Unit - 4

TURNING EFFECT 0F FORCES

Modern day communication is possible through artificial satellites that move around the earth in geostationary orbits which is possible because of turning effects of forces. Driving of Vehicles, bicycle balancing while walking the tight rope requires the knowledge of the turning effects of force.

Students Learning Outcomes (SLOs)

After learning this unit students should be able to:

- Define like and unlike parallel forces
- State head to tail rule of vector addition of forces/vectors.
- Describe how a force is resolved into its perpendicular components
- Determine the magnitude and direction of a force from its perpendicular components.
- Define moment of force or torque as moment = force x perpendicular distance from pivot to the line of action of force.
- Explain the turning effect of force by relating it to everyday life.
- Illustrate by describing a practical application of moment of force in the working of bottle opener, spanner, door/windows handle etc.
- State the principle of moments
- Verify the princi1ple of moments by using a meter rod balanced on a wedge
- Define the center of mass and center of gravity of a body
- Determine the position of center of mass/gravity of regularly and irregularly shaped objects
- Define couple as a pair of forces tending to produce rotation.
- Prove that the couple has the same moments about all points
- Demonstrate the role of couple in the steering wheels and bicycle pedals
- Define equilibrium and classify its types by quoting examples from everyday life.
- State the two conditions for equilibrium of a body
- Solve problems on simple balanced systems when bodies are supported by one pivot only
- Describe the states of equilibrium and classify them with common examples.
- Explain effect of the position of the Centre of mass on the stability of simple objects.
- Demonstrate through a balancing toy, racing car etc., that the stability of an object can be improved by lowering the Centre of mass and increasing the base area of the objects.


Fig 4.1


Fig 4.2

Have you ever seen a driver changing wheel? Why does he use a long spanner? Sometimes he adds a piece of pipe to the spanner to increase the length as shown in figure 4.1. Have you visited a circus? Where you might have seen a man walking on a tight rope carrying a long beam. How that beam helps him to keep balance while walking on the tight rope. After learning this unit, you will be able to answer these questions and some other similar questions.

4.1 FORCES ON BODIES

Like and unlike parallel forces

Sometimes we find objects on which more than one forces are acting. In most cases, some or all of the forces are found acting in the same direction. For example, you might have seen many people pushing a car to move it Fig4.2. Why do all of them push it together in same direction? All of these forces are called like parallel forces because these are acting along same line. Like parallel forces can add up to a single resultant force, therefore, can be replaced by a single force.

Do You Know!

- Force is a push or pull.
- It moves the objects.
- It stops the objects.
- It gives shape to the objects.
- It is a vector quantity. Therefore, it has a specific direction.
- It is measured in Newton (N).

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


Fig 4.3 (a)

Figure 4.3 (a) shows 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. These forces also add up to a single resultant force. But, when a pair of unlike forces do not act along the same line as shown in figure 4.3(b), can be responsible for rotation of objects. Such unlike parallel forces cannot be replaced by a single resultant force and form a couple. A couple can only be balanced by an equal and opposite forces directed at the two different ends of the rod.

Fig 4.3 (b)

The forces that act along opposite directions are called unlike parallel forces.

Self Assessment Questions:

Q1: what is meant by like and unlike forces?

Q2: Differentiate like and unlike forces using examples.

4.2 ADDITION OF FORCES

Force is a vector quantity. It has both magnitude (size) and direction. In diagrams it is represented by a line segment with an arrow-head at one end to show its direction of action. Length of line segment gives the magnitude of the force on suitable scale. Wherever more than one force act on an object we need to add them to get a single resultant force:

single force that has the same effect as the combined effect of the forces to be added is called resultant force.

Ordinary arithmetic rules cannot be used to add the forces. Two different methods are used for the addition of forces (i.e., in general addition of vectors):

- Graphical Method
- Analytical Method

Graphical Method

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

Head to Tail Rule

Figure 4.4 shows head to tail rule of vector addition.

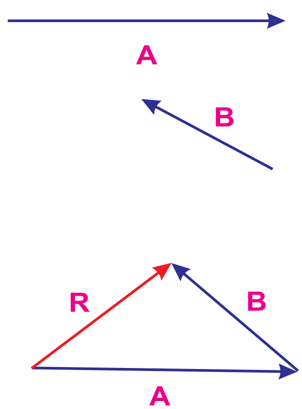


Fig 4.4

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.

Self Assessment Questions:

Q3: Define resultant of a forces.

Q4: which rule is used to find the resultant of more than two forces?

Worked Example 1

Find the resultant of three forces 15N along x-axis, 10N making an angle of 30^0 with x- axis and 10N along y-axis .

Solution

Step 1: Write the Known quantities and choose a suitable scale.

Here, F_1 = 15N along x-axis

F_2 = 10N 30^0 with x-axis

F_3 = 10N along Y-axis.

Scale 2N = 1cm.

Step 2: Draw the representative vectors for the forces F_1, F_2, F_3 according to the scale in the given directions as shown in figure 4.5.

Step 3: Take F_1 as first vector and draw F_2 and F_3 in such a way that the tail of next vector coincides with the head of the previous vector as shown in figure 4.5.

Step 4: Join the tail of the F_1 with the head of F_3 with a straight-line **F** with an arrow pointing towards F_3. According to head to tail rule, Force **F** represents the resultant force.

Step 5: Measure the length of **F** with a ruler and multiply it with $2Ncm^{-1}$ that is the magnitude of resultant. Measure the angle with protector that **F** makes with F_1. This gives the direction of resultant Force.

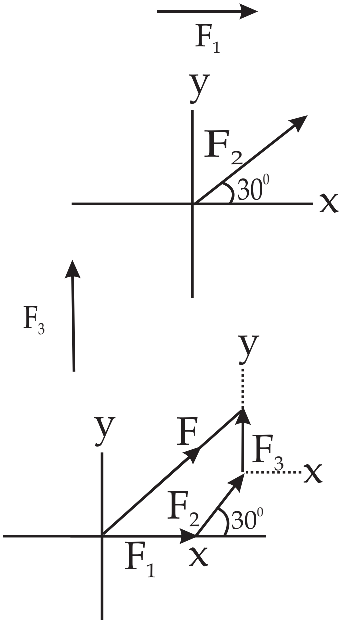
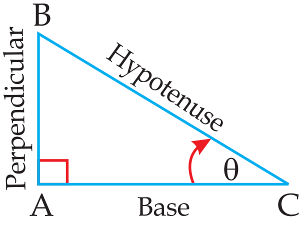


Fig 4.5

Trigonometric Ratios

The ratio between any two sides of a right-angled triangle are given specific names. There are six ratios in total out of which three are main ratios and other three are their reciprocals. Three main ratios mostly used in physics are sine, cosine and tangent. Consider a right-angled triangle ΔACB having angle θ at C.



$$\sin\theta = \frac{\text{Perpendicular}}{\text{Hypotenuse}} = \frac{AB}{BC}$$

$$\text{Cos}\,\theta = \frac{\text{Base}}{\text{Hypotenuse}} = \frac{AC}{BC}$$

$$\text{Tan}\,\theta = \frac{\text{Perpendicular}}{\text{Base}} = \frac{AB}{AC}$$

4.3 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 of a vector into mutually perpendicular components is called resolution of vectors.

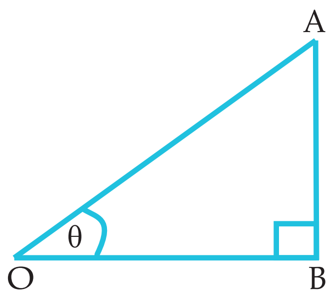


Fig 4.6

Figure 4.6 shows a force F represented by a line segment **OA** which makes an angle with x-axis. Draw a perpendicular AB on x-axis from A. The components **OB**= $\mathbf{F_x}$ and **BA** = $\mathbf{F_y}$ are perpendicular to each other. They are called the perpendicular components of **OA** = **F**. Therefore,

$$\mathbf{F = F_x + F_y} \text{ ....(4.1)}$$

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

Table: 4.1
Trigonometric ratios

Ratio θ	0°	30°	45°	60°	90°
Sin θ	0	0.5	0.7070	0.8660	1
Cos θ	1	0.8660	0.7070	0.5	0
Tan θ	0	0.577	1	1.732	θ

$$\frac{F_x}{F} = \frac{OB}{OA} = \cos\theta$$

$$\mathbf{F_x = F\cos\theta} \text{..................(4.2)}$$

Also,

$$\frac{F_y}{F} = \frac{BA}{OA} = \sin\theta$$

$$\mathbf{F_y = F\sin\theta} \text{..................(4.3)}$$

Equations 4.2 and 4.3 give the perpendicular components respectively.

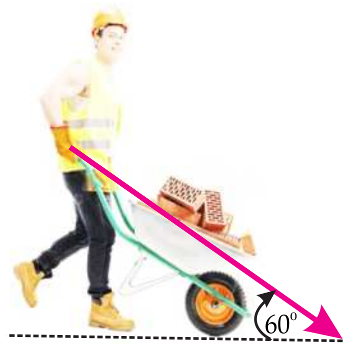


Fig 4.7

Worked Example 2

A man is pushing a wheelbarrow on a horizontal ground with a force of 300N making an angle of 60^o with ground (Fig 4.7). Find the horizontal and vertical components of the force.

Solution

Step 1: Write the known quantities and point out the quantities to be found.

F=200N

$\theta = 60^o$ with horizontal.

$F_x = ?$

$F_y = ?$

Step 2: Write the formula and rearrange if necessary.

$F_x = F\cos\theta$

$F_y = F\sin\theta$

Step 3: Put the values in the formula and calculate.

$F_x = 300N x \cos 60^o$

$= 300N x 0.5$

$= 150\ N$

$F_y = F\sin\theta$

$F_y = 300N x \sin 60^o$

$= 300N x 0.8660$

$= 259.8N$

Therefor, horizontal and vertical components of pushing force are 150 N and 259.8N respectively.

Determination of Force from its Perpendicular Components

This is opposite to the process of resolution. If the perpendicular components of a force are known then the process of determining the force itself from the perpendicular components is called composition.

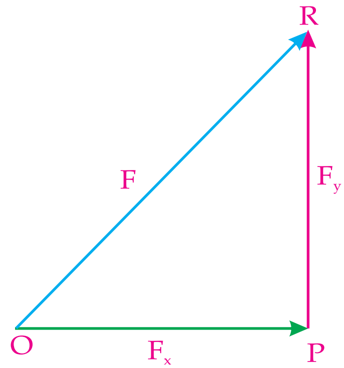


Fig 4.8

Suppose F_x and F_y are the perpendicular components of the force F and are represented by line segments **OP** and **PR** with arrowhead respectively as shown in figure 4.8.

Applying the head to tail rule:

OR = OP + PR

Here **OR** represents the force **F** whose x and y – components are F_x and F_y respectively.

Thus,

$$F = F_x + F_y$$

In order to find the magnitude of **F** apply Pythagorean theorem to right angled triangle OPR i.e.,

$$(OR)^2 = (OP)^2 + (PR)^2 \quad \text{or} \quad F^2 = F_x^2 + F_y^2$$

Therefore,

$$\mathbf{F} = \sqrt{F_x^2 + F_y^2} \quad \text{.................................(4.4)}$$

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

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

$$\theta = \tan^{-1}\frac{F_y}{F_x} \quad \text{...............................(4.5)}$$

Fig 4.9

Self Assessment Questions:

Q5: What is meant by resolution of forces?

Q6: How the direction of a vector is obtained from its components?

4.4 TORQUE OR MOMENT OF FORCE

A door handle is fixed at the outer edge of the door so that it opens and closes easily (Figure 4.9). 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 (fig 4.10).

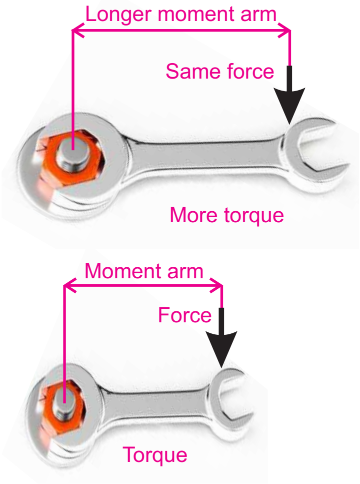


Fig 4.10

The **turning effect of force** is called **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.

Moment of force about a point = Force × Perpendicular distance from point

or $\tau = F \times d$.................(4.6)

depending on their direction, SI unit of the torque or moment of force is newton -metre (Nm).

Moments are described as **clockwise** or **anticlockwise.**

Weblinks

Web links for moment of force.

- http://www.saburchill.com/physics/chapters/0018.html
- http://www.walter.fendt.de/ph11e/lever.htm
- http://www.lovephysics.com/tur

Worked Example 3

A car driver tightens the nut of wheel using 20 cm long spanner by exerting a force of 300N. Find the torque.

Solution

Step 1: Write the known quantities and point out the quantity to be found.

F= 300N

L= 20 cm = 0.20m

τ=?

Step 2: Write the formula and rearrange if necessary.

$\tau = F \times L$

Step 3: Put the values in formula and calculate

$\tau = 300N \times 0.20m = 60Nm$

Thus, torque of 60Nm is used to tighten the nut.

Self Assessment Questions:

Q7: List the factors on which moment of force depends.

Q8: What will be moment of force? When 500N force is applied on a 40cm long spanner to tighten a nut.

4.5 PRINCIPLE OF MOMENT

Fig 4.11

Two children playing on the see-saw (Fig.4.11). 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. According to 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.

Self Assessment Questions:

Q9: How is the see- saw balanced?

Q10: Give three examples in which principle of moment is observed.

Worked Example 4

Consider a meter rod supported at mid-point O as shown in figure 4.12. The block of 20N is suspended at point A 30cm from O. Find the weight of the block that balances it at point B, 20cm from O.

Solution

Step 1: write known quantities and point out unknown quantities.

$W_1 = 20N$

Moment arm of W_1 = OA = 30cm =0.30m

Moment arm of W_2 = OB = 20cm

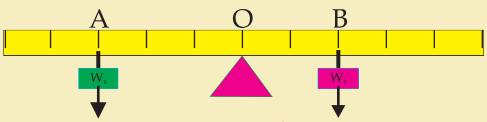


Fig 4.12

Step 2: write formula and re arrange if necessary.

Clockwise moments = anticlockwise moments

$W_1 \times OA = W_2 \times OB$

$$W_2 = \frac{W_1 \times OA}{OB}$$

Step 3: Put the values and calculate.

$$W_2 = \frac{20N \times 0.3m}{0.20m}$$

$= 30N$

Thus, the weight of the block suspended at point B is 30N.

4.6 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 earth attracts every part of it.

The centre of mass of a uniform metre rod is at its centre and when supported at that point, it can be balanced as shown in figure 4.13a. If it is supported at any other point it topples because the moment of its weight **W** about the point of support is not zero as shown in figure 4.13 b.

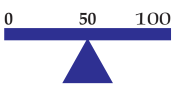


Fig 4.13 (a)

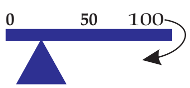


Fig 4.13 (b)

Center of Gravity of Some Regular Shaped objects

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

- The Center of gravity of uniform rod is its mid-point as shown in figure 4.14 a
- The Center of gravity of uniform square or a rectangular sheet is the point of intersection of its diagonals as shown in figure 4.14b and 4.14c.
- The Center of gravity of solid or hollow sphere is the Center of the sphere as shown in figure 4.14d.

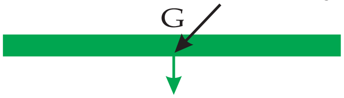


Fig 4.14 (a)

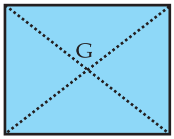


Fig 4.14 (b)

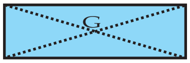


Fig 4.14 (c)

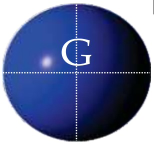


Fig 4.14 (d)

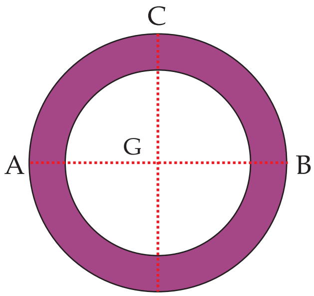


Fig 4.14 (e)

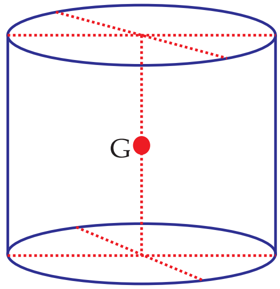


Fig 4.14 (f)

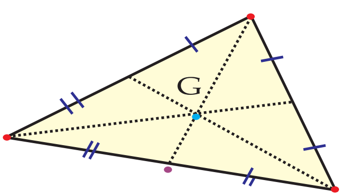


Fig 4.14 (g)

- The Center of gravity of uniform circular ring is the Center of ring as shown in figure 4.14e.
- The Center of gravity of uniform circular disc is its Center as shown in figure 4.14d
- The Center of gravity of a uniform solid or hollow cylinder is the mid-point on its axis as shown in figure 4.14f.
- The Center of gravity of a uniform triangular sheet is the point of intersection of its medians as shown in figure 4.14g.

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 retort stand through a pin as shown in figure 4.15a.
Step 3: Hang a plumb line or weight from the pin in front of the lamina as shown in figure 4.15b.
Step 4: When the plumb line is steady, trace the line on the lamina.
Step 5: Repeat steps 2 to 4 for second and third hole. The point of intersection of three lines is the position of Center of gravity.

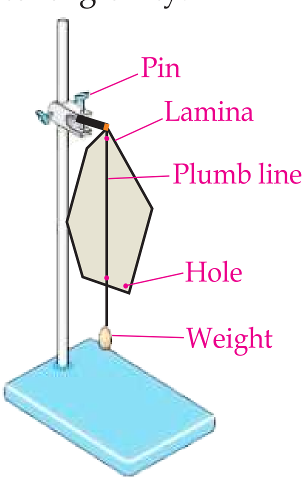


Fig 4.15 (a)

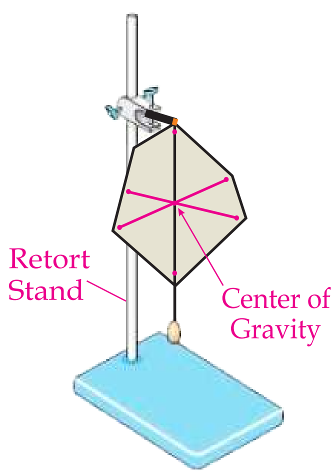


Fig 4.15 (b)

4.7 COUPLE

When a boy riding the bicycle pushes the pedals, he exerts forces that produces a torque as shown in figure 4.16. This torque turns the toothed wheel making the rear wheel to rotate. These forces act in opposite direction and form a **couple**.

Fig 4.16

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

Figure 4.17 shows the forces required to turn steering wheel of a car. The two equal and opposite forces balance, so the wheel will not move up, down or sideways. However, the wheel is not in equilibrium.

The pair forces will cause it to rotate.

A pair of forces like that in figure 4.17 is called couple. A couple has turning effect but does not cause an object to accelerate. To form a couple, two forces must be:

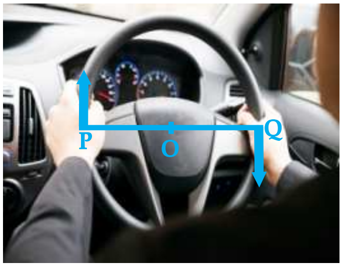


Fig 4.17

- Equal in magnitude
- Parallel, but opposite in direction
- Separated by a distanced.

The turning effect or moment of a couple is known as its torque. We can calculate the **torque** of the couple in figure 4.17 by adding the moments of each force about the Center O of the wheel:

Torque of couple = $(F \times OP) + (F \times OQ)$

$= F \times (OP+OQ)$

$= \mathbf{F \times d}$ ....(4.6)

Torque of couple = one of the forces × perpendicular distance between the forces.

Self Assessment Questions:

Q11: Write three necessary conditions for two forces to form a couple.

Q12: If two forces 5N each form a couple and the moment arm is 0.5m .Then what will be torque of the couple?

Fig 4.18
A chair lift hanging on supporting ropes.

4.8 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 (Fig4.18).

There are two types of equilibrium.

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

Static Equilibrium

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

Fig 4.19
A wall hanging is in equilibrium.

A wall hanging (fig 4.19), 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 (Fig. 4.20).

Fig 4.20
A paratrooper jumping from helicopter

Conditions for Equilibrium

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

First Condition for Equilibrium

According to this condition for equilibrium sum of the all forces acting on a body must be equal to zero. Suppose n number of forces F_1, F_2, F_3, ………, F_n are acting on a body then according to first condition of equilibrium:

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

$\mathbf{\Sigma F = 0}$ ……………………(4.7)

The symbol Σ (a Greek Letter Sigma) is used for summation. Equation 4.7 is known as first condition for equilibrium.

In terms of x and y components of the forces acting on the body first condition for the equilibrium can be expressed as:

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

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

$\mathbf{\Sigma F_x = 0}$ ……………………(4.8)

$\mathbf{\Sigma F_y = 0}$ ……………………(4.9)

A basket of apples resting on the table or a clock hanging on the wall are at rest and hence satisfy first condition for equilibrium. A paratrooper moving down with terminal velocity also satisfies first condition for equilibrium.

Weblinks

Teacher may encourage learners to visit the conditions of equilibrium on internet at

http://www.ul.ie/-gaughrn/Gildea/page4.html

Second Condition For Equilibrium

First condition for the equilibrium does not confirm that a body is in equilibrium because a body may have angular acceleration even though first condition is satisfied. For example, consider two forces F_1 and F_2 are acting on a body as shown in figure 4.21a. The two forces are equal and opposite to each other. The line of action of two forces is same, thus resultant will be zero. The first condition for equilibrium is satisfied,

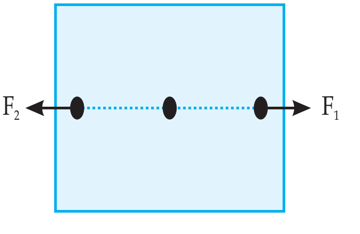


Fig 4.21 (a)

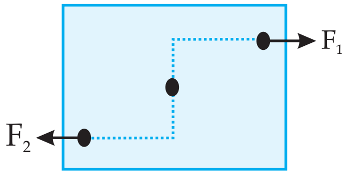


Fig 4.21 (b)

hence we may think that the body is in equilibrium. However, if we change the position of the forces as shown in figure4.21b. Now the body is not in equilibrium even though first condition for equilibrium is still satisfied. This shows that there must be an additional condition for equilibrium to be satisfied for a body to be in equilibrium. This is called second condition for equilibrium.

Sum of all clockwise and anticlockwise torques acting on a body is zero. Mathematically,

$\Sigma\tau = 0$ ....(4.10)

Worked Example 5

A uniform rod of length 2.0m is placed on a wedge at 0.5m from its one end (Fig4.22). A force of 150N is applied at one of its ends near the wedge to keep it horizontal. Find the weight of the rod and the reaction of the wedge.

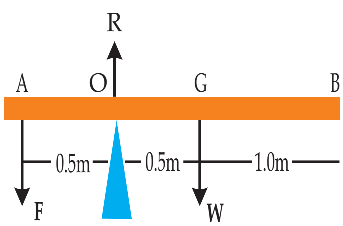


Fig 4.22

Solution

Step 1: Write the known quantities and point out unknown.

$F = 150N$

$OA = 0.5\,m$

$AG = BG = 1.0m$

$OG = AG - AO = 1.0m - 0.5m$

$= 0.5m$

$W = ?$

$R = ?$

Step 2: Write formula and substitute values.

For W applying second condition of equilibrium, taking torques about O.

$\Sigma\tau = 0$

$F \times AO + R \times 0 + W \times OG = 0$

$150 \times 0.5 - W \times 0.5 = 0$ or

$$W \times 0.5m = 150 \times 0.5m$$

$$W = \frac{150N \times 0.5m}{0.5m}$$

$$W = 150N$$

For R applying first condition of equilibrium

$$\Sigma F_y = 0$$

$$R - F - w = 0$$

$$R - 150N - 150N = 0 \text{ or}$$

$$R = 300N$$

Therefore, weight of the rod is 150N and reaction of the wedge is 300N.

Weblinks

Encourage student to visit the below link for states os equilibrium.

http://www.citycollegiate.com/staticsXlb.htm

States of Equilibrium

There are three states of equilibrium:

- Stable equilibrium
- Unstable equilibrium and
- Neutral equilibrium

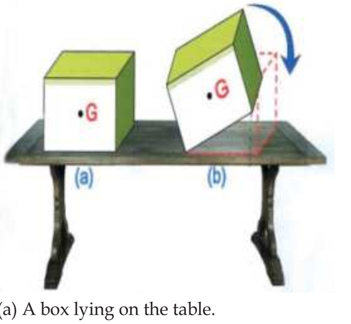
A body may be in one of the above states of equilibrium.

Stable Equilibrium

Suppose a box is lying on the table. It is in equilibrium. Tilt the box slightly about its one edge as shown in figure4.23. 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:
- Its Centre of gravity is at lowest position
- When it is tilted its Centre of gravity rises
- It returns back to stable state by lowering its Centre of gravity



(a) A box lying on the table.
(b) The box returns to its previous position when left free after a slight tilt..

Fig 4.23

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

Unstable Equilibrium

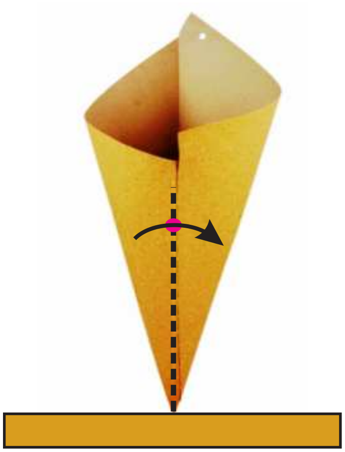


Fig 4.24

Take a paper cone and try to keep it in vertical position on its vertex as shown in figure 4.24. 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:

- Its Centre of gravity is at highest position
- When it is tilted its Centre of gravity is lowered
- Its previous position cannot be restored by raising its

Neutral Equilibrium

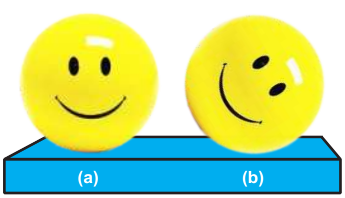


Fig 4.25

Consider a ball placed on a horizontal surface as shown in figure 4.25a. 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 4.25b. 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:

- 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 same height.
- All the new states in which body is moved are the stable states.

Do You Know!

A man walking on tight rope carries a long beam which helps him to maintain balance by lowering his Center of mass.

Self Assessment Questions:

Q13: List three states of equilibrium.

Q14: Why a body in unstable equilibrium does not return back to it original position when given a small tilt?

4.9 STABILITY

In most situation we are interested in maintaining stable equilibrium, or balance for example design of structures, racing cars and in working with human body. Consider a refrigerator (Fig. 4.26a) if it is tilted slightly (fig.4.26b) it will return back to its original position due to torque on it. But if it is tilted more (Fig.4.26c), it will fall down. The critical point is reached when the centre of gravity shifts from one side of the pivot point to the other. When the centre of gravity is on the one side of the pivot point, the torque pulls the refrigerator back onto its original base of support (Fig. 4.26b). If the refrigerator is tilted further, the centre of gravity crosses onto the other side of the pivot point and the torque causes the refrigerator to topple (Fig.4.26c). In general,

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 base of support.

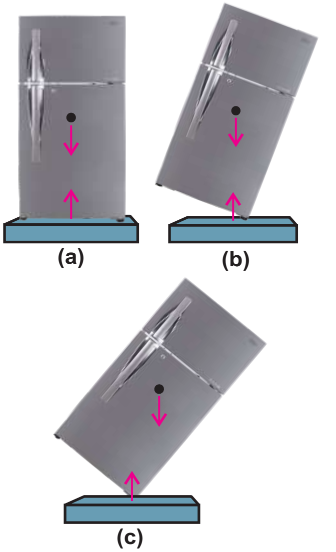


Fig 4.26

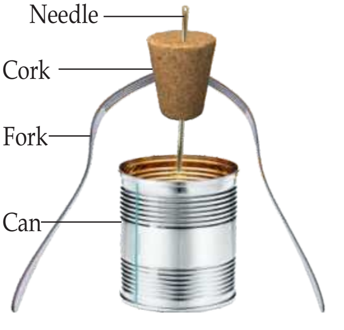


Fig 4.27

Fig 4.28

A sewing needle fixed in a cork is shown in figure 4.27. The forks are hanged on the cork to balance it on the tip of the needle. The forks lower the centre of mass of the system. If it is disturbed will return back to original position. A perched parrot is shown in figure 4.28. it is made heavy at tail which lowers its centre of gravity. it can keep itself upright when tilted. In

Do You Know!

The sports cars are made heavy at bottom which lowers the Center of mass and hence increases the stability.

general, larger the base and lower the centre of gravity, more stable the body will be.

Self Assessment Questions:

Q15: Why racing cars are made heavy at bottom?

Q16: Why the base area of Bunsen burner is made large?

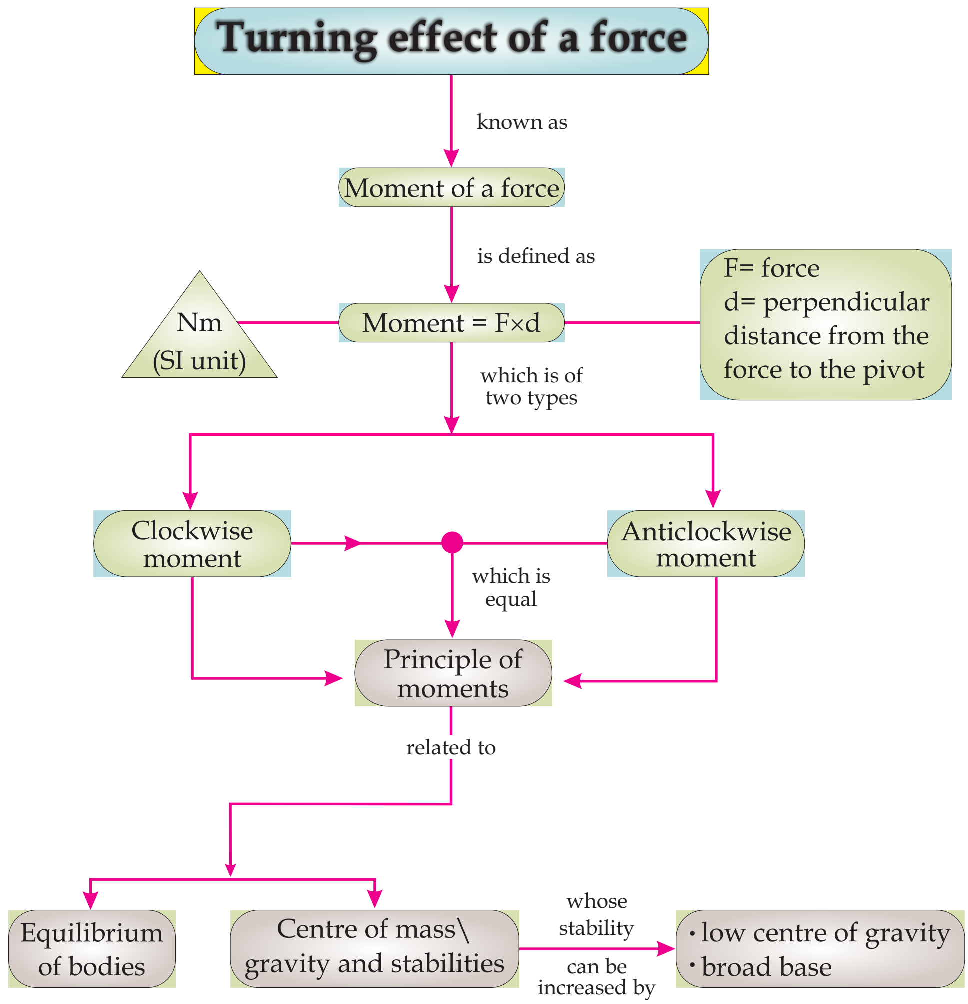
SUMMARY

- Lines of action of parallel forces are parallel to each other.
- Parallel forces with same direction are called like parallel forces.
- Parallel forces with opposite directions are called unlike parallel forces.
- The sum of the two or more forces is called the resultant of forces.
- The graphical method for addition of forces is called head to tail rule.
- Splitting of a force into two perpendicular components is called resolution of force. The components are $F_x = F\cos\theta$, $F_y = F\sin\theta$
- Perpendicular components can be used to determine a force as
- $F = \sqrt{F_x^2 + F_y^2}$ $\quad \theta = \tan^{-1}\frac{F_y}{F_x}$
- Turning effect of force is called moment of force or torque.
- The product of the force and the moment arm of the force is equal to the torque.
- The principle of moment states that a body is in equilibrium, if sum of the clockwise moments acting on a body is equal to the sum of the anticlockwise moments acting on the body.
- The Center of mass or Center of gravity is a point where whole weight of the body acts vertically downward.
- Two equal and opposite forces acting along different lines of action form a couple.
- First condition for equilibrium is satisfied if net force acting on a body is zero.
- Second condition for equilibrium is satisfied if sum of clockwise torques acting on a body is equal to the

sum of the anticlockwise torques.

- A body is said to be in stable equilibrium if it returns back to previous position after slight tilt.
- A body is said to be in unstable equilibrium if it does not return to previous position on releasing after a slight tilt.
- A body is to be in neutral equilibrium if it does not return back to previous position but remains in equilibrium at new position after disturbance.

CONCEPT MAP


Turning effect of a force
known as
Moment of a force
is defined as
Moment = F×d
Nm
(SI unit)
F= force
d= perpendicular distance from the force to the pivot
which is of two types
Clockwise moment
Anticlockwise moment
which is equal
Principle of moments
related to
Equilibrium of bodies
Centre of mass\ gravity and stabilities
whose stability can be increased by
• low centre of gravity
• broad base

End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

1. A pair of unlike parallel forces having different lines force produce----------.
   a) equilibrium b) torque
   c) a couple d) unstable equilibrium
2. Head to tail rule can be used to add------------ forces.
   a) two b) three
   c) five d) any number of
3. A force of 15 N makes an angle of 60° with horizontal. Its vertical component will be:
   a) 15N b) 10N
   c) 13N d) 7 N
4. A body is in equilibrium when it has
   a) uniform speed b) uniform acceleration
   c) both a and b d) zero acceleration
5. A body is in stable equilibrium after slight tilt if its Centre of gravity
   a) remains above the point of contact
   b) remains on one side of point of contact
   c) passes over the point of contact
   d) is at lowest position
6. A body is in unstable equilibrium after slight tilt if its center of gravity
   a) remains on one side of the point of contact
   b) remains above the point of contact
   c) passes over the point of contact
   d) is positioned at its bottom

7. A body is in neutral equilibrium when its Centre of gravity
   a) Is at the lowest position
   b) Remains at same height
   c) Is at highest position
   d) Is at its base
8. Bunsen burner is made stable by
   a) Increasing its length
   b) Increasing its mass
   c) Decreasing its base area
   d) Increasing its base area
9. A tight rope walker carries a long pole to
   a) Increase his weight
   b) Raise his Centre of gravity
   c) Lower his Centre of gravity
   d) Keep his Centre of gravity in fixed position
10. Stability of a racing car is increased by
   a) Increasing its height
   b) Raising its Centre of gravity
   c) Decreasing its width
   d) Lowering its Centre of gravity

Section (B) Structured Questions

Forces on bodies

1. a) Define like and unlike forces.
   b) A pair of like parallel forces 15N each are acting on a body. Find their resultant.
   c) Two unlike parallel forces 10 N each acting along same line. Find their resultant.

Addition of forces

2. a) Describe the head to tail rule of vector addition of forces.
   b) Three forces 12 N along x-axis, 8 N making an angle of 45° with x-axis and 8 N along y-axis.
   i) Find their resultant
   ii) Find the direction of resultant

Resolution of forces

3. a) How a force can be resolved into its perpendicular components?
   b) A gardener is driving a lawnmower with a force of 80 N that makes an angle of 40° with the ground.
   i) Find its horizontal component
   ii) Find its vertical component
4. a) How can you determine a force from its rectangular components?
   b) Horizontal and vertical components of a force are 4 N and 3 N respectively. Find
   i) Resultant force
   ii) Direction of resultant

Moment of force

5. a) What do you mean by moment of force? [3]
   b) A spanner of 0.3 m length can produce a torque of 300Nm.
      i) determine the force applied on it [2]
      ii) What should be the length of the spanner if torque is to be increased to 500Nm with same applied force [3]

Principle of moments

6. a) State the principle of moment
   b) A uniform meter rule is supported at its center is balanced by two forces 12 N and 20 N
      i) if 20 N force is placed at a distance of 3m from pivot find the position of 12 N force on the other side of pivot
      ii) if the 20N force is moved to 4cm from pivot then find force to replace 12N force.

Center of mass

7. a) Define Center of mass or Center of gravity.
   b) How will you determine the Center of mass or Center of gravity?

Couple

8. a) Define couple as a pair of forces tending to produce torque
   b) A mechanic uses a double arm spanner to turn a nut. He applies a force of 15 N at each end of the spanner and produces a torque of 60 Nm. What is the length of the moment arm of the couple?

c) If he wants to produce a torque of 80Nm with same spanner then how much force he should apply?

Equilibrium

9. a) state two conditions necessary for an object to be in equilibrium.

   b) A uniform metre rule is balanced at the 30 cm mark when a load of 0.80 N is hung at the zero mark.

      i) At what point on the rule is the Centre of gravity of the rule?

      ii) calculate the weight of the rule