

Questions

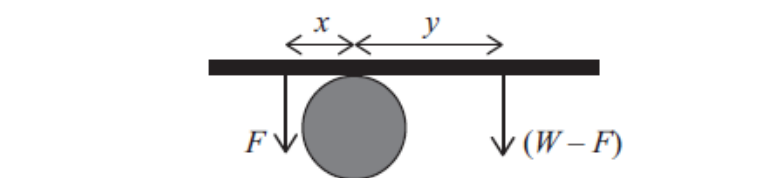
Q1.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A student puts a piece of wood on top of a cylinder. He stands on the wood with his feet at distances x and y from the cylinder.

The weight of the student is W .

The diagram shows the force of each foot acting on the wood.



The wood is horizontal and in equilibrium.

The weight of the wood is negligible.

Which of the following expressions is equal to W ?

☐ A $\frac{Fx}{y} + F$

☐ B $\frac{Fx}{y} - F$

☐ C $\frac{Fy}{x} + F$

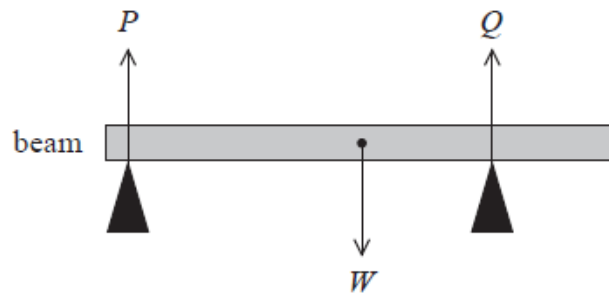
☐ D $\frac{Fy}{x} - F$

(Total for question = 1 mark)

Q2.

Select one answer from A to D and put a cross ☐ in the box. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

A beam is balanced on two supports as shown.



The beam has a weight W and the reaction forces at the two supports are P and Q .

Which of the following statements about the magnitudes of the forces is correct?

- ☒ **A** $P > Q$
- ☐ **B** $Q > W$
- ☐ **C** $Q > P$
- ☐ **D** $(P + Q) > W$

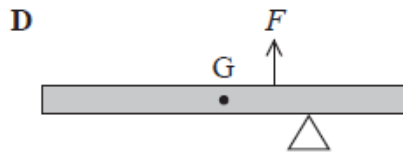
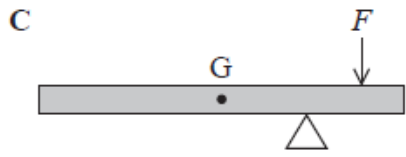
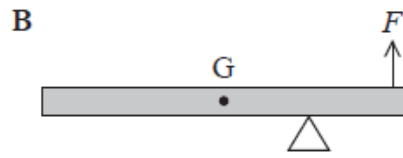
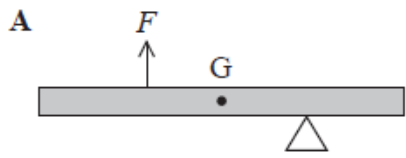
(Total for question = 1 mark)

Q3.

Answer the question with a cross in the box you think is correct ☐. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☐.

A beam is supported by a pivot as shown in the diagrams. The centre of gravity of the beam is at G. The beam is acted on by a force F .

Which diagram shows an arrangement where the beam could **not** be in equilibrium?



☐ **A**

☐ **B**

☐ **C**

☐ **D**

(Total for question = 1 mark)

Q4.

All quantities may be expressed in terms of SI base units.

Which of the following are the base units for the moment of a force?

(1)

☐ **A** kg m s^{-2}

☐ **B** $\text{kg m}^2 \text{s}^{-2}$

☐ **C** kg m s^{-1}

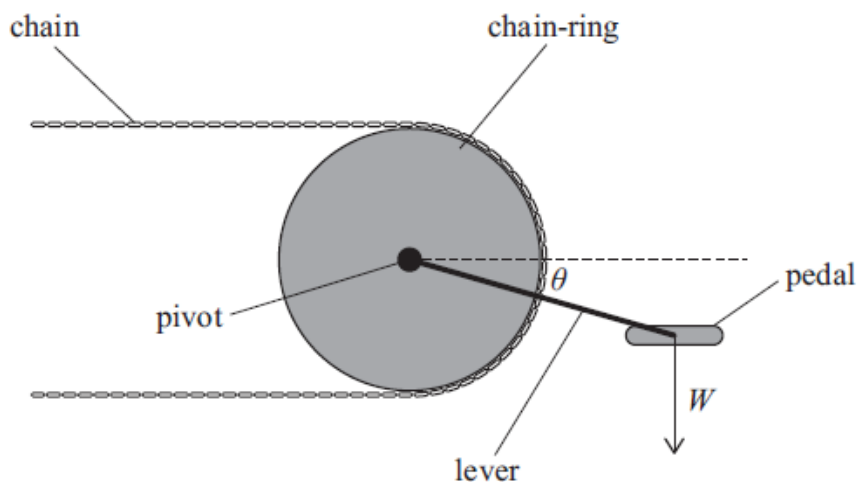
☐ **D** $\text{kg m}^2 \text{s}^{-3}$

(Total for question = 1 mark)

Q5.

A bicycle pedal is connected to a circular 'chain-ring' by a lever. A person of weight W stands on the pedal.

The lever is at an angle θ to the horizontal, as shown.



(a) Determine the moment of W about the pivot when θ is 24° .

$W = 580 \text{ N}$

length of lever = 0.21 m

(3)

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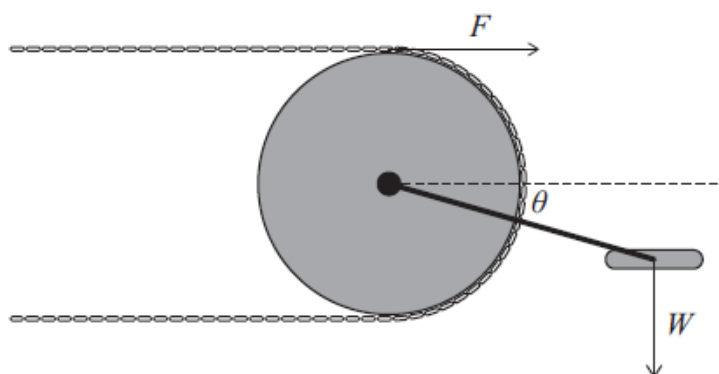
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Moment = ...

(b) The chain-ring exerts a force F on the chain, as shown.



F is proportional to the moment of W about the pivot.

Explain how F changes as θ increases from 0° to 90° .

You do not need to do any calculations.

(2)

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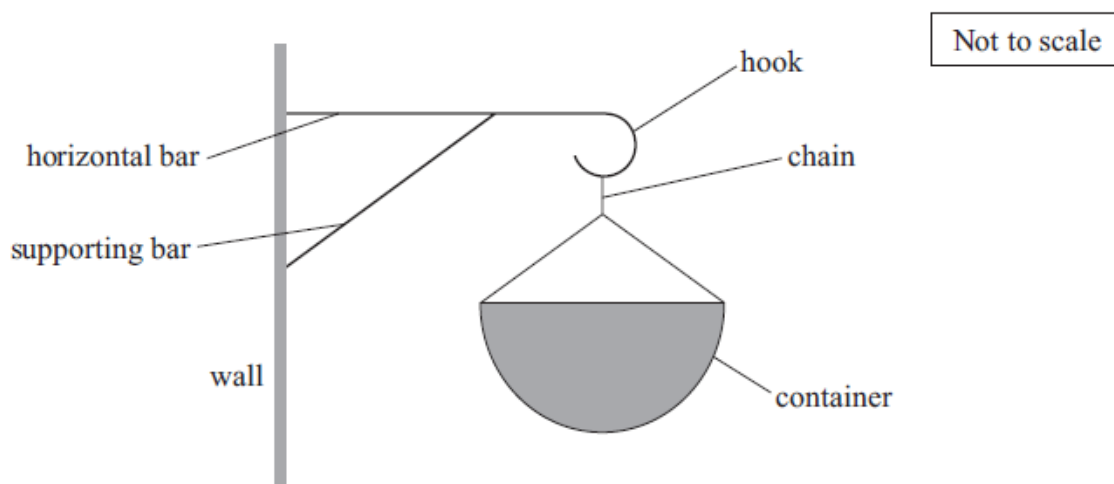
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(Total for question = 5 marks)

Q6.

A container is used to hold plants. The container hangs by a chain from a bracket attached to a wall, as shown.



The bracket has a horizontal bar with a hook at one end. There is a supporting bar beneath the horizontal bar.

(a) The container is in equilibrium.

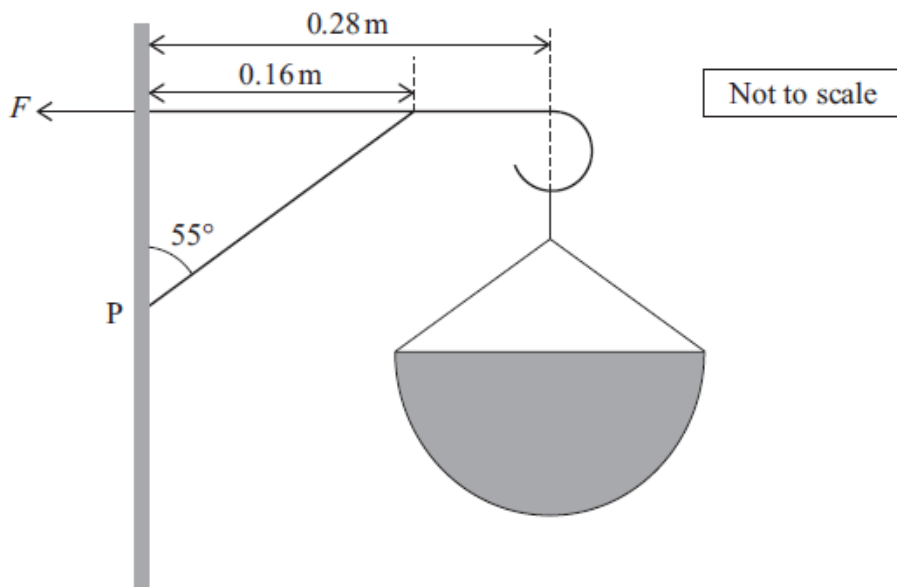
State why the centre of gravity of the container is vertically below the chain.

(1)

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(b) A screw in the wall exerts a force F on the horizontal bar, as shown.



The weight of the container is 34 N .

The mass of the bracket is negligible.

Determine force F .

You should take moments about point P .

(4)

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$F =$

(Total for question = 5 marks)

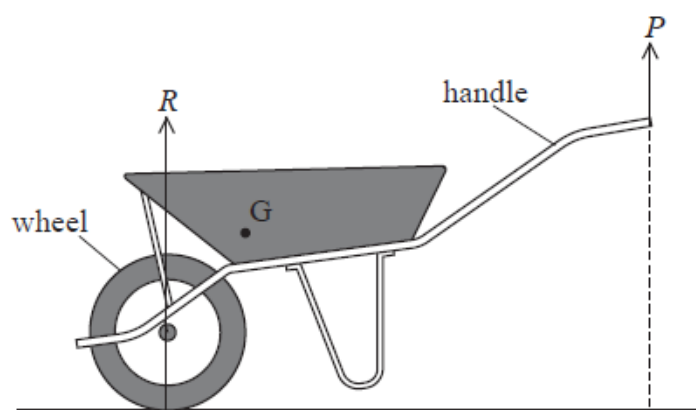
Q7.

A woman supports a stationary wheelbarrow by exerting an upward force P on the handles. An upward force R from the ground acts on the wheel, as shown.

The centre of gravity G of the wheelbarrow is marked on the diagram.



(Source: © Cavan Images/Alamy Stock Photo)



(a) Explain, by considering moments about G , why P is less than R .

(3)

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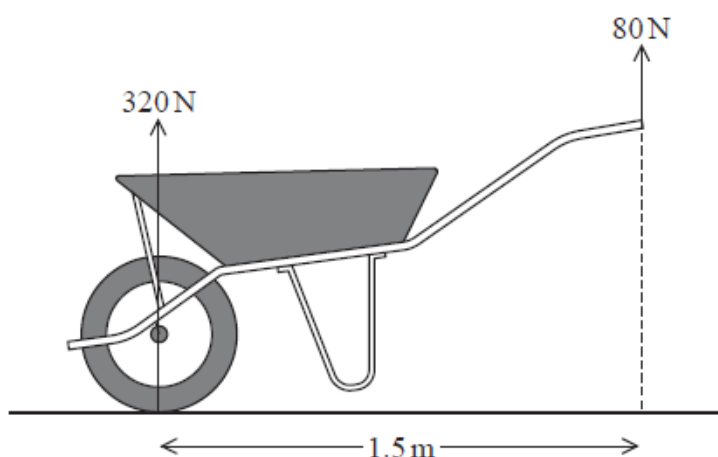
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(b) The horizontal distance between the centre of the wheel and the handles is 1.5 m.

The magnitudes of P and R are as shown.



Determine the horizontal distance between the centre of gravity of the wheelbarrow and the centre of the wheel.

(4)

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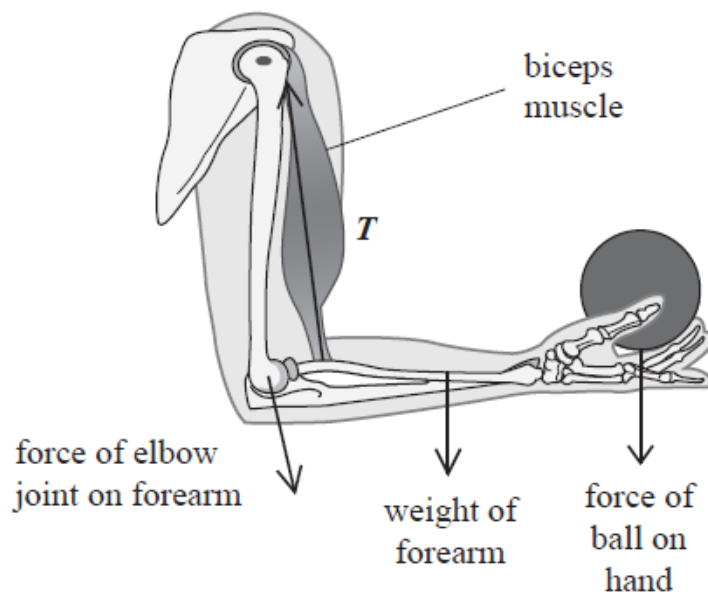
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Horizontal distance = ...

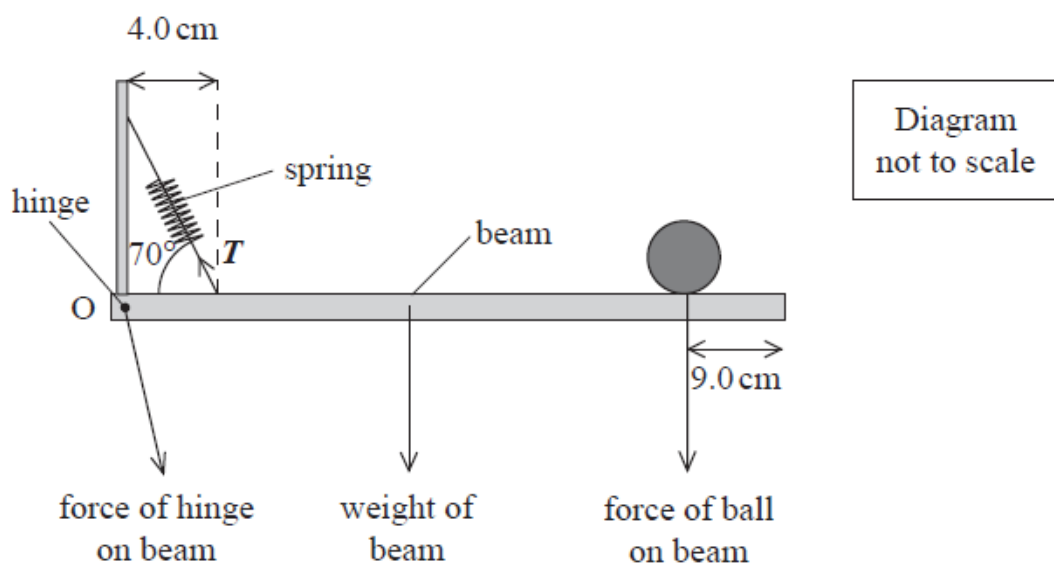
(Total for question = 7 marks)

Q8.

Muscles move body parts by contracting and relaxing. For the forearm to hold a ball in the position shown, the biceps muscle contracts, creating a tension T in the muscle as shown.



A student modelled the forces on the forearm using a uniform beam and spring arrangement as shown below. The length and weight of the beam were the same as the length and weight of the forearm.



(a) It can be assumed that the biceps muscle acts as a spring at an angle of 70° to the beam, 4.0 cm from the pivot O.

Determine the magnitude of T . You will need to estimate the total length of the forearm and hand.

force of ball on beam = 4.5 N
weight of beam = 15 N

(5)

Estimate of total length of forearm and hand = ...

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$T =$

(b) Explain a limitation of using a beam to model the forearm.

(2)

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(Total for question = 7 marks)

Q9.

Two brackets, A and B, support a shelf of length 1.2 m. Bracket A is positioned 0.15 m from the left-hand end of the shelf. A book is placed 0.35 m from the left-hand end of the shelf as shown.



(a) The normal contact forces of each bracket on the shelf are equal.

Determine the distance of bracket B from the left-hand end of the shelf.

weight of book = 8.5 N
weight of shelf = 14 N

(5)

This image shows a full page of white paper with horizontal dashed lines, typical of primary school writing paper. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Distance = ...

(b) Bracket B is moved closer to the left-hand end of the shelf.

Explain the effect on the magnitude of the normal contact force of bracket B on the shelf.

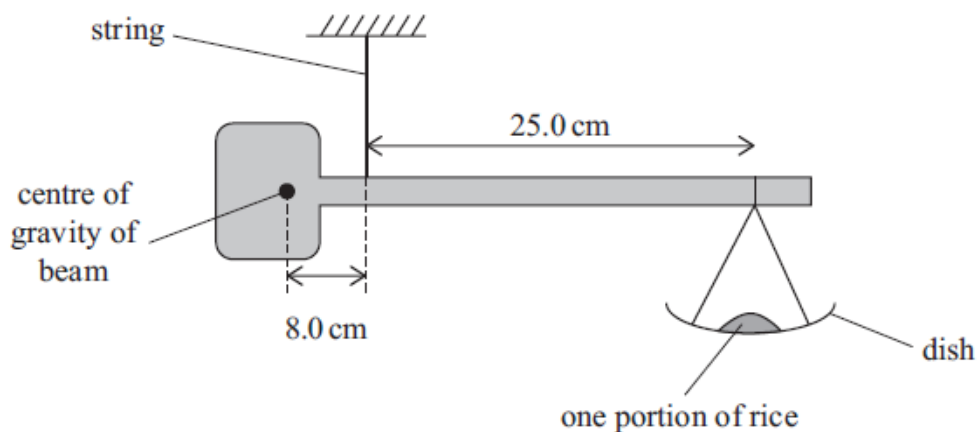
(2)

(Total for question = 7 marks)

Q10.

A balance is formed by a beam suspended from a string. A dish is hung from the beam and the balance is used to measure a fixed portion of rice.

When the dish contains one portion of rice, the balance is in equilibrium, as shown.



(a) State the conditions needed for an object to be in equilibrium.

(2)

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(b) The dish is moved along the beam so that the horizontal distance from the string to the dish is 7.0 cm.

Rice is added to the dish until the balance is in equilibrium.

Deduce whether the dish now contains 3 portions of rice.
You should include a calculation of the weight of 1 portion of rice.

weight of beam = 3.1 N
weight of empty dish = 0.64 N

(6)

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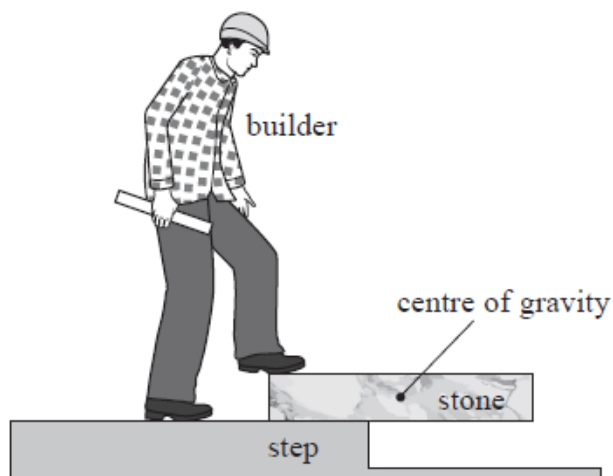
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(Total for question = 8 marks)

Q11.

A builder is making a path using uniform rectangular stones. A stone is resting horizontally on a step and is held in equilibrium by the builder's foot.

The centre of gravity of the stone is at its centre, as shown.



(a) (i) State what is meant by equilibrium.

(2)

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(ii) State what is meant by the centre of gravity of an object.

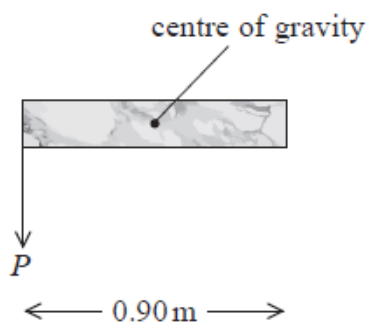
(1)

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(b) The builder applies the minimum force P that will keep the stone in equilibrium.

(i) The position and direction of P are shown on the diagram below.

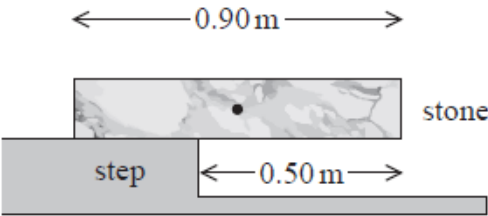


Complete the diagram above by adding labelled arrows to show the positions and directions of the other forces acting on the stone.

(2)

(ii) The stone has a weight of 415 N and a length of 0.90 m.

The length of the stone beyond the edge of the step is 0.50 m, as shown below.



The centre of gravity is at the centre of the stone.

Calculate the magnitude of P .

(3)

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Magnitude of P = ...

(Total for question = 8 marks)

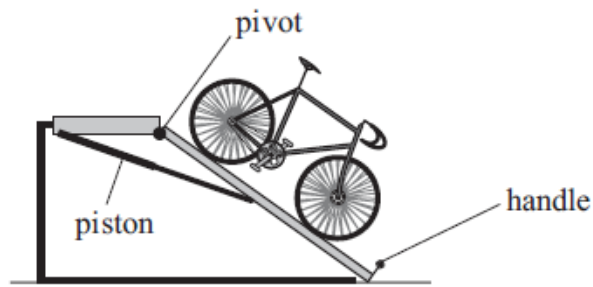
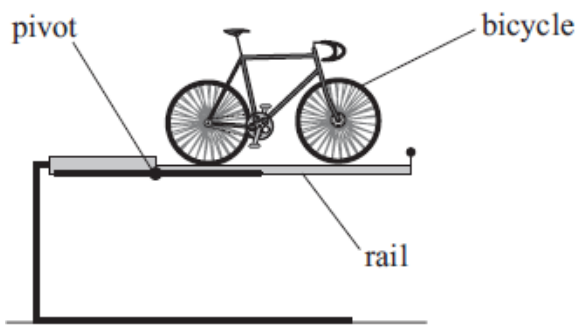
Q12.

A student stores her bicycle on a rack.

The bicycle rests on a rail that can rotate about a pivot.
To take the bicycle off the rack, the student uses a handle to lower one end of the rail to the ground.

A piston applies a force to the rail as the rail is lowered to the ground.

The diagrams show the bicycle on the rack before and after the rail has been lowered to the ground.



(a) When the rail is in equilibrium, the principle of moments applies.

State what is meant by the principle of moments.

(1)

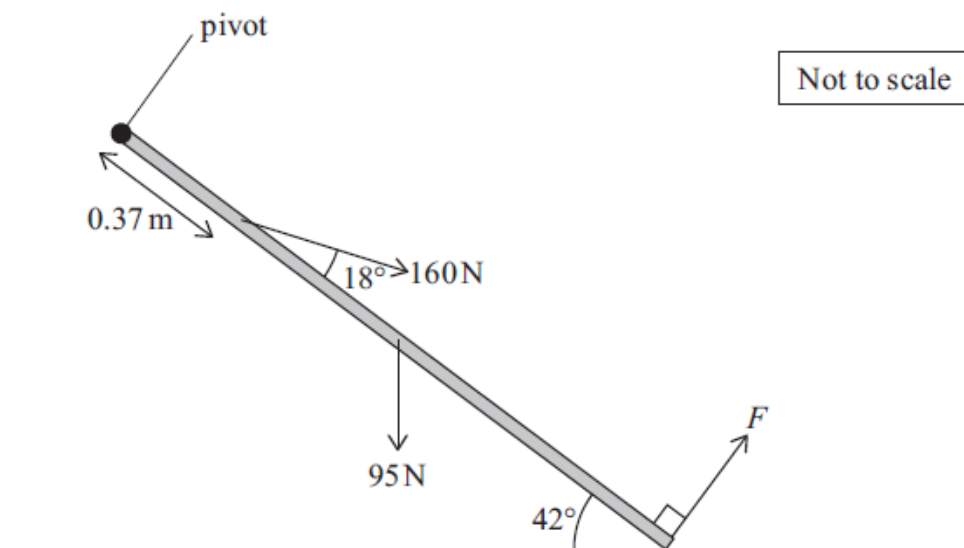
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(b) After taking the bicycle off the rack, the student lifts the rail back to its original position.

(i) The uniform rail has a length of 1.40 m and a weight of 95 N.

The student applies a force F to the handle, perpendicular to the rail. The piston applies a force of 160 N to the rail.

The diagram shows these forces acting on the rail.



Determine the minimum value of F needed to lift the end of the rail off the ground.

(5)

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Minimum value of $F = \dots\dots\dots$

The force needed to lift the rail is different when the force is vertical compared with when the force is perpendicular to the rail.

You do not need to include any further calculations.

[illegible]

(Total for question = 9 marks)

The photograph shows Tower Bridge, a bridge in London. The middle part of the bridge can be raised in two sections to allow boats to travel along the river. Each section can rotate about a pivot.

section of
bridge

pivot



(Source: © BrianAJackson/Getty Images)

(a) State what is meant by the principle of moments.

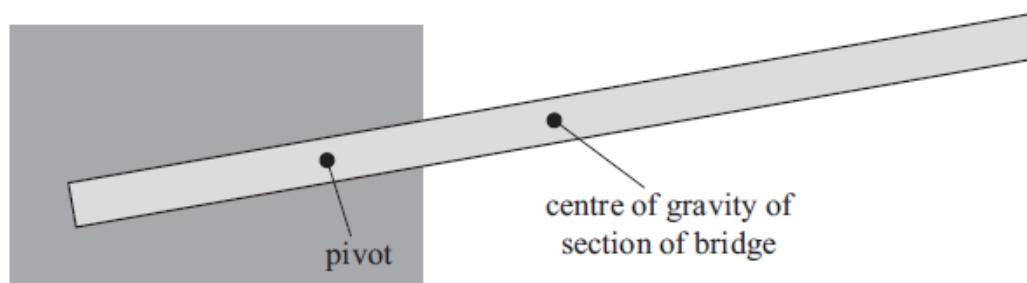
(1)

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(b) To raise a section of the bridge, a motor applies a moment about the pivot.

(i) The diagram shows a section of the bridge being raised.



Explain the direction of the moment about the pivot, caused by the motor, as the section is raised.

(2)

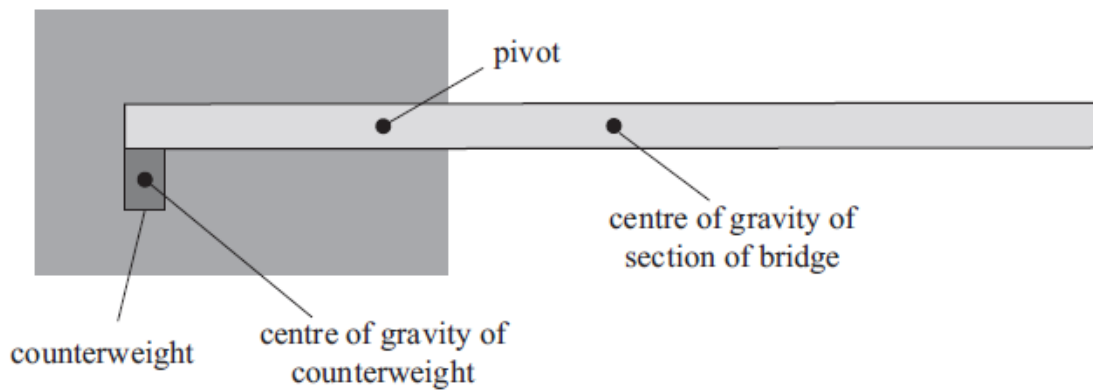
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(ii) Each section of the bridge has a heavy counterweight fixed to one end, as shown.



Explain how adding the counterweight affects the work done by the motor to raise the section of the bridge.

(3)

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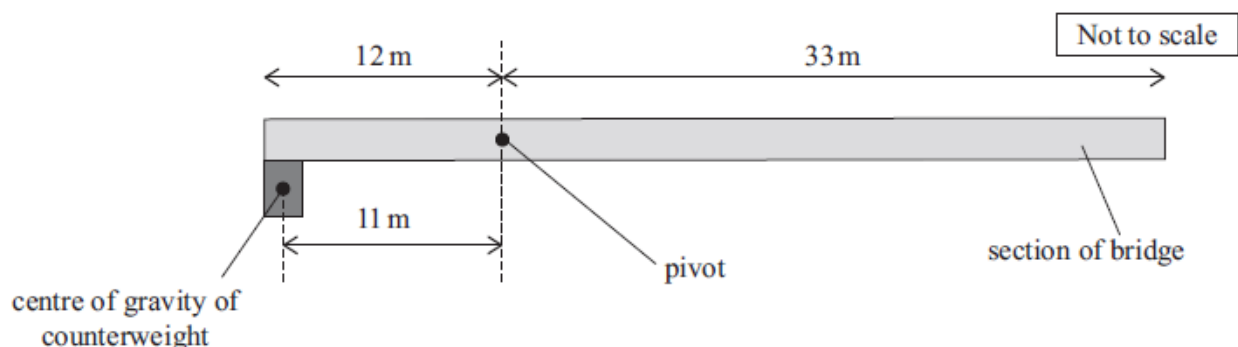
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(iii) The section of the bridge is uniform. The pivot is 12 m from one end of the section of the bridge and 33 m from the other end.

The perpendicular distance from the centre of gravity of the counterweight to the pivot is 11 m, as shown.



A bus was moving across Tower Bridge when the motor began to raise the section of the bridge.

When the centre of gravity of the bus was 28 m from the pivot, the section of the bridge was in equilibrium.

Determine the magnitude of the moment produced by the motor on this section of the bridge.

weight of bus = 71 kN

weight of section of bridge = $1.2 \times 10^7 \text{ N}$
weight of counterweight = $4.0 \times 10^6 \text{ N}$

(4)

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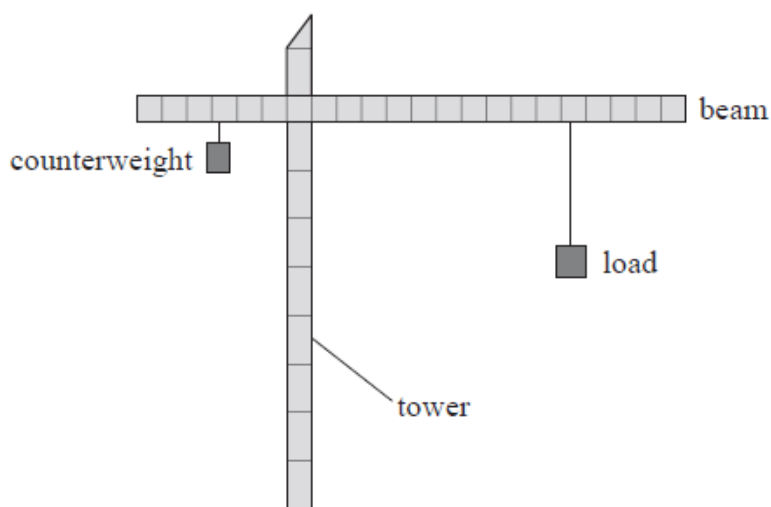
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Magnitude of moment produced by motor = ...

(Total for question = 10 marks)

Q14.

The diagram shows a crane lifting a load. There is a large mass called a counterweight attached to the crane, on the opposite side of the tower to the load.



(a) The crane has an electric motor with an efficiency of 47%.

The crane lifts a load of $4.4 \times 10^4 \text{ N}$. The load moves through a vertical distance of 15 m in a time of 70 seconds.

Determine the average power input to the electric motor.

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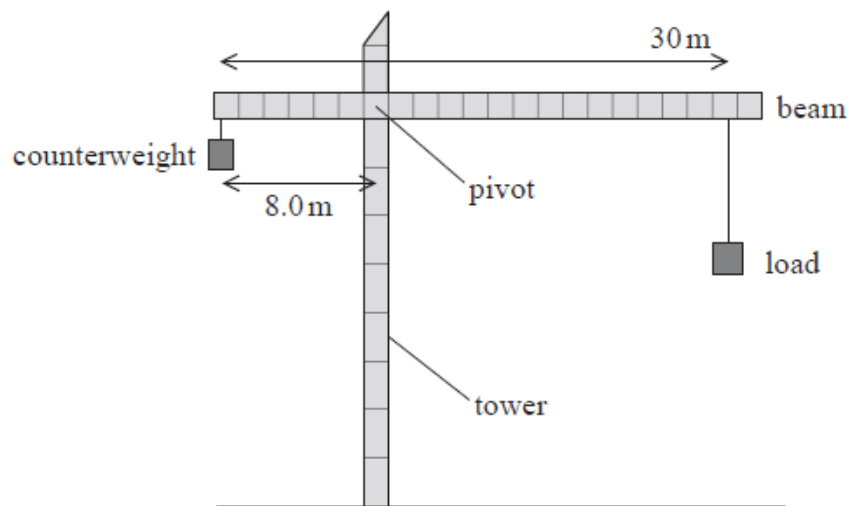
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Average power input = ...

(b) The horizontal distance from the load to the tower can be changed. The horizontal distance from the counterweight to the tower can also be changed.



(i) Explain how the counterweight needs to move when the load is moved away from the tower.

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(ii) The beam is uniform with a weight of $3.0 \times 10^4 \text{ N}$.

The counterweight has a weight of $1.1 \times 10^5 \text{ N}$.

The load has a weight of $4.4 \times 10^4 \text{ N}$.

Deduce whether the load can be moved to the end of the beam without the crane toppling.

(5)

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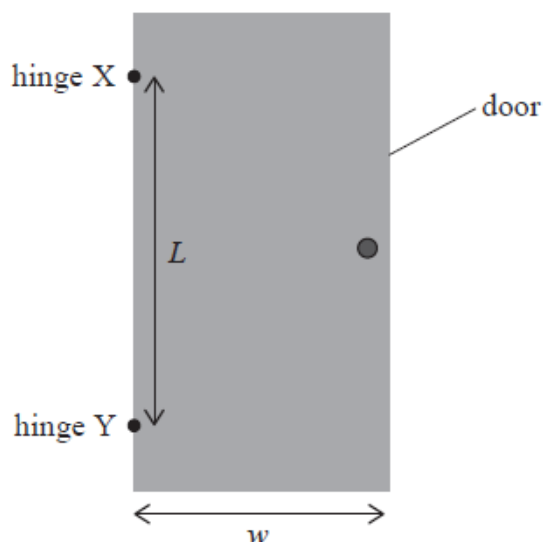
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(Total for question = 13 marks)

Q15.

A uniform door of width w is supported by two hinges, X and Y.
X and Y are a vertical distance L apart as shown.



(a) State the conditions needed for the door to be in equilibrium.

(2)

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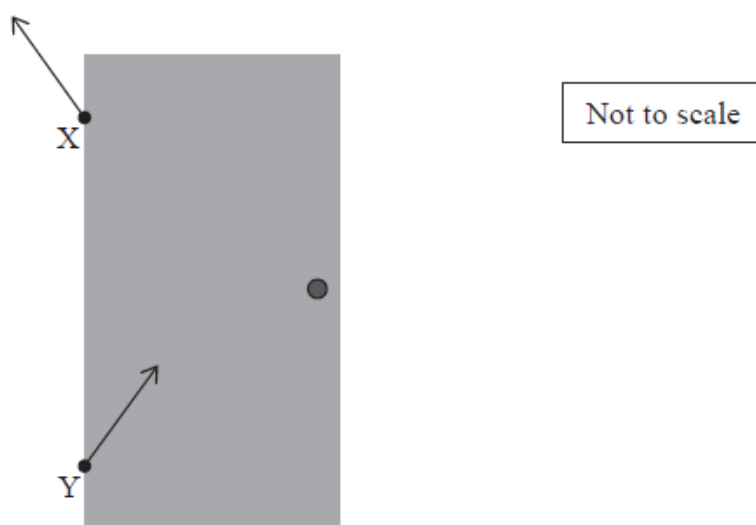
(b) Give the meaning of the term centre of gravity.

(1)

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(c) The diagram shows the force acting on the door at each hinge.



The mass of the door is 14.4 kg.

The weight of the door causes a moment about each hinge.

(i) Show that the horizontal component of the force of hinge Y on the door is about 40 N.

$$L = 1.60 \text{ m}$$

$$w = 0.85 \text{ m}$$

(5)

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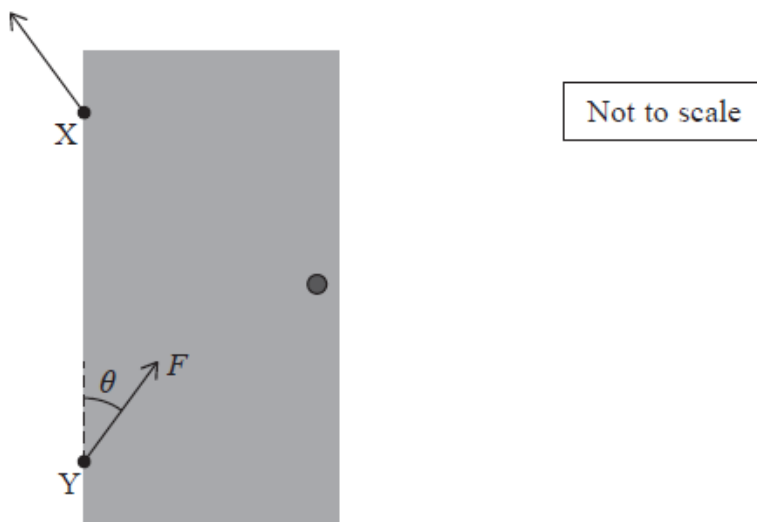
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(ii) The vertical component of the force of each hinge on the door is equal to half the weight of the door.

Hinge Y exerts a force F on the door at an angle θ to the vertical, as shown.



Determine the force F and the angle θ .

(4)

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$$F = ...$$

$$\theta = ...$$

(iii) An identical door is supported by hinges that are much closer together.

Explain how a smaller value of L affects F and θ .

You should consider moments about point X.

(4)

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(Total for question = 16 marks)