Moments and resultant moments

121 marks

Hints online, answers free with an account: mathswariz.uk/worksheets/a-level-mechanics-year-2-moments/

Date

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A Do Now

Quick questions to start. Some use earlier lessons; some set a slip that costs marks.

A1 Needed today [2 marks]

A point P is $8\ \text{m}$ from a point O. The line OP makes an angle of $35°$ with a straight line ℓ through O. Find the perpendicular distance from P to ℓ.

Answer .....

A2 Needed today [2 marks]

A force of $20\ \text{N}$ acts at $30°$ above the horizontal. Find its horizontal and vertical components.

Answer .....

A3 Needed today [2 marks]

A particle of mass $4\ \text{kg}$ rests on a light horizontal scale pan. The pan is held at rest by two vertical strings, each with tension $T\ \text{N}$. Find T.

Answer .....

A4 Common slip [2 marks]

A force of $6\ \text{N}$ turns a rod clockwise about a point P. The perpendicular distance from P to the line of action of the force is $0.5\ \text{m}$. Ali writes "moment $= 3$". Write the moment in full and say what Ali left out.

Answer .....

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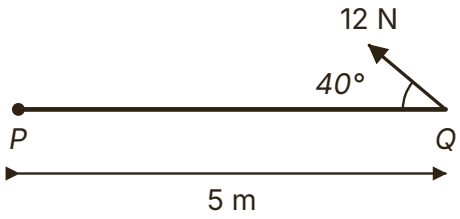
B Example, then your turn

A-Level

Your teacher works through each example with you. Then try the one beside it.

EXAMPLE 1

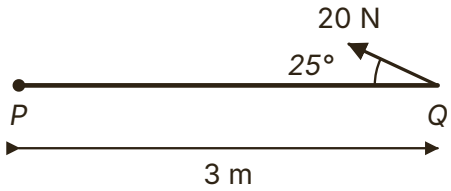
PQ is a light rod of length $5\ \text{m}$. Find the moment about P of each force. (a) A force of $15\ \text{N}$ whose line of action is $4\ \text{m}$ from P, turning the rod clockwise. (b) A force of $12\ \text{N}$ acting at Q at an angle of $40°$ to the rod, as shown. (c) A force of $9\ \text{N}$ acting at Q along the rod, towards P.



Hint Moment $=$ force $\times$ perpendicular distance from P to the line of action. When the force is at an angle, either use the perpendicular distance $5\sin 40°$, or split the force and use only the component perpendicular to the rod.

B1 [4 marks]

PQ is a light rod of length $3\ \text{m}$. Find the moment about P of each force. (a) A force of $8\ \text{N}$ whose line of action is $2.5\ \text{m}$ from P, turning the rod clockwise. (b) A force of $20\ \text{N}$ acting at Q at $25°$ to the rod, as shown. (c) A force of $5\ \text{N}$ acting at Q along QP.

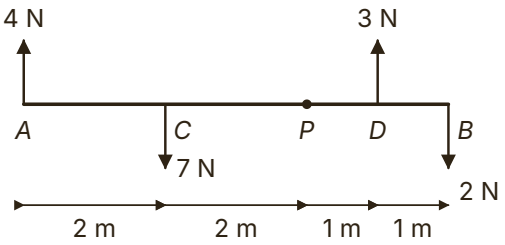


Answer .....

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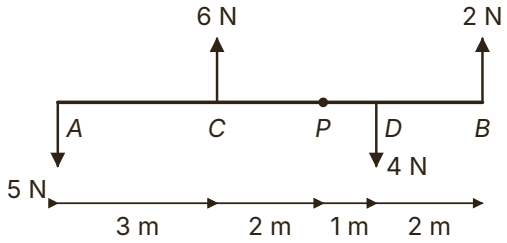
EXAMPLE 2

A light rod AB of length $6\ \text{m}$ has four forces acting on it, all perpendicular to the rod, as shown. P is the point on the rod with $AP = 4\ \text{m}$. Find the resultant moment about P.



Hint Choose a positive sense first. For each force: is it to the left or to the right of P, and does it push up or down? An upward force to the left of P turns the rod clockwise.

B2 A light rod AB of length $8\ \text{m}$ has four forces acting perpendicular to it, as shown, with $AC = 3\ \text{m}$, $AP = 5\ \text{m}$ and $AD = 6\ \text{m}$. Find the resultant moment about P and the resultant moment about A. [5 marks]

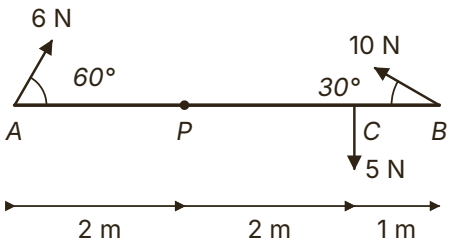


Answer .....

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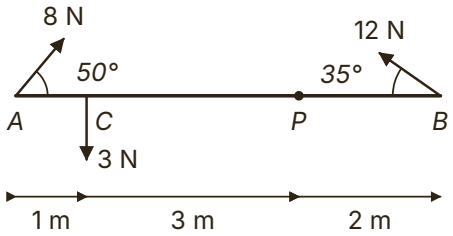
EXAMPLE 3

A light rod AB of length $5\ \text{m}$ has forces of $6\ \text{N}$ at A, $10\ \text{N}$ at B and $5\ \text{N}$ at C, where $AC = 4\ \text{m}$, acting as shown. P is the point on the rod with $AP = 2\ \text{m}$. Find the resultant moment about P.



Hint Split each sloping force into a component along the rod and a component perpendicular to it. The components along the rod pass through P.

B3 A light rod AB of length $6\ \text{m}$ has forces of $8\ \text{N}$ at A, $12\ \text{N}$ at B and $3\ \text{N}$ at C, where $AC = 1\ \text{m}$, acting as shown. P is the point with $AP = 4\ \text{m}$. Find the resultant moment about P. [5 marks]

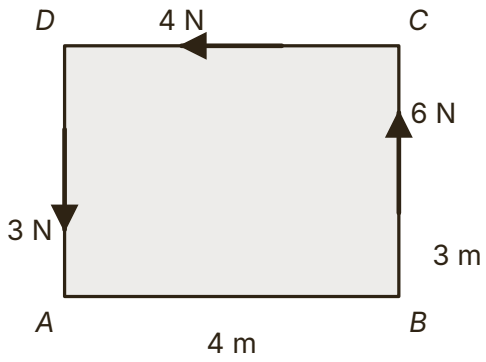


Answer .....

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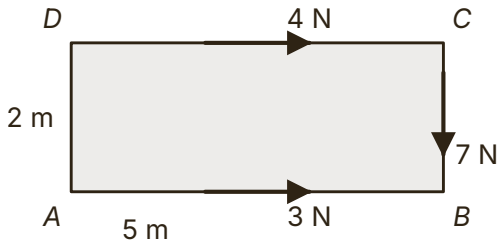
EXAMPLE 4

$ABCD$ is a rectangular lamina with $AB = 4\ \text{m}$ and $AD = 3\ \text{m}$. Forces of $6\ \text{N}$, $4\ \text{N}$ and $3\ \text{N}$ act along BC, CD and DA respectively, in the directions shown by the order of the letters. Find the resultant moment of the forces (a) about A, (b) about the centre O of the lamina.



Hint For a force along a side, the perpendicular distance from a corner is the length of the side it is perpendicular to. A force along DA passes through A. From the centre, every side is half a length away.

B4 $ABCD$ is a rectangular lamina with $AB = 5\ \text{m}$ and $BC = 2\ \text{m}$. Forces of $3\ \text{N}$, $7\ \text{N}$ and $4\ \text{N}$ act along AB, CB and DC respectively, in the directions shown by the order of the letters. Find the resultant moment of the forces about A and about C. [5 marks]

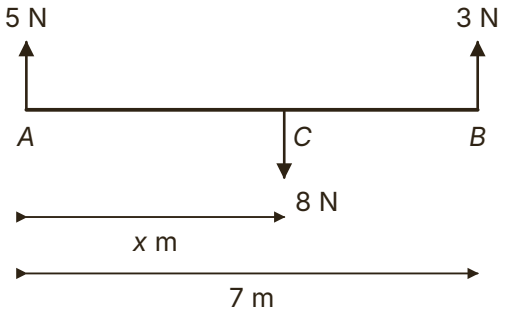


Answer .....

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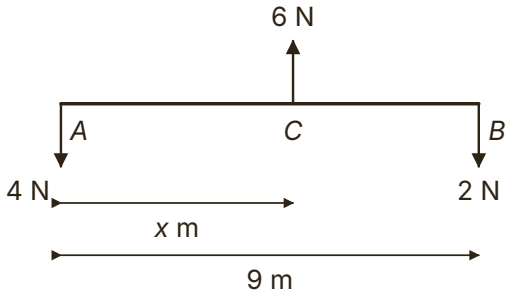
EXAMPLE 5

A light rod AB of length $7\ \text{m}$ has forces of $5\ \text{N}$ at A, $8\ \text{N}$ at C and $3\ \text{N}$ at B, all perpendicular to the rod, as shown, where $AC = x\ \text{m}$. The resultant moment about B is $11\ \text{N m}$ clockwise. (a) Find x. (b) Find the other value of x that is possible if you are told only that the magnitude of the resultant moment about B is $11\ \text{N m}$.



Hint Write the resultant moment about B in terms of x, with a stated positive sense. Then set it equal to $+11$ (clockwise) or -11 (anticlockwise).

B5 A light rod AB of length $9\ \text{m}$ has forces of $4\ \text{N}$ at A, $6\ \text{N}$ at C and $2\ \text{N}$ at B, all perpendicular to the rod, as shown, where $AC = x\ \text{m}$. The resultant moment about A is $12\ \text{N m}$ anticlockwise. (a) Find x. (b) Find the other possible value of x if you are told only that the magnitude of the resultant moment about A is $12\ \text{N m}$. [5 marks]



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Answer .....

C Practice

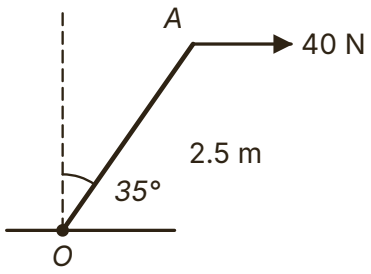
A-Level

C1 A light rod PQ has length $4\ \text{m}$. A force of $25\ \text{N}$ acts at Q at an angle of 30° to the rod. Sam writes: "moment about $P = 25 \times 4 = 100\ \text{N m}$". (a) Explain Sam's mistake and find the correct magnitude of the moment. (b) Find the two possible angles between the force and the rod for which the magnitude of the moment about P would be $80\ \text{N m}$. [5 marks]

Answer .....

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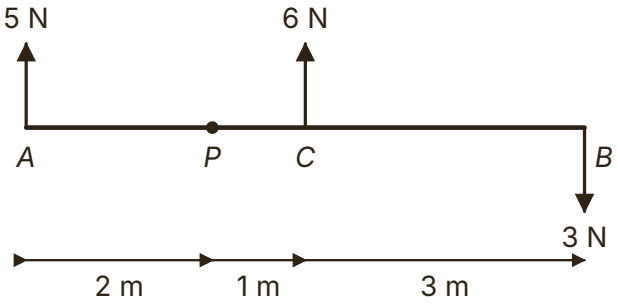
C2 A light rod OA of length $2.5\ \text{m}$ makes an angle of 35° with the vertical. A horizontal force of $40\ \text{N}$ acts at A, as shown. Priya writes: "moment about $O = 40 \times 2.5 \sin 35^\circ = 57.4\ \text{N m}$". Explain her mistake and find the moment of the force about O, stating its sense. [5 marks]



Answer .....

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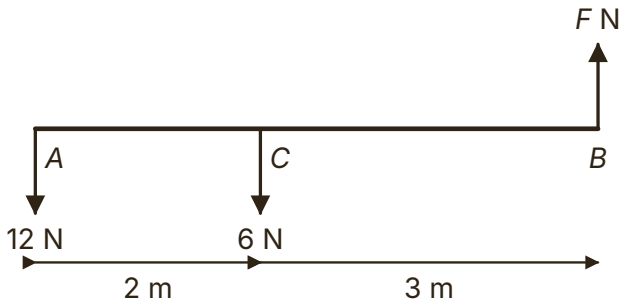
C3 A light rod AB of length $6\ \text{m}$ has forces acting perpendicular to it as shown. Jack finds the resultant moment about P by writing $5 \times 2 + 3 \times 4 + 6 \times 1 = 28\ \text{N m}$. Explain his mistake and find the resultant moment about P. [4 marks]



Answer .....

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C4 A light rod AB of length $5\ \text{m}$ has forces of $12\ \text{N}$ at A, $6\ \text{N}$ at C, where $AC = 2\ \text{m}$, and $F\ \text{N}$ at B, acting perpendicular to the rod as shown. The resultant moment about A is zero. Lena writes $12 + 6 \times 2 = 5F$. (a) Explain Lena's mistake and find F. (b) Find the resultant moment about C. [5 marks]



Answer .....

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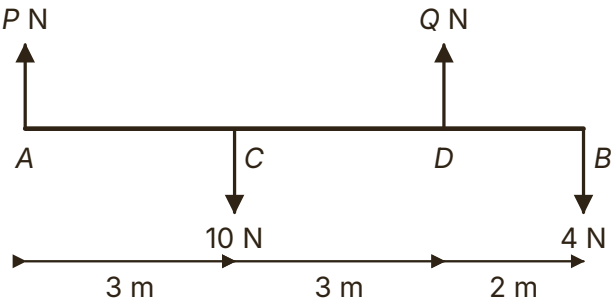
C5 A force $(3\mathbf{i} + 4\mathbf{j})\ \mathrm{N}$ acts at the point with position vector $(2\mathbf{i} + 5\mathbf{j})\ \mathrm{m}$ relative to the origin O, where $\mathbf{i}$ is horizontal and $\mathbf{j}$ is vertically up. Tom says: "moment about $O = |\mathbf{F}| \times |\mathbf{r}| = 5 \times \sqrt{29} = 26.9\ \mathrm{N\ m}$". (a) Explain why Tom is wrong. (b) Find the moment about O, stating its sense, and the perpendicular distance from O to the line of action of the force. [5 marks]

Answer .....

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D1 A light rod AB has length $8\ \text{m}$. The points C and D lie on the rod with $AC = 3\ \text{m}$ and $AD = 6\ \text{m}$. Forces of magnitude P N, 10 N, Q N and 4 N act at A, C, D and B respectively, perpendicular to the rod, in the directions shown. The resultant moment of the forces about A is $2\ \text{N m}$ clockwise. The resultant moment of the forces about B is $14\ \text{N m}$ anticlockwise.

(a) Show that $Q = 10$. [3 marks]



Answer .....

(b) Find P. [3 marks]

Answer .....

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(c) The point E lies on AB and the resultant moment of the forces about E is zero. Find the distance AE. [3 marks]

Answer .....

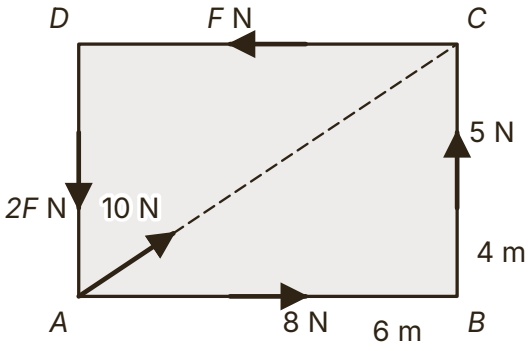
(d) State the magnitude and direction of the resultant of the four forces. Hence explain why the resultant moment is not zero about every point of the rod. [2 marks]

Total for D1: 11 marks

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D2 $ABCD$ is a rectangular lamina with $AB = 6\ \text{m}$ and $BC = 4\ \text{m}$. Forces of magnitude $8\ \text{N}$, $5\ \text{N}$, $F\ \text{N}$ and $2F\ \text{N}$ act along AB, BC, CD and DA respectively, in the directions shown by the order of the letters. A force of $10\ \text{N}$ acts along AC, in the direction from A to C.

(a) Find, in terms of F, the resultant moment of the forces about C. [3 marks]



Answer .....

(b) The resultant moment about C is $80\ \text{N m}$. Find F. [2 marks]

Answer .....

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(c) Find the resultant moment of the forces about the centre O of the lamina. Explain why the $10\ \text{N}$ force does not appear in your working. [4 marks]

Answer .....

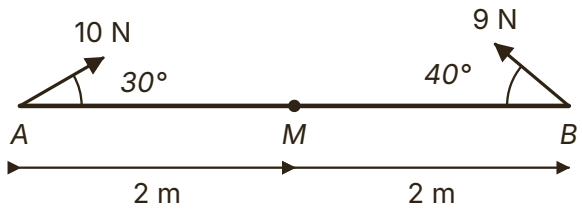
Total for D2: 9 marks

D3

A light rod AB has length $4\ \text{m}$ and midpoint M. A force of $10\ \text{N}$ acts at A at $30°$ to AB and a force of $9\ \text{N}$ acts at B at $40°$ to BA, as shown. Kai writes: "moment about $M = 10 \times 2\cos 30° $ clockwise $+ 9 \times 2\cos 40°$ anticlockwise $= 17.32 - 13.79 = 3.53\ \text{N m}$ clockwise."

Kai is wrong.

(a) Explain Kai's mistake. [2 marks]



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(b) Find the resultant moment about M. [3 marks]

Answer .....

(c) The $9\ \mathrm{N}$ force is replaced by a force of magnitude $X\ \mathrm{N}$ acting at B in the same direction. The resultant moment about M is now zero. Find X. [3 marks]

Answer .....

Total for D3: 8 marks

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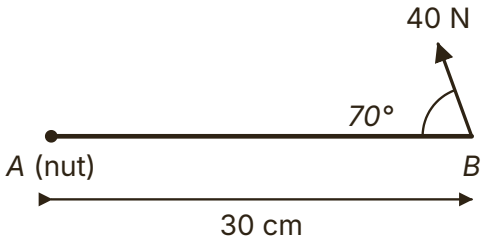
D4 Relative to a fixed origin O, a force $(p\mathbf{i} + q\mathbf{j})\ \mathrm{N}$ acts at the point with position vector $(3\mathbf{i} + 2\mathbf{j})\ \mathrm{m}$ and a force $(2\mathbf{i} - \mathbf{j})\ \mathrm{N}$ acts at the point with position vector $(\mathbf{i} + 4\mathbf{j})\ \mathrm{m}$. The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are horizontal and vertically up, in the plane of the forces. The resultant moment of the two forces about O is zero, and their resultant moment about the point with position vector $5\mathbf{i}\ \mathrm{m}$ is $20\ \mathrm{N\ m}$ clockwise. Find the values of p and q, and the magnitude of the force $(p\mathbf{i} + q\mathbf{j})\ \mathrm{N}$. [7 marks]

Answer .....

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D5 A mechanic uses a spanner to turn a nut. The spanner is modelled as a light rod AB of length $30\ \text{cm}$, with the nut at A. The forces all act in the plane in which the spanner turns.

(a) A force of $40\ \text{N}$ is applied at B at an angle of $70°$ to BA, as shown. Find the moment of this force about A, in N m. [3 marks]



Answer .....

(b) The nut turns when the moment about A is at least $15\ \text{N m}$. Find the least force, applied at B, that turns the nut, and state its direction. [3 marks]

Answer .....

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(c) The mechanic can push with a force of at most $45\ \text{N}$. He slides a tube over the spanner so that he can push at a greater distance from A. Find the least distance from A at which he must push. [3 marks]

Answer .....

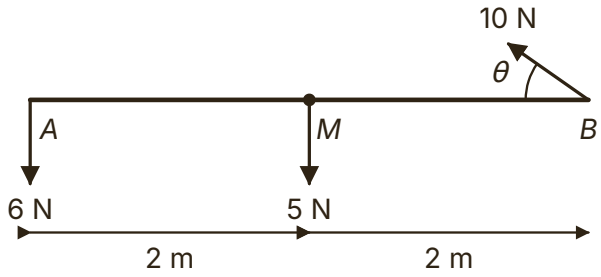
(d) State one limitation of modelling the spanner as a light rod. [2 marks]

Total for D5: 11 marks

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D6 A light rod AB has length $4\ \text{m}$ and midpoint M. A force of $6\ \text{N}$ acts vertically downwards at A and a force of $5\ \text{N}$ acts vertically downwards at M. A force of $10\ \text{N}$ acts at B, making an angle θ with BA, as shown. The rod is horizontal. The resultant moment of the three forces about A is $12\ \text{N m}$ anticlockwise.

(a) Find the two possible values of θ, where $0 < \theta < 180°$. [4 marks]



Answer .....

(b) Explain why there are two possible directions for the force at B. [2 marks]

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(c) Find the resultant moment of the three forces about M. [3 marks]

Answer .....

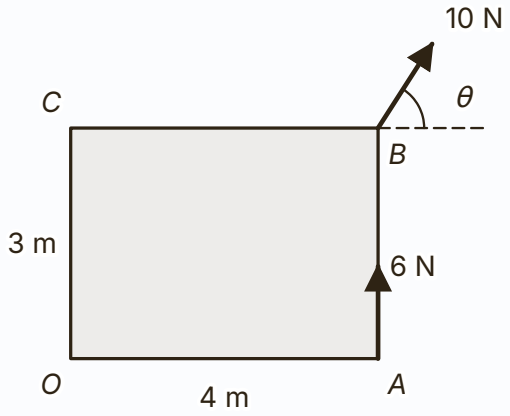
Total for D6: 9 marks

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No route is given. The hints are at the end of the sheet. Use one at a time.

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E1 $OABC$ is a rectangular lamina with $OA = 4\ \text{m}$ and $AB = 3\ \text{m}$, lying in a vertical plane with OA horizontal. A force of $6\ \text{N}$ acts vertically upwards at A. A force of $10\ \text{N}$ acts at B in the plane of the lamina, at an angle θ measured anticlockwise from the direction of $\overrightarrow{OA}$, as shown, where $0 \leq \theta < 360°$. Find the values of θ for which the resultant moment of the two forces about O is zero. Find also the greatest possible magnitude of the resultant moment about O, the value of θ that gives it, and its sense. [10 marks]



Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Split the $10\ \text{N}$ force into $10\cos\theta$ parallel to OA and $10\sin\theta$ perpendicular to it. Find the moment of each part about O.

Hint 2 You should get the resultant moment, anticlockwise positive, as $24 + 40\sin\theta - 30\cos\theta$.

Hint 3 Write $40\sin\theta - 30\cos\theta$ in the form $R\sin(\theta - \alpha)$ with $R > 0$ and $0 < \alpha < 90°$.

How did it go?

Colour one circle on each line: not yet, nearly, yes.

I can find the moment of a force about a point, giving the units and the sense.	○ ○ ○
I can use a perpendicular distance or a perpendicular component when a force acts at an angle.	○ ○ ○
I can find the resultant moment of several forces on a rod or a rectangular lamina.	○ ○ ○
I can find an unknown force, distance or angle from a given resultant moment.	○ ○ ○

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