UNIT 4

STRUCTURE 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 the same line. Find their resultant.

Ans

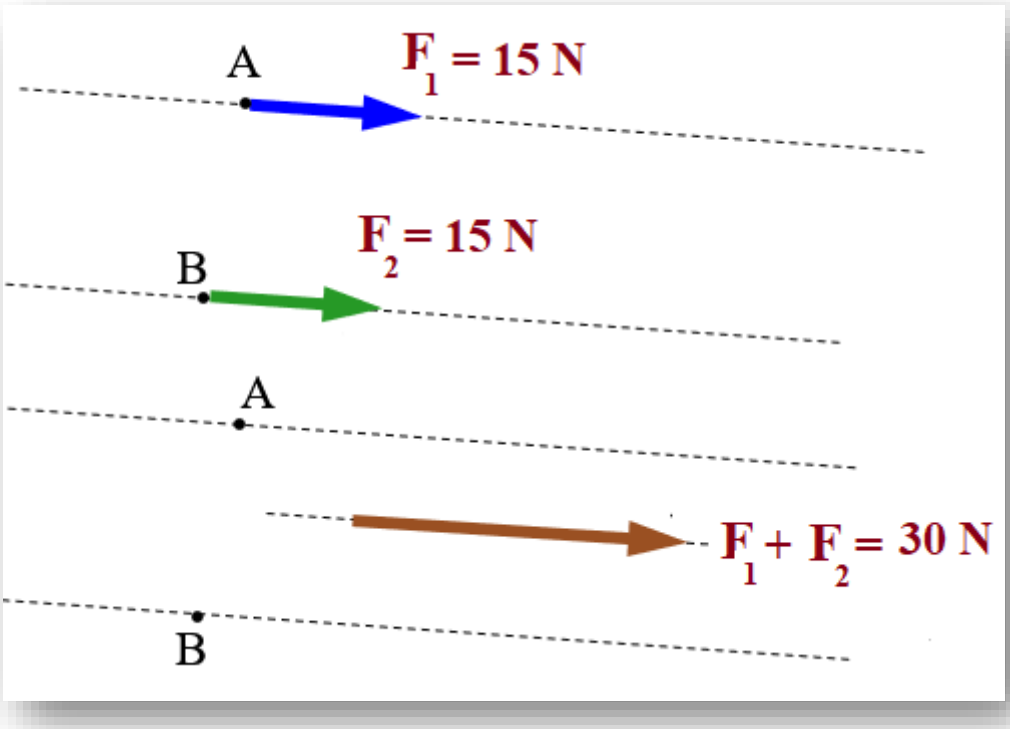
LIKE PARALLEL FORCES

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

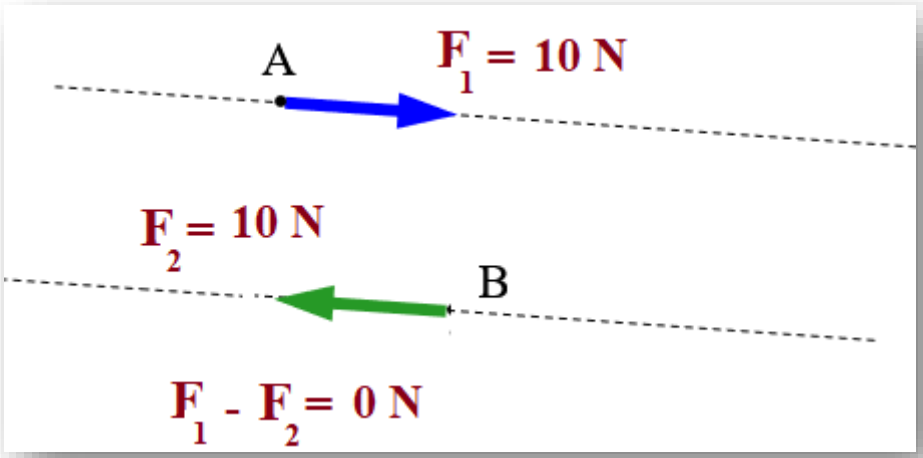
UNLIKE PARALLEL FORCES

The forces that act along the opposite direction are called like parallel 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 the 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 the x-axis, 8 N making an angle of 45 with the x-axis and 8 N along the y-axis.
      i) Find their resultant ii) Find the direction of the resultant

Force to be found.
F= 8 N
θ = 45 with horizontal

$F_X = F\cos\theta = 8 \times \cos 45 = 5.65N$

$F_y = F\sin\theta = 8 \times \sin 45 = 5.65N$

Forces along x axis

$F_X = 12 + 5.65 = 17.65$ N

$F_y = 5.65 + 8 = 13.65$ N

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

$$F \sqrt{(17.65)^2 + (13.65)^2}$$

$$F \sqrt{497.845}$$

$$F = 22.31N$$

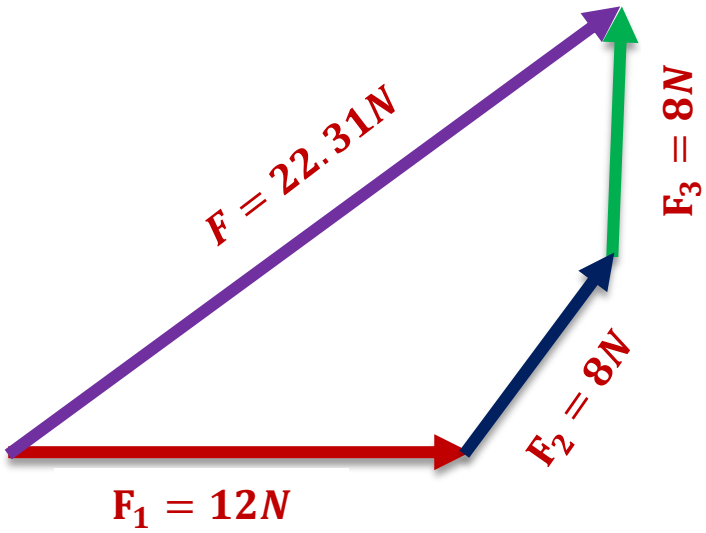
DIRECTION

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

$$\theta = \tan^{-1}\left(\frac{13.65}{17.65}\right)$$

$$\theta = \tan^{-1}(0.7733)$$

$$\theta = 37.71^0$$



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 o of 80 N that makes an angle of 40 with the ground.
   i) Find its horizontal component
   ii) Find its vertical component

ANS:

3. a) How a force can be resolved into its perpendicular components?(see notes)

b) A gardener is driving a lawnmower with a force o of 80 N that makes an angle of 40 with the ground.
i) Find its horizontal component
ii) Find its vertical component

DATA

Force F = 80 N

angle θ = 45^0

TO DETERMINE

horizontal component $F_x = ?$

vertical component $F_y = ?$

SOLUTION

horizontal component

$$F_x = F\cos\theta = (80)(\cos 45^0)$$
$$F_x = (80)(0.7071) = 56.6\ N$$

vertical component

$$F_x = F\sin\theta = (80)(\sin 45^0)$$
$$F_x = (80)(0.7071) = 56.6\ N$$

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

ANS:

a) How can you determine a force from its rectangular components? (See notes)

b) Horizontal and vertical components of a force are 4 N and 3 N respectively. Find
i) Resultant force ii) Direction of resultant

DATA

horizontal component $F_x = 4\ N$

vertical component $F_y = 3N$

TO DETERMINE

Resultant force $F = ?$

Direction of resultant $\theta = ?$

FORMULA

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

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

SOLUTION

Resultant force

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

$$F = \sqrt{(4)^2 + (3)^2} = \sqrt{16 + 9}$$

$$F = \sqrt{25} = 5$$

Direction of resultant

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

$$\theta = \tan^{-1}\left(\frac{3}{4}\right) = \tan^{-1}(0.75)$$

$$\theta = 36.86^0$$

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]

ANS:

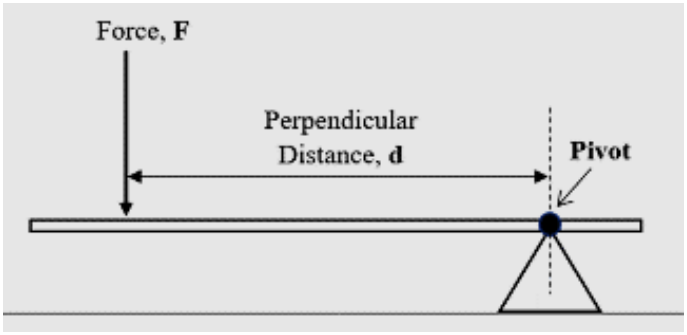
a) What do you mean by moment of force?

MOMENT OF FORCE

The moment of force is defined as the product of the force and the perpendicular distance from the line of action of force to the pivot.

Moment of force = (force) x (perpendicular distance from the pivot to line of action of force)

Moment of force = F x d



UNIT

The SI unit for moment of force is **Newton metre (Nm)**

b) A spanner of 0.3 m in length can produce a torque of 300Nm.
i) determine the force applied to it [2]
ii) What should be the length of the spanner if torque is to be increased to 500Nm with the same applied force

DATA

length $d = 0.3\ m$

torque $\tau = 3Nm$

TO DETERMINE

(i) force $F = ?$

(ii) length $d = ?$

force $F = same$

torque increased $\tau = 500\ Nm$

FORMULA

$\tau = F\ d$

SOLUTION

force

$\tau = F\ d$

$F = \frac{\tau}{d}$

$F = \frac{3}{0.3} = 10\ N$

Length

$\tau = F\ d$

$d = \frac{\tau}{F}$

$d = \frac{500}{10} = 50\ m$

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 the pivot then find force to replace 12N force.

Ans:

a) State the principle of moment

The principle of the moment, which can be stated as follows

If an object is balanced, the total clockwise moment about a pivot equals the total anticlockwise moment about that pivot

Sum of the clockwise moment = Sum of the anti-clockwise 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 the pivot then find force to replace 12N force.

DATA

Force $F_1 = 12\ N$

Force $F_2 = 20\ N$

distance $d_2 = 3\ m$

TO DETERMINE

(i) distance $d_1 = ?$

(ii) length $d_2 = 4\ cm = \frac{4}{100}$

$d_2 = 0.04\ m$

force $F = same$

torque increased $\tau = 500\ Nm$

FORMULA

$\tau = F\ d$

SOLUTION

(i) distance d_1

$F_1 \times d_1 = F_2 \times d_2$

$12 \times d_1 = 20 \times 3$

$12 \times d_1 = 60$

$d_1 = \frac{60}{12} = 5\ m$

(ii) distance F_1

$F_1 \times d_1 = F_2 \times d_2$

$F_1 \times 5 = 20 \times 0.04$

$12 \times d_1 = 0.8$

$d_1 = \frac{0.8}{12} = 0.067\ m$

$d_1 = 0.067 \times 100\ cm = 6.7\ cm$

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?

ANS:

CENTER OF MASS

*The **center of mass** of a body is the point at which the **entire mass of the body can be considered to be concentrated.** Denoted usually by **CM***

CENTER OF GRAVITY

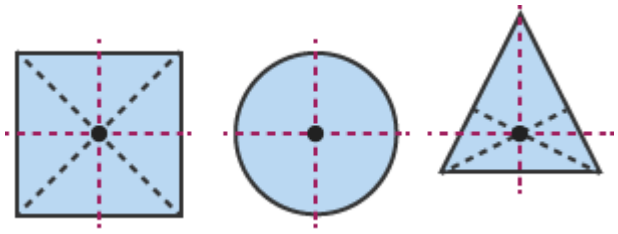
*The **center of gravity** of a body is the point at which the **entire weight of the body can be considered to act vertically downward***

*DETERMINING THE **CENTER OF MASS (CM)** OR **CENTER OF GRAVITY (CG)***

1. For a Regular, Symmetric Object

Method:

*The center of mass lies **at the geometric center***



***Uniform circular disc:** at the Centre.*

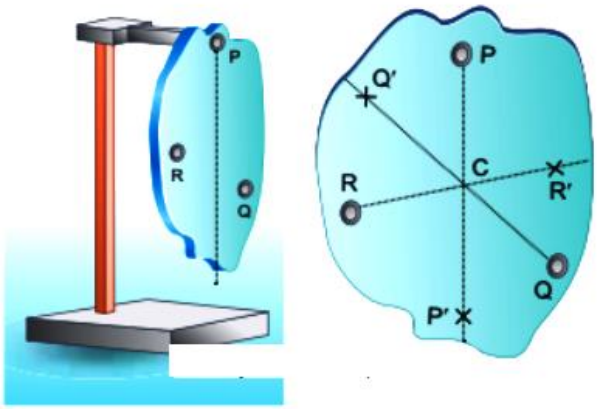
***square:** at the **intersection of diagonals**.*

***Triangle:** at the **intersection of medians** (centroid).*

2. For an Irregular Object

SUSPENSION METHOD

1. Hang the object from a point.
2. Let it **come to rest** freely; a **plumb line** (string with weight) will show the **vertical line passing through the CM** .
3. Mark the line on the object.
4. Hang the object from another point and repeat.
5. The **intersection of the three lines** is the **center of mass**



COUPLE

8. a) Define couple as a pair of forces tending to produce torque (see notes)
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?

DATA

Force $F = 15\ N$

torque $\tau = 60\ Nm$

TO DETERMINE

length $d = ?$

FORMULA

$\tau = F\,d$

SOLUTION

force

$\tau = F\,d$

$d = \frac{\tau}{F}$

$d = \frac{60}{15} = 4\ m$

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

DATA

torque $\tau = 80\ Nm$

length $d = 4\ m(\ same\ spanner)$

TO DETERMINE

Force $F = ?$

FORMULA

$\tau = F\,d$

SOLUTION

force

$\tau = F\,d$

$F = \frac{\tau}{d}$

$F = \frac{80}{4} = 20\ N$

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

ANS:

To be in **equilibrium** , an object must satisfy **two conditions** :

1 Translational (or force) equilibrium:

The **net force** acting on the object must be **zero** .

Mathematically:

$$\sum F_x = 0 \quad \text{and} \quad \sum F_y = 0$$

*This ensures the object does **not accelerate linearly***

2 Rotational (or moment/torque) equilibrium:

The **net moment (torque)** about any axis must be **zero** .

Mathematically:

$$\sum \tau = 0$$

*This ensures the object does **not rotate** .*

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

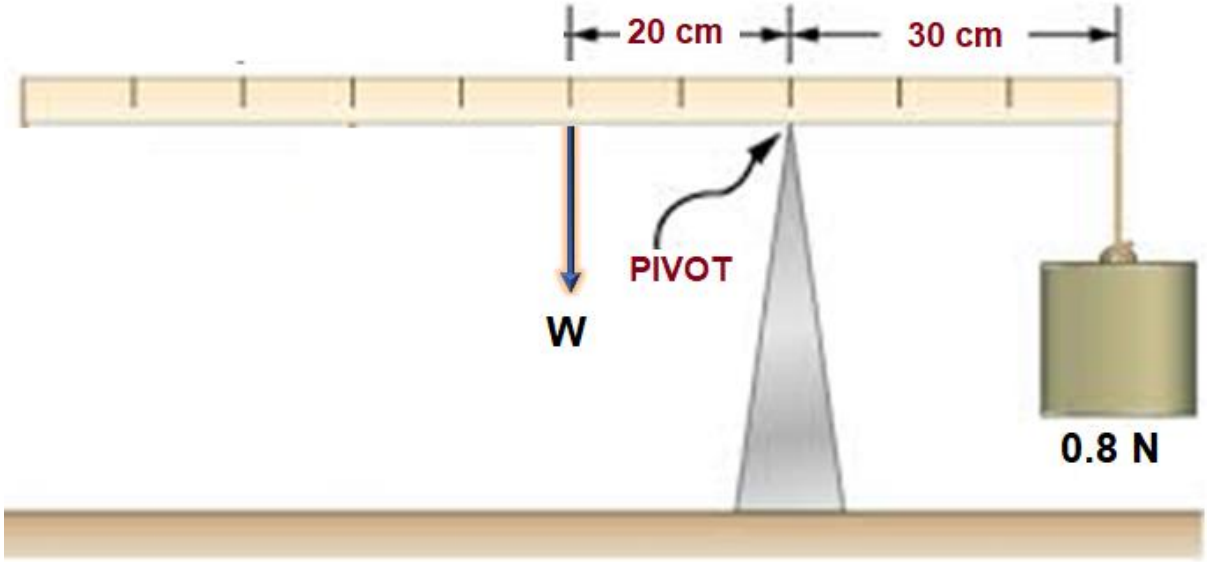
ANS:

For a **uniform metre rule** , the mass is evenly distributed, so its centre of gravity lies at the **midpoint(50 cm)**

*Take moments about the **pivot (30 cm mark)** :*

Distance of load from pivot = 30−0=30 cm

Distance of rule's weight (at 50 cm) from pivot = 50−30=20 cm



Apply equilibrium condition:

Clockwise moment = Anticlockwise moment

$$(0.8 \ x \ 30) = (W \ x \ 20)$$

$$24 = 20\,W$$

$$\frac{24}{20} = W$$

$$1.2\,N = W$$