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Question

Moments

A-level Maths Topic Summaries - Mechanics

Subject & topics: Mechanics | Dynamics **Stage & difficulty:** A Level P3

Fill in the boxes to complete the notes on moments.

Part A

Introducing moments

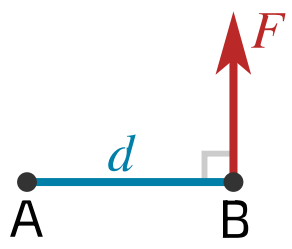

Figure 1: A rod AB, with a force F acting at B.

A moment is a measure of the [ ] of a force. Moments have both a [ ] and a direction ([ ] or anticlockwise).

In **Figure 1** a force acts on a rod AB at point B. The force is [ ] to the rod. The size of the moment is equal to the force times the distance from A to B.

$$\text{Size of moment} = [\ ]$$

The direction of the moment about A is [ ].

As a moment is a force multiplied by a distance, the units for moments are [ ] (or sometimes $\mathrm{N\,cm}$).

For an object in equilibrium, the total of the moments about any point is [ ].

Items:

anticlockwise | clockwise | $F \times d$ | $\mathrm{N\,m}$ | perpendicular | size | turning effect | zero

Part B

Non-perpendicular forces

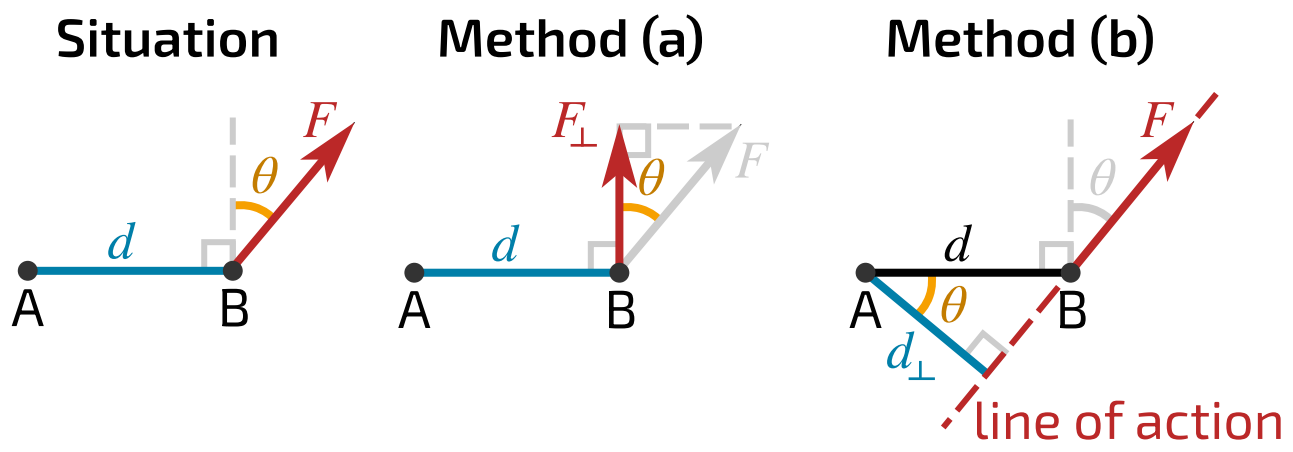

Figure 2: A rod AB, with a non-perpendicular force F acting at B.

Figure 2 shows a situation in which the force at B is not perpendicular to the rod AB. The force is at an angle θ to the perpendicular.

The direction of the moment of the force about A is anticlockwise. There are two equivalent ways to calculate the size of the moment. In both cases we need to resolve once.

Method (a)

We start by finding $F_\perp$, the component of the force perpendicular to the rod. We get $F_\perp =$ [ ]. The moment is equal to $F_\perp$ times the distance from A to B.

$$\text{Moment} = F_\perp \times d = \boxed{} \times d$$

Method (b)

The **line of action** of a force is the line along which the force acts.

We start by finding $d_\perp$, the perpendicular distance from A to the line of action of the force. We get $d_\perp =$ [ ]. The moment is equal to the force multiplied by the perpendicular distance to the line of action.

$$\text{Moment} = F \times d_\perp = F \times \boxed{}$$

Items:

$d\cos\theta$ $d\sin\theta$ $F\cos\theta$ $F\sin\theta$

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Question

Moments 3ii

Subject & topics: Maths **Stage & difficulty:** A Level P2

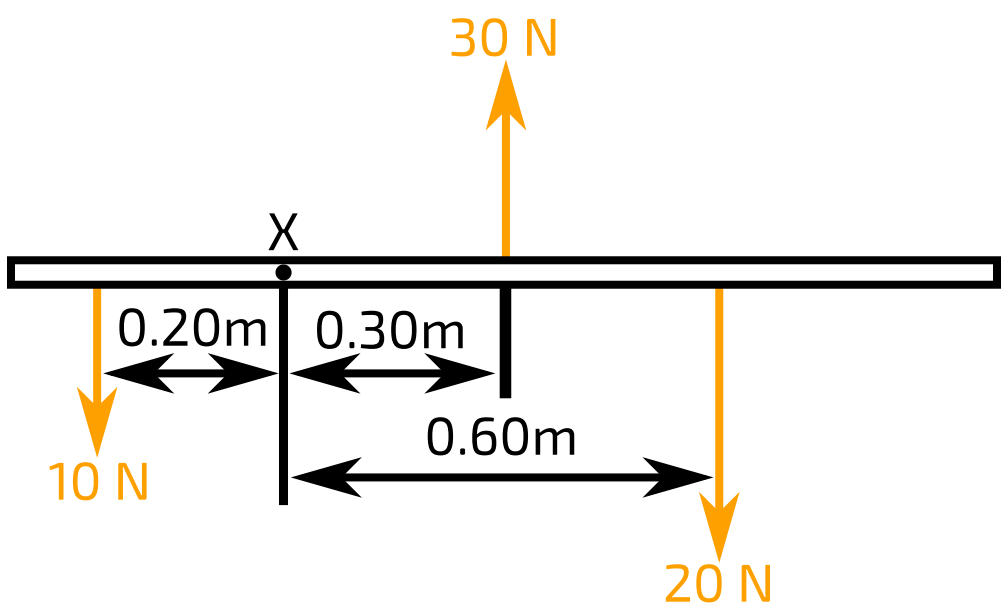

Figure 1: Three forces acting on a rod.

Figure 1 shows three forces acting on a rod.

Part A

Moments about X

Find the clockwise moment about point X.

Find the sum of the two anticlockwise moments about point X.

Part B

Is the rod in equilibrium?

Is the rod in equilibrium? If not, in which direction will it rotate?

- Yes
- No, and it will rotate clockwise
- No, and it will rotate anticlockwise
- No, but it is impossible to tell which way it will rotate
- It's impossible to tell whether it is in equilibrium

Part C

Additional force

An additional force of $4\,\mathrm{N}$ can be applied so that the system is then in equilibrium.

Find the distance from X of the line of action for the additional force. The line of action must be applied perpendicular to the length of the rod.

Adapted with permission from UCLES, A Level, January 2011, OCR Physics A G481, Question 6

Question deck:

STEM SMART Single Maths 43 - Moments

Question

Moments 4ii

Subject & topics: Maths **Stage & difficulty:** A Level P2

A concrete paving slab has mass $45\,\mathrm{kg}$ and dimensions $0.600\,\mathrm{m} \times 0.600\,\mathrm{m} \times 0.050\,\mathrm{m}$. **Figure 1** shows the paving stone in equilibrium.

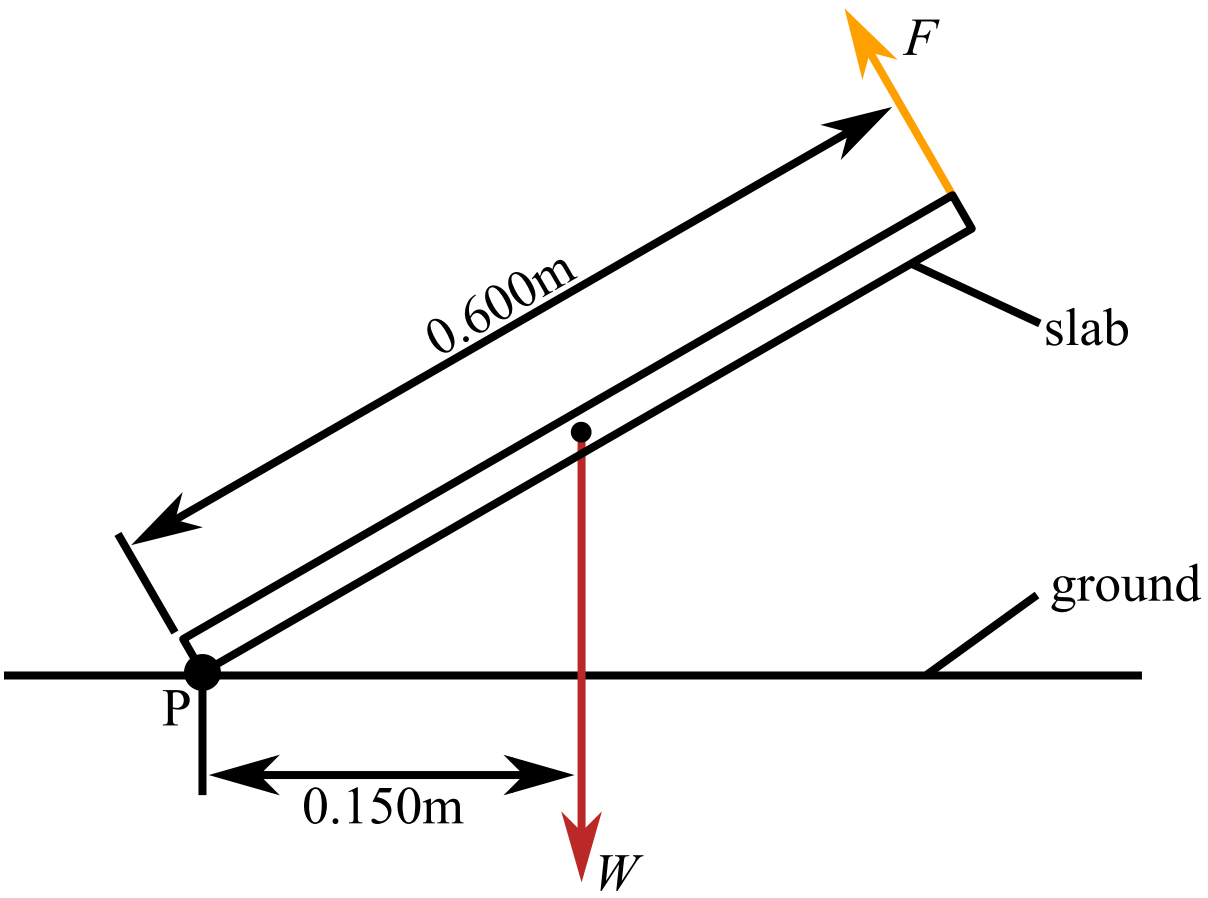

Figure 1: A concrete paving slab in equilibrium.

Part A

Magnitude of F

Two forces acting on the slab are shown. The weight of the slab is W, which is shown acting downwards from the centre of the slab. The force F is applied at right angles to the end of the slab.

By taking moments about P, determine the size of the force F.

Part B

Assumptions necessary

Which of these assumptions are used in part A? Choose all options that apply.

- [ ] We assumed that the ground is smooth, so that there is no friction force between the slab and the ground to consider.
- [ ] We assumed that the force F is provided by a string that is light, so that there is no mass associated with the force F to consider.
- [ ] We assumed that the mass is uniformly distributed throughout the slab so the weight is acting through the geometrical centre of the slab (ie, the centre of mass).

Adapted with permission from UCLES, A Level, June 2010, OCR Physics A G481, Question 6

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Question

Moments 5i

Subject & topics: Maths **Stage & difficulty:** A Level P2

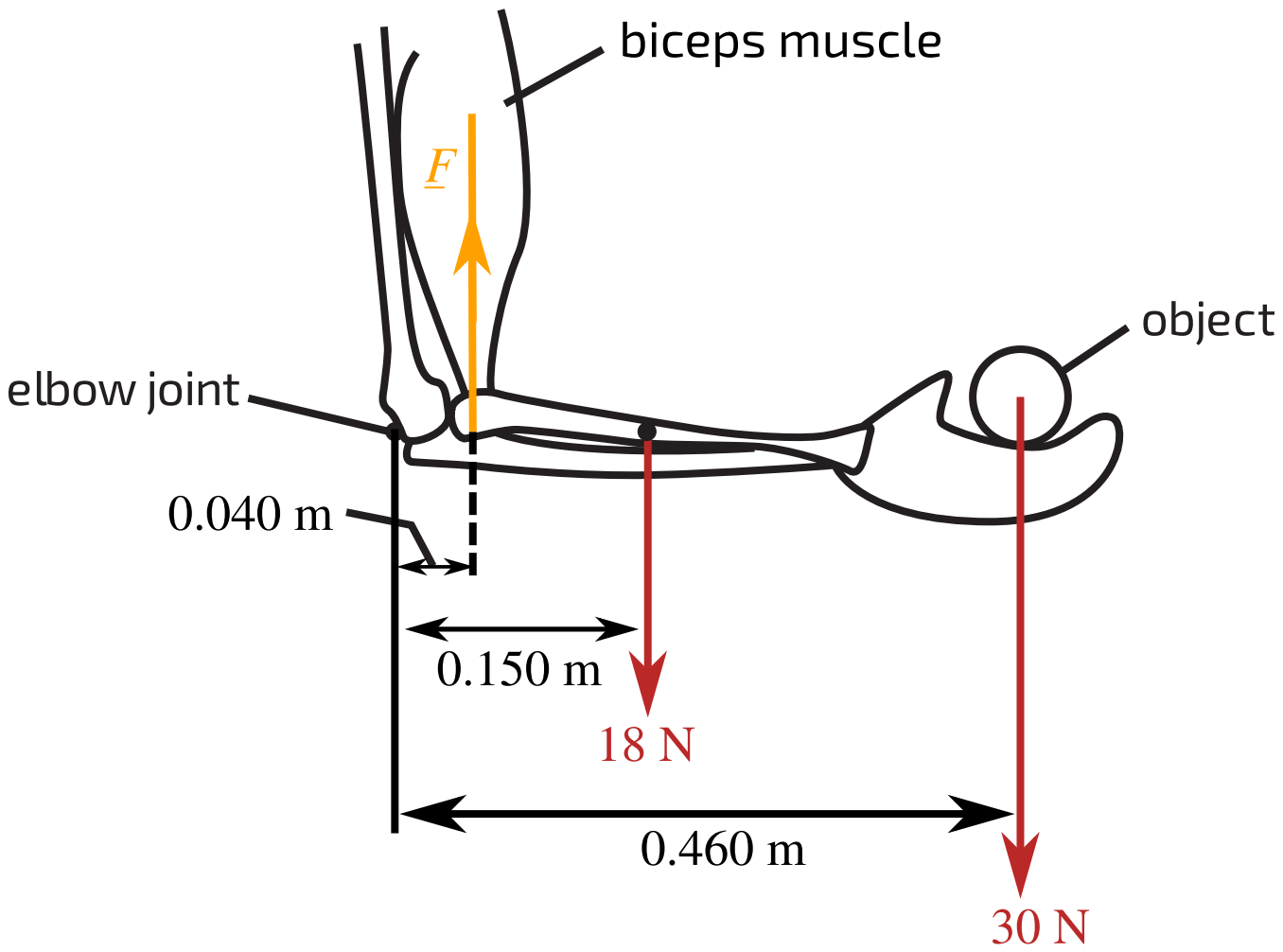

Figure 1: A human arm lifting an object.

Figure 1 shows a human arm lifting an object. The lower arm is horizontal and its centre of gravity is $0.150\,\mathrm{m}$ from the elbow joint. The weight of the lower arm is $18\,\mathrm{N}$. The biceps muscle exerts a vertical force F on the arm. The horizontal distance between the elbow joint and the point of attachment of the muscle to the lower arm bone is $0.040\,\mathrm{m}$. The weight of the object held in the hand is $30\,\mathrm{N}$ and its centre of gravity is $0.460\,\mathrm{m}$ from the elbow joint. The arm is in equilibrium.

Part A

Total clockwise moment

Calculate the total clockwise moment about the elbow joint correct to 3 significant figures.

Part B

Further from body

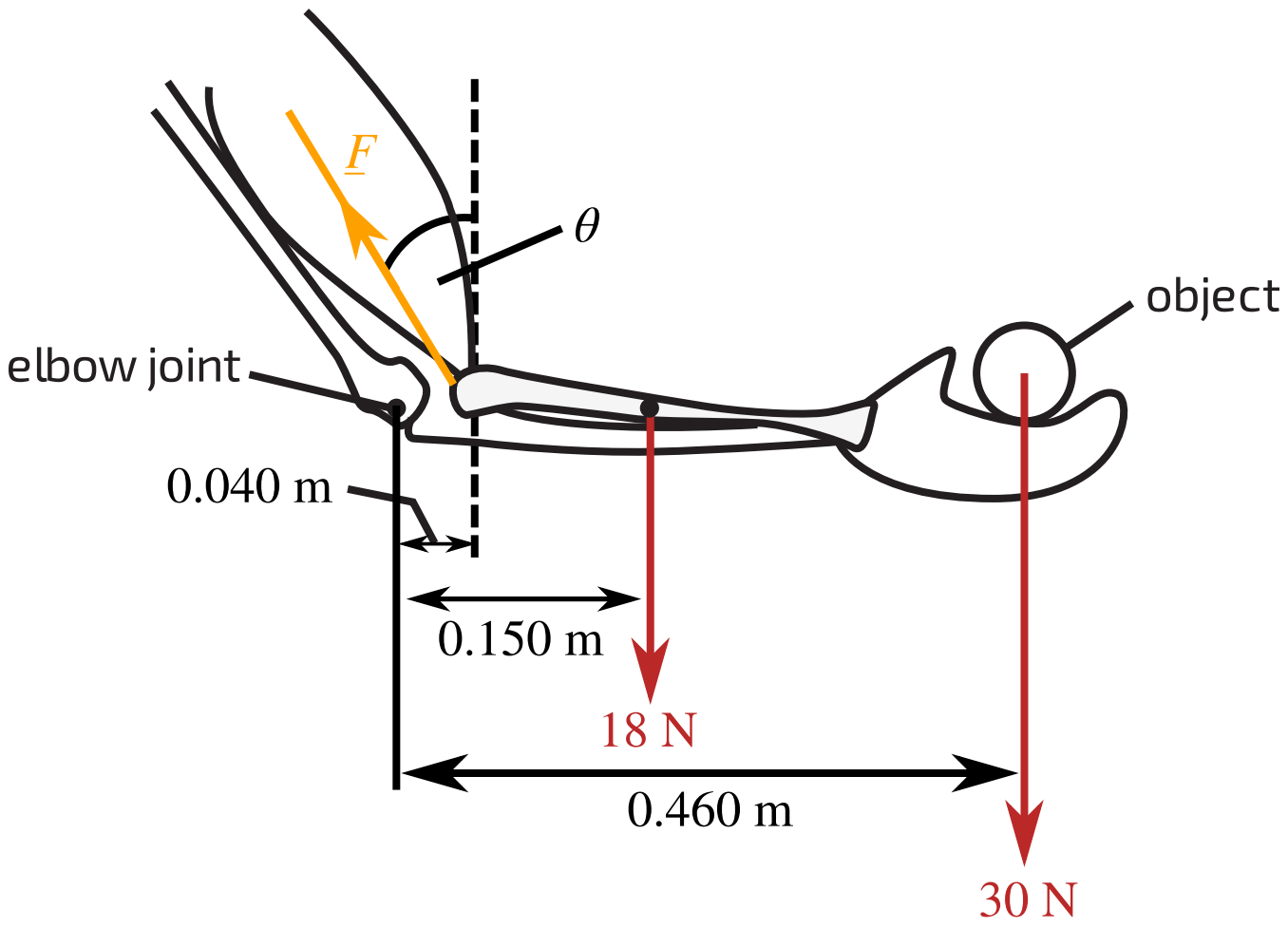

Figure 2: An arm holding a ball with the lower arm moved away from the body.

As the lower arm is moved away from the body, the force F exerted by the biceps muscles acts at an angle θ to the vertical as shown in **Figure 2**. The lower arm remains horizontal and in equilibrium.

Describe what happens to the anticlockwise moment and the force F as the angle θ is increased.

As θ increases, the anticlockwise moment about the elbow joint [ ] and the magnitude of the force F [ ].

Used with permission from UCLES, A Level, January 2012, OCR Physics A, Question 4

Question deck:

STEM SMART Single Maths 43 - Moments

Question

Moments 5ii

Subject & topics: Maths **Stage & difficulty:** A Level P2

Figure 1 shows a kitchen cupboard securely mounted to a vertical wall. The cupboard rests on a support at A.

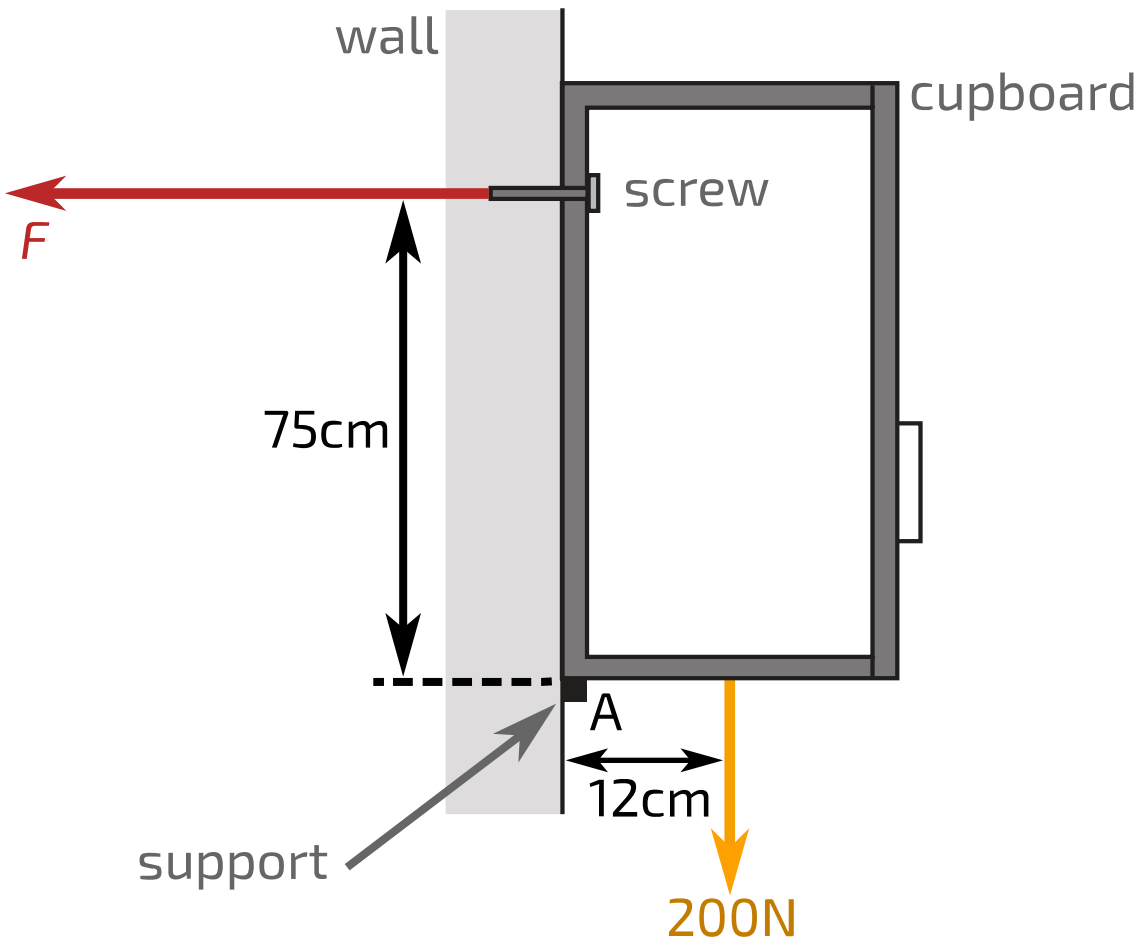

Figure 1: The forces acting on a cupboard.

The total weight of the cupboard and its contents is $200\,\mathrm{N}$. The line of action of its weight is at a distance of $12\,\mathrm{cm}$ from A. The screw securing the cupboard to the wall is at a vertical distance of $75\,\mathrm{cm}$ from A.

Part A

Determine F

The direction of the force F provided by the screw on the cupboard is horizontal as shown in **Figure 1**. By taking moments about A, determine the value of F.

Part B

Screw secured closer

State and explain how your answer to the previous question would change, if at all, if the same screw was secured much closer to A.

Let d represent the distance from the line of action of F to the support at A. The clockwise moment is [ ], so the anticlockwise moment is also [ ] as the system must stay in equilibrium. Hence, we have the equation [ ].

Therefore, $F \propto$ [ ], meaning that as the distance d [ ] (ie, if the screw is secured closer to A), the force [ ].

Items:

$12\,\mathrm{N\,m}$ $24\,\mathrm{N\,m}$ $2.4\,\mathrm{N\,m}$ $Fd = 24$ $\frac{F}{d} = 24$ $F = 24d$ d^2 d $\frac{1}{d}$ increases stays the same decreases

Adapted with permission from UCLES, A Level, May 2009, OCR Physics A G481, Question 5

Question deck:

STEM SMART Single Maths 43 - Moments

Question

Moments 3i

Subject & topics: Maths **Stage & difficulty:** A Level P2

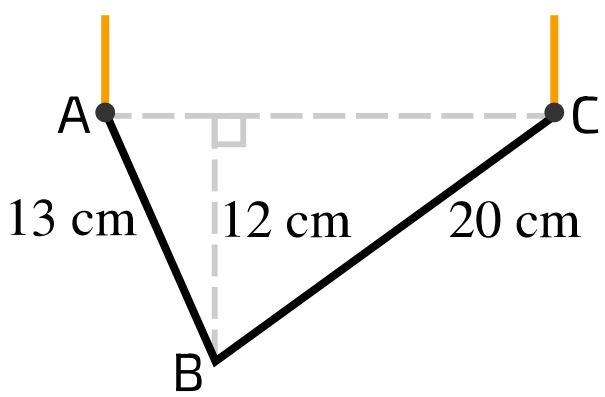

Figure 1: A rigid body consisting of two rods.

A rigid body ABC consists of two uniform rods AB and BC, rigidly joined at B. The lengths of AB and BC are $13\,\mathrm{cm}$ and $20\,\mathrm{cm}$ respectively, and their weights are $13\,\mathrm{N}$ and $20\,\mathrm{N}$ respectively. The distance of B from AC is $12\,\mathrm{cm}$. The body hangs in equilibrium, with AC horizontal, from two vertical strings attached at A and C.

Part A

Tension in string at A

Find the tension in the string attached at A correct to 3 significant figures.

Part B

Tension in string at C

Find the tension in the string attached at C correct to 3 significant figures.

Used with permission from UCLES, A Level, Specimen Paper 2004, OCR M2, Question 4

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Question

Moments 2ii

Subject & topics: Maths **Stage & difficulty:** A Level P2

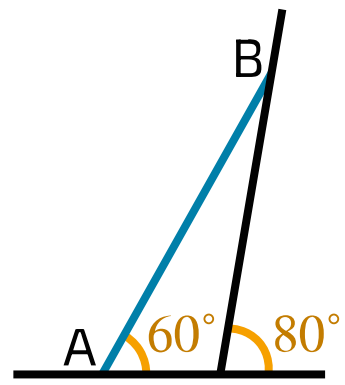

Figure 1: A uniform rod AB resting in equilibrium in a vertical plane against a smooth wall.

A uniform rod AB, of weight $25\,\mathrm{N}$ and length $1.6\,\mathrm{m}$, rests in equilibrium in a vertical plane with the end A in contact with rough horizontal ground and the end B resting against a smooth wall which is inclined at $80\,^\circ$ to the horizontal. The rod is inclined at $60\,^\circ$ to the horizontal.

Calculate the magnitude of the force acting on the rod at B. Give your answer to 3 significant figures.

Question deck:
STEM SMART Single Maths 43 - Moments

isaac You work it out.

Question

Moments 4i

Subject & topics: Maths **Stage & difficulty:** A Level P2

A uniform square board of mass $10.0\,\mathrm{kg}$ and side $2.00\,\mathrm{m}$ is modelled as a lamina ABCD. The board is in equilibrium in a vertical plane with the point A on rough horizontal ground. The edge AD rests on a fixed wedge whose point of contact, E, is smooth. The distance AE is $1.50\,\mathrm{m}$ and the edge AD makes an angle of 15.0° with the horizontal (see **Figure 1**).

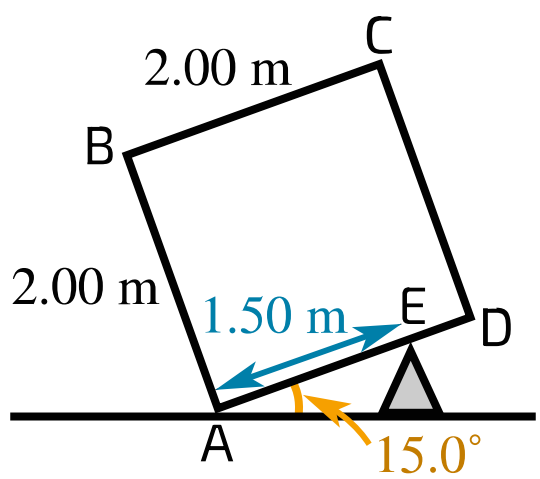

Figure 1: Board $ABCD$ resting in equilibrium on a smooth wedge.

Part A

Force at E

Calculate the magnitude of the force which the board exerts on the wedge at E.

Part B

Frictional force at A

Calculate the magnitude of the frictional force acting at A.

Part C

Value of m

A small object of mass $m\,\mathrm{kg}$ is now fixed to the board at B. Assuming that the board does not slip, calculate the maximum value of m for which the board remains on the wedge.

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Question deck:

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Question

Moments 2i

Subject & topics: Maths **Stage & difficulty:** A Level P2

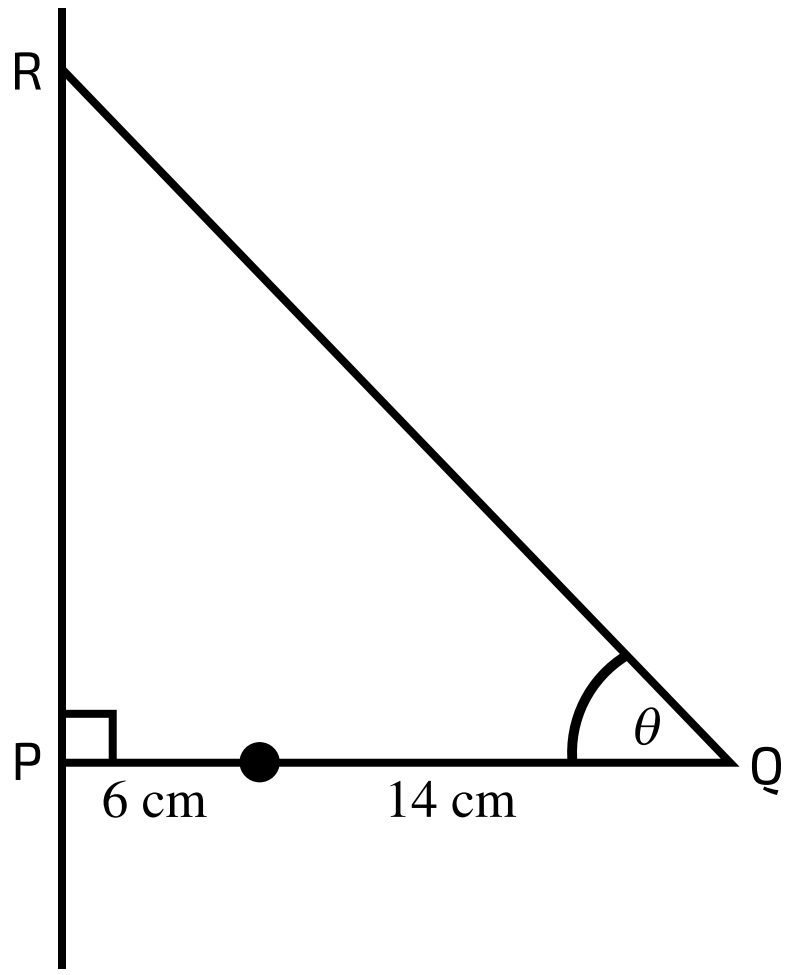

Figure 1: A uniform rod PQ resting against a rough vertical wall at P and held in a horizontal position, perpendicular to the wall, by a light inextensible string at Q.

A uniform rod PQ has weight $18\,\mathrm{N}$ and length $20\,\mathrm{cm}$. The end P rests against a rough vertical wall. A particle of weight $3\,\mathrm{N}$ is attached to the rod at a point $6\,\mathrm{cm}$ from P. The rod is held in a horizontal position, perpendicular to the wall, by a light inextensible string attached to the rod at Q and to a point R on the wall vertically above P, as shown in the diagram. The string is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{3}{5}$. The system is in limiting equilibrium.

Part A

Tension in the string

Find the tension in the string to 3 significant figures.

Part B

Magnitude of the force

Find the magnitude of the force exerted by the wall on the rod to 3 significant figures.

Part C

Coefficient of friction

Find the coefficient of friction between the wall and the rod. Give your answer to 3 significant figures.

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Question deck:

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Question

Moments 1ii

Subject & topics: Maths **Stage & difficulty:** A Level P2

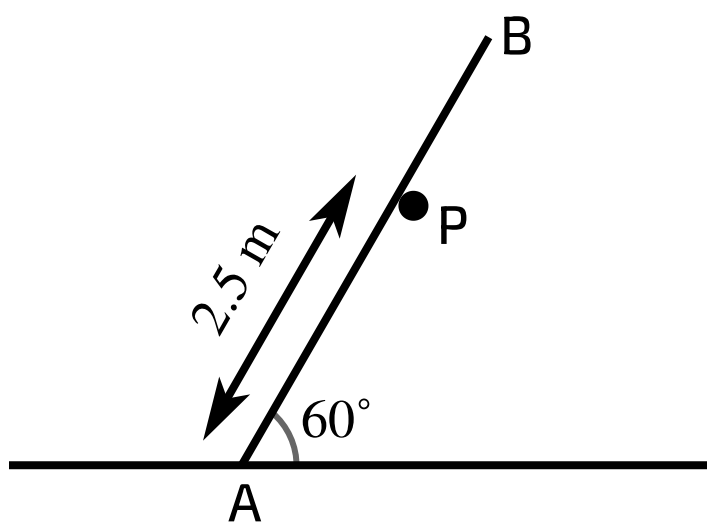

Figure 1: A uniform rod AB, in limiting equilibrium, is supported by a peg at P and A is on rough horizontal ground.

A uniform rod AB, of mass $3\,\mathrm{kg}$ and length $4\,\mathrm{m}$, is in limiting equilibrium with A on rough horizontal ground. The rod is at an angle of 60° to the horizontal and is supported by a small smooth peg P, such that the distance AP is $2.5\,\mathrm{m}$ (see Figure 1).

Part A

Force on the rod

Find the force acting on the rod at P. Give your answer to 2 significant figures.

Part B

Coefficient of friction

Find the coefficient of friction between the ground and the rod. Give your answer to 2 significant figures.

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