Ratna Sagar

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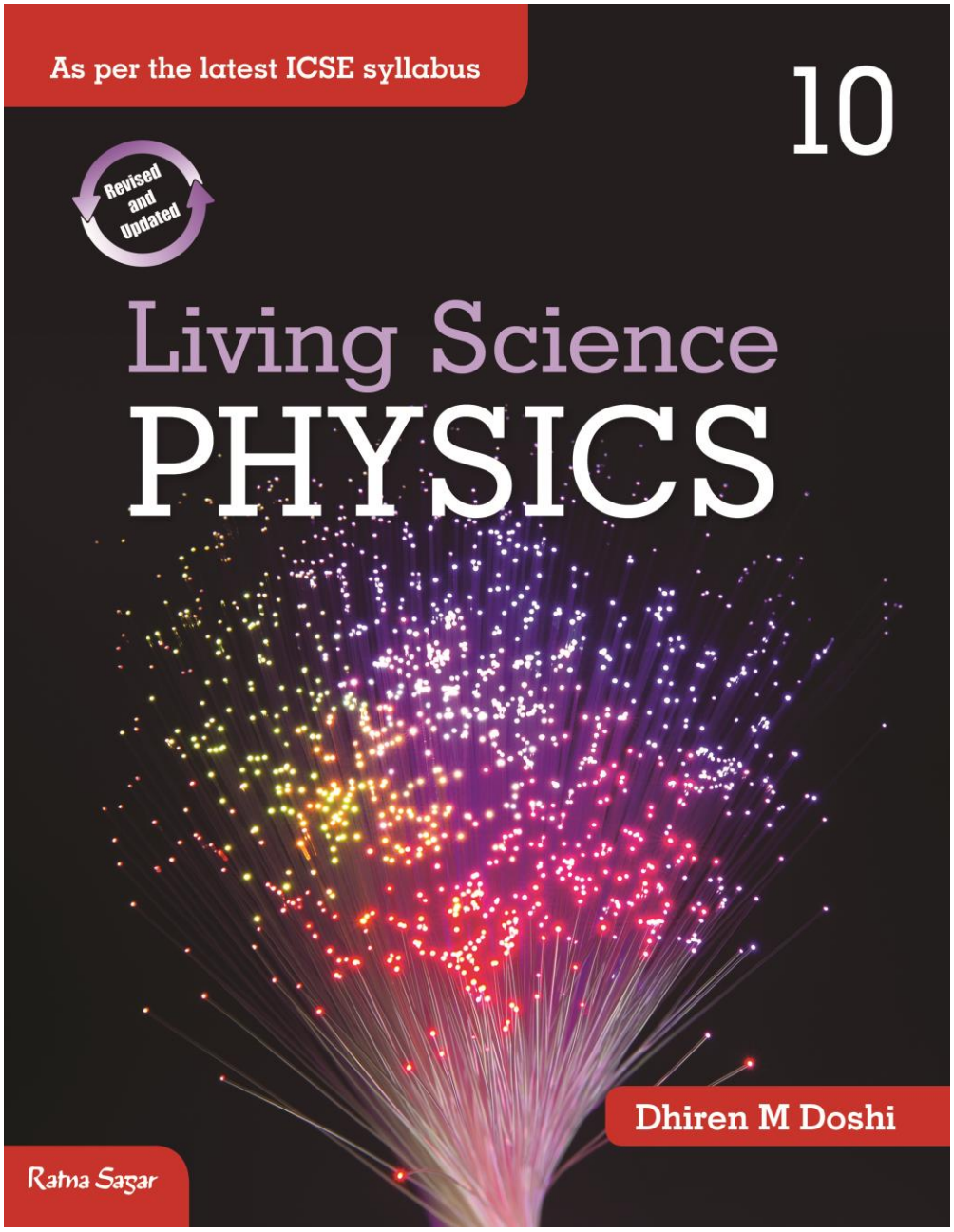
ICSE
Living Science
Physics

Class 10

Chapter-1 Turning Forces


As per the latest ICSE syllabus
10
Revised and Updated
Living Science
PHYSICS
Dhiren M Doshi
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LEARNING OBJECTIVES

Moment of a Force and Equilibrium

- ❖Translational and rotational motions
- ❖Moment of a force or torque
- ❖Clockwise and anticlockwise moments
- ❖ Equilibrium of bodies
- ❖ Principle of moments
- ❖ Couple

Centre of Gravity

- ❖ Position of centre of gravity(G)

Uniform Circular Motion

What is force?

Force is a push or a pull which changes or tends to change the state of rest or of uniform motion, the direction of motion or the shape and the size of a body.

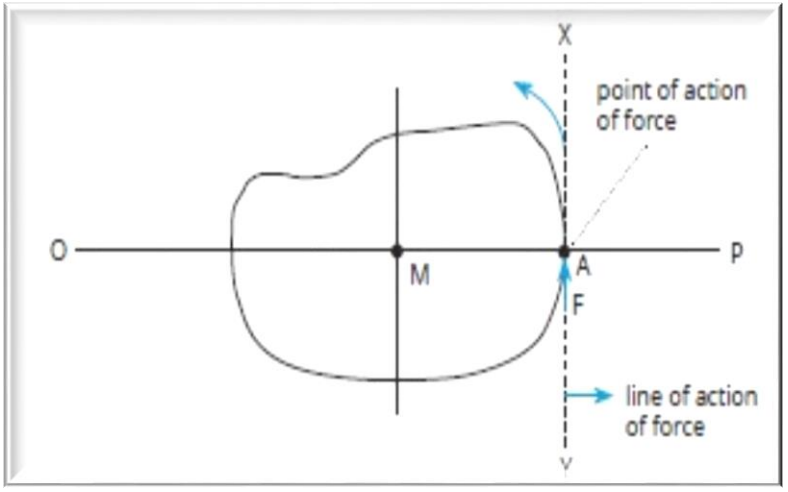
Translational and Rotational Motions

A rigid body executes translational motion when each particle of the body has the same displacement in the same time interval.

A rigid body executes rotational motion when each particle of the body (except those on the axis of rotation) moves in a circular path.

Moment of a Force or Torque

Torque is the measure of the capacity of a force to turn a body. In other words, the turning effect of a force acting on a body about an axis is called the torque about the axis.



Moment Arm: The perpendicular distance from the axis of rotation to the line of action of force is called the moment arm of the force.

Defining Torque

The torque produced by a force about an axis is equal to the product of the magnitude of the force and the perpendicular distance of the line of action of force from the axis of rotation.
It is denoted by the Greek letter τ (tau).

Torque, τ = Force × Perpendicular distance of the line of force from axis of rotation

$$\tau = F \times d$$

Factors affecting the Torque

So we can say, the turning of a body by a force depends on the following two factors:

1. The magnitude of the force applied: A greater force produces a greater turning effect and vice versa.

2. The perpendicular distance from the axis of rotation to the line of action of force (moment arm): Greater the moment arm, greater is the turning effect produced and vice versa.

Units of moment of force or torque

Unit of moment of force = unit of force × unit of distance

The SI unit of force is newton (N) and that of distance is metre (m).

Therefore, the **SI unit** of torque is **N m** (newton metre).

The **CGS unit** of torque is **dyne cm** (dyne centimetre).

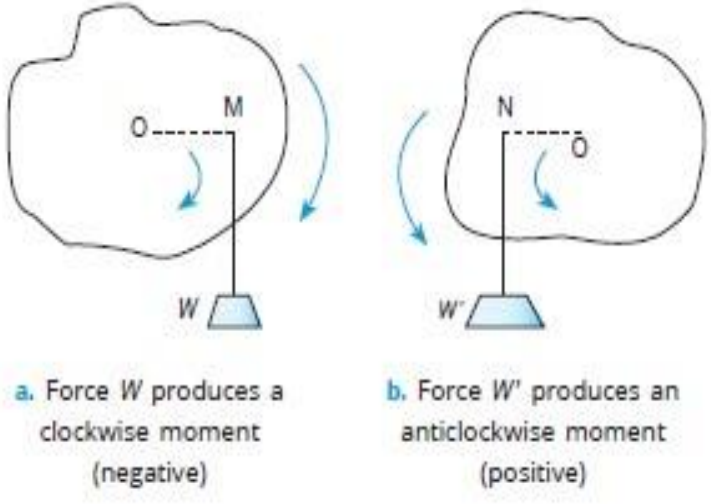
$1\ N\ m = 10^5\ dyne \times 10^2\ cm$

$1\ N\ m = 10^7\ dyne\ cm$

Clockwise and anticlockwise moments

If the force has a tendency to turn or rotate the body in clockwise direction, the moment of force is called **clockwise moment**. The clockwise moment is taken as negative

If the force has a tendency to turn or rotate the body in anticlockwise direction, the moment of force is called **anticlockwise moment**. The anticlockwise moment is taken as positive



a. Force *W* produces a clockwise moment (negative)

b. Force *W'* produces an anticlockwise moment (positive)

Equilibrium of Bodies

when a large number of external forces act on a body and when they produce no change in its state of rest or of uniform motion, then the body is said to be in equilibrium.

When the body remains in the state of rest under the influence of various external forces, it is said to be in **static equilibrium**. Beam balance is in static equilibrium

When a body remains in the state of uniform motion (translational or rotational), it is said to be in **dynamic equilibrium**. Earth is in the state of dynamic equilibrium.

Principle of Moment

According to the principle of moments, **if a body under the action of a number of coplanar forces is in rotational equilibrium, then the algebraic sum of the moments of all forces about a given axis is zero**.

Clockwise moments + Anticlockwise moments = 0
(negative) (positive)

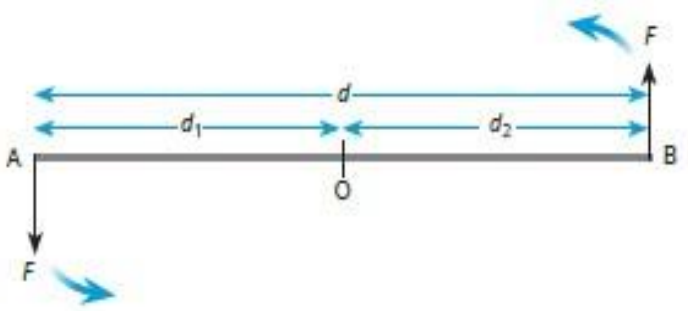
In other words:

If a body is in rotational equilibrium, then the sum of all the clockwise moments about a given axis is equal to the sum of all the anticlockwise moments about the same axis.

Sum of all the clockwise moments = Sum of all the anti-clockwise moments

Couple

Let us consider the moments:



Moment of force F at the end A = $F \times d1$

Moment of force F at the end B = $F \times d2$

Total moment of both the forces

$= F \times d1 + F \times d2$

$= F \times (d1 + d2)$

$= F \times d$

= Either force $\times$ Perpendicular distance between the two forces

= Force $\times$ Couple arm

Two equal, opposite and parallel forces whose lines of action are not same, acting on a body form a couple and produce a rotational effect.

1. Arm of couple (*d*): Perpendicular distance between the two equal and opposite parallel forces is called the arm of couple.

2. Moment of couple: The product of one of the forces of the couple and arm of the couple is called the moment of couple.

Moment of couple = Force $\times$ Arm of couple

$= F \times d$

If the couple has a tendency to rotate the body in anticlockwise direction, its moment is taken **positive**. If the tendency of rotation is clockwise, the moment is taken **negative**.

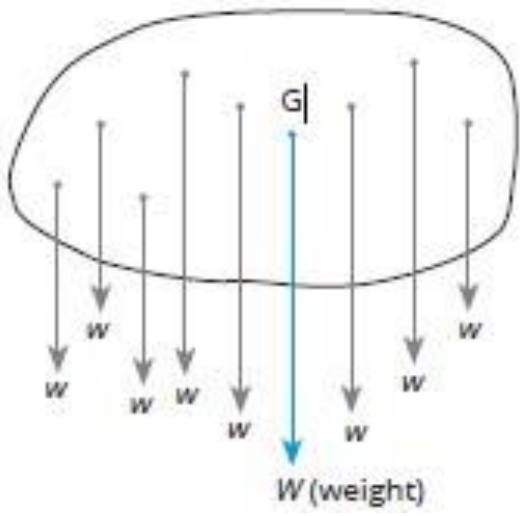
Examples of Couple Action in Daily Life

1. Opening or closing a water tap
2. Winding a clock with its key
3. Opening and closing a bottle cap
4. Steering the wheel of a motor car
5. Turning of a screwdriver

Centre of Gravity

The centre of gravity of a body is the point at which the body experiences the total gravitational pull.

When a body is supported at its centre of gravity (G), it remains in equilibrium.



The centre of gravity of a body is a point at which the resultant of the parallel forces called the weight of the body acts vertically downwards due to gravity, no matter in which position the body is placed.

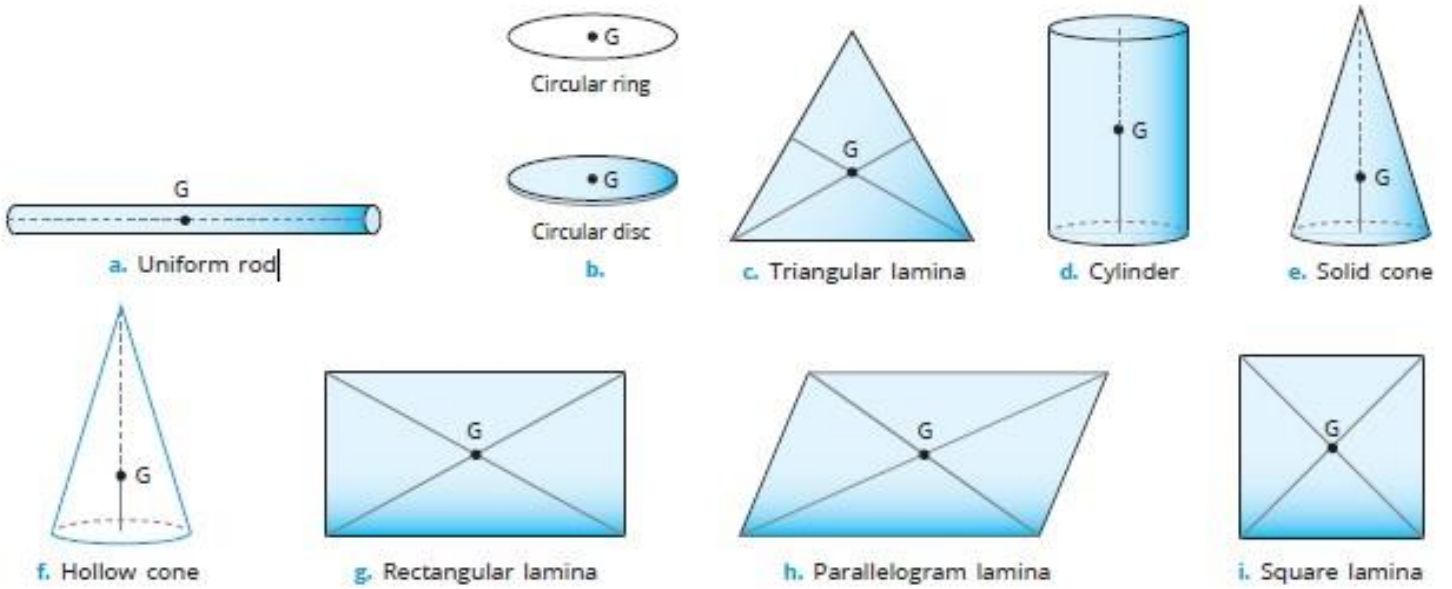
Position of Centre of Gravity (G)

The position of centre of gravity of a body of given shape and mass depends on the **distribution of mass in the given shape**. It may lie inside the body, or outside the body.

Centre of gravity inside the body

For regular homogeneous bodies

A body which has a definite geometrical shape and whose density is uniform throughout, will have its centre of gravity at its **geometric centre**.

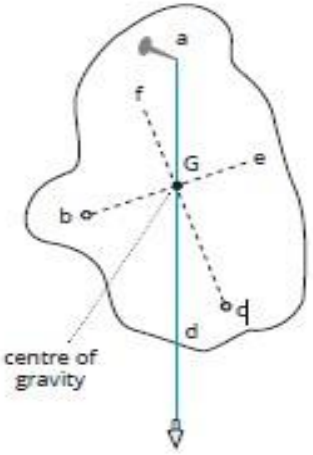


Centre of gravity of some regular bodies

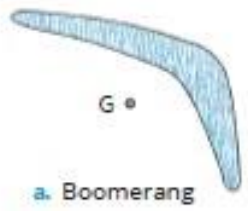
Centre of gravity of some irregular bodies

Centre of gravity of an irregularly shaped body can be determined by the method of balance using a plumb line.

This principle of finding the centre of gravity is very usefu in designing various things by designers. It is also employed in loading and balancing of irregularly shaped bodies.



Centre of gravity outside the body



a. Boomerang

1. In case of L-shaped bodies, such as boomerang, the centre of gravity lies outside the body.

b. Doughnut

2. The centre of gravity of a doughnut lies in the middle of the hole.

3. The centre of gravity of a horseshoe magnet does not lie within the body of the material.

4. The centre of gravity of a motor tyre does not lie within the body of the material.

5. The centre of gravity of a necklace lies outside the body of the necklace

c. Necklace

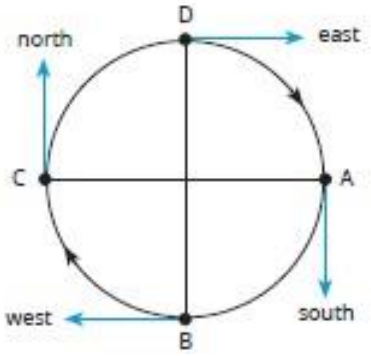
6. If a wire is bent in the form of a circle to form a circular ring, its centre of gravity will be at the centre of the circle which is outside the body of the circular ring.

Uniform Circular Motion

1. When a body moves in a circular path with uniform speed (constant speed), its motion is called **uniform circular motion.**

2.when a body moves with a uniform speed along a circular path, its velocity is not uniform because **the direction of motion changes** infinite times for motion through one circle.

3. The direction of the velocity is along the tangent to the circle at any point in its motion. The direction of velocity constantly changes.

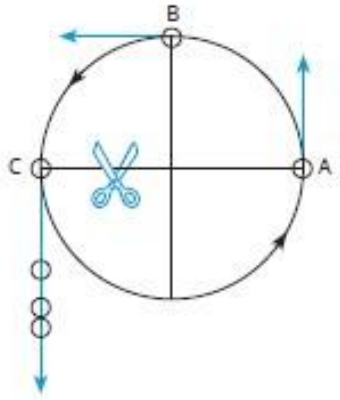


How does a body move along a circular path with uniform speed?

Suppose a stone is tied to a string and swing around in a circle at a constant speed in anticlockwise direction. What keeps the stone moving in a circle? There is a force acting along the string towards the centre of the circle. This force is called the centripetal force. It is this force that keeps the stone moving in a circle.

So, **centripetal force is a centre-seeking force that causes an object to move in a circular path**. According to Newton's first law of motion, a moving object will travel in a straight line unless acted on bv a force.

So, if the string were suddenly cut, the stone would no longer be subjected to the centripetal force and would travel in a straight line in a direction tangent to the circular path of the stone.



According to Newton's third law of motion, to every action there is an equal and opposite reaction. In centripetal force, the action is balanced by a reaction force called centrifugal force (centre-fleeing force).

The centrifugal force is outward-directed fictitious force exerted on a body when it is moving in a circular path.
The two forces – centripetal force and centrifugal force are equal in magnitude and opposite in direction.

SUMMARY

1. Force: Force is a push or pull which changes or tends to change the state of rest or of uniform motion, the direction of motion or the shape and size of a body.

2. Torque: Torque is the measure of the capacity of a force to turn a body.

3. Moment of force: Torque (moment of force) produced by a force about an axis is equal to the product of the magnitude of the force and its moment arm about the axis.

4. Convention of moments: By convention, the clockwise moment is taken as negative and the anticlockwise moment is taken as positive.

5. Equilibrium: When a large number of external forces act on a body and produce no change in its state of rest or of uniform motion, then the body is said to be in equilibrium.

6. Principle of moments: According to the principle of moments, if a body under the action of a number of coplanar forces is in rotational equilibrium, the the algebraic sum of the moments of all the forces about a given axis is zero.

7. Couple: Two equal, parallel but opposite forces acting on a body whose lines of action are not same form a couple.

8. Examples of couple action in daily life: a. Opening or closing a water tap **b.** Winding a clock with its key **c.** Opening or closing a bottle cap **d.** Steering a car.

9. Centre of gravity: The centre of gravity of a body is a point at which the resultant of the parallel forces due to the molecules or particles, called the weight of the body acts vertically downwards due to gravity, no matter in which position the body is placed.

10. Centre of gravity of regular bodies: The centre of gravity of regular bodies lies at the geometric centre.

11. Centripetal force: It is a centre-seeking force that causes an object to move in a circular path.

12. Centrifugal force: It is an outward-directed fictitious force exerted on a body when it is moving in a circular path.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