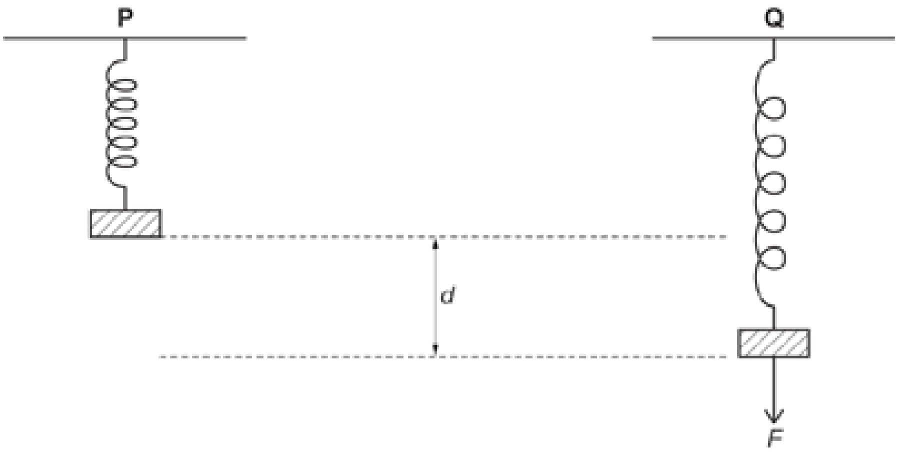
1(a). The length of an unloaded spring is approximately 4 cm.

The force constant *k* of the spring is 0.62 N cm^{-1}.

The figure below shows a block of mass 0.20 kg attached to one end of the spring. The other end of the spring is attached to a fixed support vertically above the block.

In position **P** the block rests in equilibrium. The extension of the spring is 3.2 cm.

In position **Q** a downwards force *F* has been applied to the block, so that it now rests a distance *d* below its position at **P**. The extension of the spring is now 8.5 cm.



The force *F* is removed.

i. Calculate the magnitude of the block's initial acceleration at the instant that the force *F* is removed.

Assume that the spring is not extended beyond its limit of proportionality.

acceleration = ... m s^{-2} **[3]**

ii. The block now moves with simple harmonic motion.

Calculate the frequency of this motion.

frequency = ... Hz **[3]**

(b). The block is replaced by a strong magnet **L** of slightly greater mass.

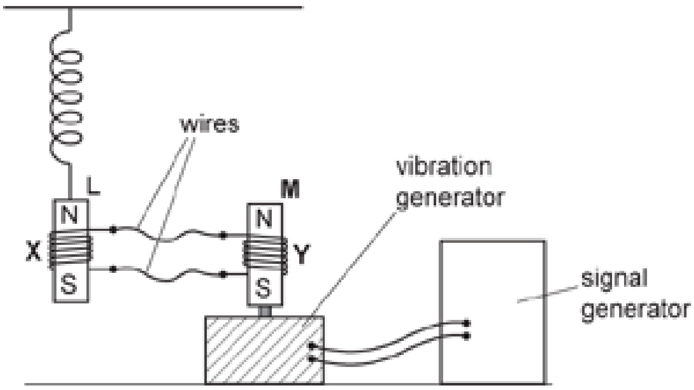
The oscillation frequency of this new arrangement is 2.5 Hz.

The magnet **L** is placed inside a coil **X** of insulated copper wire.

The coil **X** is connected with long wires to a second, identical coil **Y**.

A second strong magnet **M** is placed inside **Y** and attached to a vibration generator.

The vibration generator is then forced to oscillate with a frequency of approximately 2.5 Hz by adjusting the signal generator.



i. As magnet **M** oscillates, it moves in and out of coil **Y**.

The magnet **L** also begins to oscillate.

Explain why **L** oscillates.

[3]

ii. The frequency of the vibration generator is now varied between 0.5 Hz and 5.0 Hz.

Suggest how the amplitude and frequency of the oscillations of **L** will change as the frequency of the generator is varied.

You may draw a diagram to support your answer.

[3]

2. A model of an aircraft is being tested in a wind tunnel. The model is fixed in position by a support, and air is blown horizontally towards it by fans.

In one second, 35 kg of air moving at 50 m s^{-1} hits the model. After flowing around the model, the airflow is diverted downwards at an angle of 30° to the horizontal. The speed of the diverted airflow remains at 50 m s^{-1}.

i. Calculate the horizontal and vertical components of the velocity of the diverted airflow.

horizontal component of velocity = ... m s^{-1}

vertical component of velocity = ... m s^{-1}

[2]

ii. Explain how the airflow around the model produces a force on the model.

[2]

iii. Calculate the **vertical** lift force *F* acting on the model due to the airflow around it.

F = ... N **[3]**

3. A car drives over a bridge at speed *v*. The path of the car is part of a vertical circle of radius *r*. The mass of the driver is *m*.
At the top of the bridge the driver of the car experiences apparent weightlessness and no normal contact force from the car seat.
The acceleration of free fall is *g*.

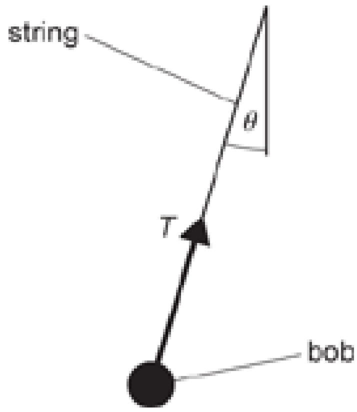
Which statement is correct?

A $mg = 0$
B $v \geq gr$
C $v^2 \geq gr$
D $mv^2 \geq gr$

Your answer ☐ **[1]**

4. The bob of a pendulum is displaced slightly so that the string forms a small angle $\theta < 10°$ with the vertical.

The tension in the string is T. The small angle approximation applies.



Which of the following pairs of quantities would give approximately, within 2 significant figures, the same value for the horizontal component of T?

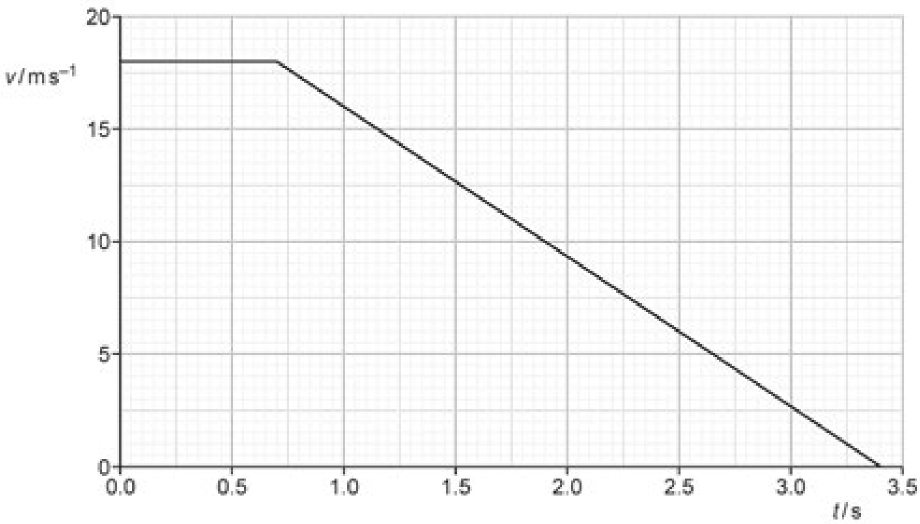
1 $T\cos\theta$ and $T\sin\theta$
2 $T\cos\theta$ and $T\tan\theta$
3 $T\sin\theta$ and $T\tan\theta$

A 1 only
B 1 and 3
C 3 only
D 2 and 3

Your answer [1]

5. The brakes of a car of mass 1200 kg are being tested on a track. The driver sees a hazard and applies the brakes.

The graph shows the variation of the velocity v of the car with time t from when the driver sees the hazard to when the car stops.



i. Calculate the acceleration *a* of the car while the brakes are applied.

a = ...m s^{-2} **[1]**

ii. Calculate the average braking force *F* while the brakes are applied.

F = ... N **[1]**

iii. Calculate the total stopping distance *d* of the car.

d = ... m **[2]**

iv. Calculate the work *W* done by the brakes to stop the car.

W = ... J **[2]**

6(a).

A sealed container contains *n* moles of an ideal gas. The gas has pressure *p*, absolute temperature *T* and occupies volume *V*.

The mass of one mole of the gas is *M*.

Use an ideal gas equation to show that the density *ρ* of the gas is given by the expression $\rho = \frac{pM}{RT}$.

[3]

(b). An airship has a cabin suspended underneath a gasbag inflated with helium.

The airship is floating above the ground and is stationary.

The volume of the gasbag is 12 000 m^3.
The temperature of the helium and the surrounding air is 20°C.
Atmospheric pressure is 1.0×10^5 Pa.
The molar mass of air is 0.029 kg mol^{-1}.
The volume of the cabin is negligible compared to the volume of the gasbag.

i. Show that the density of air under the conditions described is about 1.2 kg m^{-3}.

[1]

ii. Calculate the weight of air displaced by the airship.

weight of air .... N **[2]**

iii. Explain why the weight of air displaced by the airship has the same magnitude as the weight of the airship and its contents.

[2]

iv. The pressure of the helium in the gasbag is maintained at a value only slightly greater than atmospheric pressure.
Suggest why a larger pressure is not used.

[2]

(c). The airship engine drives a fan which moves 7.8 kg of air per second at a relative speed of 45 m s^{-1}, so the airship starts to move.

All other conditions given in **(b)** remain the same.

Calculate the thrust that the engine produces.

thrust ....N **[2]**

(d). The airship has a higher maximum speed at high altitudes, but also produces less thrust from the engine.

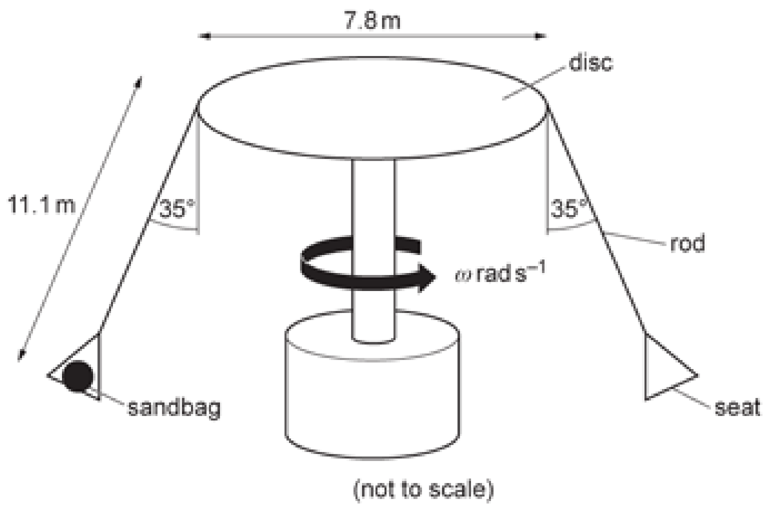
Explain these observations.

[2]

7(a). The diagram below shows a fairground ride. Each rider is secured in a seat suspended by a rod.

The distance from the top of the rod to the base of the seat is 11.1 m.

The rod is attached to the edge of a disc of diameter 7.8 m.



To test the equipment a sandbag is attached to the seat and the ride is started.

The combined mass of the seat and the sandbag is 12 kg.

The rod makes an angle of 35° with the vertical.

i. Draw an arrow labelled T on the diagram to represent the tension in the rod.

[1]

ii. Show that the radius of the circular path followed by the sandbag is about 10 m.

[2]

iii. Calculate the tension *T* in the rod.

T = ...N **[3]**

iv. Show that the angular velocity of the ride is about 0.8 radians per second.

[2]

(b). When the seat is at its highest point the sandbag is 17 m above the ground. The sandbag is released from the seat to model an object being dropped by a rider.

i. Calculate *t*, the time taken for the sandbag to reach the ground.

t = ... s **[2]**

ii. Using your answer to **(a)(iv)**, determine the horizontal displacement *s* travelled by the sandbag before hitting the ground.

s = ...m **[3]**

iii. Determine, with reasons, the effect on the horizontal displacement travelled if the object released from the ride was a shoe from a rider.

[3]

8. The table shows some data on the planet Venus.

Mass / kg	4.87×10^{24}
Radius / km	6050
Density of atmosphere at surface / kg m^{-3}	65
Period of rotation about its axis / hours	5830

Two identical space probes, **A** and **B**, land on a flat surface on Venus.

Probe **A** lands at the north pole. Probe **B** lands on the equator.

Each probe has mass 760 kg and volume 1.7 m^3.

i. Calculate the centripetal acceleration *a* of probe **B** at the equator due to the rotation of Venus about its axis.

a = ... ms^{-2} **[3]**

ii. The atmosphere exerts the same upthrust on each probe.

Using your answer to **(a)**, calculate the upthrust acting on each probe.

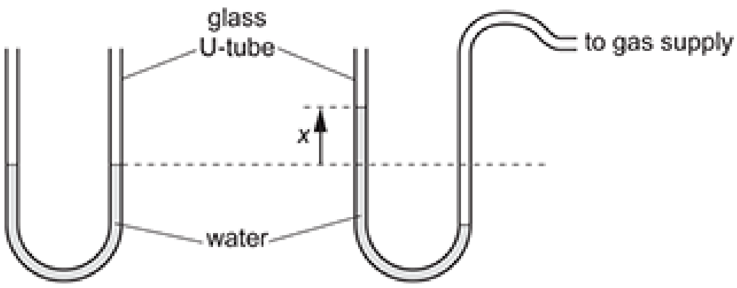
upthrust = ... N **[3]**

iii. Explain which probe will experience the greater normal contact force from the surface of Venus.

[3]

9.

The diagram shows a glass U-tube partially filled with a mass of water.



One end of the U-tube is connected to a gas supply of **constant** pressure and the other end is open to the atmosphere. The displacement of the water from its equilibrium position is x.
The density ρ of water is 1000 kg m^{-3}.

i. The pressure from the gas supply raises the water in the U-tube.
The vertical distance between the two levels of water in the two vertical sections of the U-tube is 10.0 cm (x = 5.0 cm).

Δp is the difference between the gas pressure and atmospheric pressure.
Calculate Δp.

Δp = ... Pa **[2]**

ii. When the gas supply is disconnected, the water levels in the U-tube oscillates with simple harmonic motion. The acceleration a of the water level in the left-hand side of the U-tube is given by the equation

$$a = -\frac{2\rho g A}{m}x$$

where m is the mass of the water in the U-tube, A is the internal cross-sectional area of the U-tube, ρ is the density of water, g is the acceleration of free fall and x is the displacement of the water level in the left-hand side of the U-tube.

For this U-tube, $A = 1.0 \times 10^{-4}$ m^2 and m = 0.052 kg.

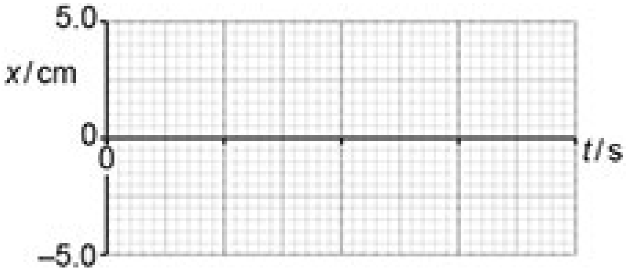
Show that the period T of the oscillations is about 1 second.

1

[3]

2 The oscillations of the water level are slightly **damped**.
At time t = 0, x = 5.0 cm.

Sketch a suitable graph of displacement x against time t for the oscillating water level. Add suitable values to the time t axis.



[3]

The U-tube is now connected to another gas supply where the pressure oscillates at a
3 frequency of about 1 Hz.

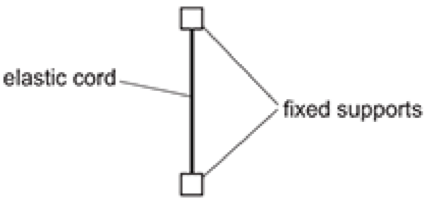
Explain the effect this will have on the water in the U-tube.

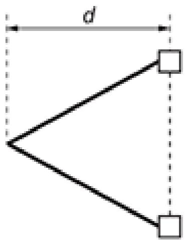
____

____

____ **[2]**

10. A simple catapult is made by an elastic cord fixed to two supports, as shown below.

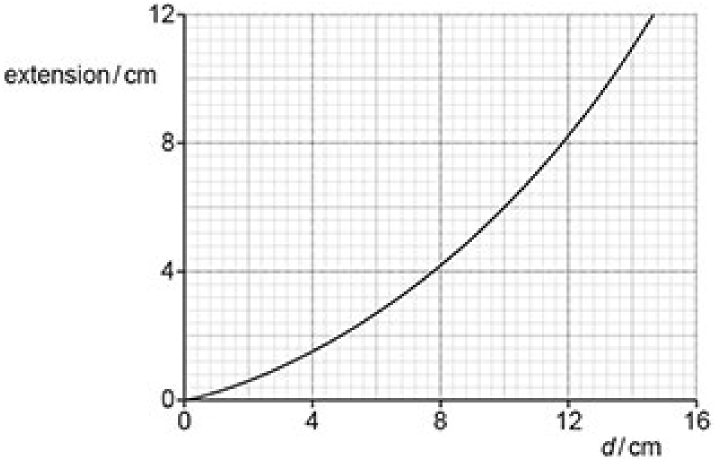




The unstretched length of the cord is the same as the distance between the supports.
The distance that the centre of the cord has been pulled back is d.

The cord has a force constant of 500 Nm^{-1}.

The variation of the extension of the cord with distance *d* is shown below.



A small ball of mass 30 g is placed at the centre of the cord and drawn back with *d* = 10 cm.

The ball is released and launched horizontally from a height of 1.5 m above the horizontal ground.

i. Use the graph to show that the elastic potential energy *E* in the cord is about 1 J.

[3]

ii. Show that the maximum speed at which the ball leaves the catapult is about 8 ms^{-1}.

[2]

iii. Calculate the horizontal distance *R* travelled by the ball before it strikes the horizontal ground. Ignore the effects of air resistance in your calculation.

R = ... m **[3]**

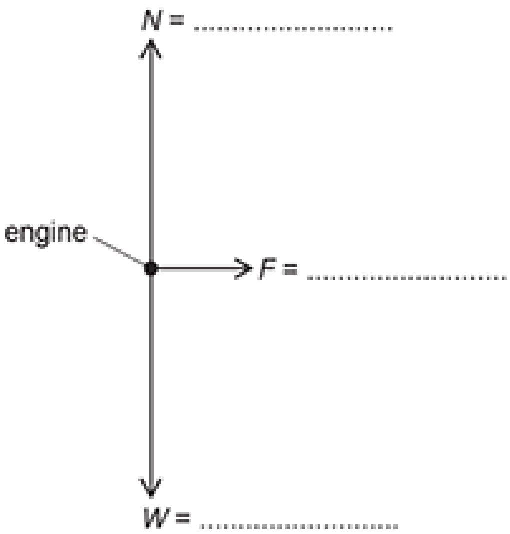
iv. Explain how the value of *R* calculated in **(iii)** compares with the actual value.

[2]

11. An electric engine of mass 17 000 kg has a constant power output of 280 kW and it can reach a maximum speed of 42 ms^{-1} on horizontal rails. The maximum kinetic energy of the engine is 15 MJ.

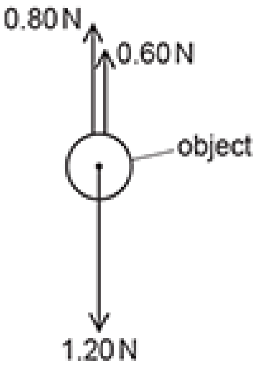
The engine is moving along the horizontal rails at the constant maximum speed of 42 ms^{-1}.
The weight of the engine is *W*, the total normal contact force from the rails is *N* and the total friction between the wheels and the rails is *F*.
F is responsible for the motion of the engine to the **right**.

Complete the free body diagram for the engine by showing a missing force, and the magnitudes of all the forces. There is space for you to do any calculations below the diagram.



[3]

12. The diagram below shows the directions and magnitudes of the three forces acting on an object at a specific time as it moves through water.



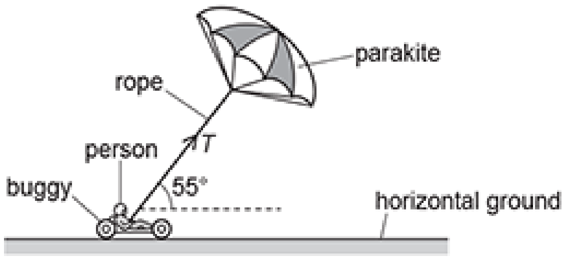
The weight of the object is 1.20 N, the upthrust on the object is 0.80 N and the drag is 0.60 N.

Which statement is correct about this object at this specific time?

A It has reached its terminal velocity.
B It is accelerating.
C It is decelerating.
D It is moving upwards.

Your answer ☐ **[1]**

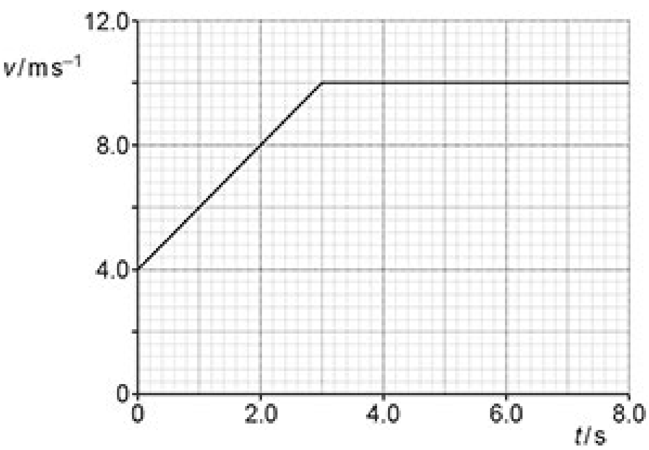
13. A person in a buggy is attached to a large parakite by a rope, as shown below.



Strong wind acting on the parakite moves the buggy along horizontal ground.

The rope makes an angle of 55° to the horizontal. The total mass of the buggy and person is 150 kg.

The velocity *v* against time *t* graph for the buggy is shown below.



At t = 1.0 s the buggy is accelerating.

i. Use the graph to show that the acceleration of the person at t = 1.0 s is 2.0 m s^{-2}.

[1]

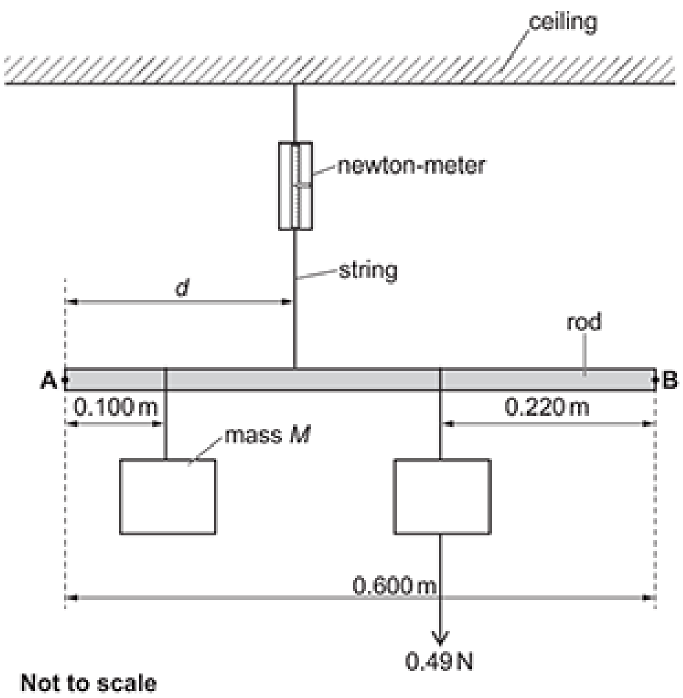
ii. At t = 1.0 s the tension T in the rope is 680 N and the total **horizontal** resistance acting on the buggy and person is R.

Calculate R by resolving the tension in the rope horizontally.

R = ... N **[3]**

14.

The diagram shows a uniform rod which is in equilibrium. The rod has a circular cross-section and has length 0.600 m and weight 2.1 N.



Mass M is suspended at a distance of 0.100 m from point **A**.
A weight of 0.49 N is suspended at a distance of 0.220 m from point **B**.
A string is attached to the rod at a distance d from point **A**.
The tension in the string, measured by the newton-meter (force meter), is 3.9 N.

i. Show that M is about 0.13 kg.

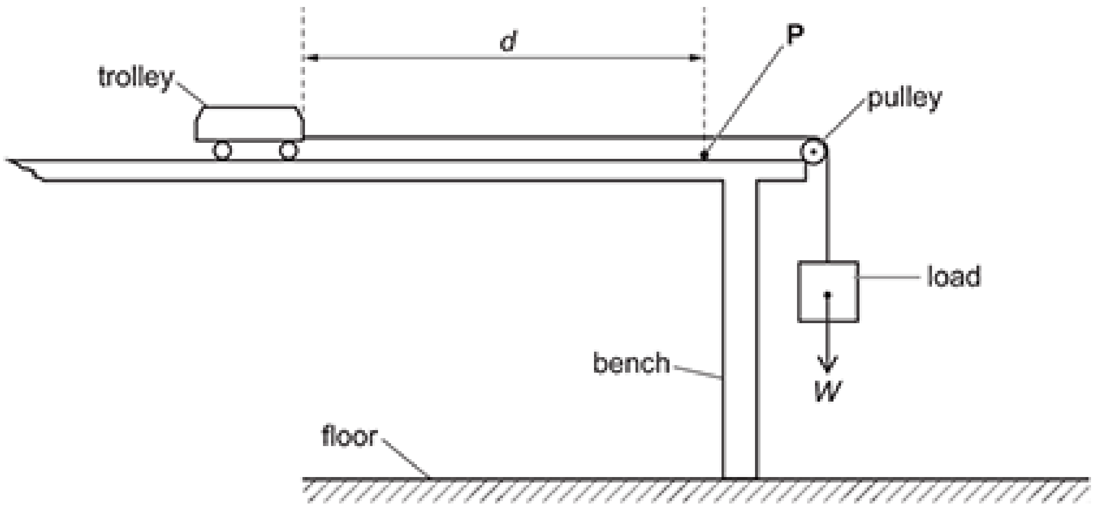
[2]

ii. By taking moments about point **A**, determine d.

d = ... m **[3]**

15. *A student is investigating the motion of a trolley as it accelerates from rest along a horizontal surface.

The diagram shows the trolley on a horizontal surface. A load of weight W accelerates the trolley.



Point **P** is a distance d from the initial position of the trolley.
A light gate connected to a timer is used to determine the velocity v of the trolley at point **P**.

It is suggested that the relationship between v and the mass M of the trolley is $\frac{1}{v^2} = \frac{M}{2dW - Q} + R$

where Q and R are constants.

Describe, with the aid of a suitable diagram,

- how an experiment can be safely conducted to test this relationship between *v* and *M*, and,
- how the data can be analysed to determine Q and R.

[6]

END OF QUESTION PAPER