SLO 4: Turning Effect of Forces

4.1 Forces on Bodies

4.1.1 Define Like And Unlike Parallel Forces

The forces that act along the same direction are called like parallel forces. Many people pushing a car together in same direction. All of these forces are called like parallel forces because these are acting along same line. Parallel forces can add up to a single resultant force, therefore, can be replaced by a single force.

The forces that act along opposite directions are called unlike parallel forces. A ceiling fan suspended in a hook through supporting rod. The forces acting on it are; weight of the fan acting vertically downwards and tension in the supporting rod pulling it vertically upwards. These two forces are also parallel but opposite to each other and acting along the same line. Thus, these forces are called unlike parallel forces

4.1.2 Explain The Turning Effect Of Force By Relating It To Everyday Life

A door handle is fixed at the outer edge of the door so that it opens and closes easily. A larger force would be required if handle were fixed near the inner edge close to the hinge. Similarly, it is easier to tighten or loosen a nut with a long spanner as compared to short one.

"The turning effect of force is called moment of force or Torque"

It depends upon:

1. The magnitude of force.
2. The perpendicular distance of the point of application of force from the Pivot or fulcrum.

"Moment of force about a point = Force x Perpendicular distance from point"

$$\boldsymbol{\tau} = \mathbf{F} \times \mathbf{d}$$

Depending on their direction, S.I unit of the torque or moment of force is newton -metre (Nm). Moments are described as clockwise or anticlockwise.

4.1.3 Solve Word Problems Related To The Moment Of Force Or Torque

Practice questions available on worksheet.

4.2 Principle of Moments

4.2.1 State The Principle Of Moments

The sum of the clockwise moments about a point is equal to the sum of the anticlockwise moments about that point.

Two children playing on the see-saw. Fatima is sitting on right side and Faheem on the left side of the pivot. When the clockwise turning effect of Fatima is equal to the anticlockwise turning effect of Faheem, then see-saw balances. In this case they cannot swing. When the sum of all the clockwise moments on a body is balanced by the sum of all the anticlockwise moments, this is known as principle of moments.

4.2.2 Solve Word Problems Related To The Principle Of Moments

$$clockwise\ torque = anticlockwise\ torque$$

4.3 Centre of Gravity

4.3.1 Define Centre Of Gravity And Centre Of Mass Of A Body

Centre of Gravity (CG)
The centre of gravity of a body is the point at which the entire weight of the body appears to act.

- It depends on gravity.
- It can be outside the object (e.g., ring or boomerang).
- In a uniform gravitational field, it is the same as the centre of mass.
- For a uniform ruler, CG lies at its midpoint.
- For an irregular object like a hammer, CG lies closer to the heavier end.

Centre of Mass (CM)
The centre of mass of a body is the point at which the entire mass of the body appears to be concentrated.

- It depends only on mass distribution, not gravity.
- It always lies within the object in most cases (though not always for hollow shapes).
- Important for analysing motion in space or zero gravity.
- For a uniform ball, CM is at its centre.
- In a system of two masses, CM lies closer to the heavier mass.

4.3.2 Effects Of Position Of The Centre Of Gravity On The Stability Of Simple Objects

Centre of Gravity (CG) is the point where the whole weight of an object seems to act from. It decides how balanced or stable the object is.

- The lower the CG is, the harder it is to fall. These objects are more balanced. Example: A wide stool is hard to tip over.
- The higher the CG, the easier it is to fall over. These objects are less balanced. Example: A tall vase falls easily.
- Centre of Gravity outside the base then object falls. Example: If you lean too far and your CG goes beyond your feet, you will fall.

Plane Lamina
A plane lamina is a flat, thin sheet of material (like cardboard or metal) with negligible thickness. It can be square, triangular, circular, or any other 2D shape. The centre of gravity of a plane lamina is the point where the entire weight of the lamina appears to act when suspended freely. For a uniform lamina (same material and thickness everywhere), the CG is at its geometrical centre. It is the point of balance.

SHAPE OF LAMINA	CENTRE OF GRAVITY LOCATION
Rectangle/Square	At the intersection of diagonals (centre)
Triangle	At the intersection of medians
Circle	At the centre of the circle
Sphere	At the centre of the sphere
Cylinder	Centre of Axis
Metric Rule	Centre of the rod

4.4 Equilibrium

4.4.1 Define Equilibrium

When a body does not possess any acceleration neither linear nor angular it is said to be in equilibrium.

For example, a book lying on table in rest, a paratrooper moving downwards with terminal velocity, a chair lift hanging on supporting ropes.

4.4.2 Classify The Different Types Of Equilibrium

Static Equilibrium

A body at rest is said to be in static equilibrium. A wall hanging, buildings, bridges or any object lying in rest on the ground are some examples of static equilibrium.

Dynamic Equilibrium

A moving object that does not possess any acceleration neither linear nor angular is said to be in dynamic equilibrium. For example, uniform downward motion of steel ball through viscous liquid and jumping of the paratrooper from the Helicopter.

4.4.3 State The Conditions Of Equilibrium

A body must satisfy certain conditions to be in equilibrium. There are two conditions for equilibrium:

1. A body is said to be in translational equilibrium only if the vector sum of all the external forces acting on it is equal to zero. $\sum F = 0$
2. A body is said to be in rotational equilibrium only if the vector sum of all the external torque acting on it is equal to zero. $\sum \tau = 0$

4.4.4 Explain Different Conditions Of Equilibrium With Examples

TYPE	EXAMPLE	EXPLANATION
TRANSLATIONAL	Book resting on a table	The downward weight of the book is balanced by the upward normal force from the table → No net force.
	Person hanging still on a rope	The tension in the rope balances the weight of the person → No net force, no movement.
	Car moving at constant speed	The engine force balances friction + air resistance → The car doesn't speed up or slow down.
ROTATIONAL	Seesaw balanced with two people	If the clockwise torque = anticlockwise torque, the seesaw is in balance (no turning).
	Door staying still even when forces are applied	If you push on a door near the hinge and your friend pulls with equal force farther away, the door doesn't rotate → torques cancel.
	Balanced weighing scale	Equal weights on both sides produce equal and opposite torques → No rotation.

4.4.5 Describe States Of Equilibrium And Classify Them With Common Examples

Stable Equilibrium

Suppose a box is lying on the table. It is in equilibrium. Tilt the box slightly about its one edge. On releasing it returns back to its original position. This state of body is known as stable equilibrium. A body is in stable equilibrium if when slightly displaced and then released it returns to its previous position. A body is in stable equilibrium when:

1. Its Centre of gravity is at lowest position
2. When it is tilted its Centre of gravity rises
3. It returns back to stable state by lowering its Centre of gravity

A body remains in stable state of equilibrium as long as its Centre of gravity acts through the base of body.

Unstable Equilibrium

Take a paper cone and try to keep it in vertical position on its vertex. it topples down on releasing. This state of body is known as unstable equilibrium. A body is said to be in unstable equilibrium when slightly tilted does not return back to its previous position. A body is in unstable equilibrium when:

1. Its Centre of gravity is at highest position
2. When it is tilted its Centre of gravity is lowered
3. Its previous position cannot be restored by raising its Centre of gravity.

Neutral Equilibrium

Consider a ball placed on a horizontal surface. It is in equilibrium. When it is displaced from its previous position it remains in its new position still in equilibrium. This is called neutral equilibrium. A body is said to be in neutral equilibrium when displaced from previous position remains in equilibrium in new position. A body said to be in neutral equilibrium when:

1. Its Centre of gravity always remains above the point of contact.
2. When it is displaced from its previous position its Centre of gravity remains at same height.
3. All the new states in which body is moved are the stable states