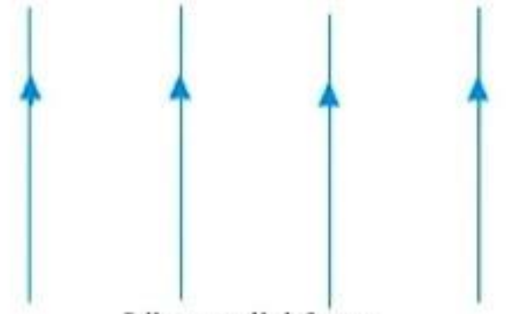
LIKE PARALLEL FORCES

The forces that act along the same direction are called like parallel forces.



Like parallel forces

RESULTANT OF TWO PARALLEL FORCE IN SAME DIRECTIONS

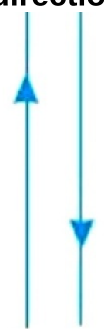
Consider two like parallel forces F_1 and F_2 acting on a body at A and B , as shown in figure.

The resultant force is given by

$$R = F_1 + F_2$$

UNLIKE PARALLEL FORCES

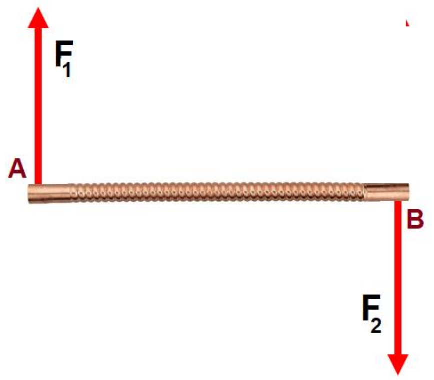
The forces that act along the opposite direction are called like parallel forces.



UNLIKE PARALLEL FORCES

THE RESULTANT OF TWO PARALLEL FORCES IN OPPOSITE DIRECTIONS:

Consider two forces unlike forces of F_1 and F_2 acting on a body at A and B , as shown in figure.



The resultant force is given by

$$R = F_1 - F_2$$

It means that the resultant of two unlike forces is equal to the difference of the magnitude of the two forces.

ADDITION OF FORCES

Two different methods are used for the addition of forces (i.e., in general, the addition of vectors):

Graphical Method

Analytical Method

GRAPHICAL METHOD

This method is used to add one-dimensional vector quantities. In this method head to tail rule of vector addition is used for the addition of forces.

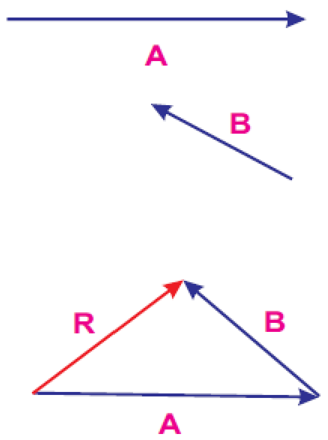


Fig 4.4

Head to Tail Rule

Figure 4.4 shows head to tail rule of vector addition.

Step 1

Choose a suitable scale

Step 2

Draw all the force vectors according to scale. Vectors A and B in this case.

Step 3

Now take any vector as first vector and draw next vector in such a way that its tail coincides with head of the previous. If number of vectors is more than two then continue the process till last vector is reached.

Step 4

Use a straight line with arrow pointed towards last vector to join the tail of first vector with the head of last vector. This is the resultant vector.

RESOLUTION OF FORCES

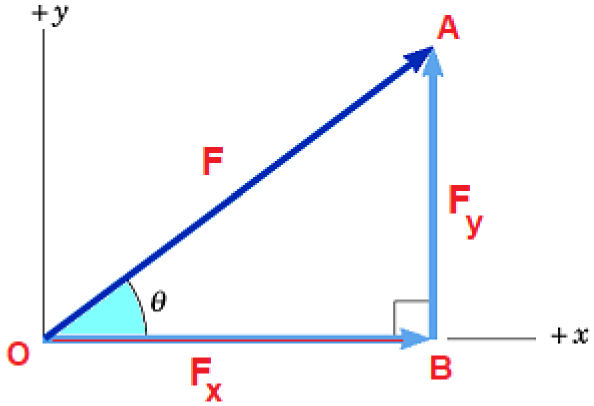
A force (vector) may be split into components usually perpendicular to each other; the components are called perpendicular components and the process is known as resolution of Vectors.

The process of splitting a vector into mutually perpendicular components is called the resolution of vectors.

EXPLANATION:-

Consider a force $\vec{F}$ represented by a line segment $\overrightarrow{OA}$ which makes an angle with x-axis. Draw a perpendicular AB on x-axis from A. The components $\overrightarrow{OB} = \overrightarrow{F_x}$ and $\overrightarrow{BA} = \overrightarrow{F_y}$ are perpendicular to each other. They are called the perpendicular components of $\overrightarrow{OA} = \vec{F}$. Therefore,

$$\vec{F} = \overrightarrow{F_x} + \overrightarrow{F_y} \ldots\ldots\ldots\ldots(1)$$



The trigonometric ratios can be used to find the magnitudes Fx and Fy . In right-angled triangle ΔAOB.

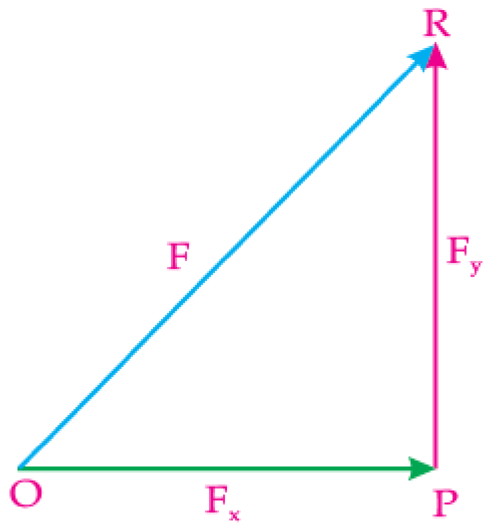
X-Component	Y-Component
In Δ AOB: $Cos\theta = \frac{Base}{Hyp}$ $Cos\theta = \frac{OP}{OQ}$ $Cos\theta = \frac{F_x}{F}$ Or $F_x = F\,Cos\theta$	In Δ AOB: $Sin\theta = \frac{perp}{Hyp}$ $Sin\theta = \frac{OP}{QP}$ $Sin\theta = \frac{A_Y}{A}$ $F_y = F\,Sin\theta$

Determination of Force from its Perpendicular Components

The process by which a vector can be reconstituted from its rectangular components is known as the composition of a vector.

EXPLANATION:-

Suppose $\vec{F_x}$ and $\vec{F_y}$ are the perpendicular components of the force $\vec{F}$ and are represented by line segments **OP** and **PR** with arrowhead respectively as shown in.



Applying the head-to-tail rule:

$$\overline{OR} = \overline{OP} + \overline{PR}$$

Here **OR** represents the force $\vec{F}$ whose x and y components are $\vec{F_x}$ and $\vec{F_y}$ respectively. Thus,

$$\vec{F} = \vec{F_x} + \vec{F_y}$$

To find the magnitude of **F** apply the Pythagorean theorem to right angled triangle OPR

$$(Hyp)^2 = (base)^2 + (perp)^2$$

$$F^2 = F_x^2 + F_y^2$$

$$F = \sqrt{F_x^2 + F_y^2}$$

The direction of **F** with x-axis is given by

$$\tan\theta = \frac{\text{Perp}}{\text{Base}}$$

$$\tan\theta = \frac{F_y}{F_x}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

TORQUE OR MOMENT OF FORCE

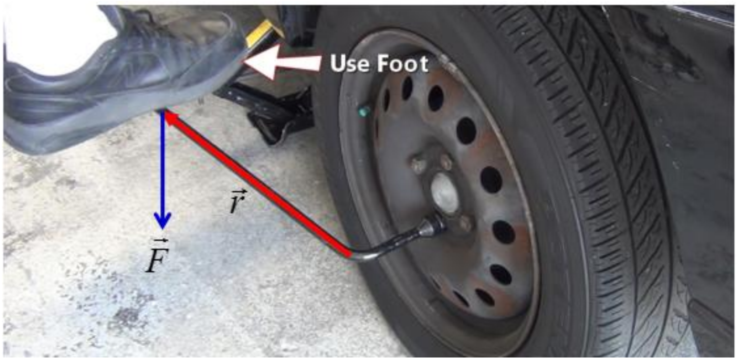
The turning effect of force is called the moment of force or Torque.

It depends upon:

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

$$\text{Moment of force} = \text{force} \times \left(\begin{array}{c} \text{Perpendicular distance from the pivot} \\ \text{to the line of action of force} \end{array} \right)$$

$$\tau = F(d)$$



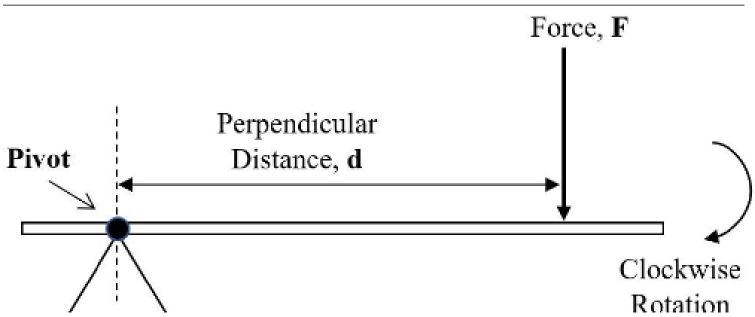
UNIT

SI unit of the torque or moment of force is newton -metre (Nm).

TYPE OF MOMENTS

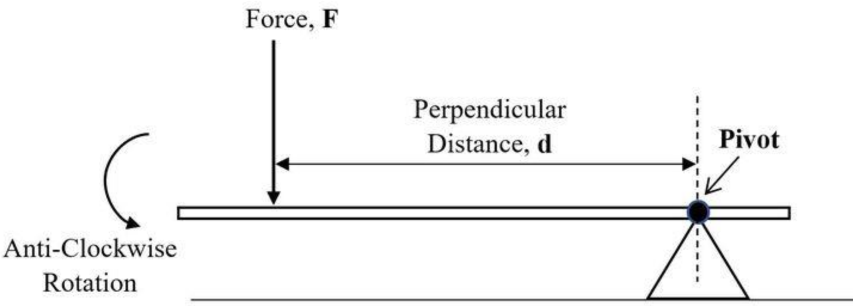
CLOCKWISE MOMENT

If the effect of the body is to turn clockwise, the moment of force is called the clockwise moment and it is taken negative.



THE ANTICLOCKWISE MOMENT

If the effect of the body is to turn anticlockwise, the moment of force is called the anticlockwise moment and it is taken positive.



PRINCIPLE OF MOMENT

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

$$Sum\ of\ the\ clockwise\ moment\ =\ Sum\ of\ the\ anticlockwise\ moment$$

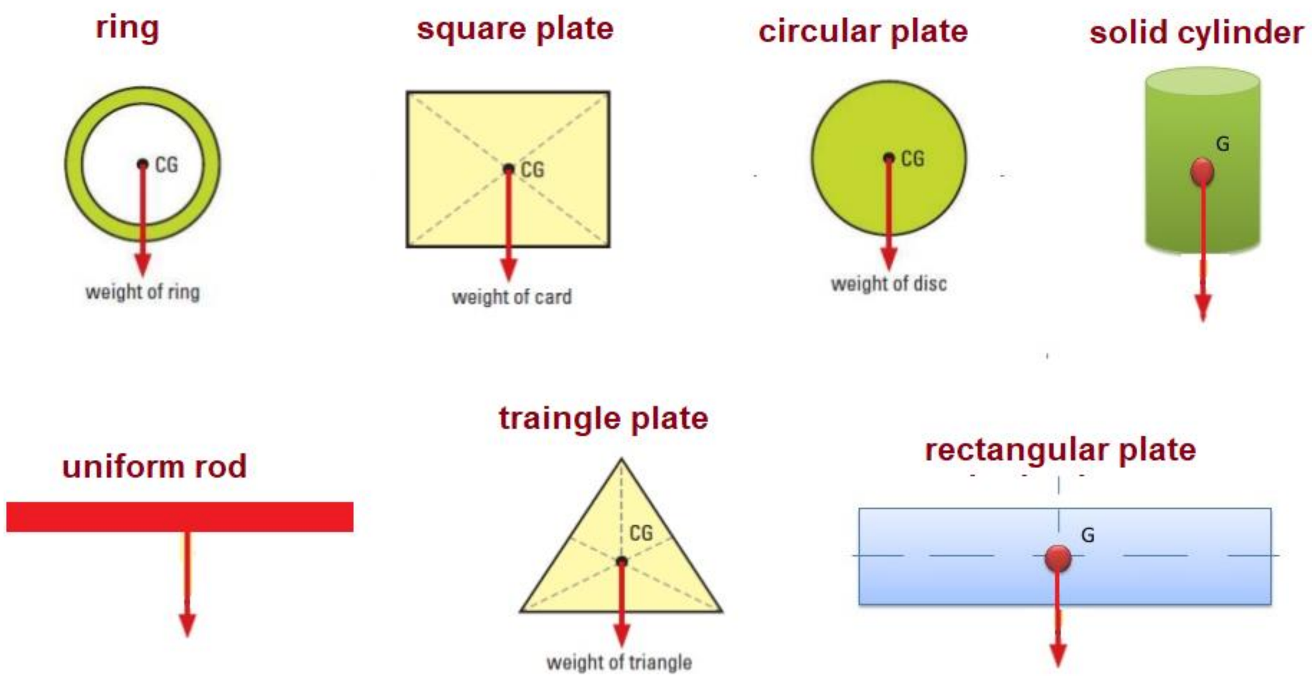
CENTRE OF MASS OR CENTRE OF GRAVITY

A body behaves as if its whole mass is concentrated at one point, called its **centre of mass** or **centre of gravity**, even though the earth attracts every part of it.

Center of Gravity of Some Regular Shaped objects

The Center of gravity of regularly shaped uniform objects is their geometrical Center.

- ► The Center of gravity of a uniform rod is its midpoint as shown in the figure
- ► The Center of gravity of a uniform square or a rectangular plate is the point of intersection of its diagonals as shown in Figures
- ► The Center of gravity of a solid or hollow sphere is the Center of the sphere as shown in Figure
- ► The Center of gravity of a uniform triangular plate is the point of intersection of its medians as shown in the figure



CENTER OF GRAVITY OF IRREGULAR SHAPED THIN LAMINA

Step 1: Make three small holes near the edges of the lamina farther apart from each other.

Step 2: Suspend the lamina freely from one whole on a retort stand through a pin as shown in the figure.

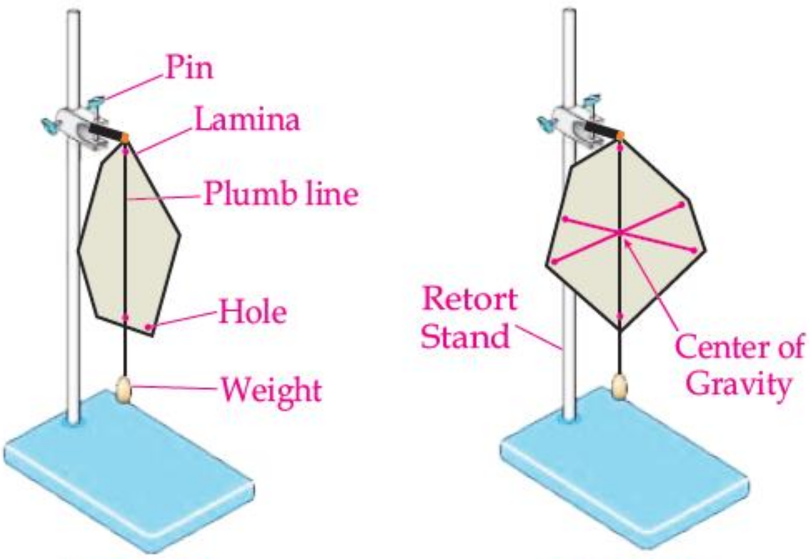


Fig 4.15 (a) Fig 4.15 (b)

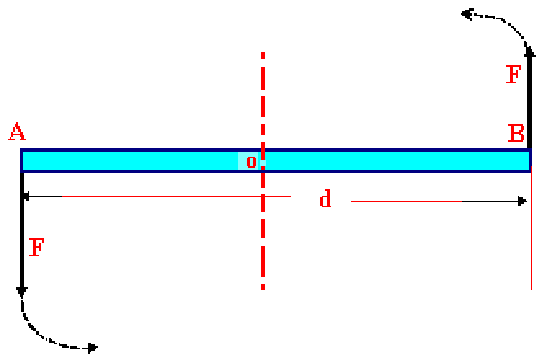
Step 3: Hang a plumb line or weight from the pin in front of the lamina as shown in the figure
Step 4: When the plumb line is steady, trace the line on the lamina.
Step 5: Repeat steps 2 to 4 for the second and third holes. The point of intersection of the three lines is the position of the Center of gravity.

COUPLE

Two unlike parallel forces of the same magnitude but not acting along the same line form a couple.

DERIVATION.

Consider a couple of two forces on a Body.
Let the couple act at points A and B The total torque is about 'o'



$$\textit{torque of couple} = \tau_1 + \tau_2$$

$$\tau = \mathbf{F}(OA) + \mathbf{F}(O$$

$$\tau = \mathbf{F}[(OA) + (OB)]$$

$$\tau = \mathbf{F}\, d$$

$$\textit{torque of the couple} = (\textit{one of the force})\,(\textit{separation of the forces})$$

EQUILIBRIUM

When two or more than two forces act on a body simultaneously in such a manner that there is no change either in its translational motion or its rotational motion. The body is said to be in equilibrium.
Or
When a body does not possess any acceleration neither linear nor angular it is said to be in equilibrium.

There are two types of equilibrium.

- **Static Equilibrium**
- **Dynamic Equilibrium**

Static Equilibrium

A body at rest is said to be in static equilibrium.

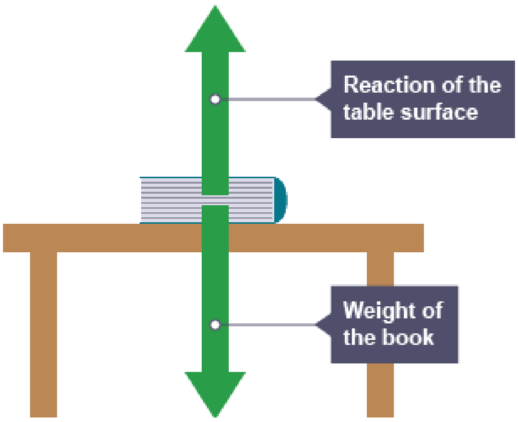
Dynamic Equilibrium

A moving object that does not possess any acceleration neither linear nor angular is said to be in dynamic equilibrium.

EXAMPLES OF BODIES IN EQUILIBRIUM:

A book living on a table is said To be in static equilibrium because two force acting on the book are its weight and the Normal reaction of the surface of table are

Equal in magnitude but opposite in direction.



When a Para trooper jumps from an airplane. He moves downward due to the force of gravity. But when Its parachute opens, the air pulls the parachute upward and cancels the weight of the person. In this way, after Some time the paratrooper moves with uniform velocity In a downward direction and set a state of dynamic equilibrium.

CONDITIONS OF EQUILIBRIUM

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

I. (FIRST CONDITION OF EQUILIBRIUM) (OR FORCE CONDITIONS)

STATEMENT.

"A body is said to be in equilibrium if the resultant of all the forces acting on the body is zero "

Mathematically, $\sum F = 0$

Alternate Statement: The first condition can be stated as:
"A body is said to be in equilibrium if the algebraic sum of the forces acting alone on X and Y axes is Zero"

$$\sum F = 0$$

EXPLANATION

Let **F_1, F_2 , F_3, F_4, ………………… F_n** be the n external forces acting on a body. The first condition of equilibrium is that the vector sum of all the forces acting on a body vanishes. This can be written as

$$F_1 + F_2 + F_3 + F_4 + \ldots + F_n = 0$$

$$\sum F = 0$$

where Σ, the Greek letter sigma, means the summation of the forces. If each force is resolved along the x and y axes, The sum of the components along x-axis is

$$F_{1x} + F_{2x} + F_{3x} + \ldots\ldots\ldots\ldots + F_{nx} = 0$$

$$\sum F_X = 0$$

The sum of the components along y-axis is

$$F_{1y} + F_{2y} + F_{3y} + \ldots\ldots\ldots\ldots + F_{ny} = 0$$

$$\sum F_y = 0$$

That means that the first condition of equilibrium,

$$\sum F = 0$$

CONCLUSION

To maintain transitional equilibrium in a body the vector sum of all the forces acting on the body is equal to zero

SECOND CONDITION OF EQUILIBRIUM

STATEMENT.

A body is said to an equilibrium if the vector sum of all the torques acting on it is zero

Mathematically $\sum \tau = 0$

EXPLANATION

Consider a body acted upon by n torques, then

$$\tau_1 + \tau_2 + \tau_3 + \ldots\ldots\ldots\ldots\ldots + \tau_n = 0$$

Symbolically, $\sum \tau = 0$

STATES OF EQUILIBRIUM

There are three states of equilibrium:

- Stable equilibrium
- Unstable equilibrium and
- Neutral equilibrium

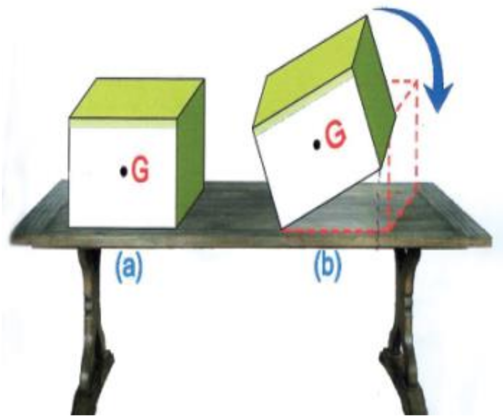
A body may be in one of the above states of equilibrium.

Stable Equilibrium

A body is in stable equilibrium if it returns to its previous position after being slightly displaced and then released.

Example

Suppose a box is lying on the table. It is in equilibrium. Tilt the box slightly about its one edge as shown in the figure. on releasing it returns to its original position. This state of the body is known as stable equilibrium.



KEY POINTS

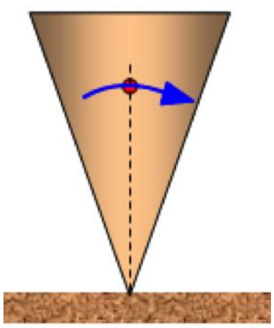
- A body is in stable equilibrium when:
- Its Centre of gravity is at the lowest position
- When it is tilted its Centre of gravity rises
- It returns back to a stable state by lowering its Centre of gravity

UNSTABLE EQUILIBRIUM

A body is said to be in unstable equilibrium when slightly tilted and does not return to its previous position.

EXAMPLE

Take a paper cone and try to keep it in a vertical position on its vertex as shown in the figure. it topples down on releasing. This state of the body is known as unstable equilibrium.



Unstable equilibrium

KEY POINTS

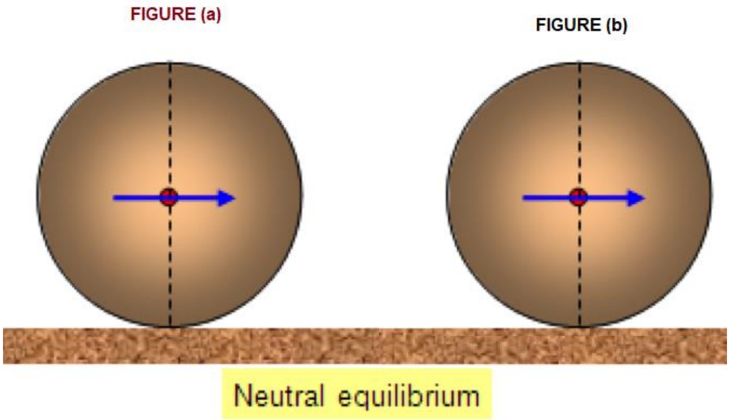
- A body is in unstable equilibrium when:
- Its Centre of gravity is at its highest position
- When it is tilted its Centre of gravity is lowered
- Its previous position cannot be restored by raising its

NEUTRAL EQUILIBRIUM

A body is said to be in neutral equilibrium when displaced from the previous position and remains in equilibrium in the new position.

EXAMPLE

Consider a ball placed on a horizontal surface as shown in Figure (a). It is in equilibrium. When it is displaced from its previous position it remains in its new position still in equilibrium as shown in Figure (b). This is called neutral equilibrium.



KEY POINTS

A body is said to be in neutral equilibrium when:

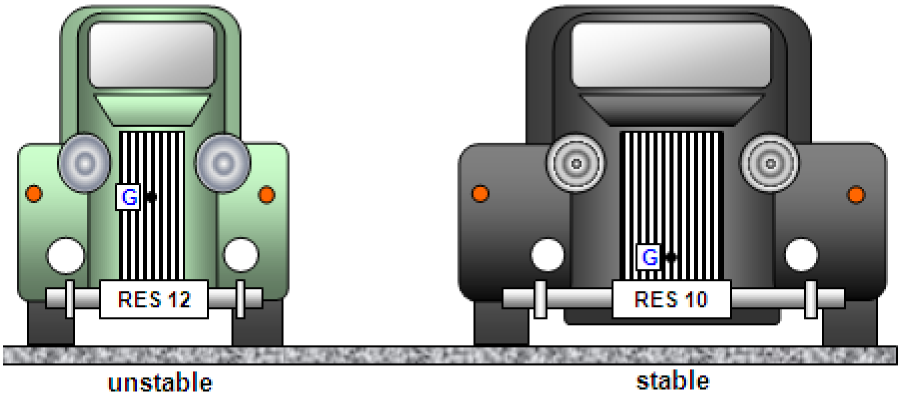
- Its Center of gravity always remains above the point of contact.
- When it is displaced from its previous position its Centre of gravity remains at the same height.
- All the new states in which the body is moved are the stable states.

STABILITY

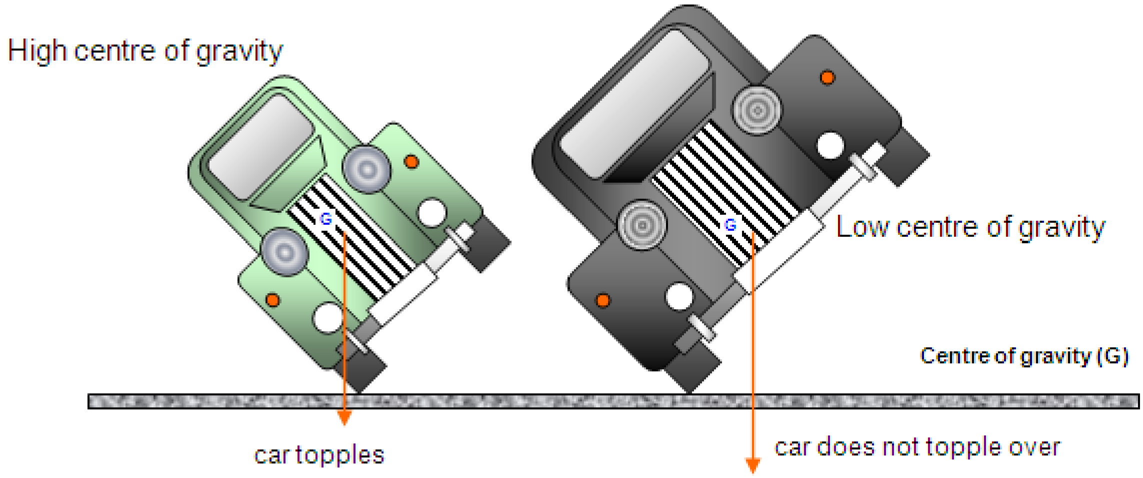
A body whose center of gravity is above its base of support will be stable if a vertical line projected downward from the center of gravity falls within the base of support.

EXAMPLE

The position of the centre of gravity of an object affects its stability. The lower the centre of gravity (G) is, the more stable the object. The higher it is the more likely the object is to topple over if it is pushed. Racing cars have low centres of gravity so that they can corner rapidly without turning over.



The following diagrams show that the position of the centre of gravity is important in toppling. The higher the centre of gravity the more likely an object is to topple over if it is tilted.



A perched parrot is shown in figure. it is made heavy at the tail which lowers its centre of gravity. it can keep itself upright when tilted. In general, the larger the base and lower the centre of gravity, the more stable the body will be.

The effect of size of the base is shown by the three stools in Figure. The centres of gravity of all the stools are the same height above the ground but because stool (c) has a much smaller base it topples over if they are all tilted to the same angle while the other two stools return to a level position. Notice that the centre of gravity is not inside the material of the stool.