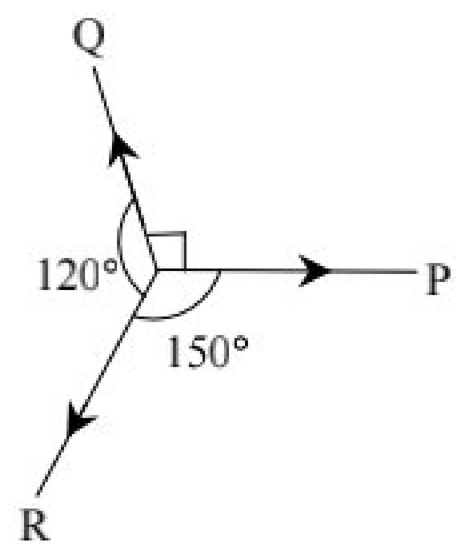
UNIT 8: MECHANICS

Chapter 18

Statics

Exercise 18.1

1. Three forces acting on a particle are in equilibrium; the angle between the first and second is 90° and that between the second and third is 120°; find the ratio of the forces.



Sol^n: Let the three forces P, Q, R acting at O are in equilibrium. Here, angle between P an Q is 90^o, angle between Q and R is 120^o

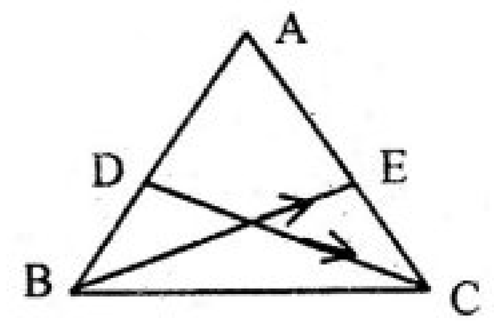
$\therefore$ Angle between Q and R will be $360^o - (90^o + 120^o) = 150^o$

Using Lami's Theorem, we have

$$\frac{P}{\sin 120°} = \frac{Q}{\sin 150°} = \frac{R}{\sin 90°}$$

$$\Rightarrow \frac{P}{\frac{\sqrt{3}}{2}} = \frac{Q}{\frac{1}{2}} = \frac{R}{1} \quad \Rightarrow \frac{P}{\sqrt{3}} = \frac{Q}{1} = \frac{R}{2} \quad \Rightarrow \quad P : Q : R = \sqrt{3} : 1 : 2.$$

2. The sides AB and AC of a triangle ABC are bisected in D and E; show that the resultant of forces represented by BE and DC is represented in magnitude and direction by $\frac{3}{2}$ BC.



Sol^n: Since AB and AC are bisected at D and E, so $\overrightarrow{CE} = \frac{\overrightarrow{CE}}{2}$ and $\overrightarrow{DB} = \frac{\overrightarrow{AB}}{2}$ .... (i)

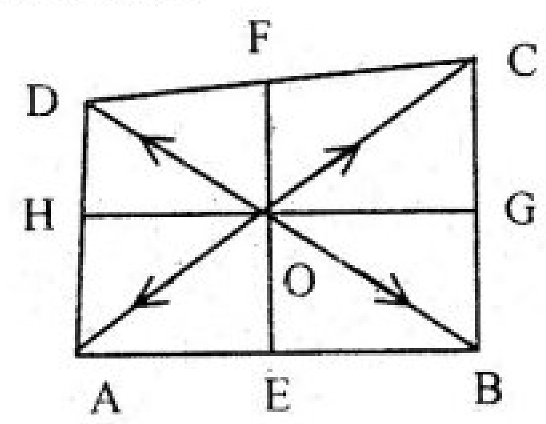
Now, the resultant force represented by BE and DC is

$$\overrightarrow{BE} + \overrightarrow{DC} = \left(\overrightarrow{BC} + \overrightarrow{CE}\right) + \left(\overrightarrow{DB} + \overrightarrow{BC}\right)$$

$$= \left(\overrightarrow{BC} + \frac{\overrightarrow{CA}}{2}\right) + \left(\frac{\overrightarrow{AB}}{2} + \overrightarrow{BC}\right) \text{ [using (i)]}$$

$$= 2\overrightarrow{BC} + \frac{1}{2}\left(\overrightarrow{CA} + \overrightarrow{AB}\right) = 2\overrightarrow{BC} + \frac{1}{2}\overrightarrow{CB} = 2\overrightarrow{BC} - \frac{1}{2}\overrightarrow{BC} = \frac{3}{2}\overrightarrow{BC}.$$

3. Find a point within a quadrilateral such that, if it be acted on by forces represented by the lines joining it to the angular points of the quadrilateral, it will be in equilibrium.



Sol^n: We have, $\overrightarrow{OA} + \overrightarrow{OB} + \overrightarrow{OC} + \overrightarrow{OD} = \vec{0}$ .... (i)

Let E, F, G, H are the middle points of the sides AB, DC, BC and AD respectively. Then, $\overrightarrow{OE} = \frac{\overrightarrow{OA} + \overrightarrow{OB}}{2}$ and $\overrightarrow{OF} = \frac{\overrightarrow{OC} + \overrightarrow{OD}}{2}$.

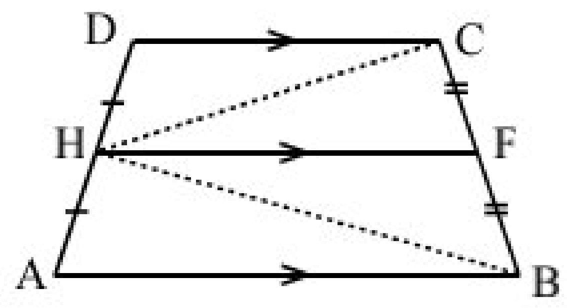
Now, $\overrightarrow{OE} + \overrightarrow{OF} = \frac{\overrightarrow{OA} + \overrightarrow{OB}}{2} + \frac{\overrightarrow{OC} + \overrightarrow{OD}}{2} = \frac{1}{2}[\overrightarrow{OA} + \overrightarrow{OB} + \overrightarrow{OC} + \overrightarrow{OD}] = \frac{1}{2} \times \vec{0} = \vec{0}$

Which shows that, $\overrightarrow{OE}$ and $\overrightarrow{OF}$ are equal and opposite. i.e., $\overrightarrow{OE} = -\overrightarrow{OF}$

Hence, O is the middle point of EF. Similarly, O is the middle point of GH.

$\therefore$ The point of intersection of the lines joining the middle points of the opposite sides of the quadrilateral is required point.

4. The sides BC and DA of a quadrilateral ABCD are bisected in F and H respectively. Show that if two forces parallel and equal to AB and DC act on a particle, then the resultant is parallel to HF and equal to 2HF.



Sol^n: Let ABCD is a quadrilateral and F and H are the middle points of BC and DA respectively.

Now, the resultant of the forces parallel to AB and DC is given by

$$\overrightarrow{AB} + \overrightarrow{DC} = \left(\overrightarrow{AH} + \overrightarrow{HB}\right) + \left(\overrightarrow{DH} + \overrightarrow{HC}\right)$$

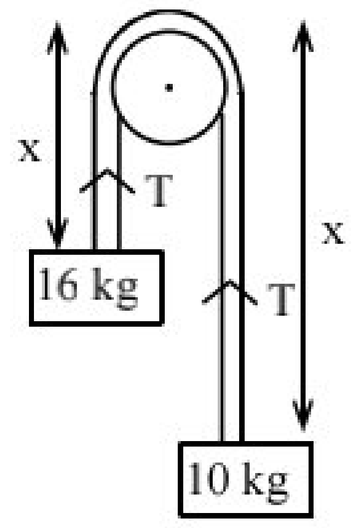
$$= \left(\overrightarrow{HB} + \overrightarrow{HC}\right) + \left(\overrightarrow{AH} + \overrightarrow{DH}\right)$$

$$= \left(2\overrightarrow{HF}\right) - \left(\overrightarrow{HA} + \overrightarrow{HD}\right)\left[\because \frac{\overrightarrow{HB} + \overrightarrow{HC}}{2} = \overrightarrow{HF}\right]$$

$$= 2\overrightarrow{HF} - \overrightarrow{0} = 2\overrightarrow{HF} \quad [\because \overrightarrow{HA} \text{ and } \overrightarrow{HD} \text{ are equal and opposite.}]$$

Hence, the resultant of $\overrightarrow{AB}$ and $\overrightarrow{DC}$ is parallel to $\overrightarrow{HF}$ and is equal to 2HF.

5. A heavy chain has weights of 10 kg and 16 kg. attached to its ends and hangs in equilibrium over a smooth pulley. If the greatest tension of the chain is 20 kg. wt., find the weight of the chain.



Sol^n: Let T be the tension of the string, length of the chain be l and mass of chain be m.

$\therefore$ Mass per unit length of chain $= \frac{m}{l}$;

Mass of $(l - x)$ length of chain $= \left(\frac{m}{l}\right)(l - x)$

Mass of x length of chain $= \left(\frac{m}{l}\right)x$;

Let, T be the tension of the string . At equilibriumwe have,

$T = 16 + \left(\frac{m}{l}\right)(l - x)$ and $T = 10 + \left(\frac{m}{l}\right)x$, since tension in the single rope is the same.

Then, $16 + \left(\frac{m}{l}\right)(l - x) = 10 + \left(\frac{m}{l}\right)x$ or, $6 = \left(\frac{m}{l}\right)(x - l + x)$ or, $6 = \left(\frac{m}{l}\right)(2x - l)$ .... (i)

It is given that greatest tension of chain is 20 kg wt. Then,

$20 = 10 + \left(\frac{m}{l}\right)x \Rightarrow 10 = \left(\frac{m}{l}\right)x$ .... (ii)

Dividing eqn (i) by (ii), we get

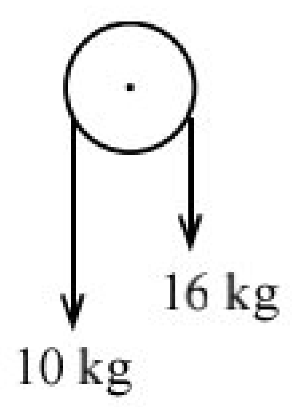
$\frac{6}{10} = \frac{2x - l}{x}$ or, $\frac{6}{10} = 2 - \frac{l}{x}$ or, $\frac{l}{x} = 2 - \frac{6}{10}$ or, $\frac{l}{x} = \frac{14}{10}$ or, $x = \frac{5}{7}l$

Putting the value of x in eq^n (i), we get

$6 = \frac{m}{l}\left(2 \times \frac{5}{7}l - l\right)$ or, $6 = \frac{m}{l}\left(\frac{3l}{7}\right) \therefore m = 14$

$\therefore$ Mass of chain = 14 kg wt.

"Alternately"



Let w_1 be the weight of the part of the chain (from top to bottom) containing the weight of 10 kg at its end. Then,

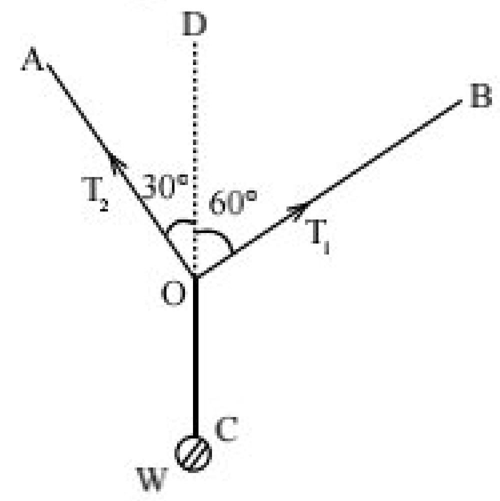
$T = w_1 + 10$ or, $20 = w_1 + 10$ or, $w_1 = 10$ kg

Again, we be the weight of the part of the chain, containing the weight of 16 kg at its another end. Then,

$T = w_2 + 16$ or, $20 = w_2 + 16$ or, $w_2 = 4$ kg

$\therefore$ Weight of the chain is $w_1 + w_2 = 10 + 4 = 14$ kg

6. Two men carry a weight 50N between two strings fixed to the weight; one string is inclined at 30° to the vertical and the other at 60°, find the tension of each string.



Sol^n: Let T_1 and T_2 be the tensions of the strings OA and OB respectively.

W = 50 N weight along OC such that $\angle AOD = 30°$ and $\angle BOD = 60°$.

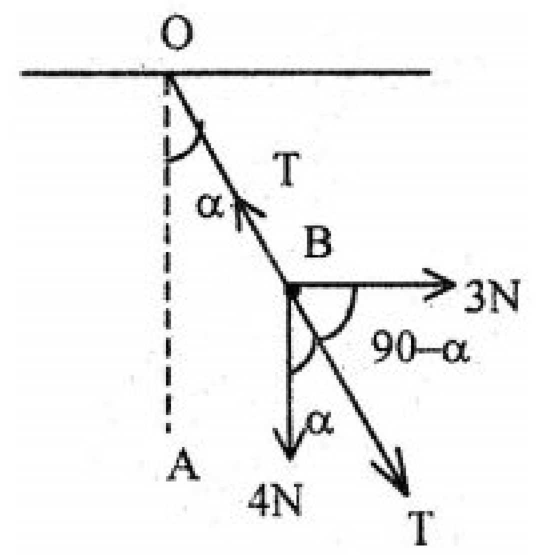
Using Lami's theorem, we have

$$\frac{T_1}{\sin \angle BOC} = \frac{T_2}{\sin \angle AOC} = \frac{W}{\sin\angle AOB}$$

or, $$\frac{T_1}{\sin 120°} = \frac{T_2}{\sin 150°} = \frac{50}{\sin 90°}$$

$\therefore$ $T_1 = \frac{50}{1} \times \frac{\sqrt{3}}{2} = 25\sqrt{3}$ N & $T_2 = \frac{50}{1} \times \frac{1}{2} = 25$ N.

7. A body weighing 4 N is supported by a string attached to a fixed point and is pulled from the vertical by a horizontal force of 3 N. Find the angle, the string will make with the vertical and the tension of the string.



Sol^n: Let α is the angle made by the string OB with the vertical OA and T be the tension of the string. Since 4N is the weight of the body acting to the body horizontally pulled from the vertical by a horizontal force 3 N. Resolving the tension T horizontally and vertically, we get

$T \cos\alpha = 4$ N and $T \sin \alpha = 3$ N .... (i)

Squaring and adding, we get

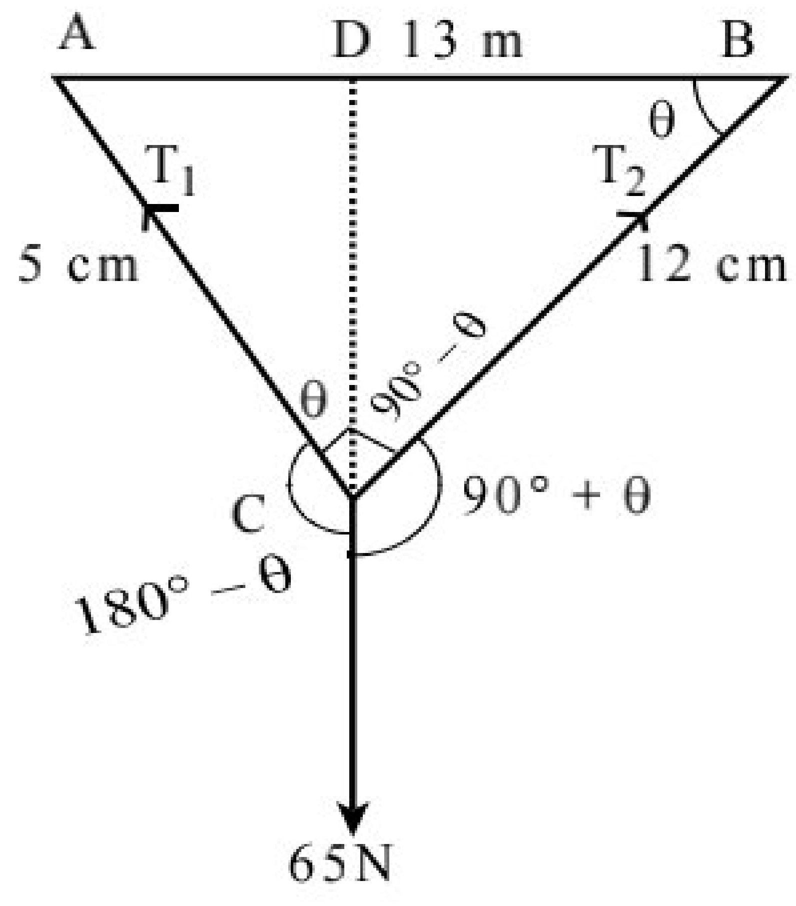
$T^2 = 4^2 + 3^2$ or, $T^2 = 25$ $\therefore T = 5$N

Substituting the values of T in (i), we get

$5\sin\alpha = 3$ or, $\sin\alpha = \frac{3}{5}$ $\therefore \alpha = \sin^{-1}\left(\frac{3}{5}\right)$.

8. A body of weight 65 N is suspended by two strings of lengths 5 m and 12 m attached to two points in the same horizontal line whose distance apart is 13 m. find the tensions of the strings.

Sol^n: Let, AC and BC be two strings of lengths 5 m and 12 m respectively attached at A and B of the horizontal line AB = 13 m.



Since $(AC)^2 + (BC)^2 = (AB)^2$ $\Rightarrow$ Triangle ACB is right angled at C.

Let the weight of 65N be acting vertically downwards along the line CE.

Produce EC to meet AB at D such that $CD \perp AB$

Let, $\angle CBA = \theta$ $\therefore \angle ACD = 90° - \angle BCD = \angle CBD = \theta$

If T_1 and T_2 are the tensions along the strings CA and CB, then three forces T_1, T_2 and 65N acting at C are in equilibrium. Using Lami's theorem, we have

$$\frac{T_1}{\sin \angle BCE} = \frac{T_2}{\sin \angle ACE} = \frac{65}{\sin \angle ACB}$$

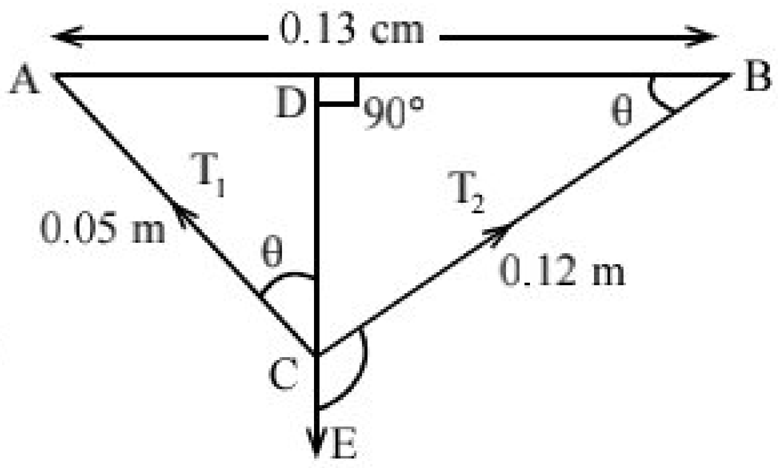
or, $\frac{T_1}{\sin(90 + \theta)} = \frac{T_2}{\sin(180 - \theta)} = \frac{65}{\sin 90°}$

or, $\frac{T_1}{\cos\theta} = \frac{T_2}{\sin\theta} = \frac{65}{1}$ $\therefore T_1 = 65 \cos\theta$ and $T_2 = 65 \sin\theta$ .... (i)

From ΔACB, we get $\cos\theta = \frac{BC}{AB} = \frac{12}{13}$ and $\sin\theta = \frac{AC}{AB} = \frac{5}{13}$

$\therefore$ $T_1 = 65 \times \left(\frac{12}{13}\right) = 60$ N and $T_2 = 65 \times \left(\frac{5}{13}\right) = 25$ N.

9. The ends of an inelastic and weightless string 0.17 m long are attached to two points 0.13 m apart in the same horizontal line and a weight of 4 N is attached to string 0.05 m form one end. Find the tension in each portion of the string.



Sol^n: Let AC and BC be two strings of length AC = 0.05 m and BC = (0.17 – 0.005) m = 0.12 m.

Here end points of the strings are attached at A and B such that AB = 0.13 m. Let the weight of 65N be acting vertically downwards along the line CE which is 0.05 m from the end A.

Since $(0.05)^2 + (0.12)^2 = (0.13)^2$ or, $(AC)^2 + (BC)^2 = (AB)^2$

$\Rightarrow$ triangle ACB is right angled at C

Produce EC to meet AB at D such that CD $\perp$ AB.

Let, $\angle CBA = \theta \therefore \angle ACD = 90° - \angle BCD = \angle CBD = \theta$

If T_1 and T_2 be the tensions along the strings CA and CB respectively then three forces T_1, T_2 and 4N acting at C are in equilibrium. Using Lami's theorem, we have

$$\frac{T_1}{\sin \angle ECB} = \frac{T_2}{\sin \angle ECA} = \frac{4}{\sin \angle ACB}$$

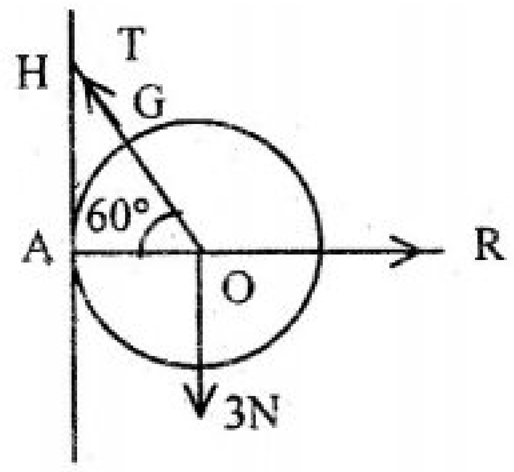
or, $\frac{T_1}{\sin (90 + \theta)} = \frac{T_2}{\sin (180 - \theta)} = \frac{4}{\sin 90°}$

or, $\frac{T_1}{\cos\theta} = \frac{T_2}{\sin \theta} = 4$ $\therefore T_1 = 4\cos\theta$ and $T_2 = 4\sin\theta$ .... (i)

From ΔACB, we get $\cos\theta = \frac{BC}{AB} = \frac{0.12}{0.13}$ and $\sin \theta = \frac{AC}{AB} = \frac{0.05}{0.13}$

$\therefore$ $T_1 = 4 \times \frac{0.12}{13} = 3.69$ N and $T_2 = 4 \times \frac{0.05}{0.13} = 1.54$ N.

10. A uniform sphere of weight 3 N rests in contact with a smooth vertical wall. It is supported by a string whose length equals the radius of the sphere, joining a point on the surface of the sphere to a point of the wall. Calculate the tension in the string and the reaction of the wall.



Sol^n: Let the point of contact of the wall and the sphere be A and GH be the string, where G and H are the point on the sphere and the point on the wall respectively. The weight 3N of the sphere acting at O, the tension T in the string HG and the reaction R at point A keeping the sphere in equilibrium. Here, HG = OG = OA and $\angle HAO = 90°$, G is the middle point of OH. Since, middle point of hypotaneous is equidistance from each vertices, we have AG = OG = OA.

$\therefore$ The triangle AOG is equilateral triangle and $\angle AOG = 60°$

Using Lami's theorem, we have

$$\frac{T}{\sin 90°} = \frac{R}{\sin (90° + 60°)} = \frac{3}{\sin (180° - 60°)}$$

or, $\frac{T}{1} = \frac{R}{\frac{1}{2}} = \frac{3}{\frac{\sqrt{3}}{2}}$ or, $T = 2R = 2\sqrt{3}$.

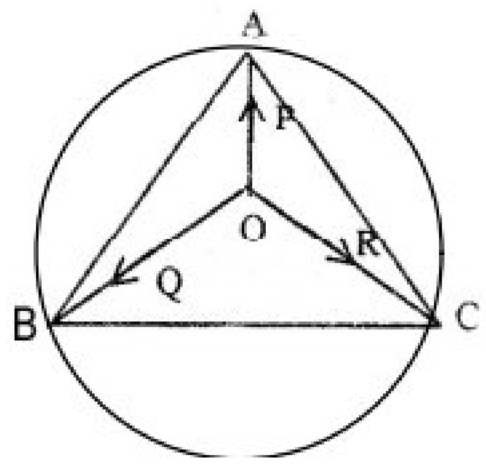
$\therefore$ $T = 2\sqrt{3} = 3.46$ N and $R = \sqrt{3} = 1.73$ N.

11. Forces P, Q, R acting along OA, OB, OC where O is the circumcentre of the triangle ABC, are in equilibrium, show that:

i) $\frac{P}{a \cos A} = \frac{Q}{b \cos B} = \frac{R}{c \cos C}$ **ii)** $\frac{P}{a^2(b^2 + c^2 - a^2)} = \frac{Q}{b^2(c^2 + a^2 - b^2)} = \frac{R}{c^2(a^2 + b^2 - c^2)}$

Sol^n: Let O be the circumcentre of the triangle ABC. Since the angles at centre O are double of the corresponding angles at the circumference.

$\therefore$ $\angle BOC = 2A$, $\angle COA = 2B$ and $\angle AOB = 2C$ .... (i)



i) Using Lami's Theorem, we have

$$\frac{P}{\sin BOC} = \frac{Q}{\sin COA} = \frac{R}{\sin AOB}$$

or, $\frac{P}{\sin 2A} = \frac{Q}{\sin 2B} = \frac{R}{\sin 2C}$

or, $\frac{P}{2\sin A.\cos A} = \frac{Q}{2\sin B.\cos B} = \frac{R}{2\sin C.\cos C}$

or, $\frac{P}{(2R \sin A)\cos A} = \frac{Q}{(2R \sin B)\cos B} = \frac{R}{(2R \sin C)\cos C}$

where R denotes the radius of circumscribed circle of the triangle ABC such that a = 2R sinA, etc.

$\therefore$ $\frac{P}{a \cos A} = \frac{Q}{b \cos B} = \frac{R}{c \cos B}$ .... (ii)

ii) We have, $a \cos A = a\frac{b^2 + c^2 - a^2}{2bc} = \frac{a^2(b^2 + c^2 - a^2)}{2abc}$,

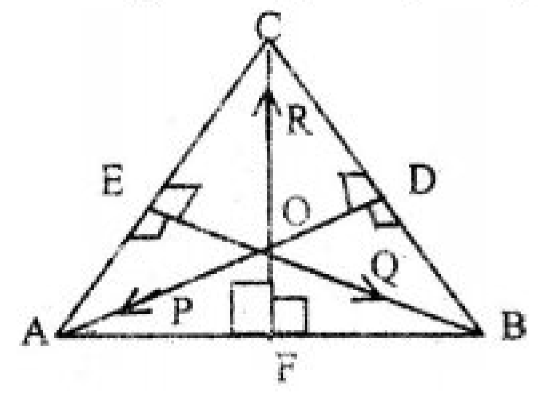
Similarly, $b\cos B = \frac{b^2(c^2 + a^2 - b^2)}{2abc}$ and $\cos C = \frac{c^2(a^2 + b^2 - c^2)}{2abc}$

Substituting the values of acosA, bcosB, ccosC on (ii), we get

$$\frac{P}{\frac{a^2(b^2 + c^2 - a^2)}{2abc}} = \frac{Q}{\frac{b^2(c^2 + a^2 - b^2)}{2abc}} = \frac{R}{\frac{c^2(a^2 + b^2 - c^2)}{2abc}}$$

$\therefore$ $\frac{P}{a^2(b^2 + c^2 - a^2)} = \frac{Q}{b^2(c^2 + a^2 - b^2)} = \frac{R}{c^2(a^2 + b^2 - c^2)}$

12. O is the orthocentre of the triangle of the triangle ABC. Forces P, Q, R acting along OA, OB, OC are in equilibrium. Prove that $\frac{P}{BC} = \frac{Q}{CA} = \frac{R}{AB}$.



Sol^n: Let ABC be the triangle and AD, BE, CF are the perpendiculars from its vertices to the sides BC, CA and AB respectively. Then the point of intersection of them is O, called orthocentre of the triangle ABC.

Now, we find $\angle BOC$

Since $\angle OEA = \angle OFA = 90°$ and $\angle BOC = \angle EOF \therefore \angle EOF + \angle EAF = 180° \Rightarrow \angle BOC = \pi - A$

Thus, $\angle BOC = \pi - A$, $\angle COA = \pi - B$, $\angle AOB = \pi - c$ .... (i)

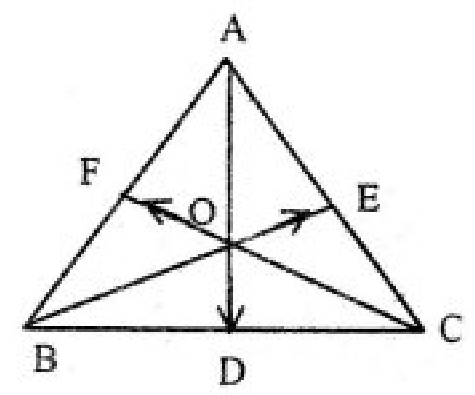
Using Lami's theorem, we have

$$\frac{P}{\sin \angle BOC} = \frac{Q}{\sin \angle COA} = \frac{R}{\sin \angle AOB} \text{ or, } \frac{P}{\sin(\pi - A)} = \frac{Q}{\sin(\pi - B)} = \frac{R}{\sin(\pi - C)}.$$

or, $\frac{P}{\sin A} = \frac{Q}{\sin B} = \frac{R}{\sin C}$ or, $\frac{P}{BC/2r} = \frac{Q}{CA/2r} = \frac{R}{AB/2r}$ [Using sine law]

$\therefore$ $\frac{P}{BC} = \frac{Q}{CA} = \frac{R}{AB}$.

13. ABC is a triangle and D, E, F are the middle points of the sides BC, CA, AB respectively. Show that the forces represented by the straight lines AD, BE, CF acting at a point are in equilibrium.



Sol^n: Since D, E, F are the midpoints of BC, CA and AB respectively.

$\therefore$ $\vec{AD} = \frac{\vec{AB} + \vec{AC}}{2}$, $\vec{BE} = \frac{\vec{BA} + \vec{BC}}{2}$, $\vec{CF} = \frac{\vec{CB} + \vec{CA}}{2}$ .... (i)

Now, the resultant of the forces $\vec{AD}$, $\vec{BE}$, $\vec{CF}$ is given by

$$\vec{AD} + \vec{BE} + \vec{CF} = \frac{\vec{AB} + \vec{AC}}{2} + \frac{\vec{BA} + \vec{BC}}{2} + \frac{\vec{CB} + \vec{CA}}{2}$$

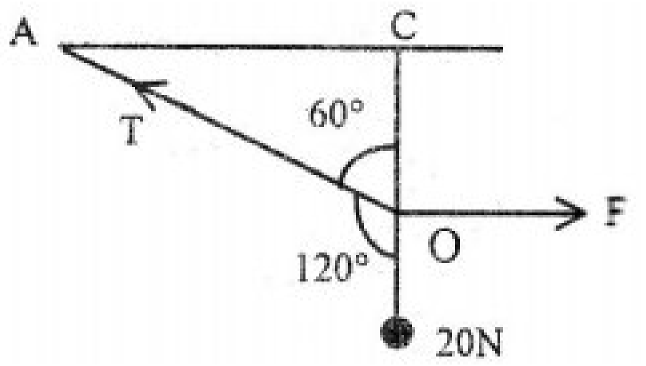
$$= \frac{1}{2}[\vec{AB} + \vec{AC} + \vec{BA} + \vec{BC} + \vec{CB} + \vec{CA}]$$

$$= \frac{1}{2}[(\vec{AB} + \vec{BA}) + (\vec{AC} + \vec{CA}) + (\vec{BC} + \vec{CB})]$$

$$= \frac{1}{2}[(\vec{AB} - \vec{AB}) + (\vec{AC} - \vec{AC}) + (\vec{BC} - \vec{BC})] = \frac{1}{2}[\vec{0} + \vec{0} + \vec{0}] = \vec{0}$$

$\therefore$ The forces represented by AD, BE and CF acting at O are in equilibrium.

14. A body of weight 20 N, which hangs by a string is pushed to one side by a horizontal force so that the string makes an angle of 60° with the vertical; find the horizontal force and the tension of the string.



Sol^n: Let, T be the tension of the string makes an angle 60^o with the vertical. force 20 N acing vertically downward is pushed by horizontal force F such that forces T, F, 20 N are equilibrium.

Using Lami's theorem, we have

$$\frac{F}{\sin 120°} = \frac{T}{\sin 90°} = \frac{20}{\sin 150°}$$

or, $\frac{F}{\sqrt{\frac{3}{2}}} = \frac{T}{1} = \frac{20}{\frac{1}{2}}$ or, $\frac{2F}{\sqrt{3}} = T = 40$

$\therefore$ $F = 20\sqrt{3}$ N and $T = 40$ N.

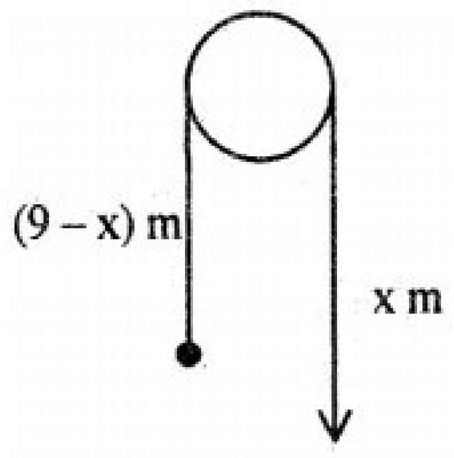
15. A heavy chain of length 9 m and weighing 18 N has a weight of 6 N attached to one end is in equilibrium hanging over a smooth peg. What length of the chain is on each side ?

Sol^n: Let length of chain on one side = x m

Then thelength of string on other side = (9 – x) metre.

Here, weight of 9 m string is 18 N

then weight of 1 m string is $\frac{18}{9} = 2$ N



here, string hanging over a smooth peg is in equilibrium

$\therefore \quad 2x = 2(9 - x) + 6 \qquad$ or, $x = \frac{24}{4} = 6$ m, which is required.

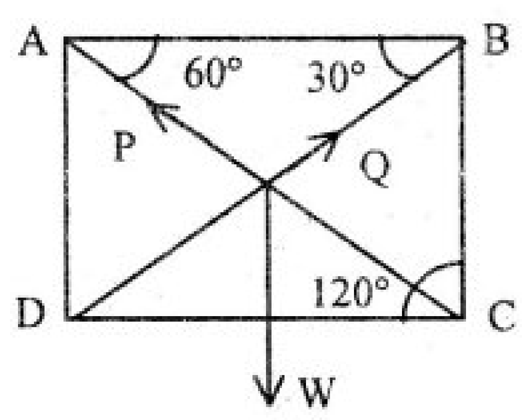
Hence, the length of the chain on each sides are x and (9 – x) metres i.e. 6 metres and 3 metres. Ans.

16. A uniform plane lamina in the form of a rhombus, one of whose angles is 120°, is supported by two forces applied at the centre in the directions of the diagonals so that one side of the rhombus is horizontal; show that if P and Q be the forces and P be the greater, then $P^2 = 3Q^2$.

Sol^n: Let the uniform plane lamina in the form of rhombus be ABCD, such that $\angle BAD = \angle BCD = 120°$ $\qquad \therefore \angle ABC = \angle ADC = 60°$

The components of the forces P and Q in vertical direction balance the weight of lamina W acting vertically downwards.

Now, resolving the forces horizontally, we have



$$P \cos 60° = Q \cos 30° \quad \text{or,} \quad P\frac{1}{2} = Q\left(\frac{\sqrt{3}}{2}\right) \quad \text{or, } P = \sqrt{3}\,Q \text{ .... (i)}$$

$\Rightarrow \quad P > Q$ and $P^2 = 3Q^2$.

Hint and Solution of MCQ's

1. *l* be the length of chain.

Let w be the weight of chain such that x is the weight along the one end where 5 kg wt is attached then w – x will be the weight along other end where 8 kg weight is attached

$\therefore \quad x + 5 = 10$ …… (i)

$\quad (w - x) + 8 = 10$ ……. (ii)

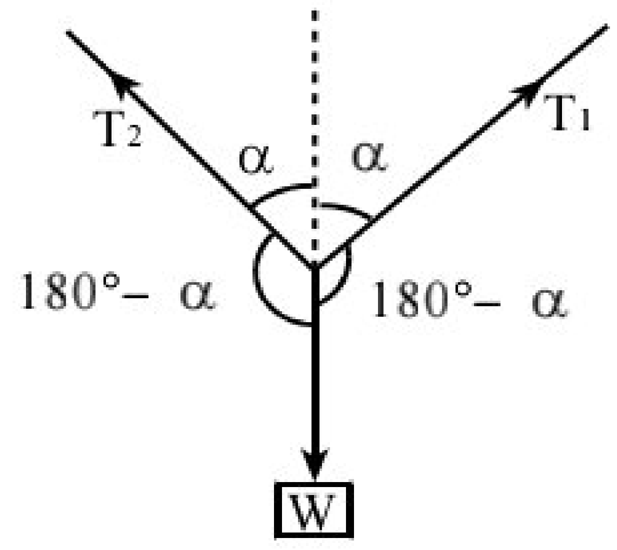
from (i) x = 5

when x = 5, from (ii)

$\quad w - 5 + 8 = 10 \qquad \Rightarrow w = 7$ kg wt.

2. Let α be equal angle, made by weight w acting vertically downward, to the strings attached on the weight

If T_1 and T_2 are the tension then



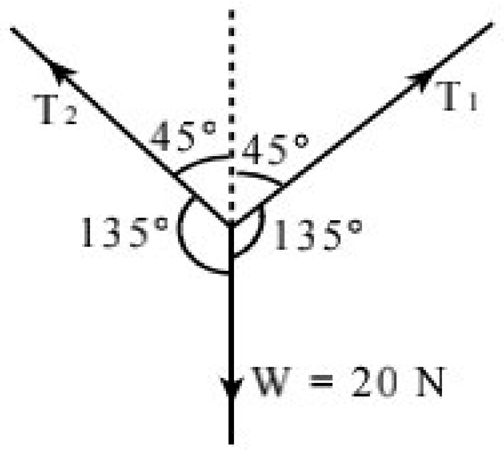
$$\frac{T_1}{\sin(180^o - \alpha)} = \frac{T_2}{\sin(180^o - \alpha)} = \frac{w}{\sin 2\alpha}$$

$$\Rightarrow \quad T_1 = \frac{w \sin\alpha}{\sin 2\alpha} = \frac{w}{2\cos\alpha}$$

$$\Rightarrow \quad T_2 = \frac{w \sin\alpha}{\sin 2\alpha} = \frac{w}{2\cos\alpha}$$

$\therefore \quad$ the tension of the strings are equal

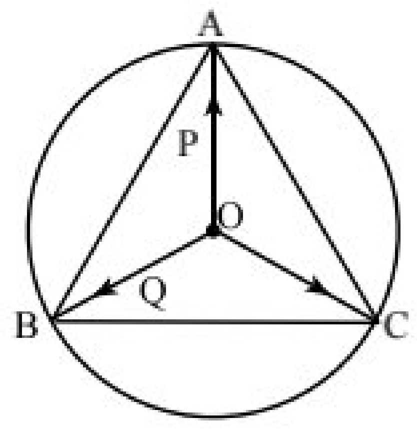
3. Let $\alpha = 45^o$ be the angles made by two strings, whose tension are T_1 and T_2, to the vertical line then, using (2) we get



$$T_1 = T_2 = \frac{w}{2\cos\alpha} = \frac{20}{2\cos 45^o} = 10\sqrt{2}\text{ N}$$

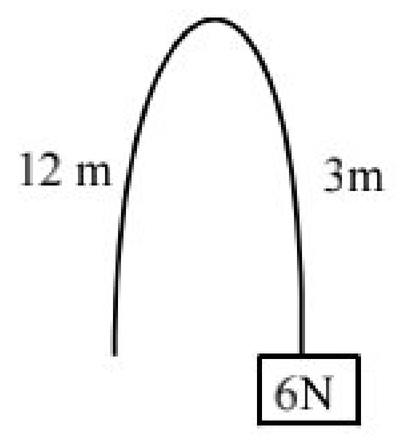
4. Using Lami's theorem

$$\frac{P}{\sin BOC} = \frac{Q}{\text{Sin } AOC} = \frac{R}{\sin AOB}$$



$$\Rightarrow \quad \frac{P}{\sin 2A} = \frac{Q}{\sin 2B} = \frac{R}{\sin 2C}$$

5. Let w be the weight of chain for $(12 + 3)m = 15m$ length.



$\therefore$ weight for 3m chain $= \frac{3w}{15} = \frac{w}{5}$ N.

weight for 12m chain $= \frac{12w}{15} = \frac{4w}{5}$ N

Here, $\frac{w}{5} + 6 = \frac{4w}{5}$

$\Rightarrow$ $w + 30 = 4w$

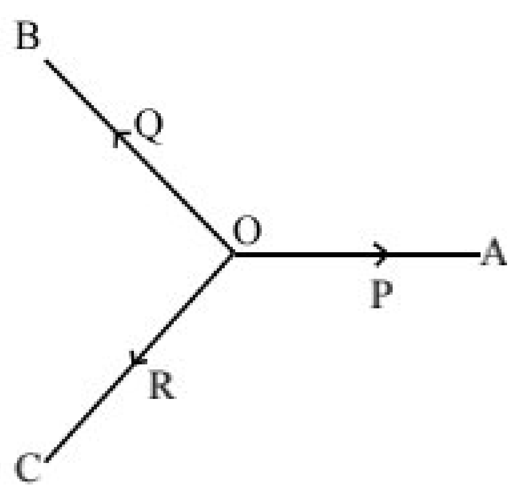
$\Rightarrow$ $3w = 30$

$\Rightarrow$ $w = 10N$.

6. The statement is Lami's theorem.

7. If $\vec{P}$, $\vec{Q}$, $\vec{R}$, the three forces acting at a point can be represented by the sides of a triangle taken in order, then forces are in equilibrium

i.e. $\vec{P} + \vec{Q} + \vec{R} = 0$.

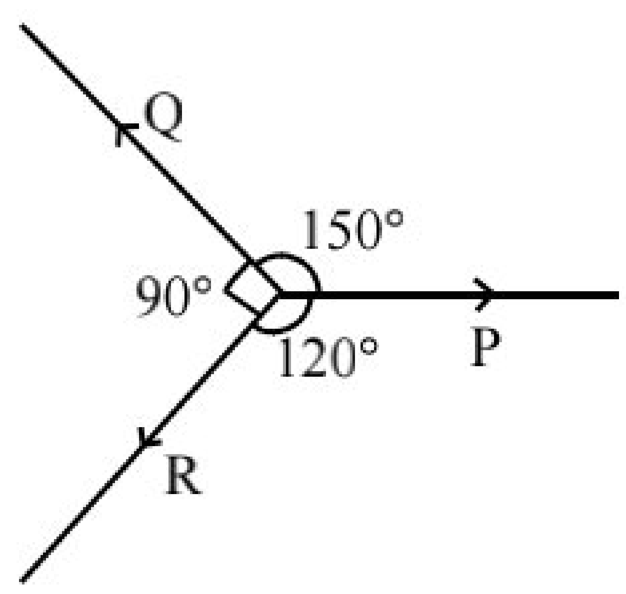


8. If three forces P, Q, R acting at O along OA, OB, OC in equilibrium, then using Lami's theorem

$$\frac{P}{\text{Sin}BOC} = \frac{Q}{\text{Sin}COA} = \frac{R}{\text{Sin}AOB}$$

9. Here, three forces acting at a point are in equilibrium, so using lami's theorem

$$\frac{P}{\sin 90^o} = \frac{Q}{\sin 120^o} = \frac{R}{\sin 150^o}$$



$$\Rightarrow \quad \frac{P}{1} = \frac{Q}{\frac{\sqrt{3}}{2}} = \frac{R}{\frac{1}{2}}$$

$$\Rightarrow \quad P: Q: R = 1: \frac{\sqrt{3}}{2} : \frac{1}{2}$$

$$\therefore \quad P: Q: R = 2: \sqrt{3} : 1.$$