Chapter: 04

Turning Effect of Forces

Exercise MCQs

1. Two equal but unlike parallel forces having different lines of action produce:

Ⓐ a torque Ⓑ a couple Ⓒ equilibrium Ⓓ neutral equilibrium

2. The number of forces that can be added by head to tail:

Ⓐ 2 Ⓑ 3 Ⓒ 4 Ⓓ any number

3. The Number of perpendicular components of a force is:

Ⓐ 1 Ⓑ 2 Ⓒ 3 Ⓓ 4

4. A force of 10N is making an angle of 30o with the horizontal. It's horizontal the component will be:

Ⓐ 4N Ⓑ 5N Ⓒ 7N Ⓓ 8.7N

5. A couple is formed by:

Ⓐ two forces perpendicular to each other
Ⓑ two like parallel forces
Ⓒ two equal and opposite forces in the same line
Ⓓ two equal and opposite forces not in the same line

6. A body is in equilibrium when its:

Ⓐ acceleration is uniform Ⓑ speed is uniform
Ⓒ speed and acceleration are uniform Ⓓ acceleration is zero

7. A body is a neutral equilibrium when its centre of gravity:

Ⓐ is at its highest position Ⓑ is at the lowest position
Ⓒ keeps its height if displaced Ⓓ is situated at its bottom

8. Racing cars are made stable by:

Ⓐ increasing their speed Ⓑ decreasing their mass
Ⓒ lowering their centre of gravity Ⓓ decreasing their width

Answer Key:

1	B	5	D
2	D	6	B
3	B	7	C
4	D	8	C

Short Questions

1. Define the following.

(a) Resultant vector **(b) Torque**

(c) Centre of mass **(d) Centre of gravity**

Ans:

(a) Resultant vector:

A resultant vector is a single vector that has the same effect as the combined effect of all the vectors to be added.

(b) Torque (τ):

The tuning effect of a force is called torque or moment of the force.

Formula:

$$\tau = r \times f$$

Unit:

Newton metre (Nm)

(c) Centre of mass:

Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

(d) Centre of gravity:

The centre of gravity of a body is defined as the point where the whole weight of the body appears to act vertically downward.

2. How head to head-to-tail rule help to find the resultant forces?

Ans: Head-to-tail rule:

The vectors are added graphically such that the tail of the 2nd vector coincides with the head of the 1st vector and so on. The resultant of all vectors is obtained by coinciding the tail of 1st vector to the head of the last vector.

The resultant of two forces can be found by using the method for adding vectors

when the vectors are geometric representations.

3. When a body is said to be in equilibrium?

Ans: A body is said to be in equilibrium if it satisfies both conditions of equilibrium.

- A body is in equilibrium if the net force acting on it is zero.

$$\Sigma F = 0, \quad \text{or} \quad \Sigma F_y = 0, \quad \Sigma F_x = 0$$

- A body is said to be in equilibrium if the resultant torque acting on it is zero.

$$\Sigma \tau = 0$$

4. How can a force be resolved into its rectangular components?

Ans: The decomposition or division of a vector into its components is called the resolution of a vector.

OR

The splitting of a single vector into two mutually perpendicular components is called the resolution of that force.

The process of splitting up vectors (forces) into their component forces is called resolution of force. If a force is formed from two mutually perpendicular components then such components are called **perpendicular components.**

Determination of Rectangular components of a vector:

Suppose a vector **F** acts on a body by making an angle θ with the x-axis which is represented by the vector **OA** as shown in the figure. Draw perpendicular **BA** from the **A** on x-axis as **AB.** According to head to tail rule, **OA** is the resultant vector of **OB** and **BA.**

So,

$$\mathbf{CA = OB + BA} \quad \text{----------} \quad (1)$$

Since the angle between **BA** and **OB** is 90°, hence these are called the perpendicular components of the vector **OA** representing F.

Horizontal or x-component

The component **OB** along x-axis is represented by F_x, and is called the X-component or horizontal component of the vector **F.**

Vertical or y-component:

The component **BA** is represented by F_y and is called the y-component or vertical component of the vector **F.**

So equation (1) can be represented by,

$$F = F_x + F_y$$

Magnitude of Rectangular components:

The magnitude of the perpendicular components F_x, and F_y of forces F_x, and F_y can be found by using the trigonometric ratios. In right angled triangle **OAB**,

$$\cos\theta = \frac{OB}{OA} \quad \text{OR} \quad OB = OA\cos\theta$$

But $OB = F_x$ OR $OA = F$

Hence, $F_x = F\cos\theta$

Similarly,

$$\sin\theta = \frac{BA}{OA} \quad \text{OR} \quad BA = OA\sin\theta$$

But $BA = F_y$ OR $OA = F$

Hence, $F_y = F\sin\theta$

These two components are the two sides of the right-angled triangle whereas hypotenuse represents the magnitude of the actual vector.

5. Differentiate the following.

(a) Like and unlike parallel forces.

(b) Torque and couple.

(c) Stable and neutral equilibrium.

Ans: Difference between Like Parallel Forces and Unlike Parallel Forces is:

Like Parallel Forces	Unlike Parallel Forces
If two parallel forces act in the same direction then they are called like parallel forces.	If two parallel forces act in opposite direction they are called unlike parallel forces.

Difference Torque and couple is:

Torque	Couple
➢ The turning effect of a force is called torque. ➢ Torque is produced under the action of only one force.	➢ A couple is formed by two unlike parallel forces of the same magnitude but not along the same line. ➢ A couple is produced under the action of two unlike parallel forces.

Difference Stable and neutral equilibrium:

Stable Equilibrium	Neutral Equilibrium
In stable equilibrium centre of mass of a body lies at the lowest position.	In neutral equilibrium, the centre of gravity lies at the same height.

6. Explain the first condition for equilibrium.

Ans: First condition for equilibrium:

"A body is said to satisfy the first condition for equilibrium if the resultant of all the forces acting on it is zero".

$$\Sigma F = 0$$

i.e. $\Sigma F_x = 0$

$\Sigma F_y = 0$

7. What is the second condition for equilibrium?

Ans: Second condition for equilibrium:

"A body satisfies the second condition for equilibrium when the resultant torque acting on it is zero".

Mathematically:

$$\Sigma \tau = 0.$$

8. Why there is a need for the second condition for equilibrium if a body satisfies the first condition for equilibrium?

Ans: Reason: Two equal and opposite forces having different lines of action form a couple, which produces angular acceleration. Although, the first condition for equilibrium is satisfied but still in this case, the object needs to satisfy the second condition to ensure an equilibrium state.

9. Give an example of a moving body which is in equilibrium.

Ans: A paratrooper coming down with terminal velocity (constant velocity) is in equilibrium as all the forces acting on it is equal to zero, which satisfies the first condition for equilibrium.

10. Why a body cannot be in equilibrium due to single force acting on it?

Ans: Single force acting on a body is not balanced and produces acceleration. Therefore under the influence of a single force, a body cannot be in equilibrium.

11. Think of a body which is at rest but not in equilibrium.

Ans: A body thrown upward is at rest just for a while at the highest point. But the force of gravity still acts on it to produce acceleration. Thus, the body is at rest but not in equilibrium.

12. Why the height of vehicles is kept as low as possible?

Ans: Vehicles are made heavy at the bottom and their height is kept to be minimum. This lowers their centre of gravity and helps to increase their stability. As to make them stable, their centre of mass must be kept as low as possible.

13. Explain what is meant by stable, unstable, and neutral equilibrium. Give one example in each case.

Ans: **Stable equilibrium:**

Equilibrium is considered stable if, after a slight tilt, it returns to its previous positions.

Example:

A book lying on a table

Unstable equilibrium:

If a body does not return to its previous position when set free after a slight tilt, then the equilibrium is unstable.

Example:

A pencil standing on its point

Neutral equilibrium:

If a body remains in its new position when disturbed from its previous position, it is said to be in neutral equilibrium.

Example:

Rolling Ball

Important Formulas

- Magnitude $= F = \sqrt{F_x^2 + F_y^2}$
- Direction $= \theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$
- Torque $= \tau = r \times F$
- Conditions of equilibrium

i. $\Sigma F = 0$ i.e. $\Sigma F_x = 0,\ \Sigma F_y = 0$

ii. $\Sigma \tau = 0$ i.e. $\tau_1 = \tau_2$

- $F_x = F \cos\theta$
- $F_y = F \sin\theta$

Numerical

1. Find the resultant of the following forces:

(a) 10N along x-axis (b) 6N along y-axis (c) 4N along the negative x-axis

Ans: Given data:

F_1 = 10N along x-axis

F_2 = 6N along y-axis

F_3 = 4N along x-axis

Solution:

Scale 2N = 1cm

10N = 5cm

6N = 3cm

4N = 2cm

2. Find the rectangular components of a force of 50N making an angle of 30° with the x-axis.

Ans: Given data:

Force = F = 50N

Angle = θ = 30°

Required:

Horizontal component of force = F_x = ?

Vertical component of force = F_y = ?

Solution:

As we know that,

$$F_x = F \cos \theta$$

By putting the values, we have

$$F_x = 50 \times \cos 30^o$$

$$F_x = 50 \times 0.866$$

$$F_x = 43.3 \text{ N}$$

As we know that,

$$F_y = F \sin \theta$$

$$F_y = 50 \times \sin 30^o$$

$$F_y = 50 \times 0.5$$

$$F_y = 25 \text{ N}$$

Result:

Horizontal component of force = F_x = 43.3 N

Vertical component of force = F_y = 25 N

3. Find the magnitude and direction of a force if its x-component is 12N and y-component is 5N?

Ans: Given data:

$F_x = 12\ N$

$F_y = 5\ N$

To Find:

$F = ?$

$\theta = ?$

Solution:

We know that,

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

$$F = \sqrt{(12)^2 + (5)^2}$$

$$F = \sqrt{144 + 25}$$

$$F = \sqrt{169}$$

$$\mathbf{F = 13\ N}$$

Now,

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

$$\theta = \tan^{-1}\left(\frac{5}{12}\right)$$

$$\theta = \tan^{-1}(0.41)$$

$$\mathbf{\theta = 22.6^o \text{ with x-axis}}$$

4. A force of 100N is applied perpendicularly on a spanner at a distance of 10cm from a nut. Find the torque produced by the force.

Ans: Given data:

$F = 100N$

$r = 10cm = \frac{10}{100} m = 0.1m$

To Find:

$\tau = ?$

Solution:

$\tau = r \times F$

$$\tau = 0.1 \times 100$$

$$\boldsymbol{\tau = 10Nm}$$

5. A force is acting on a body making an angle of 30° with the horizontal. The horizontal component of the force is 20N. Find the force.

Ans: Given data:

$$\theta = 30^o$$

$$F_x = 20\ N$$

To Find:

$$F = ?$$

Solution:

As we know that,

$$F_x = F\cos\theta$$

$$20 = F\cos 30^o$$

$$F = \frac{20}{\cos 30^o}$$

$$F = \frac{20}{0.866}$$

$$F = 23.09\ N$$

$$\boldsymbol{F = 23.1\ N}$$

6. The steering of a car has a radius 16cm. Find the torque produced by a couple of 50N.

Ans: Given data:

$$F = 50N$$

$$r = 16cm = \frac{16}{100}m = 0.16m$$

Perpendicular distance between forces = $r = 0.16 + 0.16$

$$r = 0.32m$$

To Find:

$$\tau = ?$$

Solution:

$$\tau = \text{Force} \times \text{Perpendicular distance between forces}$$

$$\tau = 50 \times 0.32$$

$$\boldsymbol{\tau = 16Nm}$$

7. A picture frame is hanging by two vertical strings. The tensions in the springs are 3.8N and 4.4N. Find the weight of the picture frame.

Ans: Given data:

$T_1 = 3.8N$

$T_2 = 4.4N$

To Find:

Weight = W = ?

Solution:

As picture frame is in equilibrium

$\Sigma Fx = 0, \qquad \Sigma Fy = 0$

Therefore

$T - W = 0$

$(T_1 + T_2) - W = 0$

$T_1 + T_2 = W$

$3.8 + 4.4 = W$

$8.2\ N = W$

Or **W = 8.2N**

8. Two blocks of masses 5kg and 3kg are suspended by the two strings as shown in the figure. Find the tension in each string.

Ans: Given data:

Mass of upper block = 5kg

Mass of below block = 3kg

Mass of upper block = $w_1 = m_1g = 5 \times 10 = 50N$

Mass of below block = $w_2 = m_2g = 3 \times 10 = 30N$

Required:

Tension in upper string = T_1 = ?

Tension in lower string = T_2 = ?

Solution:

From second condition of equilibrium, we have

$\Sigma F_y = 0$

OR Tension in the lower string = weight of the lower block

$T_2 = w_2$

$T_2 = 30\ N$

Tension in the upper string = weight of lower block + weight of the lower block

$T_1 = w_1 + w_2$

$T_1 = 50 + 30$

$T_1 = 80\,N$

Result:

Tension in upper string $= T_1 = 80\,N$

Tension in lower string $= T_2 = 30\,N$

9. A nut has been tightened by a force of 200N using 10cm long spanner. What length of a spanner is required to loosen the same nut with 150N force?

Ans: Given data:

$F_1 = 200N$

$F_2 = 150N$

$L_1 = 10cm = 0.1m$

To Find:

$L_2 = ?$

Solution:

$$\tau_1 = \tau_2$$

$$F_1 \times L_1 = F_2 \times L_2$$

$$L_2 = \frac{F_1 \times L_1}{F_2}$$

$$L_2 = \frac{200 \times 0.1}{150}$$

$$L_2 = 0.133m$$

$$L_2 = 0.133 \times 100cm$$

$$\mathbf{L_2 = 13.3cm}$$

10. A block of mass 10kg is suspended at a distance of 20cm from the centre of a uniform bar 1m long. What force is required to balance it at its centre of gravity by applying the force at the other end of the bar?

Ans: Given data:

Mass of block $= m = 10kg$

Weight of block $= w = mg$

Weight of block $= w = 10 \times 10$

Weight of block $= w = 100N$

Weight of block $= L = 1m$

Distance of block from center of nod $= 20cm$

Distance of block from center of nod $= \frac{20}{100}\,m = 0.20m$

Distance of force from center = 50cm

$$\text{Distance of force from center} = \frac{50}{100}\ \text{m} = 0.50\text{m}$$

To Find:

$$F = ?$$

Solution:

Now using condition of equilibrium,

$$F \times L_2 = w \times L_1$$

$$F \times L_2 = w \times L_1$$

$$F \times 0.5 = 100 \times 0.2$$

$$F = \frac{100 \times 0.2}{0.5}$$

$$\mathbf{F = 40N}$$