M2 Chapter 4: Moments

Turning Forces

Motivating problem

This… is a door.

Why do you think the handle is put on the other side of the door from the hinge?

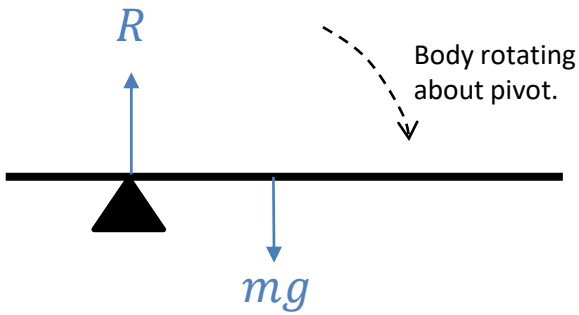
Increasing the distance of the force applied from the point of rotation increases the 'turning effect' of the force.

If I double the distance of my finger from the hinge, what happens to the force required to keep the door open?

As the distance doubles, the force required halves (we'll see why).

Rigid Bodies and Overview

We previously dealt with particles, where each object was modelled just as a single point, and considered forces acting on each point separately.



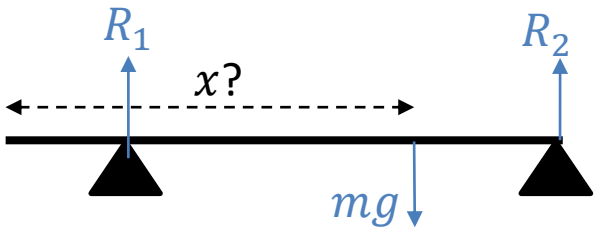
In this chapter we consider rigid bodies (in this case **rods**), which takes into account the size of the object. This means we can consider other properties, e.g. **rotation** of the body.

1:: Moments in equilibrium

Clockwise moment = Anticlockwise moment

2:: Centre of Mass

For a 'non-uniform' rod we can't model its weight as acting at the centre.



3:: On the point of Tilting

"A non uniform wooden plank of mass M kg rests horizontally on supports at A and B, as shown. When a bucket of water of mass 18kg is placed at point C, the plank is in equilibrium, and is **on the point of tilting** about B. Find the value of M and the magnitude of the reaction at B."

Moments

The ‘moment’ of a force:
… measures the **turning effect** of the force on the body on which it is acting.

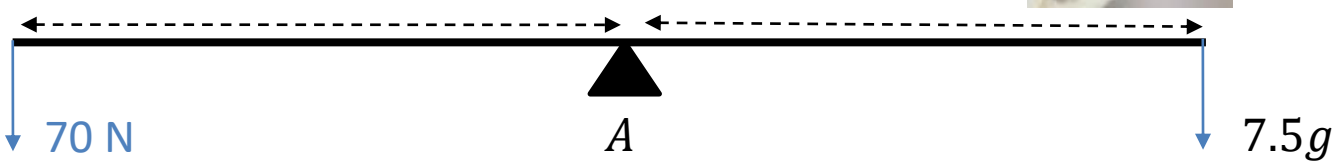
$$\boldsymbol{moment\ of\ force = force \times distance}$$

about a point

perpendicular distance

Notice that the measured distance is **perpendicular** to the force being considered.

Big Kat has a mass of 7.5kg.



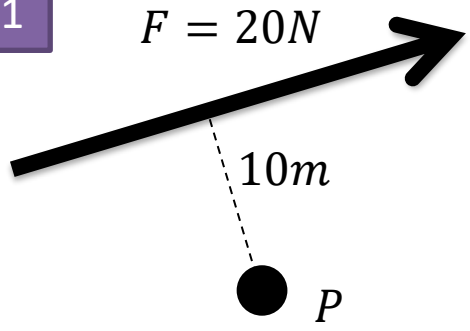
Moment about A
$= 70 \times 10 = 700\ Nm$

Moment about A
$= 7.5g \times 8 = 588\ Nm$

The anticlockwise moment is greater, so the seesaw will tilt in an anticlockwise direction.

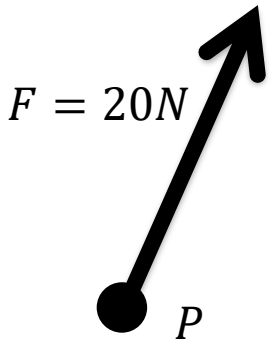
Quickfire Examples

1



Moment of force F about point P = ?

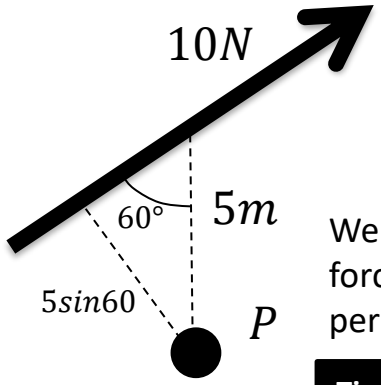
2



Moment of force F about point P

?

3

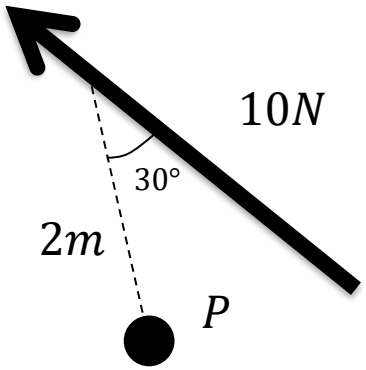


Moment of force F about point P = ?

We see what force is acting perpendicularly.

Tip: Recall that if the hypotenuse of a right-angled triangle is x then the side opposite the angle is of length $x \sin\theta$ and the adjacent to it $x \cos\theta$. You should be able to find these lengths instantly without messing about with soh-cah-toa all the time.

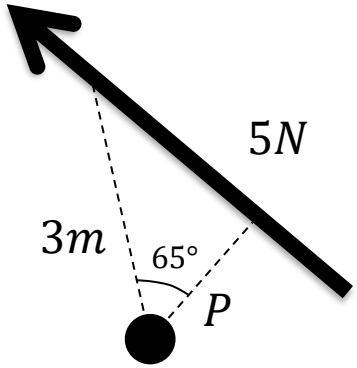
4



Moment:

?

5

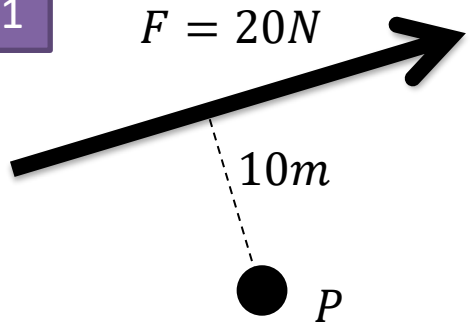


Moment:

?

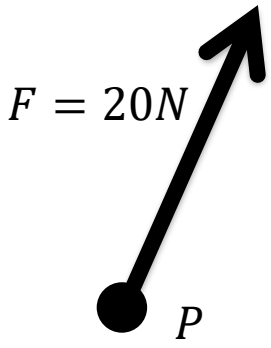
Quickfire Examples

1



Moment of force F about point P
$= \mathbf{200}\boldsymbol{Nm}$ **clockwise**

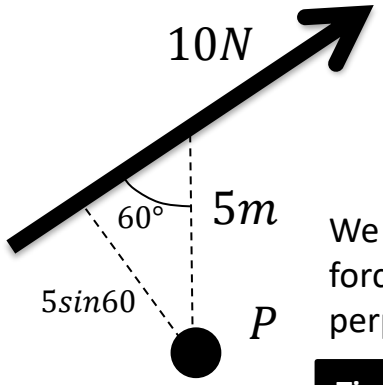
2



Moment of force F about point P
$= \mathbf{0}\boldsymbol{Nm}$

There is no 'turning' effect.

3

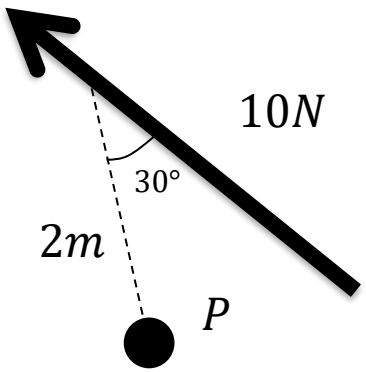


Moment of force F about point P
$= \mathbf{50}\boldsymbol{sin60\ Nm}$ **clockwise**

We see what force is acting perpendicularly.

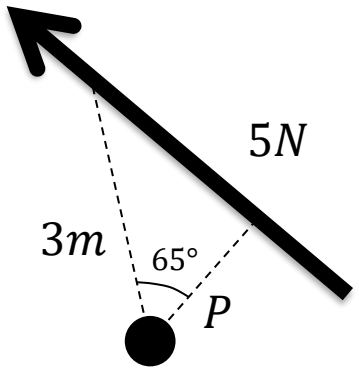
Tip: Recall that if the hypotenuse of a right-angled triangle is x then the side opposite the angle is of length $x \sin\theta$ and the adjacent to it $x \cos\theta$. You should be able to find these lengths instantly without messing about with soh-cah-toa all the time.

4



Moment:
$\mathbf{20}\boldsymbol{sin30\ Nm}$ **anticlockwise**

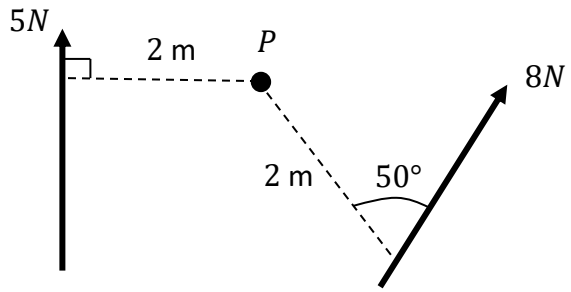
5



Moment:
$\mathbf{15}\boldsymbol{cos65\ Nm}$ **anticlockwise**

Test Your Understanding

[Textbook] The diagram shows two forces acting on a lamina. Find the moment of each of the forces about the point P.



Terminology: A *lamina* is a 2D object whose thickness can be ignored.

Moment of 5N force:

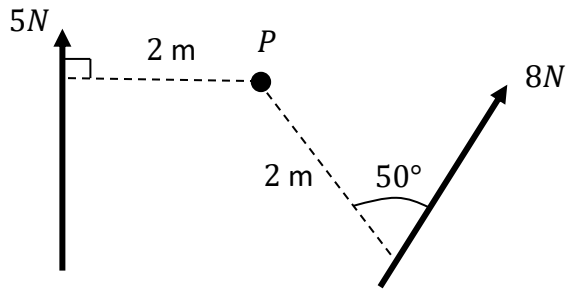
= ?

Moment of 8N force:

= ?

Test Your Understanding

[Textbook] The diagram shows two forces acting on a lamina. Find the moment of each of the forces about the point P.



Terminology: A *lamina* is a 2D object whose thickness can be ignored.

Moment of 5N force:
$= 5 \times 2 = 10$ Nm clockwise

Moment of 8N force:
$= 8 \times 2 \sin 50° = 12.3$ Nm anticlockwise (3sf)

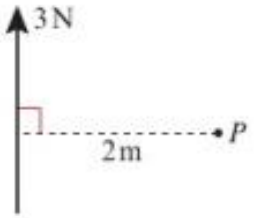
Exercise 4.1

Pearson Stats/Mechanics Year 2
Page 33-34

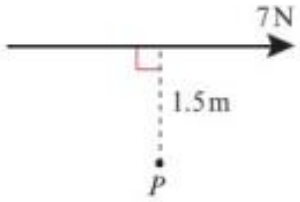
Homework Exercise

1 Calculate the moment about P of each of these forces acting on a lamina.

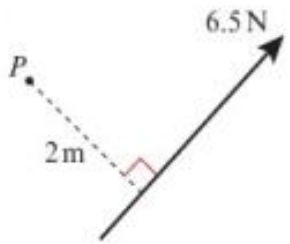
a



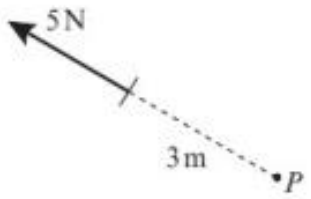
b



c

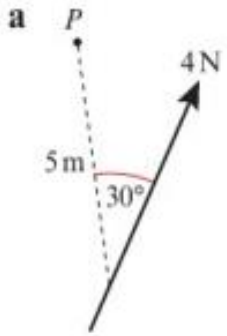


d

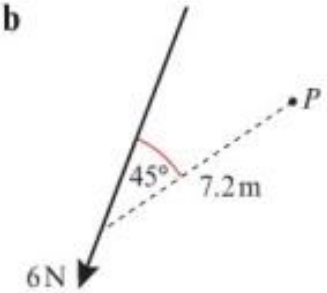


2 Calculate the moment about P of each of these forces acting on a lamina.

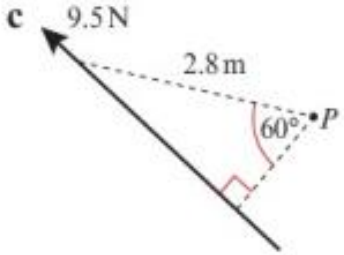
a



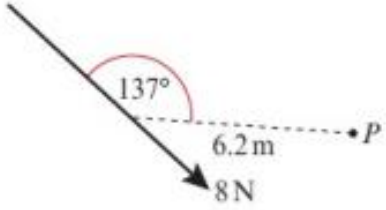
b



c

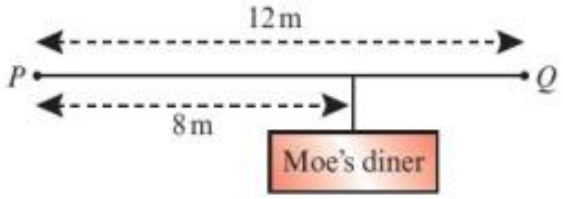


d



Homework Exercise

3 The diagram shows a sign hanging from a wooden beam. The sign has a mass of 4 kg.

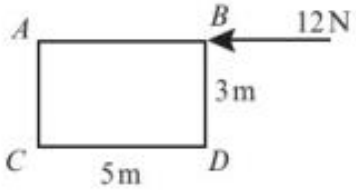


a Calculate the moment of the weight of the mass:

i about P **ii** about Q

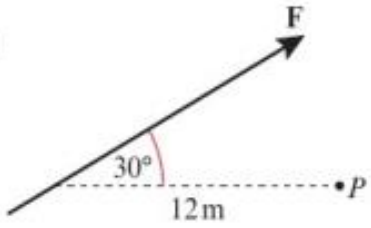
b Comment on any modelling assumptions you have made.

4 $ABCD$ is a rectangular lamina. A force of 12 N acts horizontally at B, as shown in the diagram. Find the moment of this force about:



a A **b** B **c** C **d** D

5 In the diagram, the force **F** produces a moment of 15 N m clockwise about the pivot P. Calculate the magnitude of **F**.



Homework Answers

1 **a** 6 Nm clockwise **b** 10.5 Nm clockwise
c 13 Nm anticlockwise **d** 0 Nm

2 **a** 10 Nm anticlockwise **b** 30.5 Nm anticlockwise
c 13.3 Nm clockwise **d** 33.8 Nm anticlockwise

3 **a** **i** 313.6 Nm clockwise **ii** 156.8 Nm anticlockwise
b Sign is a particle.

4 **a** 0 Nm **b** 0 Nm
c 36 Nm anticlockwise **d** 36 Nm anticlockwise

5 2.5 N