in **Figure 3**.

Figure 3



(b) An arrow of mass 21 g is placed in the bow.

The archer pulls **P** back by a distance s of 0.22 m and then releases the arrow in a horizontal direction.

Assume that there are no resistive forces acting on the arrow as it is released.

Determine the initial horizontal acceleration of the arrow.

initial horizontal acceleration = ____________________ $m\ s^{-2}$

(2)

The arrow is replaced with a different arrow of mass m.
The archer pulls **P** back by a distance sr so that the energy stored in the bow is 64 J and F is 160 N.

(c) Deduce s_r.

s_r = ____________________ m

(2)

(d) The bow has an efficiency of 0.82

The arrow leaves the bow in a horizontal direction with a velocity of 190 $km\ h^{-1}$.

Calculate m.

m = ____________________ kg

(3)

(Total 9 marks)

Q9.

Figure 1 shows a robotic helicopter that is used on Mars. The helicopter is powered by a battery. Before each flight, the battery is charged by a solar panel.

Figure 1

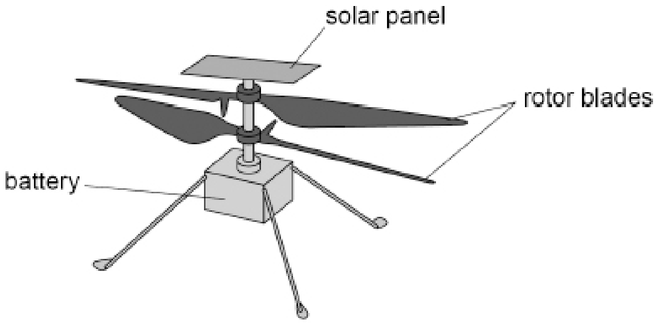
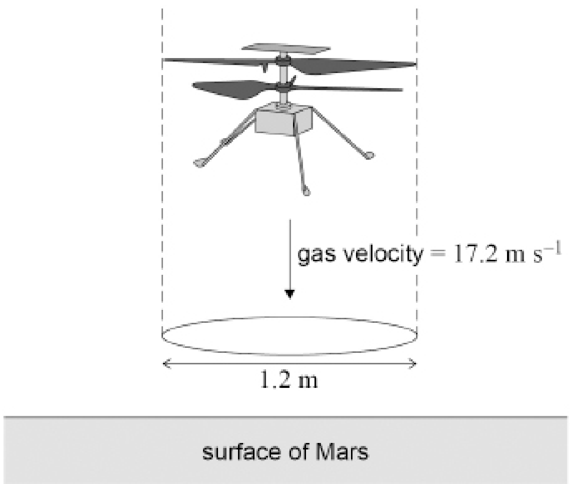


Figure 2 shows the helicopter hovering at a constant height above the surface of Mars. The rotor blades move a column of atmospheric gas vertically downwards at a velocity of 17.2 $m\ s^{-1}$. The diameter of this column is 1.2 m.

Figure 2



(a) The gas moved by the rotor blades has a density of 0.020 $kg\ m^{-3}$.

Show that the helicopter moves approximately 0.4 kg of gas every second.

(3)

The movement of the gas creates an upward force on the helicopter. This upward force enables the helicopter to hover at a constant height.

The gravitational field strength on Mars is 3.72 $N\ kg^{-1}$.

(b) Calculate the mass of the helicopter.

mass = ____________________ kg

(3)

(c) The battery stores 0.035 kW h of energy before a flight.
The flight lasts for 39 s.
The battery has a power output of 340 W during the flight.

Determine the percentage of the initial energy stored in the battery that is transferred during the flight.

percentage = ____________________ %

(2)

(d) The helicopter has a maximum flight time of a few minutes due to the limited amount of energy stored in the battery. The battery accounts for about 15% of the helicopter's mass.

A student suggests that adding another identical battery that doubles the energy available to the helicopter would double its flight time.

Deduce without calculation whether the student's suggestion is correct.

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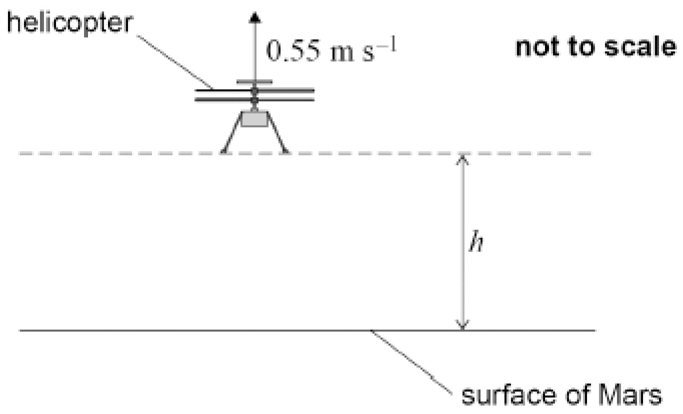
(3)

Figure 3 shows a simplified side view of the helicopter moving vertically upwards with a speed of 0.55 $m\ s^{-1}$.
At the instant shown, the helicopter is at a height h and the blades stop rotating.

Figure 3



The gravitational field strength on Mars is 3.72 $N\ kg^{-1}$.

The weight of the helicopter is the only force acting on it when the blades stop rotating. Drag forces on the helicopter are negligible as it rises to a maximum height and then falls back to the surface.

(e) Calculate the time taken for the helicopter to reach its maximum height from the instant the blades stop rotating.

time = ____________________ s

(2)

(f) When the helicopter makes contact with the surface it has a velocity of 2.2 $m\ s^{-1}$.

Calculate h.

h = ____________________ m

(2)

(g) A student suggests that the acceleration of the helicopter is constant from the instant the blades stop rotating until the helicopter makes contact with the surface.

Discuss this suggestion with reference to an appropriate Newton's law of motion.

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(2)

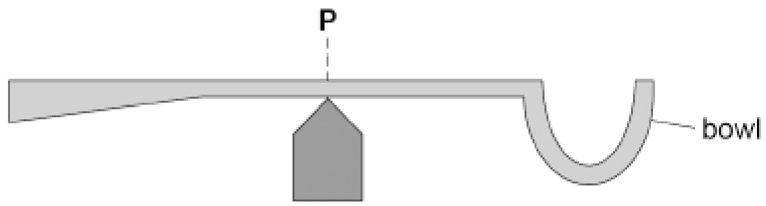
(Total 17 marks)

Q10.

Figure 1 shows a spoon used to measure the mass of food.

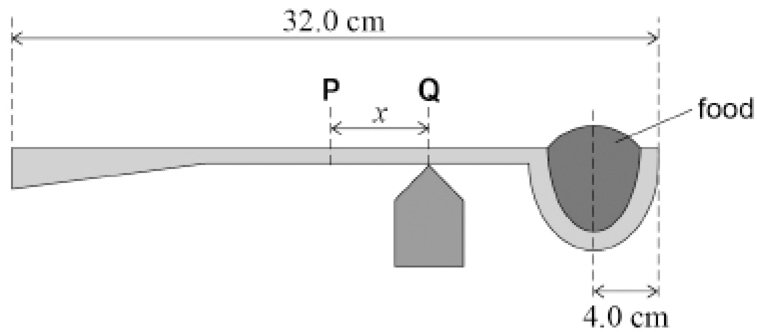
The empty spoon balances when a pivot is placed under a point **P** halfway along the spoon.

Figure 1



The spoon tilts when food of mass M is placed in the bowl. The spoon is rebalanced by moving the pivot a distance x to the right of **P**. The new position of the pivot is under point **Q** in **Figure 2**.

Figure 2



The total length of the spoon is 32.0 cm. The weight of the food acts through a line at a distance of 4.0 cm from the right-hand edge of the spoon.

(a) Explain why the spoon in **Figure 2** is balanced when the pivot is at **Q**.

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(2)

(b) The empty spoon has mass m.

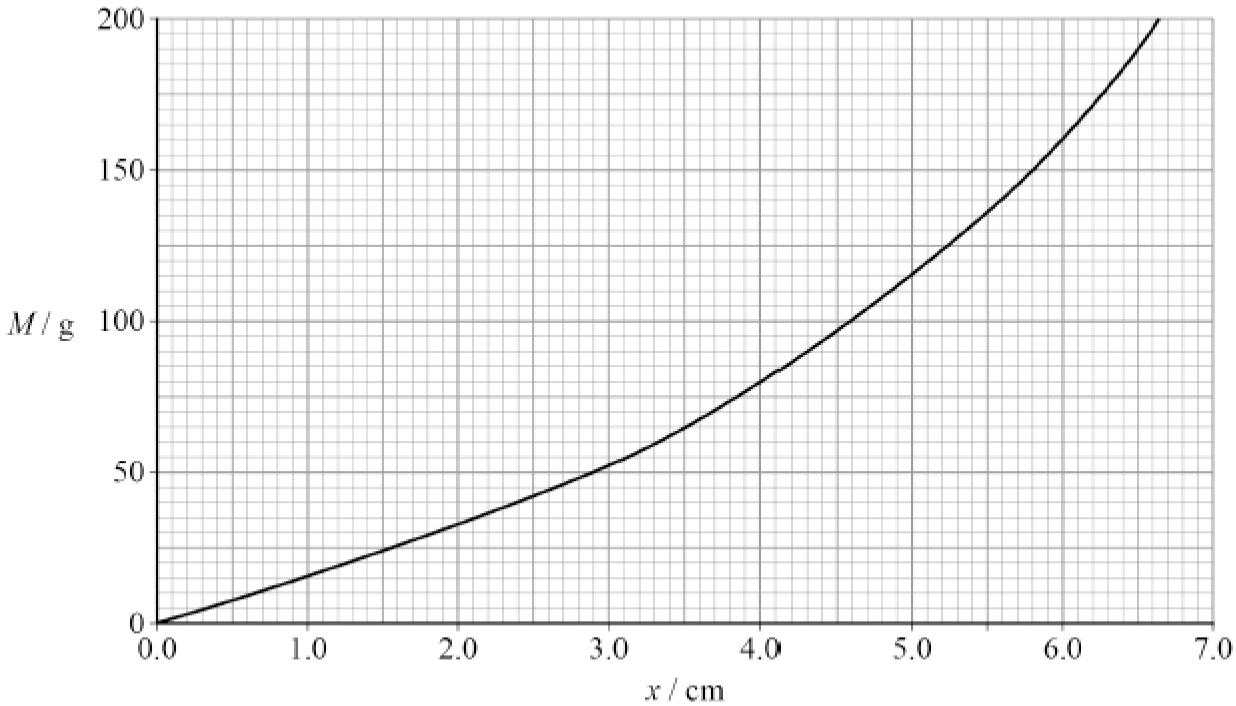
Show that, for the arrangement in **Figure 2**,

$$\frac{m}{M} = \frac{(12.0 - x)}{x}$$

(2)

(c) **Figure 3** shows how x varies with M.

Figure 3



Determine, using **Figure 3**, the weight of the empty spoon.

weight = ____________________ N

(3)

(d) A scale, in grams, is marked on the spoon between **P** and the bowl. **Figure 3** is used to calibrate this scale in intervals of 25 g.

M can be measured by balancing the spoon. The value is read from the point of the scale directly above the pivot.

State and explain how the uncertainty in the value read from the scale changes as M increases.

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(3)
(Total 10 marks)

Q11.

In 2021 the world land speed record was 1230 $km\ h^{-1}$.
This was the average speed achieved by a jet-powered car in two runs. Each run was measured over a distance of 1.61 km.

(a) The average speed for one of these runs was 343 $m\ s^{-1}$.

Calculate, in s, the time taken for the car to complete the other run.

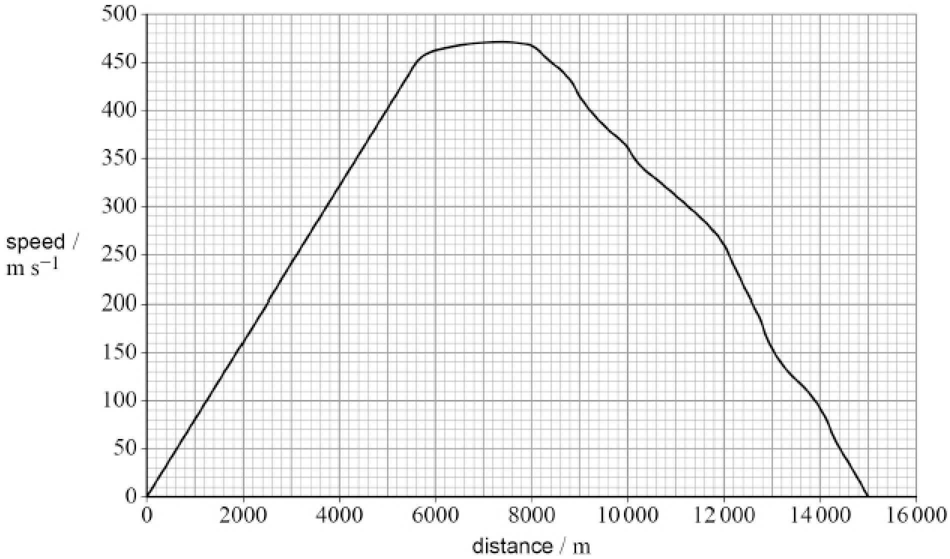
time = ____________________ s

(2)

(b) Engineers are designing a new jet-powered car to break this record.

Figure 1 shows the variation of speed with distance for the car, as predicted by the engineers.

Figure 1



The car reaches its maximum acceleration when it is 5600 m from the start. At this point the mass of the car is 6.50×10^3 kg.

Determine the kinetic energy of the car at its maximum acceleration.

kinetic energy = ____________________ J

(2)

(c) At any point on the graph in **Figure 1**, the acceleration is given by:

acceleration = speed × gradient of line

When the car is at its maximum acceleration, the power input to the jet engines is 640 MW.
Calculate the percentage of the input power used to accelerate the car at its maximum acceleration.

percentage of input power = ____________________ %

(4)

(d) Scientists recommend that the average deceleration of the driver of the car should be less than $3g$.

Deduce whether the average deceleration is less than $3g$.

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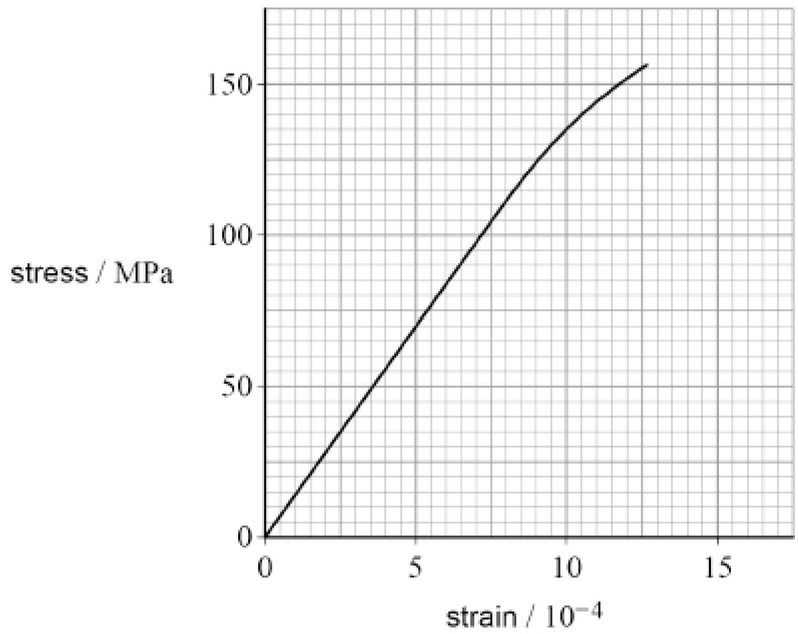
(2)

(Total 10 marks)

Q12.

Figure 1 shows the stress–strain graph for a metal in tension up to the point at which it fractures.

Figure 1



(a) Determine, using **Figure 1**, the Young modulus of the metal.

Young modulus = ____________________ Pa

(1)

(b) Explain how the graph shows that this metal is brittle.

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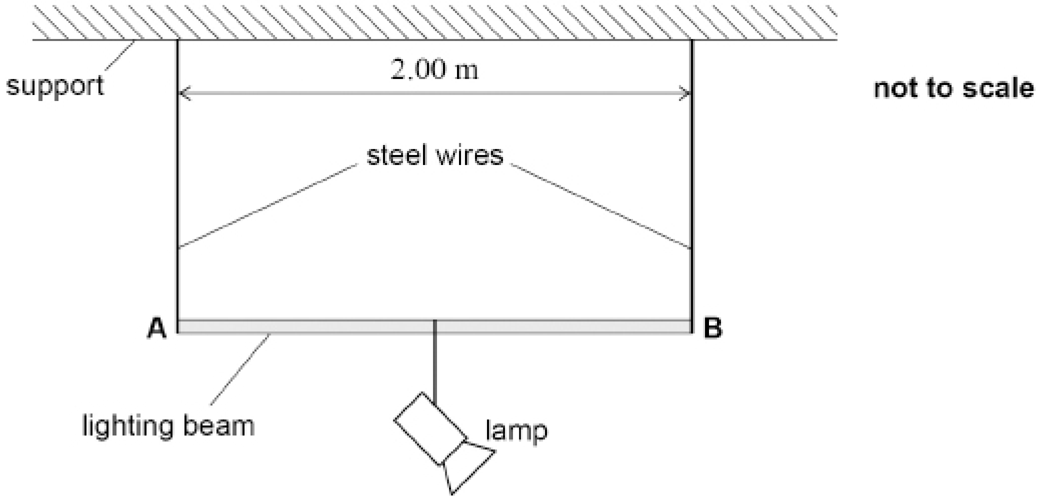
(1)

Figure 2 shows a uniform rigid lighting beam **AB** suspended from a fixed horizontal support by two identical vertical steel wires. A lamp is attached to the midpoint of **AB**.

Figure 2



The unloaded length of each steel wire was 1.20 m before it was attached to **AB**. **AB** is horizontal.

mass of **AB** = 4.4 kg
mass of lamp = 16.0 kg
distance between wires = 2.00 m
diameter of each wire = 0.800 mm
Young modulus of steel = 2.10×10^{11} Pa

(c) Calculate the extension of each wire.

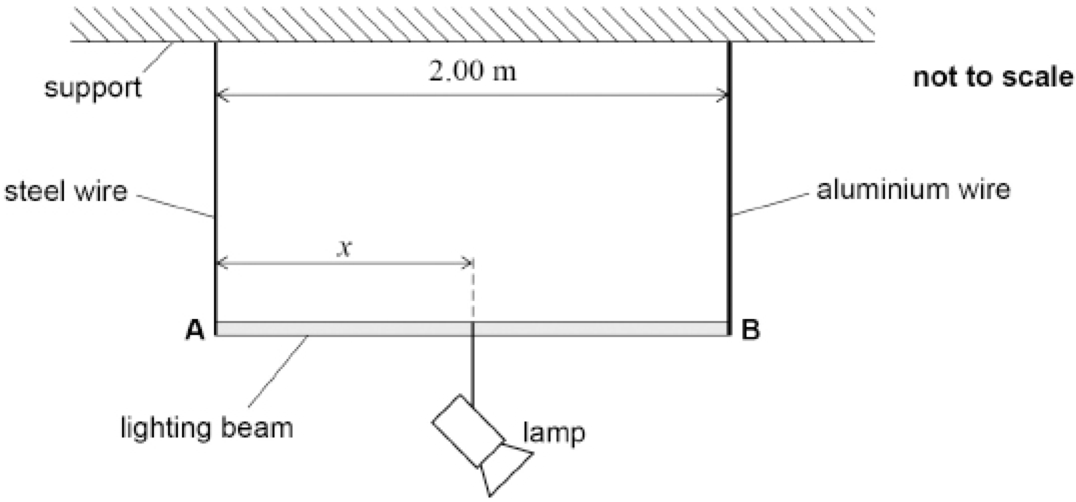
extension = ____________________ m

(3)

(d) The right-hand steel wire is removed and replaced with an aluminium wire of diameter 1.60 mm. The unloaded length of the aluminium wire is the same as that of the original steel wire.

When the lamp is at the midpoint of **AB**, one of the wires extends more than the other so that **AB** is not horizontal. To make **AB** horizontal the lamp has to be moved to a distance x from **A**. **Figure 3** shows the new arrangement.

Figure 3



The Young modulus of aluminium is 7.00×10^{10} Pa.

Deduce distance x.

x = ____________________ m

(5)

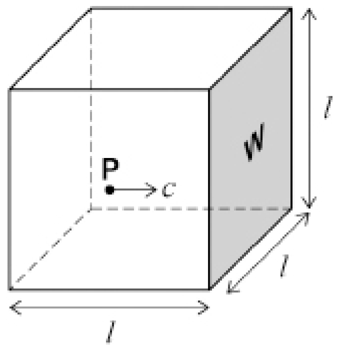
(Total 10 marks)

Q13.

(a) State what is meant by the internal energy of an ideal gas.

(1)

The figure below shows a single gas particle **P** of an ideal gas inside a hollow cube.



The cube has side length l and volume V.
P has mass m and is travelling at a velocity c perpendicular to side **W**.

(b) Explain why **P** has a change in momentum of $-2mc$ during one collision with **W**.

(1)

(c) **P** collides repeatedly with **W**.

Show that the frequency f of collisions is $\frac{c}{2l}$.

(1)

(d) Deduce an expression, in terms of m, c and V, for the contribution of **P** to the pressure exerted on **W**.
Refer to appropriate Newton's laws of motion.

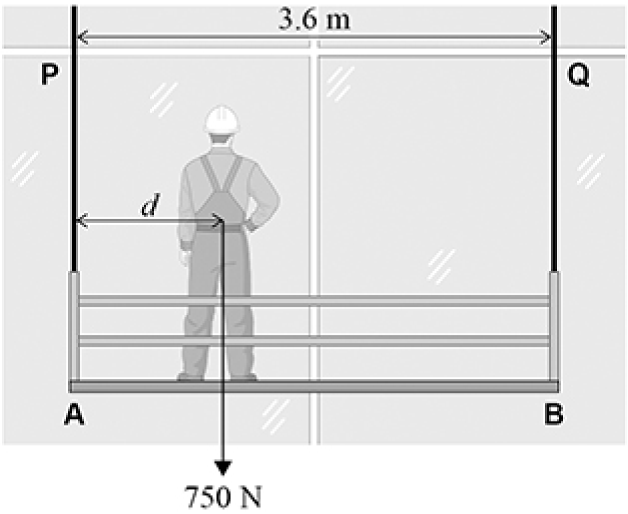
(2)
(Total 5 marks)

Q14.

Figure 1 shows a worker of weight 750 N on a uniform platform. The weight of the worker is acting at a horizontal distance d from end **A**.

Throughout this question, assume that the platform is horizontal and that all cables obey Hooke's law.

Figure 1



The platform weighs 1800 N and is suspended by vertical cables **P** and **Q**.
Each cable has an unstretched length of 3.0 m.
The horizontal distance between **P** and **Q** is 3.6 m.

(a) The worker moves to a position where the tension in the left-hand cable **P** is 1150 N.

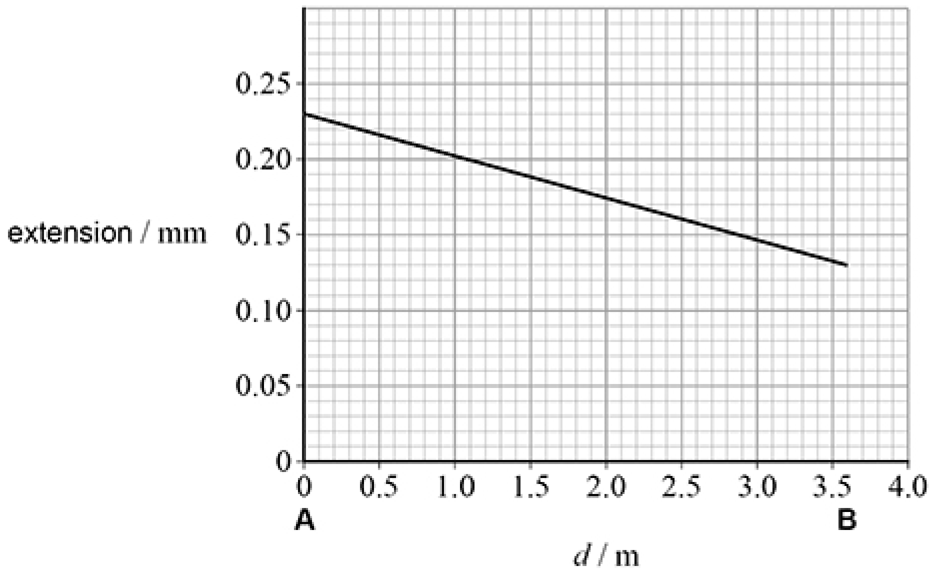
Calculate d for this position.

d = _______________ m

(3)

Figure 2 shows how the extension of **P** varies with d as the worker walks slowly along the platform from **A** to **B**.

Figure 2



The worker moves to a position **X** where the strain in **P** is 6.0×10^{-5}.

(b) Determine d for position **X**.

d = _______________ m

(2)

(c) The cable material has a Young modulus of 1.9×10^{11} N m^{-2}.

Calculate the tensile stress in **P** when the worker is at **X**.

tensile stress = _______________ N m^{-2}

(1)

(d) The original cables **P** and **Q** are replaced.

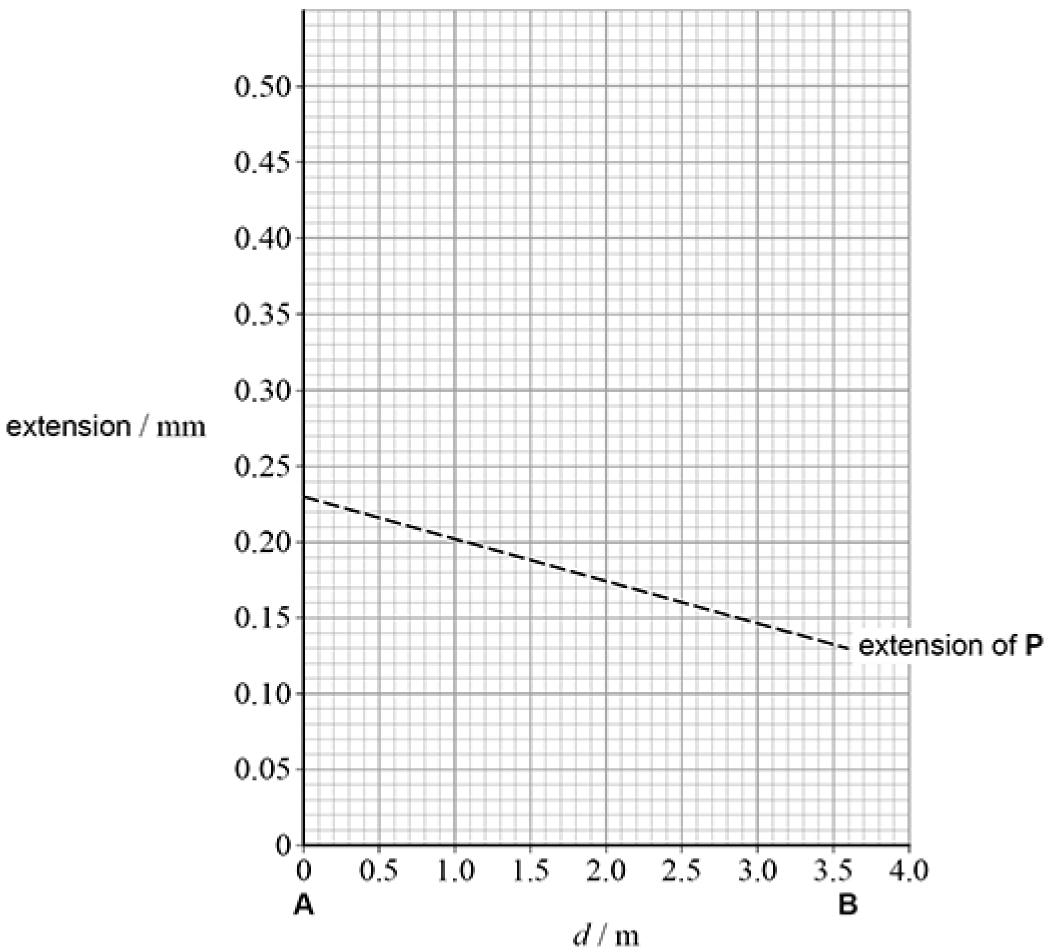
The table below shows how the properties of the original cables compare with the replacement cables.

	Unstretched length	**Radius**	**Young modulus of cable material**
Original cables	L	r	E
Replacement cables	L	$\frac{r}{2}$	$2E$

After the cables have been replaced, the worker walks slowly from **A** to **B**.

Draw on **Figure 3** a line to show the variation of the extension of the replacement left-hand cable with d.
The original line from **Figure 2** is shown on **Figure 3** as a dashed line to help you.

Figure 3

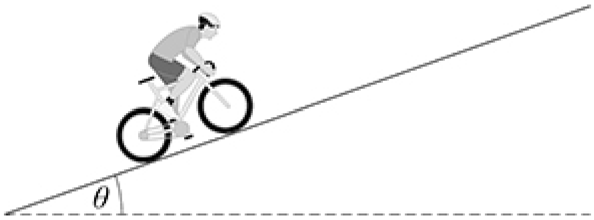


(3)
(Total 9 marks)

Q15.

(a) **Figure 1** shows a cyclist going up a hill.

Figure 1



not to scale

The angle θ of the slope of the hill is constant.
The total mass m of the cyclist and bicycle is $65\ \text{kg}$.

Write an expression for the component of the total weight parallel to the slope.

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(1)

(b) The useful power output of the cyclist is $310\ \text{W}$.
The cyclist has a steady speed of $1.63\ \text{m s}^{-1}$.

Assume that air resistance is negligible at this speed.

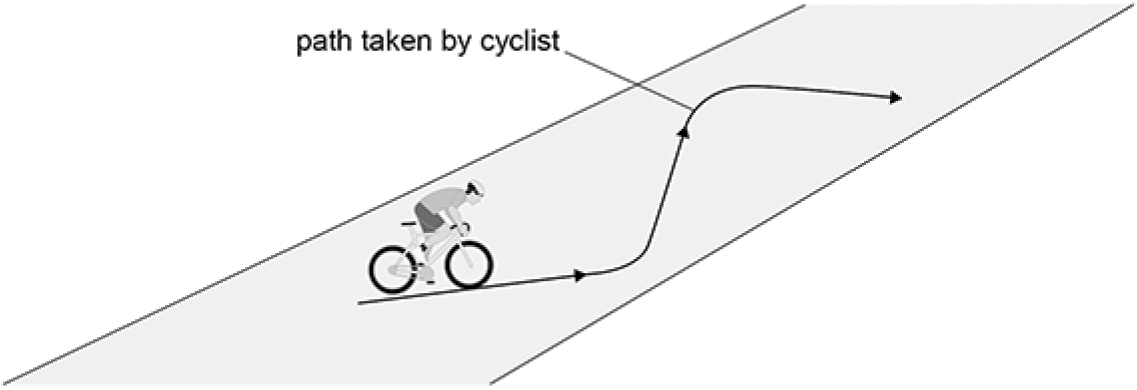
Calculate θ.

θ = _______________ °

(2)

Figure 2 shows an alternative 'zig-zag' path taken by the cyclist up the same hill. She maintains a steady speed of 1.63 m s^{-1}.

Figure 2



(c) Discuss how her useful power output when taking the path in **Figure 2** compares with her useful power output in part (b).

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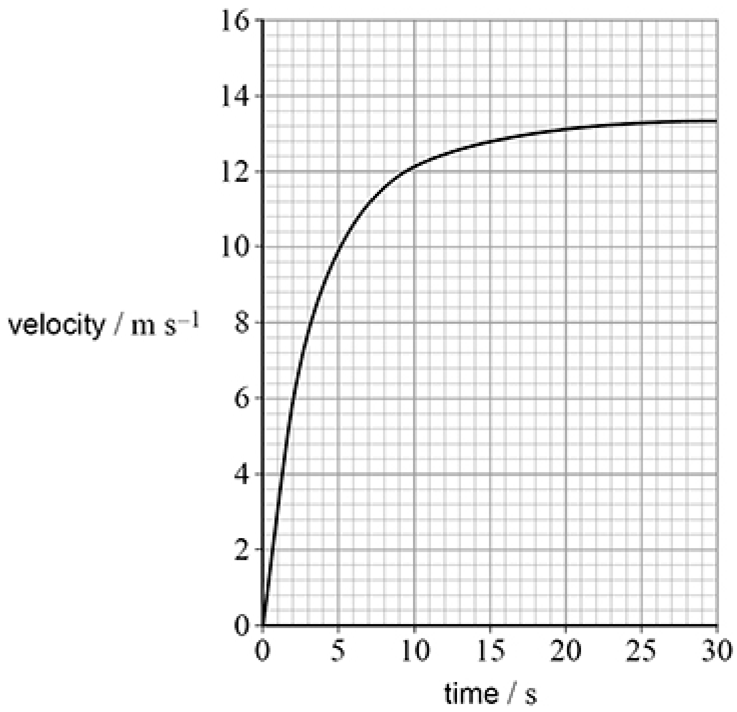
(3)

The cyclist reaches the top of the hill. She then travels back down the hill in a straight line. The bicycle rolls freely without the cyclist pushing the pedals or applying the brakes.

Figure 3 shows the variation of her velocity with time as she goes down the hill.

Figure 3



(d) Determine the acceleration of the cyclist 10.0 s after she begins to go down the hill.

acceleration = _______________ $m\ s^{-2}$

(3)

(e) Energy transfers occur as the cyclist travels down the hill.

Outline how these energy transfers explain the shape of the graph in **Figure 3**.

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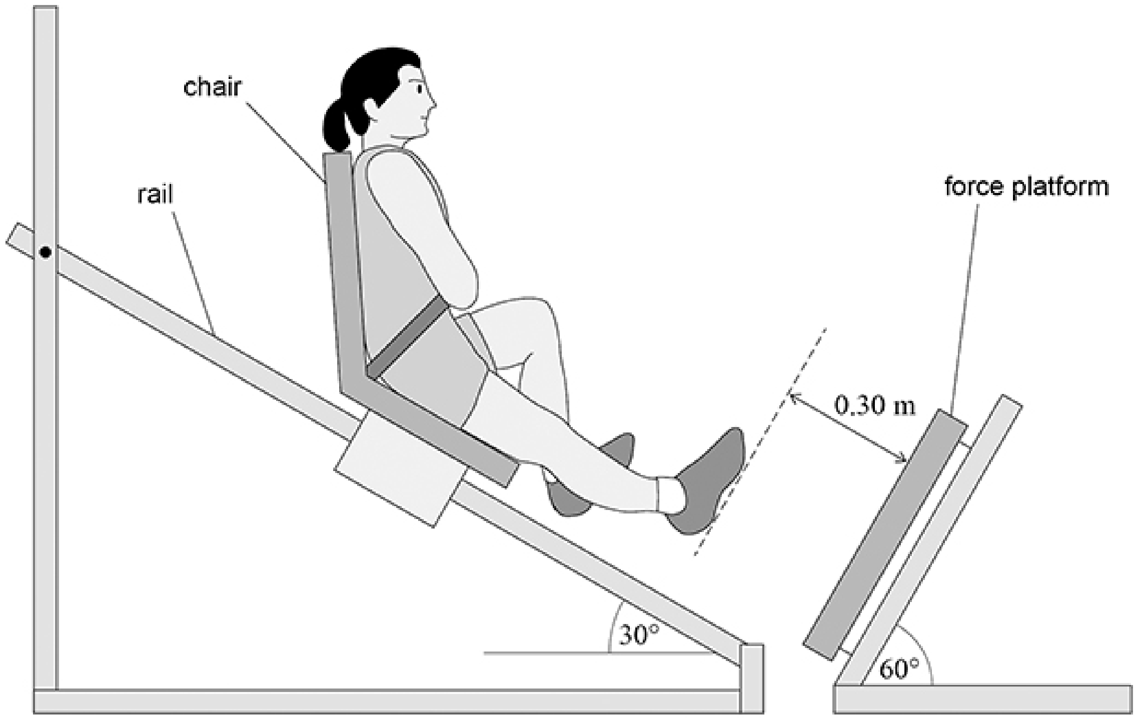
(4)

(Total 13 marks)

Q16.

Figure 1 shows apparatus used to measure the force exerted by an athlete during a single-leg jump.

Figure 1



In **Figure 1**, the athlete is strapped into a chair and held at rest halfway along a rail. The chair is then released to slide down the rail. The athlete keeps her right leg extended until her right foot makes contact with a force platform. Friction between the rail and the chair is negligible.

initial distance between right foot and platform = 0.30 m
angle between rail and floor = 30°
angle between platform and floor = 60°

(a) Show that the athlete and chair accelerate towards the platform at approximately $5\ \text{m s}^{-2}$.

(1)

(b) Calculate the speed of the athlete when her right foot makes initial contact with the platform.

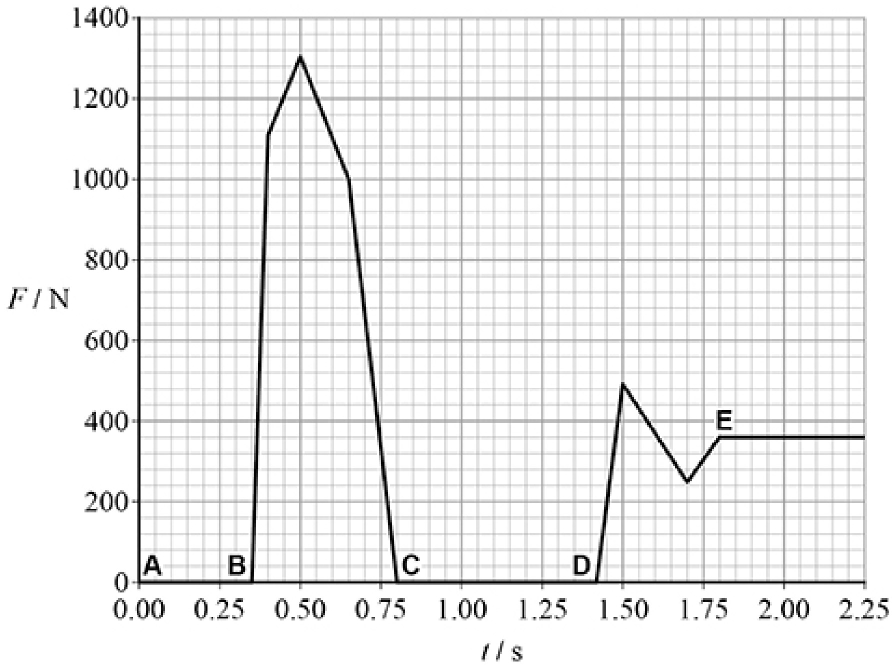
speed = _______________ m s^{-1}

(2)

After her right foot makes contact with the platform, she uses her right leg to stop moving and then push herself back up the rail. She slides down the rail again, lands on the platform with both feet and comes to rest.

Figure 2 shows the variation of force *F* on the platform with time *t* during the full motion.

Figure 2



The sequence below describes what happens at the five instances **A**, **B**, **C**, **D** and **E** shown in **Figure 2**.

A: athlete and chair are released at t = 0.00 s
B: right foot of athlete contacts the platform with leg fully extended
C: right foot loses contact with the platform
D: athlete lands on the platform with both feet
E: athlete and chair come to rest

(c) Determine the impulse provided by the force platform between **B** and **C**.

impulse = _______________ N s

(2)

(d) Determine the distance travelled by the athlete between **C** and **D**.

distance travelled = _______________ m

(3)

(e) Determine, using **Figure 2**, the combined mass of the athlete and chair.

mass = _______________ kg

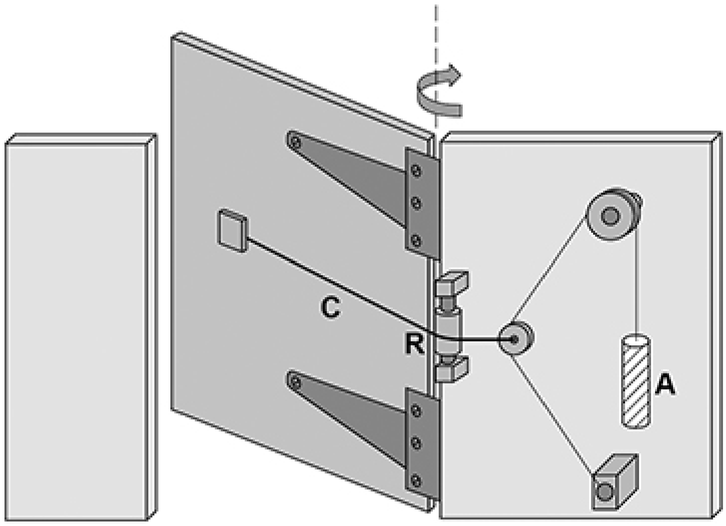
(2)

(Total 10 marks)

Q17.

Figure 1 shows a garden gate with a pulley system designed to close the gate.

Figure 1



The pulley system raises weight **A** when the gate is opened. When the gate is released, **A** falls. The horizontal cable **C** passes over pulley **R**. The tension in cable **C** causes the gate to close.

Weight **A** is a solid cylinder with the following properties:

diameter = 4.8×10^{-2} m
length = 0.23 m
weight = 35 N

The table below gives the density of three available materials.

Material	**Density / kg m^{-3}**
concrete	2.4×10^3
iron	7.8×10^3
brass	8.6×10^3

(a) Deduce which **one** of the three materials is used for **A**.

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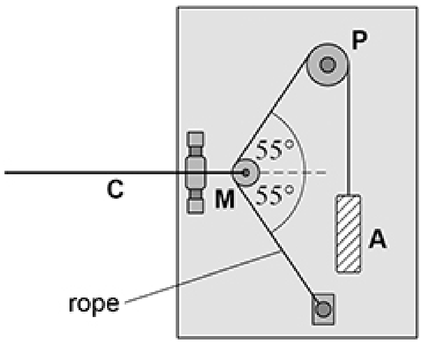
(3)

Figure 2 shows the pulley arrangement when the gate is closed.

Figure 2



Pulleys **P** and **M** are frictionless so that the tension in the rope attached to **A** is equal to the weight of **A**.
A weighs 35 N and the weight of moveable pulley **M** is negligible.

(b) Calculate the tension in the horizontal cable **C** when the gate is closed.

tension = ________________ N

(2)

(c) Pulley **M** is pulled to the left as the gate is opened.

Explain why this increases the tension in the horizontal cable **C**.

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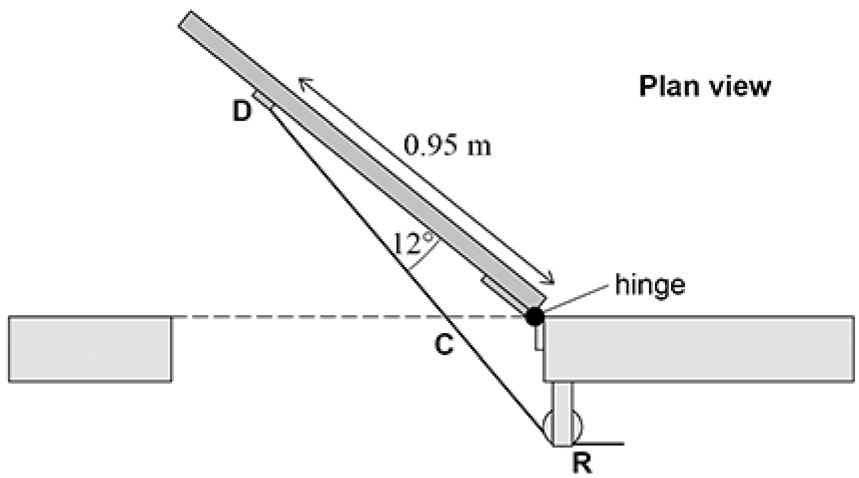
(2)

(d) **Figure 3** shows a plan view with the gate open. The horizontal cable **C** passes over pulley **R** and is attached to the door at **D**.
The angle between the door and the horizontal cable **C** is 12°.

The horizontal distance between the hinge and **D** is 0.95 m.

Figure 3



The tension in the horizontal cable **C** is now 41 N.

Calculate the moment of the tension about the hinge.

moment = ________________ N m

(2)

(e) The same system is attached to an identical gate with stiffer hinges. Now the system does not supply a sufficiently large moment to close the gate.

Discuss **two** independent changes to the design to increase the moment about the hinges due to horizontal cable **C**.

1 ______________________________

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2 ______________________________

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(4)

(Total 13 marks)