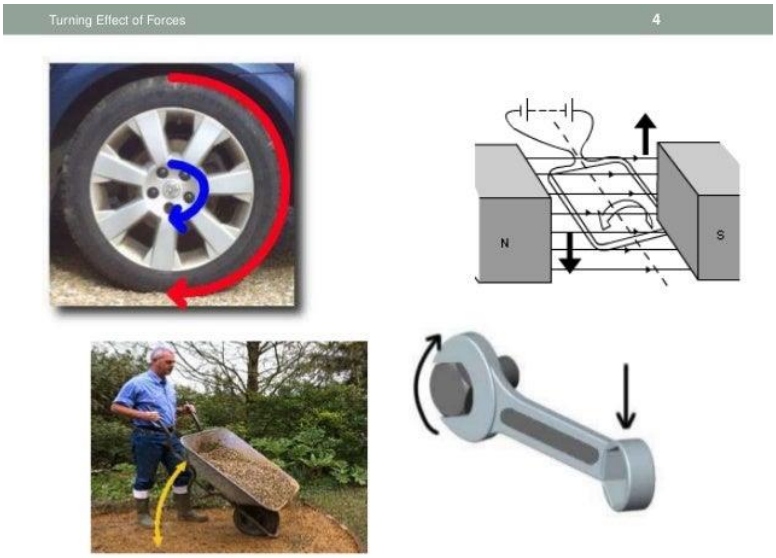
S1 New Curriculum Physics

Theme: Mechanics and properties of Matter

Chapter 2 – Turning effect of forces, centre of gravity, and stability



The **turning effect of a force**, also known as **torque or moment of force**, refers to the force's ability to cause an object to rotate about a pivot or axis. It depends on two factors:

1. **Magnitude of the force**: The greater the force applied, the greater the turning effect.
2. **Distance from the pivot**: A force applied farther from the pivot point creates a stronger turning effect.

Mathematically, torque (τ\tau) is given by:

τ= Force × Perpendicular Distance

For example, when opening a door, pushing near the handle (far from the hinge) makes it easier compared to pushing near the hinge. This principle is crucial in machines, levers, and even human joints.

The turning effect is crucial in understanding concepts such as moments, centre of gravity and stability.

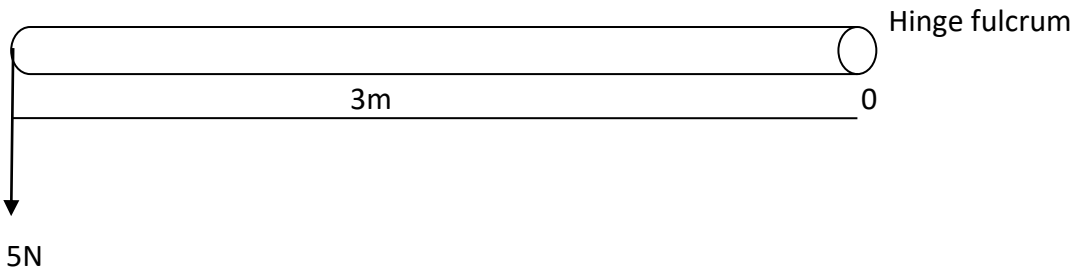
Moments

Moment a force is a product of a force and the perpendicular distance of the line of action of the force from the fulcrum (pivot).

Moment of a force = Force x perpendicular distance of the line of action of the force from the fulcrum

The SI unit of moment is Newton metre (NM). Moment is a vector quality.

Example 1



Calculate the moment of 5N

F = 5N d from fulcrum = 3m

Moment = F x d

= 5 x 3

= 15 Nm

Factors affecting moments

The moment of a force depends on:-

(i) The magnitude of a force

(ii) Perpendicular distance from the fulcrum

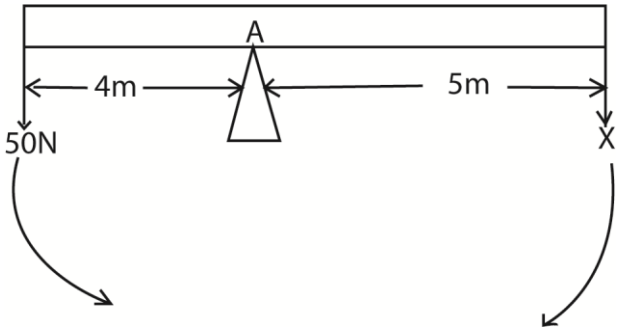
Law/Principle of moment

This states that when a body is in a state of equilibrium the sum of clockwise moments about any points is equal to the sum of anticlockwise moments about the point.

Sum of anti-clockwise moments about any point = Sum of clockwise moments about the point.

Example 2

Find the value of X in the figure below



Taking moment about A

Clockwise moments = 5x

Anticlockwise moments =50 x 4 = 200N

And by law of moment:

Sum of clockwise moments = Sum of anti-clockwise moment about any point

$5x=200$

$\frac{5x}{5}=\frac{200}{5}$

x = 40N

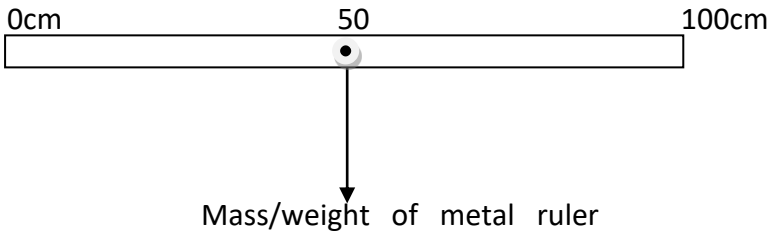
From the above it can be noted that it is easier to close the door by pushing it at a point as far away from the hinges as possible. Because the force applied can easily balance with the reaction at the hinges.

Note: When calculating moments about a point (pivot) all distances should be measured from that point

Finding the mass/weight of uniform body

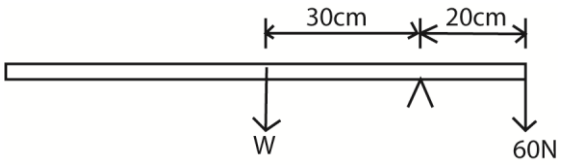
When a body is uniform, the mass or weight must act at the centre.

For a uniform metre rule the centre at which the mass of the metre rule must act is 50cm mark.



A metre rule is marked from 0-100cm mark. Its mass/weight must act in the middle which is 50cm mark. The mass or weight is calculated by applying the principle of moment.

Example 3



Find the weight W, of a uniform metre rule if a force of 60N at one end balances it as shown in the above figure

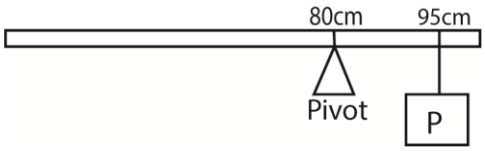
From the principle of moments

30 x w = 60 x 20

w = 40N

Example 4

Figure below shows a uniform metre rule of mass 0.1kg pivoted at the 80 cm mark. It balances horizontally when a mass P is hangs at the 95 cm mark. Find the value of P.



Take moments about the pivot

Mass a ruler = 0.1kg acts at 50cm mark

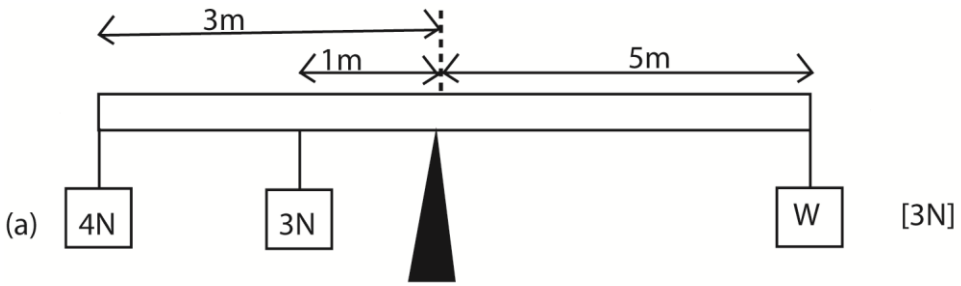
⇨ 0.1 x (80 -50) = P x (95 – 80)

$$P = \frac{0.1\ x\ 30}{15}$$

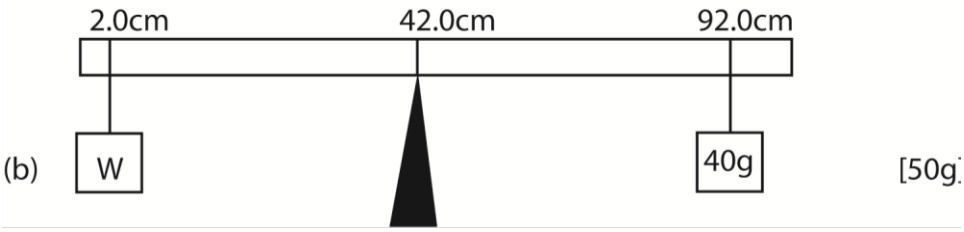
$$= 0.2kg$$

Trial 1

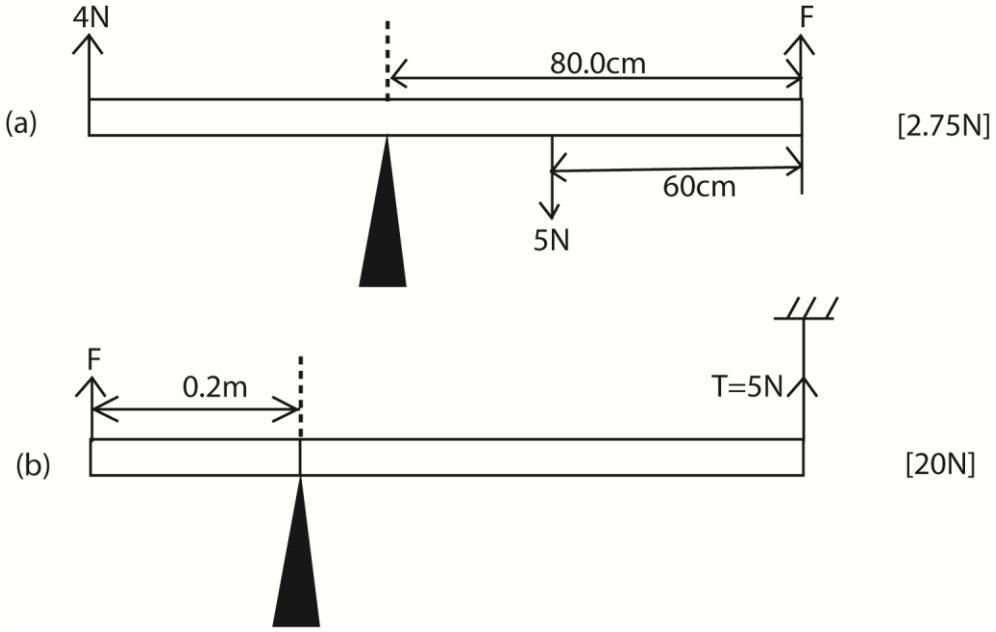
1. Find the value of W in each case in the figure below



[3N]



2. In each of the figure below a rod of 1m has negligible weight. Find the values of F.



Application of moments

(i) **Levers** – Used in tools like crowbars, scissors, and seesaws to amplify force by increasing the distance from the pivot.
(ii) **Gears and Machines** – Torque is essential in the functioning of bicycles, cars, and industrial machines.
(iii) **Steering Wheels** – Turning a car's steering wheel requires torque; a larger wheel reduces effort.
(iv) **Human Body** – Joints act as pivots, and muscles apply forces to create movement (e.g., bending an arm).
(v) **Balancing** – A person balancing on a beam distributes weight to maintain equilibrium.
(vi) **Bridge Design** – Engineers use moments to calculate load distribution and ensure stability.
(vii) **Opening Doors** – Pushing near the handle requires less force than pushing close to the hinge.

Condition for a body in equilibrium

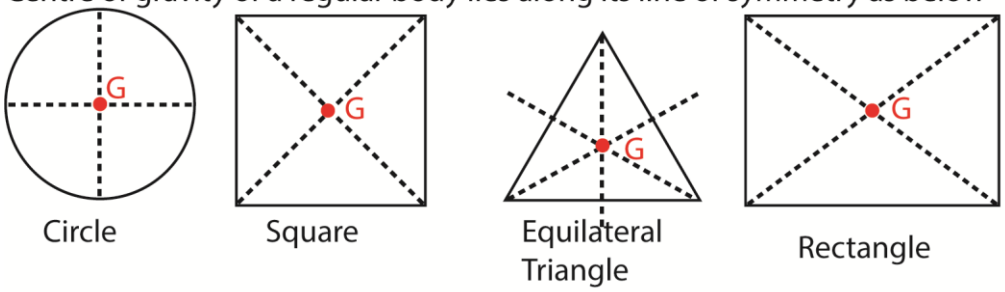
When a number of parallel forces are in equilibrium;

i) the sum of the forces in one direction is equal to the sum of the forces in the opposite direction,
ii) the sum; of the anticlockwise moments about any point is equal to the sum of the clockwise moments about the point .

Center of gravity
This is a point where the resultant force of attraction of a body acts.

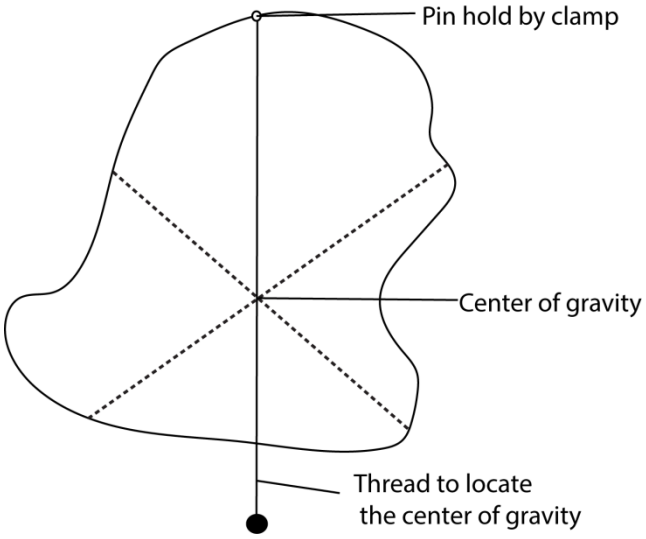
Centre of gravity of regular object
For regular shape bodies, the centre of gravity is at the geometric centre of the body e.g. the centre of gravity of a Uniform meter ruler is at 50cm mark, for circle, it is at the centre. For a rectangular and square body it is at the point of intersection of the diagonals.

Centre of gravity of a regular body lies along its line of symmetry as below



Centre of gravity of irregular body
The best way of finding the centre of gravity of an irregular object is by use a plumb line. A plumb line is made from a thread of cotton with a loop at one end and a weight tied at other end.

For an irregular card board for instance, three small holes are made at well-shaped intervals around the edge of the card



A pin is then put through one of the holes and firmly by a clamp and stand so that the card board swings on it.

The card board will come to rest with its centre of gravity below the point of support along the vertical line of plumb line.

The cardboard is hung through another hole, the point of interception of the two vertical lines is the centre of gravity.

Factors that affect stability

1. The position of center of gravity, should be low.
2. Width of the base: the wider the width of the base, the more stable the body is.

Way of increasing stability

1. Increasing the base area
2. Lowering the center of gravity

Application of center of gravity

1. cars have very heavy framed to lower center of gravity
2. Racing cars have wide wheel base to lower center of gravity.

Couples

Couples are equal and opposite parallel forces.
Moment of couple = one of the forces x perpendicular distance between them.
A couple can only produce a rotation because it is not possible to find a single force to replace a couple as it can only be balanced by an equal and opposite couple.

Stability

There are three terms used in connection with stability:
(a).Stable equilibrium.
(b). Unstable equilibrium.
(c). Neutral equilibrium.

Stable equilibrium

If the body in stable equilibrium is slightly displaced, the centre of gravity of the body is raised. And when released, the body returns to its original position.

Unstable equilibrium

If the body in unstable equilibrium is slightly displaced, the centre of gravity of the body is lowered. And when released, the body moves farther away from its original position.

Neutral equilibrium:

If the body in neutral equilibrium is slightly displaced, the centre of gravity of the body is not raised or lowered. And when released, the body stays in its new position.

Application of stability

Stability plays a crucial role in various fields, ensuring balance and preventing unwanted movement. Here are some key applications:

1. **Architecture & Construction** – Buildings, bridges, and towers are designed with stability principles to resist forces like wind and earthquakes.

2. **Vehicles** – Stability control in cars, motorcycles, and airplanes prevents tipping or rolling, improving safety.
3. **Sports** – Athletes use stability techniques in gymnastics, weightlifting, and cycling for balance and performance.
4. **Furniture & Equipment** – Chairs, ladders, and cranes are built with a low center of gravity to remain steady.
5. **Ships & Boats** – Ballast systems help ships stay stable in rough waters.
6. **Human Posture** – Proper body alignment helps maintain balance and prevents injuries.

Thanks

Dr. Bbosa Science