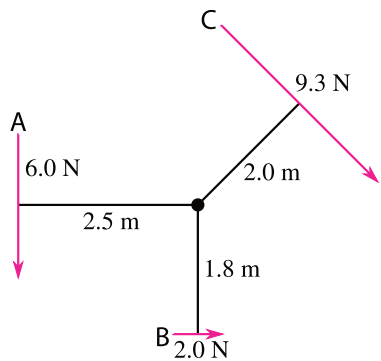
16 Moments, Turning and Balancing

The turning or twisting effect of a force is called its moment. The moment of a force depends on:

- the size of the force;
- how far the force is from the pivot or axle (the distance is measured from the pivot to the line of action of the force, at right angles to the force);
- the direction of the force. Moments can be anticlockwise (AC) or clockwise (C).

moment (Nm) = force (N) × perpendicular distance to axle (m)



Example 1
Moments of the forces in the diagram are:
A: 6 N × 2.5 m = 15 Nm AC
B: 2 N × 1.8 m = 3.6 Nm AC
C: 9.3 N × 2 m = 18.6 Nm C
In this case, the two AC moments added together equal the C moment. Because they are equal and in opposite directions, the system will not turn.

Principle of Moments:
An object will balance and not start turning if the total of the anticlockwise (AC) moments equals the total of the clockwise (C) moments.

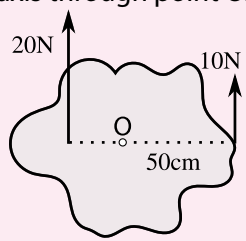
16.1 Calculate the missing values in the table. Each row is a different question. Give your answers in the units requested.

	Force	Distance from axle	Moment
(a)	4.2 N	5.4 m	(Nm)
(b)	68 N	0.15 m	(Nm)
(c)	47 N	34 cm	(Ncm)
(d)	(N)	3.2 m	18 Nm
(e)	0.034 N	(cm)	0.68 Nm

16.2 What force, acting at a distance of 25 cm from the axis of rotation of a solid body, would make a moment of 10 Nm?

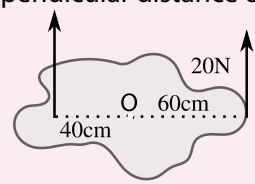
16.3 What force, acting at a distance of 2.5 m from the axis of rotation of a solid body, would make a moment of 25 Nm?

16.4 Two forces act on a rigid body free to rotate about a perpendicular axis through point O. The sizes of the forces are 10 N and 20 N.



The perpendicular distance of the line of action of the 10 N force from O is 50 cm. What is the perpendicular distance of the 20 N force from O if the body does not rotate?

16.5 Two forces act on a rigid body free to rotate about an axis perpendicular to the point O. One of the forces is 20 N and acts at a perpendicular distance of 60 cm from the axis.



If the other force acts at a perpendicular distance of 40 cm from the axis and the body is in equilibrium, what is the size of the force?

16.6 For the situations below, work out the moment of each force and state whether the object will begin to turn anticlockwise (AC), clock-

wise (C), or whether it is balanced (B). Draw a diagram of each situation to help you decide whether each moment is AC or C.

(a) A 3.2 N force to the left is 10 cm above the axle, while a 6.4 N force to the left is 5.0 cm below the axle.

(b) A downwards 65 N force is 35 cm to the left of an axle, and a 150 N force to the right is 20 cm above the axle.

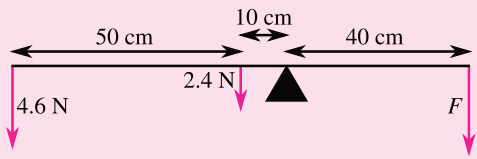
(c) An upwards 650 N force is 2.3 m to the right of an axle, while 150 N to the left is 3.6 m below the axle.

(d) A force of 10 N to the right is 2.3 m to the right of the axle, and a force of 0.20 N upwards is 0.34 m to the right of the axle.

(e) An upwards 30 N force is 35 cm to the left of an axle, while an upwards force of 15 N is 70 cm to the right of the axle.

(f) Two upwards forces act: one of 34 N which is 3.5 m to the left of the axle, the other is 25 N and is 2.6 m to the right of the axle. There is also a 10 N force to the left which is 0.80 m below the axle.

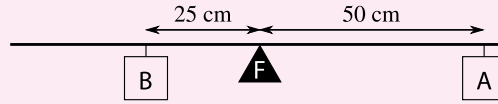
Example 2 – What force, F, is needed to make the rod balance?



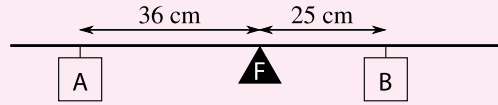
Moment of a 4.6 N force is $4.6\text{ N} \times 60\text{ cm} = 276$ Ncm AC
Moment of 2.4 N force is $2.4\text{ N} \times 10\text{ cm} = 24$ Ncm AC
Total AC moment is 300 Ncm. To balance, the moment of F must be 300 Ncm clockwise, so
$F = 300\text{ Ncm}/40\text{ cm} = 7.5\text{ N}$
In this question, the 2.4 N force is the weight of the rod. Weights are always drawn downwards from the centre of gravity - which is always in the centre of symmetric, uniform objects like rods.

16.7 Calculate the weight of the block stated in each situation below where the uniform lever arm is balanced about the fulcrum 'F'.

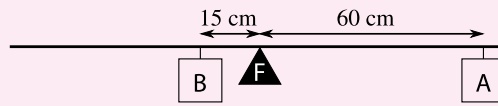
(a) If A weighs 5.0 N, what is the weight of B?



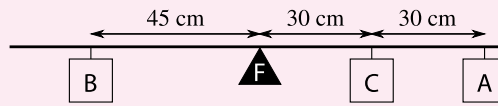
(b) If A weighs 10 N, what is the weight of B?



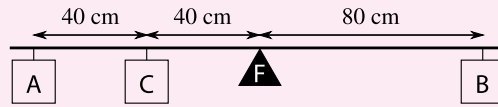
(c) If A weighs 10 N, what is the weight of B?



(d) If A weighs 10 N and B weighs 20 N, what is the weight of C?



(e) If A weighs 2.0 N and B weighs 4.0 N, what is the weight of C?



16.8 A 0.50 N weight is stuck to the 20 cm mark of a uniform metre stick, which weighed 0.50 N before the weight was added. You can balance the metre stick horizontally on your finger, if you put your finger in the right place. How far from the 0.0 cm end do you need to put your finger in order to get it to balance?