VECTORS, FORCES, DENSITY & PRESSURE

Akhtar

Scalar:

Physical Qty ⟶ magnitude + Units

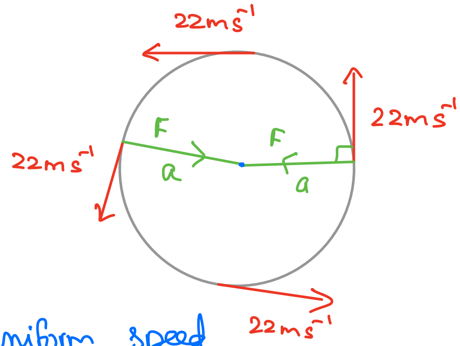
Vector:

Physical Qty ⟶ (magnitude + Units) + direction

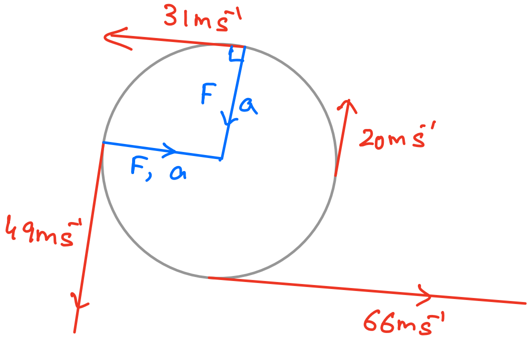
Representation of a vector:- (Graphical representation)

Representation: Straight line
- ⟶ Length drawn as per scale ↓ Magnitude
- ⟶ Arrow head ⟶ Direction

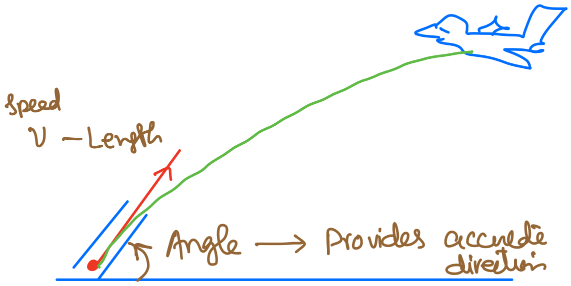
Example:

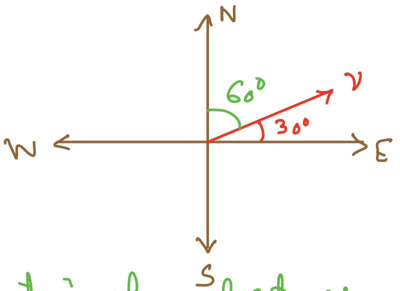


Uniform speed but variable velocity



Both speed and velocity vary





Direction of velocity v

(i) 30° with East

(ii) 60° with North

Q) Which of the following vector quantities must be in one direction?

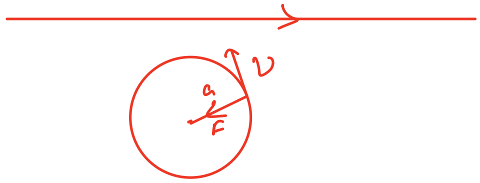
(A) s , v

(B) v , a

[✓ (C)] a , F

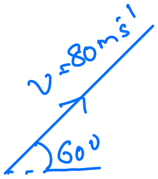
(D) s , v , F

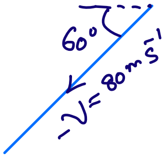
St. line motion s, a, v, F

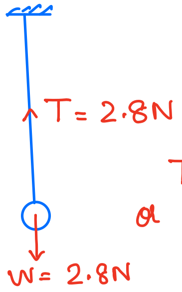


Negative of a vector :-

Another vector with same magnitude (Length) but act in opposite direction.







$T = -W = 2.8N$

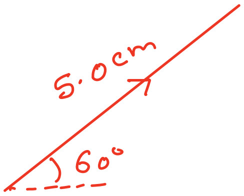
or $-T = W = 2.8N$

Scale to be considered for vector diagram

Force of 10 N act at 60° with East

Scale 1

$2N = 1.0\ cm$



Good scale due to lesser percentage error

$$\frac{\Delta L}{L} \times 100 = \left(\frac{0.1}{L\uparrow} \times 100\right)\downarrow$$

Scale 2

$5N = 1.0\ cm$

worst scale due to greater percentage error.

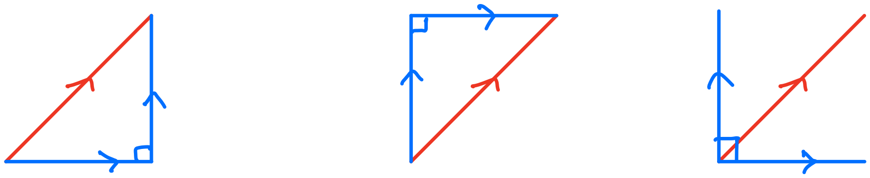
$$\frac{\Delta L}{L} \times 100 = \left(\frac{0.1}{L\downarrow} \times 100\right)\uparrow$$

Resolution of a vector :-

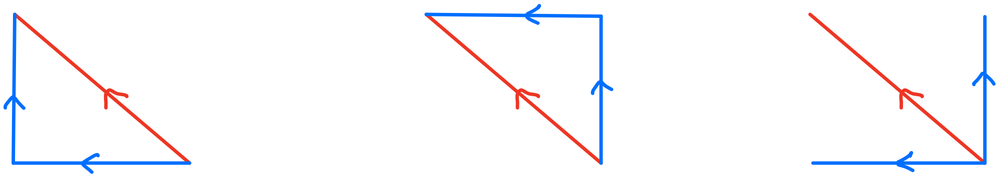
Splitting up of a vector into its mutually perpendicular components.

Examples :

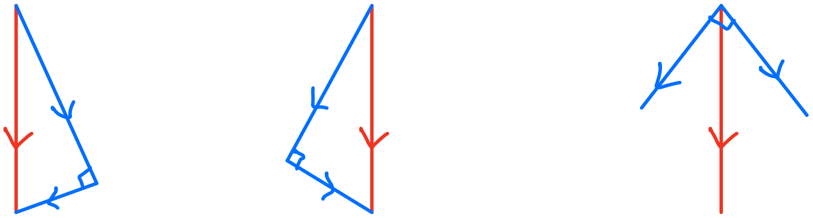
(1)



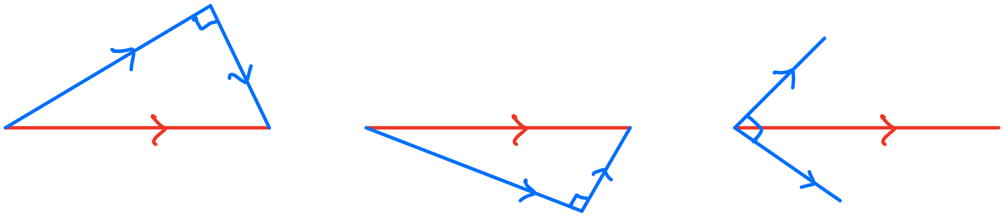
(2)



(3)

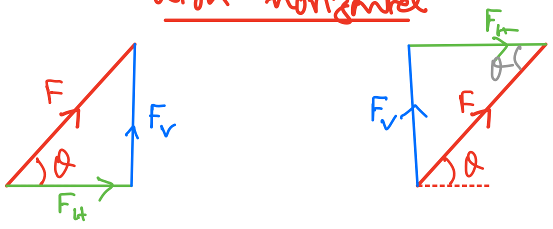


(4)

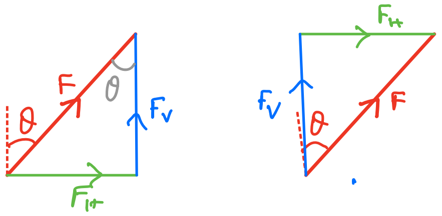


Mathematical evaluation

Case 1 If angle is provided with horizontal



Case 2 : If angle is provided with vertical :-



Horizontal component of force:

$$\cos\theta = \frac{\text{Base}}{\text{Hyp}} \Rightarrow \cos\theta = \frac{F_H}{F}$$

$$\boxed{F_H = F\cos\theta}$$

Vertical component of force:-

$$\sin\theta = \frac{\text{Perp}}{\text{Hyp}} \Rightarrow \sin\theta = \frac{F_v}{F}$$

$$\boxed{F_v = F\sin\theta}$$

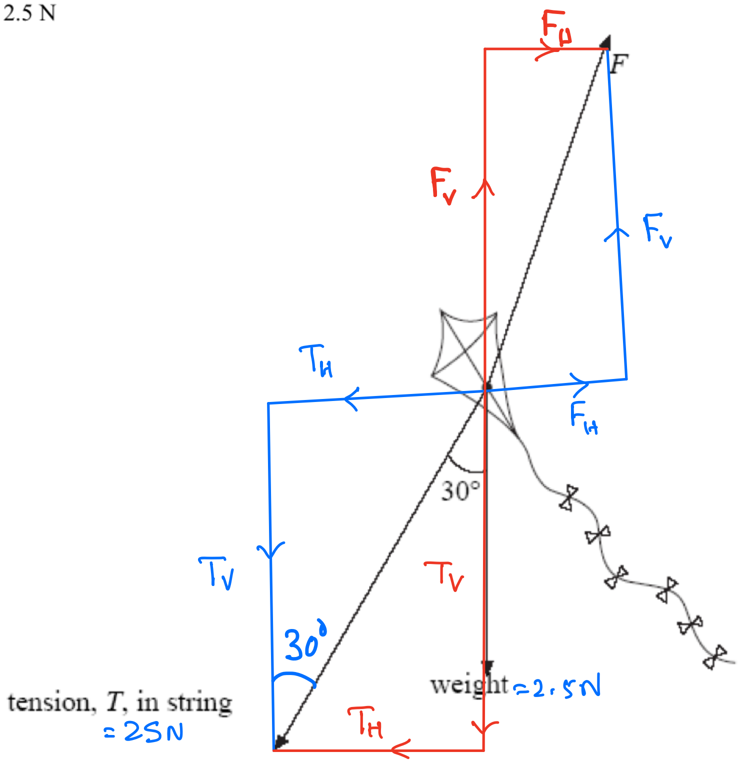
Horizontal component of force:

$$\boxed{F_H = F\sin\theta}$$

Vertical component of force:

$$\boxed{F_v = F\cos\theta}$$

The diagram shows the forces acting on a stationary kite. The force *F* is the force that the air exerts on the kite. The weight of the kite is 2.5 N



(a) Show on the diagram how force *F* can be resolved into horizontal and vertical components. [1]

(b) The magnitude of the tension, *T*, is 25 N. [1]

Calculate

(i) the horizontal component of the tension,

$T_H = T \sin 30 = 25 \sin 30 = 12.5N$

...

(ii) the vertical component of the tension.

$T_V = T \cos 30 = 25 \cos 30 = 21.7N$

(c) (i) Calculate the magnitude of the vertical component of *F*.

$F_V = T_V + W = 21.7 + 2.5 = 24.2 N$

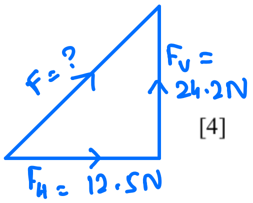
(ii) State the magnitude of the horizontal component of *F*.

$F_H = T_H = 12.5 N$

(iii) Hence calculate the magnitude of *F*.

$F = \sqrt{F_V^2 + F_H^2}$

$= \sqrt{(24.2)^2 + (12.5)^2} = 27.2N$



[4]

VECTORS

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Q1. **(a)** State the difference between a scalar quantity and a vector quantity.

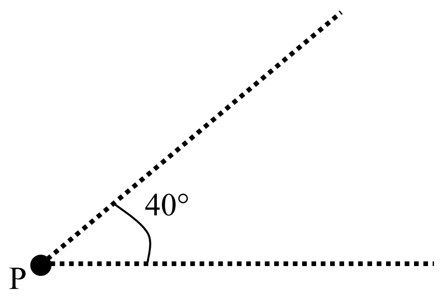
scalar: ………………………………………………………………………………………......

………………………………………………………………………………………………

vector: ………………………………………………………………………………………......

………………………………………………………………………………………………

(b) Two forces of magnitude 6.0 N and 8.0 N act at a point P. Both forces act away from point P and the angle between them is 40°. Figure below shows two lines at an angle of 40° to one another.



Draw a vector diagram to determine the magnitude of the resultant of two forces. [4]

{Q.1 / June 2004/9702-1}

Q.2 A picture of weight 5 N is suspended from a hook on a wall by a cord which has a breaking strength of 25 N. Initially (Fig. 2.1) the picture is found to be too low; the cord is shortened, with the intention of hanging the picture as in Fig. 2.2.

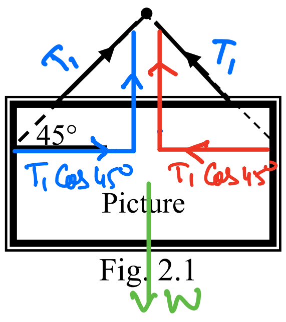


Fig. 2.1

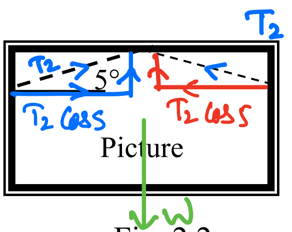


Fig. 2.2

However, when the picture is replaced the chord breaks immediately. Explain why the cord broke when supporting a load so much less than its breaking strength.

$T_1 = ?$ $T_2 = ?$

Consider vertical forces only

$T_1 \sin 45 + T_1 \sin 45 = W$

$2T_1 \sin 45 = 5.0$

$T_1 = 3.54N$

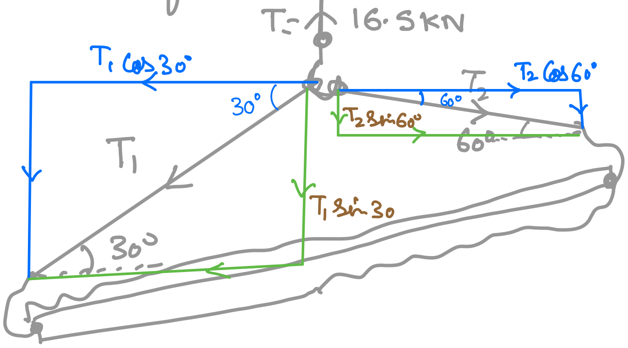
$T_2 \sin 5 + T_2 \sin 5 = W$

$2T_2 \sin 5 = 5.0$

$T_2 = 28.7N$

Since $T_2 > 25N$ is breaking strength of string, so string breaks and picture fall down due to Gravitational pull of Earth.

A non-uniform plank is suspended from the hook of tower crane as shown.



(a) Resolve tension forces T_1 and T_2 into their components.

(b) Consider resolved forces, write eq. to represent forces acting along

(i) horizontally.

$T_1 \cos 30 = T_2 \cos 60$ ------- (i)

(ii) Vertically

$T_1 \sin 30 + T_2 \sin 60 = 16.5 \times 10^3$ ----(ii)

(c) Solve eqs. in (b) (i) and (ii) simultaneously to calculate value of T_1 and T_2.

From eq. (i), $T_1 = \frac{T_2 \cos 60}{\cos 30}$ -------- (iii)

Put eq. (iii) into eq (ii)

$$\left[\frac{T_2 \cos 60}{\cos 30}\right] \sin 30 + T_2 \sin 60 = 16.5 \times 10^3$$

$$0.289 T_2 + 0.866 T_2 = 16.5 \times 10^3$$

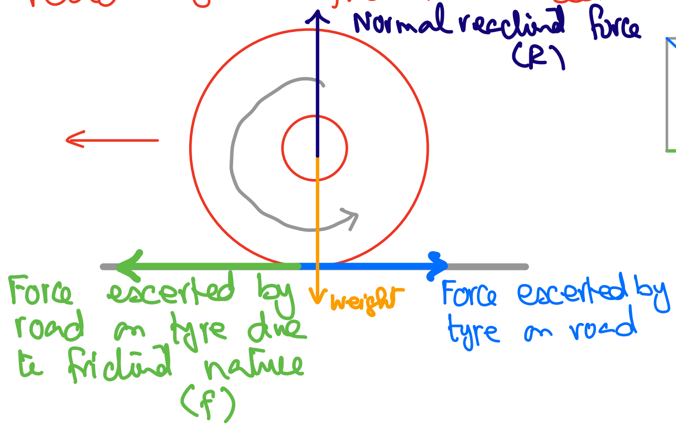
$$T_2 = \frac{16.5 \times 10^3}{1.15} \Rightarrow \boxed{T_2 = 14.3 \times 10^3 N}$$

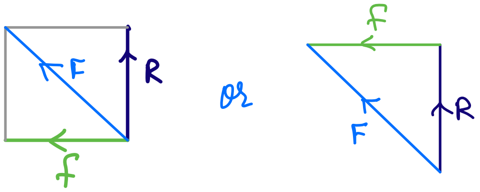
Put above value of T_2 in eq. (3)

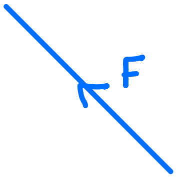
$$T_1 = \frac{(14.3\times10^3)\cos 60^\circ}{\cos 30^\circ} \Rightarrow \boxed{T_1 = 8.25\times10^3\,N}$$

Q4)

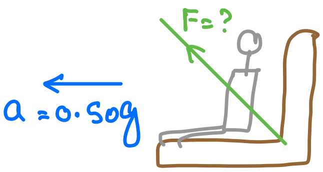
Consider frictional force and normal reaction, what is the direction of resultant force applied by road on front wheel.

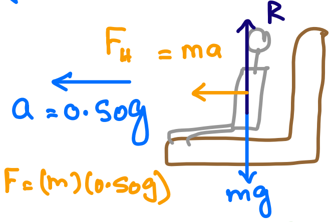


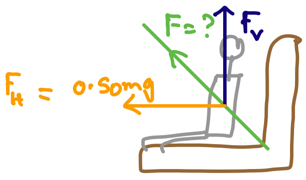


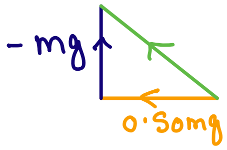


Q5) A child of mass 'm' is sitting on a car's seat which is accelerating at 0.50 g, where g is the acceleration of free fall. What is the magnitude of resultant force shown below?





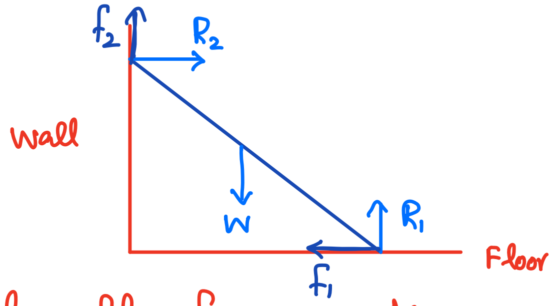




$$F = \sqrt{F_V^2 + F_H^2} \Rightarrow F = \sqrt{(-mg)^2 + (0.50mg)^2}$$

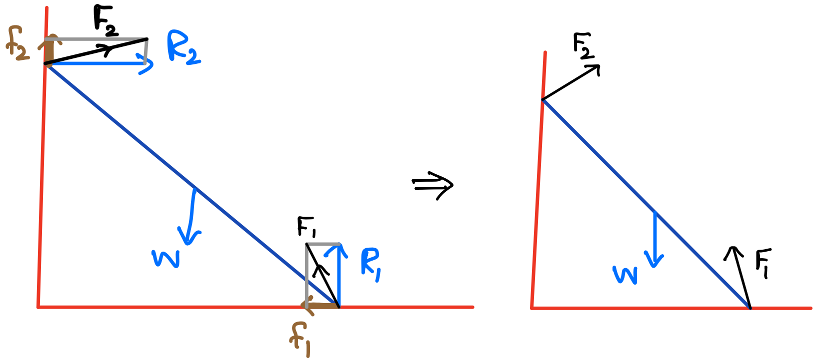
$$\boxed{F = 1.1mg}$$

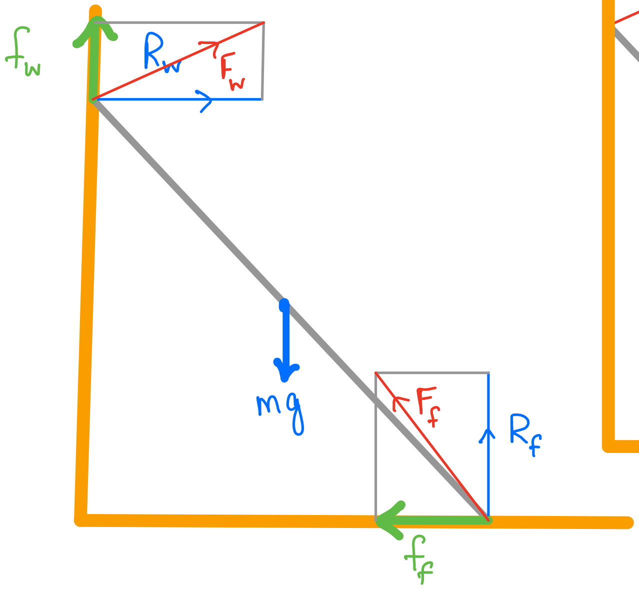
Q) A uniform ladder rests against a rough floor and a wall as shown.

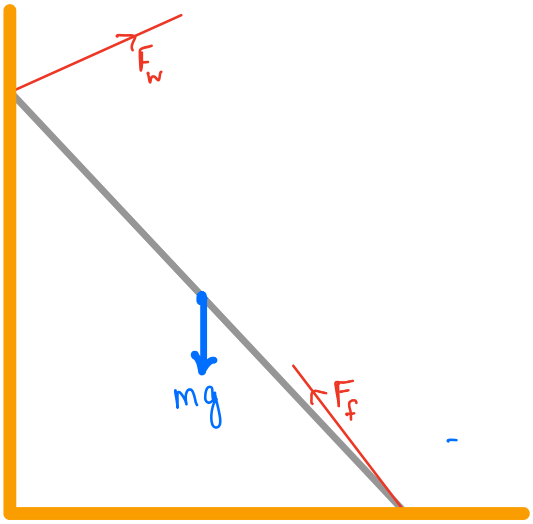


Mark and label all forces acting on the ladder.

S.No.	Force	Symbol	Position	Direction
1.	Weight of ladder	W	centre of gravity of ladder	vertically downward.
2.	Normal reaction force of floor on ladder	R_1	Contact point with floor.	vertically upward
3.	Normal reaction force of wall on ladder	R_2	Contact point with wall	Horizontally towards right side
4.	Friction force of floor on ladder	f_1	Contact point with floor	Horizontally towards left side.
5.	Friction force of wall on ladder	f_2	Contact point with wall	vertically upward.

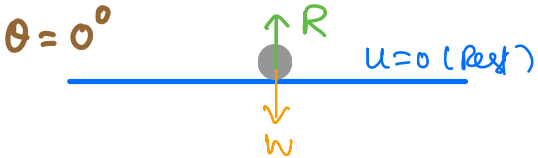




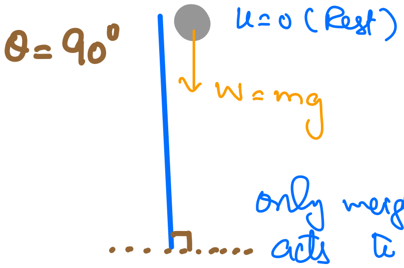


Inclined plane :-

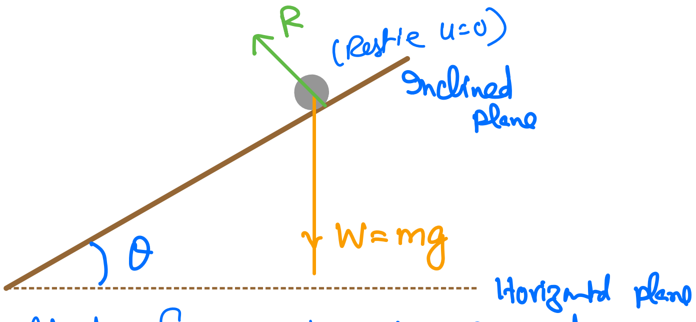
Plane which makes an angle θ $(90^\circ > \theta > 0)$ with the horizontal is Inclined plane.



forces are balanced

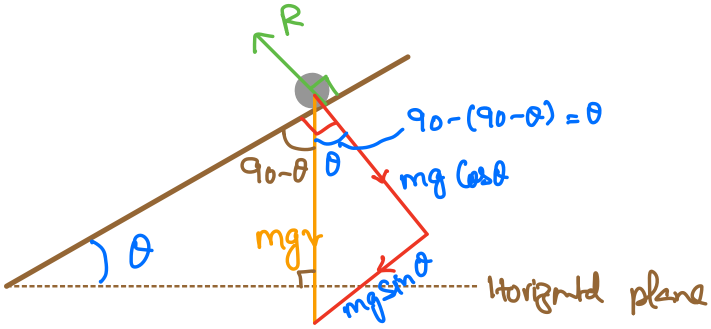


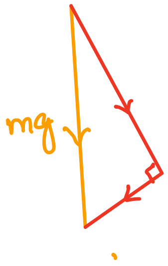
only weight acts to bring ball into motion

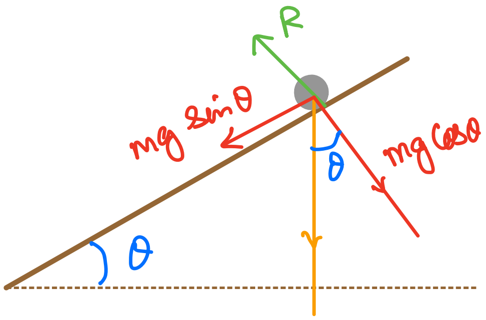


Resultant force due to R and mg brings ball into motion.

Analysis:







Forces perpendicular to inclined plane:-

$$R = mg\cos\theta \quad \text{-------------------} \quad (1)$$

Force parallel to inclined plane = mg sinθ

Therefore, mg sinθ is the resultant force acting down along the inclined plane which brings the sphere into motion from its state of rest. So by Newton's second law,

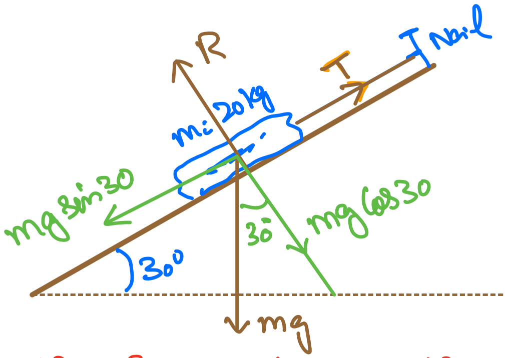
$$F = mg\sin\theta$$

$$\cancel{m}a = \cancel{m}g\sin\theta$$

$$\boxed{a = g\sin\theta}$$

Result: All objects irrespective of their masses move down along the inclined plane with same acceleration of $(g \sin\theta)$ if started from rest and frictional forces are neglected.

Q2) A log of wood tied to a string is placed on a frictionless inclined plane as shown below



(a) Show all the forces acting on the block placed on a frictionless inclined plane. [2]

(b) Resolve weight into its component and label them in mathematical form [2]

(c) Calculate tension in the string if block is at rest [2]

$$T = mg\sin 30$$
$$= (20)(9.81)(0.5) = 98.1\text{N}$$

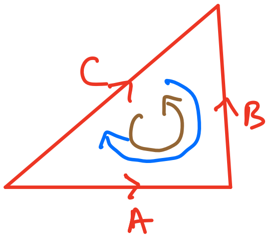
(d) If the string breaks, calculate the acceleration of block along the inclined plane.

$$\cancel{m}a = \cancel{m}g\sin\theta$$
$$a = (9.81)\sin 30$$
$$\boxed{a = 4.9\ \text{m}\,\text{s}^{-2}}$$

Mathematical representation of a vector diagram

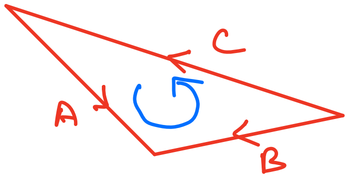
Hint: Assume a loop either in clockwise or in anticlockwise with in a vector diagram. Put +ve sign with vector if they are along the loop and −ve sign if against the loop.

Example:

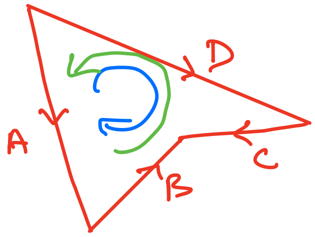


$A + B - C = 0$

$C - B - A = 0$

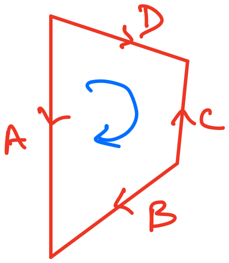


$A - B + C = 0$

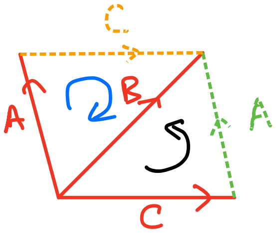


$D + C - B - A = 0$

$B - C - D + A = 0$



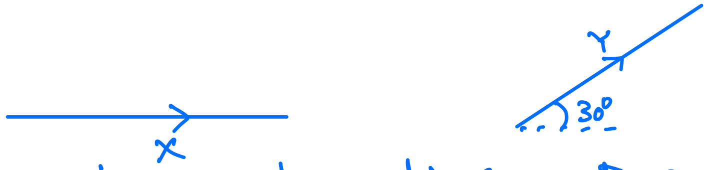
$D - C + B - A = 0$



$A + C - B = 0$

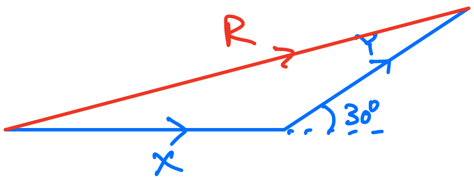
$C + A - B = 0$

Q) X and Y are two vectors as shown below.

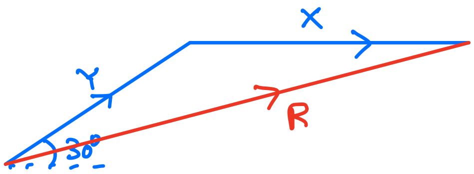


Show by vector diagram to get resultant R such that

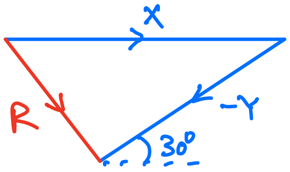
(i) $R = X + Y$



OR



(ii) $R = X - Y$



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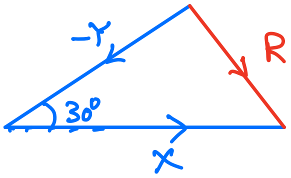
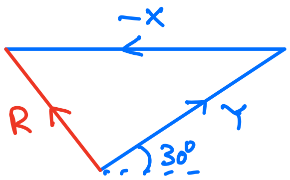


(iii) $R = Y - X$



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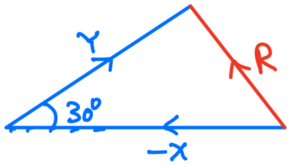
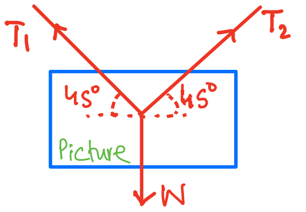


Concurrent forces :-

Concept :- Forces which are assumed to be acting at the same point. i.e point of application of all these force is same.

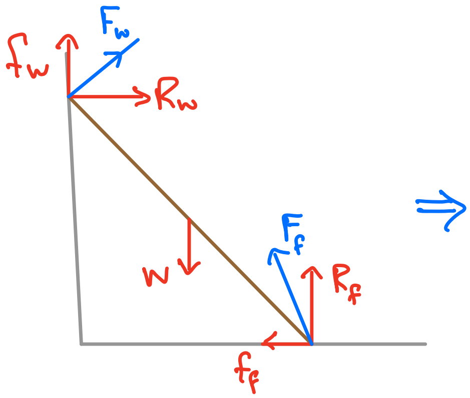
Examples:

(1)

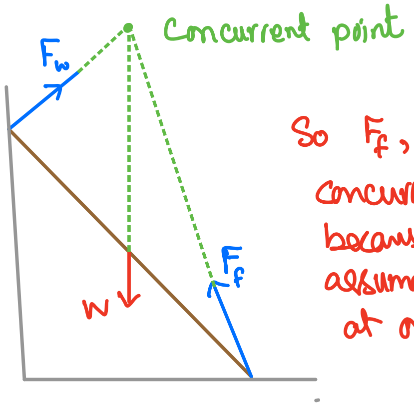


T_1, T_2 and W are concurrent forces because they are acting at the same point.

(2)

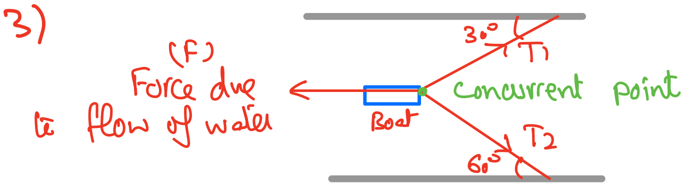


⇒



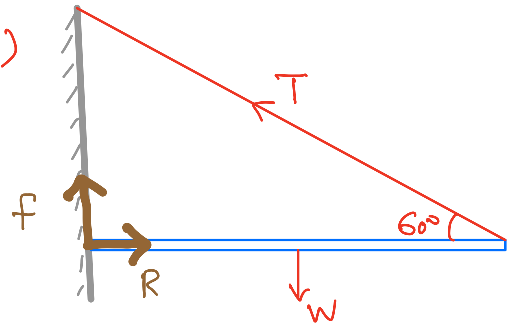
So F_f, W and F_w are concurrent forces because they are assumed to be acting at one point.

(3)

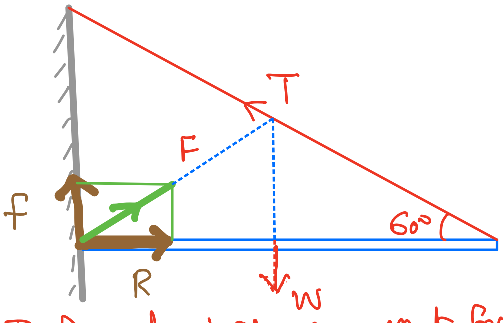


T_1, F and T_2 are concurrent forces

(4)



⇒



Here T, R and W are concurrent forces

Law of triangle of forces :-

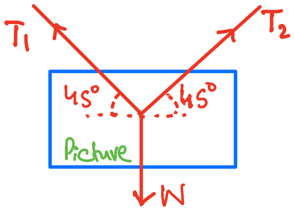
Statement :- If three forces are acting at one point (Concurrent Forces) and are represented interms of magnitude and direction by three sides of a triangle in one order then object is in equilibrium.

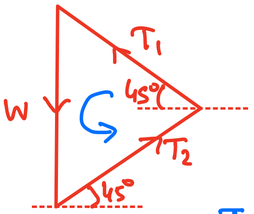
OR

If an object is in equilibrium due to three forces then these three forces represent three sides of a triangle in one order.

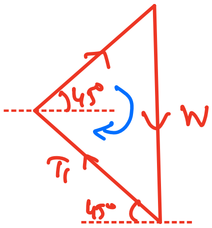
Example:

(1)





(OR)

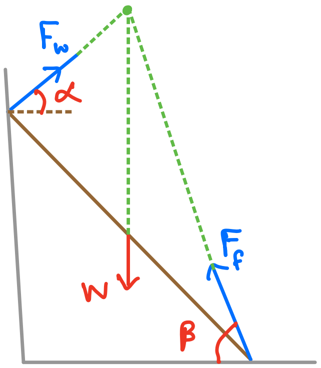


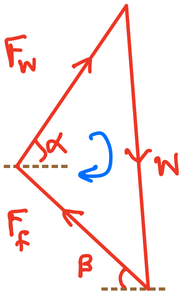
$T_2 + T_1 + W = 0$

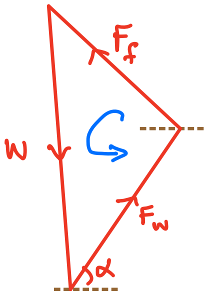
$\sum F = 0 \Rightarrow ma = 0 \Rightarrow a = 0$

So picture is in equilibrium.

(2)



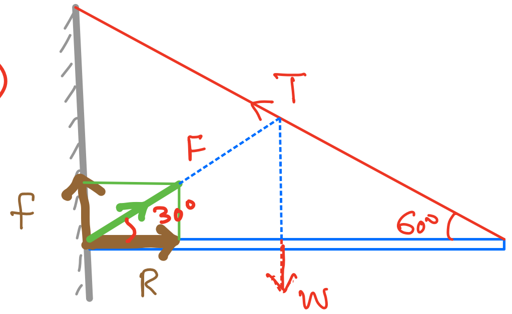


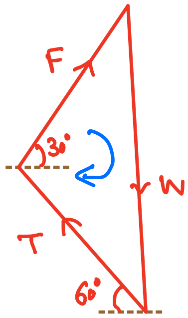


$F_f + F_W + W = 0$ so $a = 0$

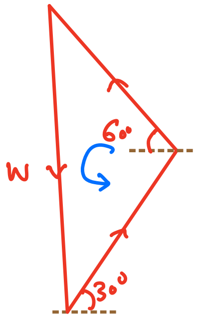
Hence ladder is in equilibrium

(4)





or



$$F + T + W = 0 \Rightarrow \sum F = 0 \Rightarrow a = 0$$

Hence plank is at rest against a wall

Equilibrium :-

Meaning: If acceleration of an object is zero than it is in equilibrium.

Types:

(i) Static equilibrium:- Object is at rest.

(ii) Dynamic equilibrium:- Object move with uniform velocity.

Conditions of equilibrium:

(1) Resultant sum of all the forces acting on the object is zero.

$$\sum F = 0$$

(2) Algebraic sum of clockwise moments must be equal to algebraic sum of anticlockwise moments.

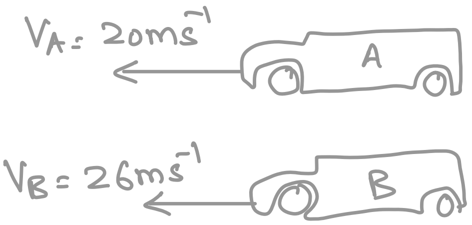
$$\sum (C.W.M) = \sum (A.C.W.M)$$

Relative speed concept:-

Hint: Speeds of both objects are
(i) subtracted if both move in same direction.
(ii) added if both move in opposite directions.

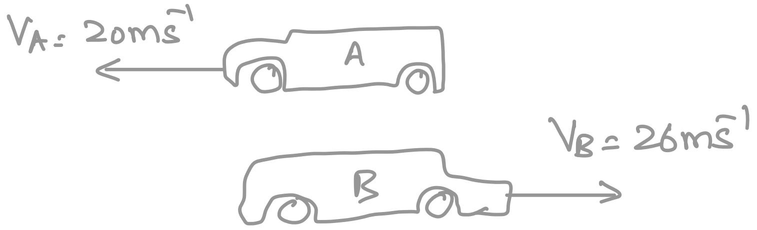
Examples:

(1) If both vehicles move in same direction:-



Speed of B relative to A or speed of A relative to B = $V_B - V_A = 26-20 = 6ms^{-1}$

(2) If both vehicles move in opposite directions:-



Speed of B relative to A or speed of A relative to B = $V_B + V_A = 26+20 = 46ms^{-1}$
i.e

Velocity of A relative to B = $46ms^{-1}$ towards left
Velocity of B relative to A = $46ms^{-1}$ towards right

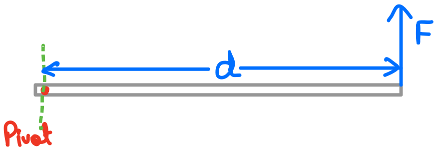
Moment of force:-

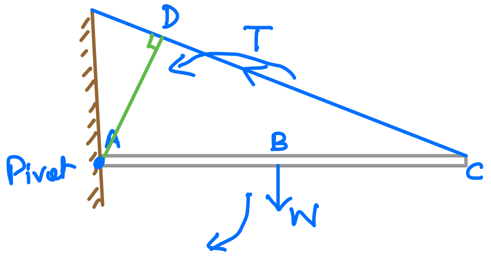
Def. Product of force and perpendicular distance from the point of application of force to the axis of rotation (pivot).

Symbol: τ (Tau – Taw)

Formula:

i) $\tau = (F)(d)$





Moment due to force

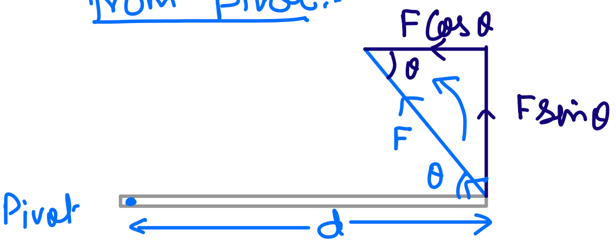
(a) Weight W:

C.W.M = $(W)(d_{AB})$

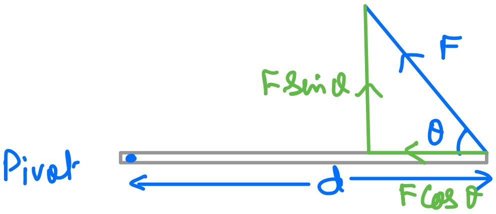
(b) Tension T:

A.C.W.M = $(T)(d_{AD})$

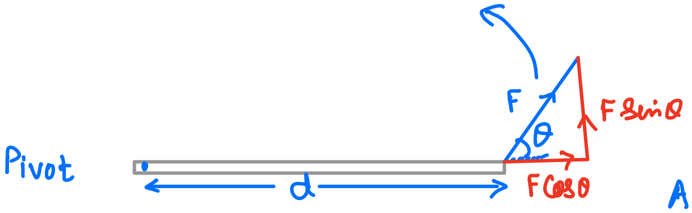
(ii) If Force makes an angle 'θ' with the distance from pivot:-



A.C.W.M = $(F\sin\theta)(d)$



A.C.W.M = $(F\sin\theta)(d)$

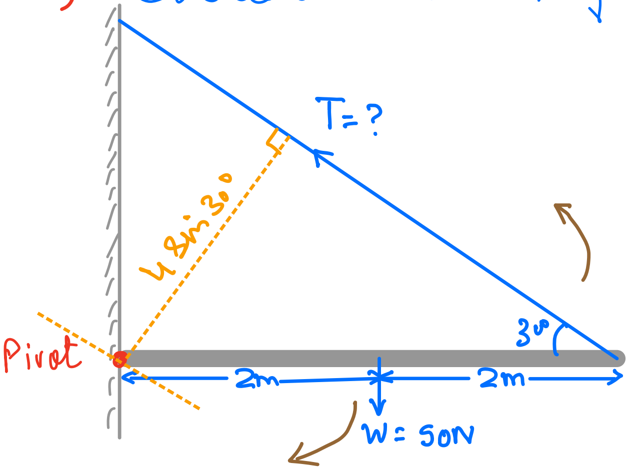


$A.C.W.M = (F\sin\theta)(d)$

Note: (i) In order to locate the perpendicular distance, draw a straight line parallel to given force and should pass through pivot.

(ii) The point of application of components of force is same where the actual force is applied.

Q) Calculate tension T if plank is in equilibrium.



$C.W.M = A.C.W.M$

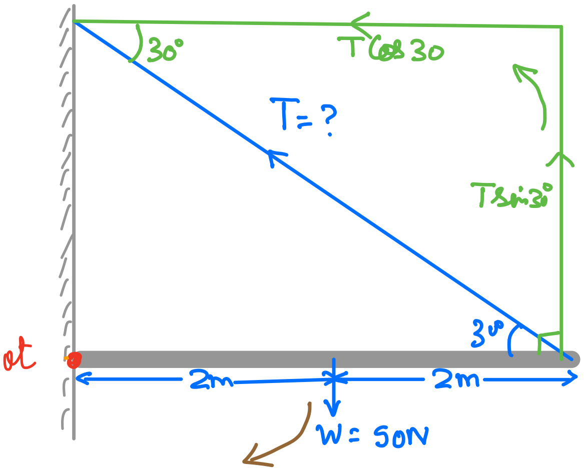
$(50)(2) = (T)(4\sin 30)$

$$T = \frac{(50)(2)}{(4)(0.5)} = 50N$$

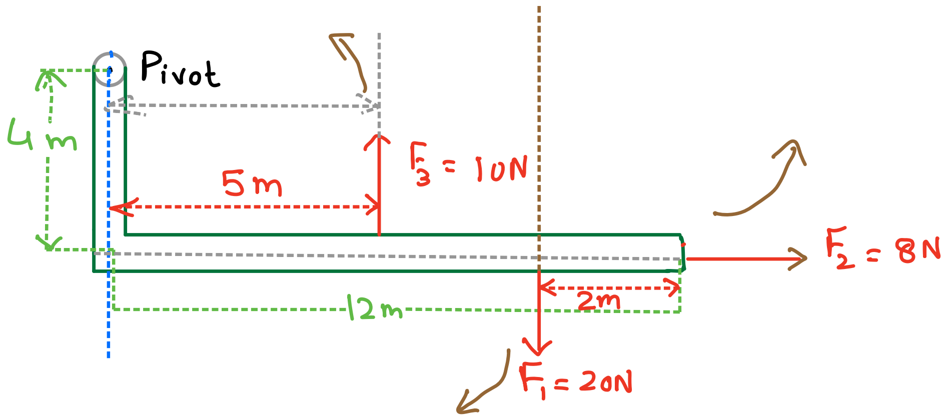
$C.W.M = A.C.W.M$

$(50)(2) = (T\sin 30)(2+2)$

$$T = \frac{(2)(50)}{(0.5)(4)} = 50N$$



Q)



(a) Calculate moment due to force

i) F_1

C.W.M = $(F_1)(d)$

$= (20)(10) = 200$ Nm

(ii) F_2

A.C.W.M = $(F_2)(d)$

$= (8)\ (4) = 32$ Nm

(iii) F_3

A.C.W.M = $(F_3)(d)$

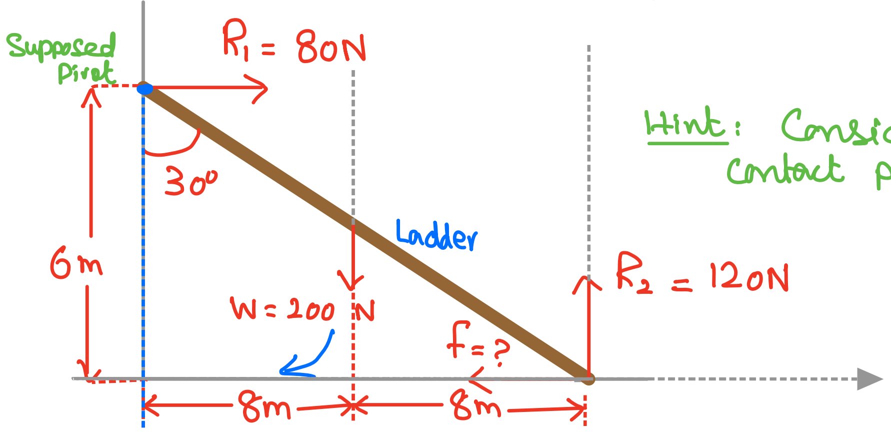
$= (10)(5) = 50$ Nm

(b) Calculate resultant moment about pivot

Resultant C.W.M = $200 - (32+50)$

$= 118$ Nm

Q) A ladder is at rest against a smooth wall and a rough ground as shown.



Hint: Consider frictionless contact point as pivot.

Calculate friction force F.

C.W.M = A.C.W.M

$$(200)(8) + (f)(6) = (120)(8+8)$$

$$f = \frac{1920-1600}{6} = 53.3\text{ N}$$

Q) A uniform plank of 1.2 m length is suspended from a string as shown. Calculate tension in the string if the plank is in equilibrium.

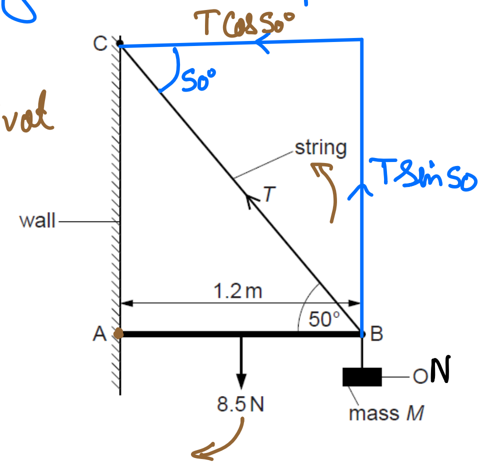
Let contact point A be the pivot

C.W.M = A.C.W.M

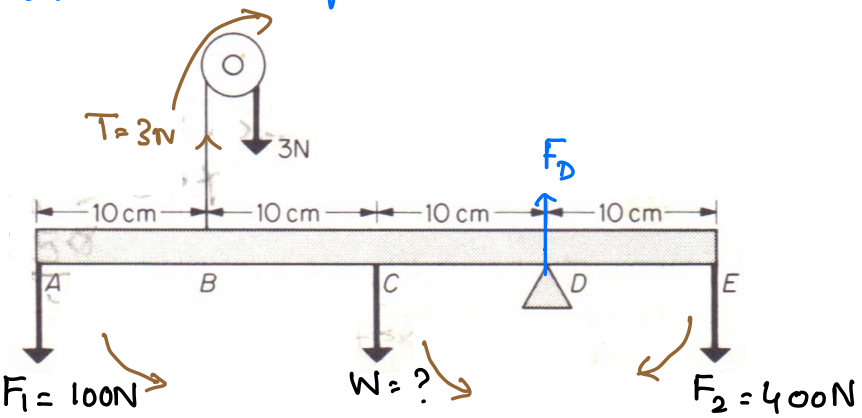
$$(8.5)(0.6) = (T\sin 50)(1.2)$$

$$T = \frac{(8.5)(0.6)}{1.2\sin 50}$$

$$= \underline{\qquad\qquad} \text{ N}$$



Q) A plank is in equilibrium as shown.



Calculate

(i) weight w of plank.

Let D be the pivot point

C.W.M = A.C.W.M

$(400)(10) + (3)(20) = (100)(30) + (W)(10)$

$4000 + 60 = 3000 + 10W$

$W = \frac{4060 - 3000}{10}$

$= 106\ N$

(ii) Force applied by wedge D in upward direction.

Σ(upward Forces) = Σ(Downward forces)

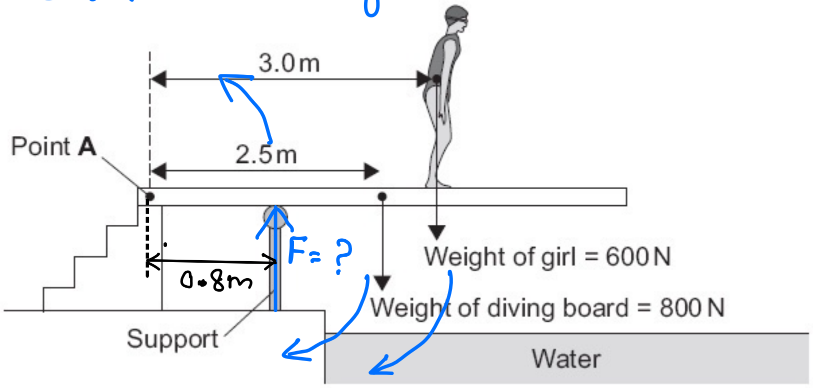
$T + F_D = F_1 + W + F_2$

$3 + F_D = 100 + 106 + 400$

$F_D = 606 - 3$

$F_1 = 603\ N$

Q) Calculate force excerted by support in upward direction if diving board is in horizontal equilibrium



Let point A be the pivot point

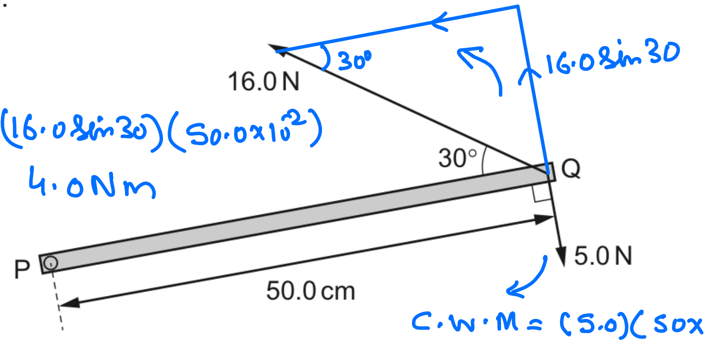
$$C.W.M = A.C.W.M$$

$$(600)(3.0) + (800)(2.5) = (F)(0.8)$$

$$F = \quad N$$

Q.10/ J-18/11 variant

8) A horizontal metal bar PQ of length 50.0 cm is hinged at end P. The diagram shows the metal bar viewed from above.



$A.C.W.M = (16.0 \sin 30)(50.0 \times 10^{-2})$
$= 4.0 Nm$

$C.W.M = (5.0)(50 \times 10^{-2}) = 2.5 Nm$

Two forces of 16.0 N and 5.0 N are in the horizontal plane and act on end Q as shown in the diagram.

Resultant moment = 4.0 - 2.5
= 1.5 Nm

What is the total moment about P due to the two forces?

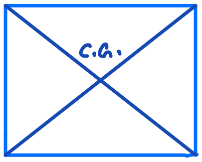
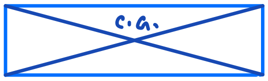
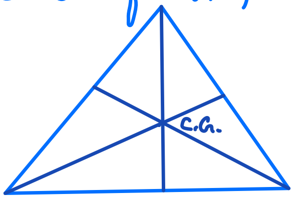
[✓ **A**] 1.5 N m **B** 4.4 N m **C** 6.5 N m **D** 9.4 N m

Centre of gravity:-

Meaning:- The point where whole weight of an object appears to act.

Note:

1- The C.G. of regular objects lie at their geometrical centre.

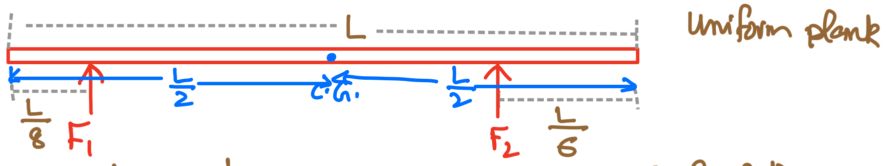
S.No.	Object	C.G.
1.	Uniform metre rule	50.0cm
2.	Uniform disc 	centre of disc
3.	Squared or rectangular plate of uniform thickness  	Point of interaction of diagonals
4.	Triangular plate of uniform thickness 	Point of interaction of medians

2 - The C.G. of irregular objects is obtained by freely suspension plumb line method. (Lamina method)

3- The moment about c.G. due to weight of object is zero because of zero perpendicular distance from pivot.

4- If pivot point is not provided in question, then its c.G. can be considered as pivot point.

Q)



If plank is in equilibrium, Calculate $\frac{F_1}{F_2}$.

Let c. G. be the pivot point

C.W.M = A.C.W.M

$$(F_1)\left(\frac{L}{2}-\frac{L}{8}\right) = (F_2)\left(\frac{L}{2}-\frac{L}{6}\right)$$

$$(F_1)\left(\frac{4L-L}{8}\right) = (F_2)\left(\frac{3L-L}{6}\right)$$

$$(F_1)\left(\frac{3\cancel{L}}{8}\right) = (F_2)\left(\frac{\cancel{L}}{3}\right)$$

$$\frac{F_1}{F_2} = \frac{8}{9}$$

3 **(a)** Explain what is meant by the *centre of gravity* of an object.

The point where whole weight of an object appears to act.

....[2]

(b) A non-uniform plank of wood XY is 2.50 m long and weighs 950 N. Force-meters (spring balances) A and B are attached to the plank at a distance of 0.40 m from each end, as illustrated in Fig. 3.1.

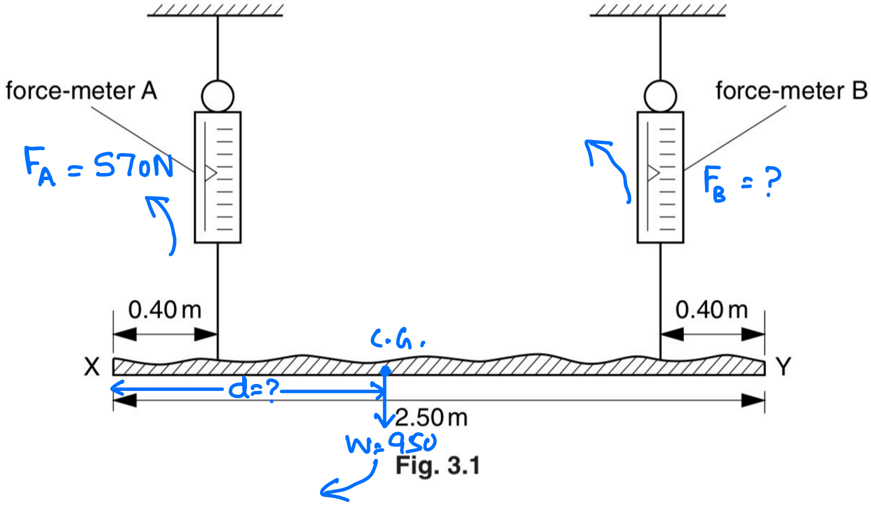


Fig. 3.1

When the plank is horizontal, force-meter A records 570 N.

(i) Calculate the reading on force-meter B.

Σ upward forces = Downward weight

$F_A + F_B = W$

$570 + F_B = 950$

reading = 380N N

(ii) On Fig. 3.1, mark a likely position for the centre of gravity of the plank.

(iii) Determine the distance of the centre of gravity from the end X of the plank.

Let end X be the pivot point

C. W. M = A. C. W. M

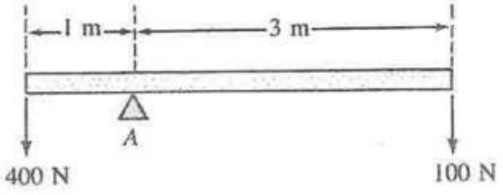
$(950)(d) = (570)(0.40) + (380)(2.50 - 0.40)$

$d = $ ______ m

distance = ... m

[6]

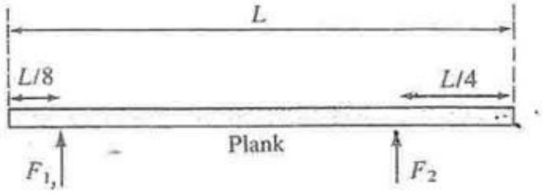
1.



A uniform rod loaded as shown in the figure above is pivoted at the point A so that it is in equilibrium. What is the weight of the rod?

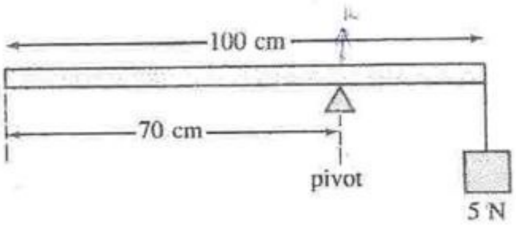
A 700 N
B 500 N
C 300 N
D 200 N
E 100 N

2. The figure shows a heavy uniform plank of length L supported by forces F_1 and F_2 at the positions $L/8$ and $L/4$ from its ends. Find the ratio of F_1 to F_2.



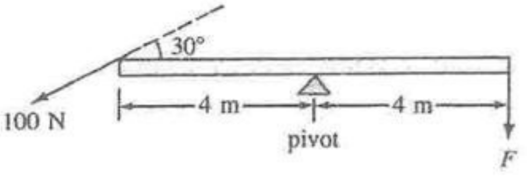
A 2 : 5
B 3 : 5
C 5 : 8
D 2 : 3
E 3 : 2

*3. A uniform metre rule of weight 2 N is pivoted at the 70 cm mark as shown in the figure below. When the rule is horizontal, what is the value, in N m, for the resultant moment about the pivot?



A zero
B 0·15
C 1·1
D 1·5
E 1·9

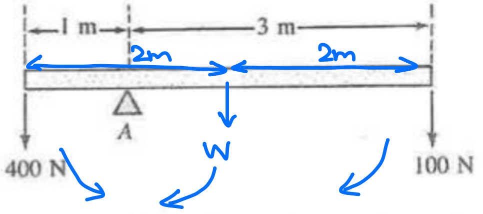
4.



In the figure above, a uniform rod is pivoted as shown. Find the value of F so that the rod is in equilibrium.

A 200 N
B 115 N
C 100 N
D 87 N
E 50 N

1.



A uniform rod loaded as shown in the figure above is pivoted at the point A so that it is in equilibrium. What is the weight of the rod?

A 700 N **C** 300 N [✓ **E**] 100 N

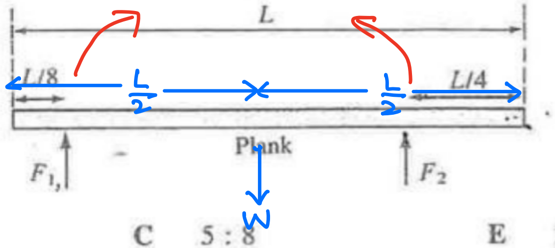
B 500 N **D** 200 N

C. W. M = A. C. W. M

$$(W)(1) + (100)(3) = (400)(1)$$

$$W = \frac{400-300}{1} \Rightarrow \boxed{W = 100\,N}$$

2. The figure shows a heavy uniform plank of length L supported by forces F_1 and F_2 at the positions $L/8$ and $L/4$ from its ends. Find the ratio of F_1 to F_2.



A 2 : 5 **C** 5 : 8 **E** 3 : 2

B 3 : 5 [✓ **D**] 2 : 3

Let C. G. be the pivot

C. W. M = A. C. W. M

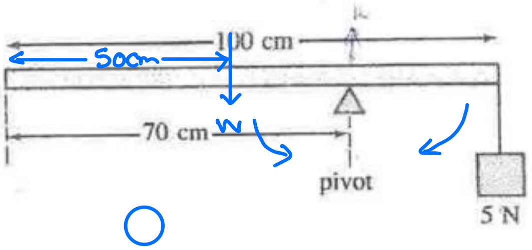
$$(F_1)\left(\frac{L}{2} - \frac{L}{8}\right) = (F_2)\left(\frac{L}{2} - \frac{L}{4}\right)$$

$$(F_1)\left(\frac{4L-L}{8}\right) = (F_2)\left(\frac{2L-L}{4}\right)$$

$$(F_1)\left(\frac{3\cancel{L}}{\cancel{8}_2}\right) = (F_2)\left(\frac{\cancel{L}}{\cancel{4}}\right) \Rightarrow (F_1)\left(\frac{3}{2}\right) = (F_2)(1)$$

$$\boxed{\frac{F_1}{F_2} = \frac{2}{3}}$$

3. A uniform metre rule of weight 2 N is pivoted at the 70 cm mark as shown in the figure below. When the rule is horizontal, what is the value, in N m, for the resultant moment about the pivot?



A zero
B 0·15
[✓ C] 1·1
D 1·5
E 1·9

$$C.W.M = (5)(100-70) = (5)(30) = 150\ Ncm$$

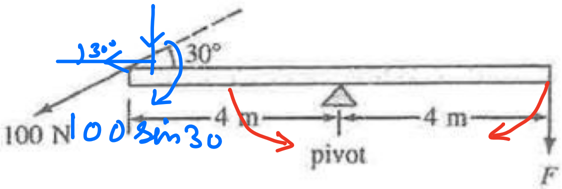
$$A.C.W.M = (2)(70-50) = (2)(20) = 40\ Ncm$$

Resultant moment is in c.w. direction

$$= 150 - 40 = 110\ Ncm$$

$$= \frac{11\cancel{0}}{10\cancel{0}}\ Nm = 1.1\ Nm$$

4.



In the figure above, a uniform rod is pivoted as shown. Find the value of F so that the rod is in equilibrium.

A 200 N
B 115 N
C 100 N
D 87 N
E 50 N

$$C.W.M = A.C.W.M$$

$$(F)(\cancel{4}) = (100 \sin 30)(\cancel{4})$$

$$F = (100)(0.5) \Rightarrow \boxed{F = 50N}$$

Nov. 20/21/ Q 1
01

(c) A fishing rod AB, made from the rod in **(b)**, is shown in Fig. 1.2.

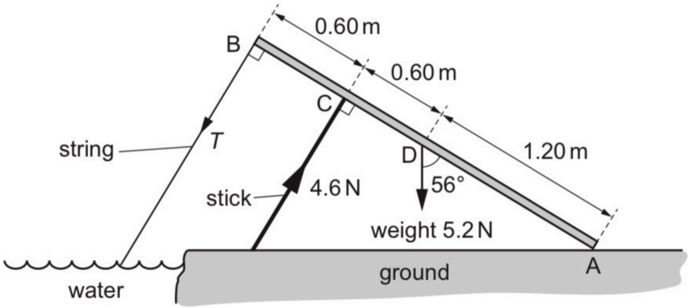


Fig. 1.2 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension T in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 1.2.

(i) Show that the component of the weight that is perpendicular to the rod is 4.3 N.

[1]

(ii) By taking moments about end A of the rod, calculate the tension T.

T = ... N [3]

[Total: 9]

Nov. 20/23/Q2

2 **(a)** State what is meant by the *centre of gravity* of a body.

....

....

.... [2]

(b) A uniform wooden post AB of weight 45 N stands in equilibrium on hard ground, as shown in Fig. 2.1.

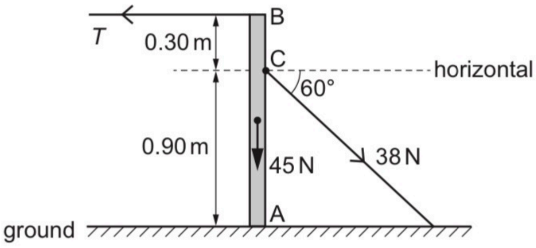


Fig. 2.1 (not to scale)

End A of the vertical post is supported by the ground. A horizontal wire with tension *T* is attached to end B of the post. Another wire, attached to the post at point C, is at an angle of 60° to the horizontal and has tension 38 N. The distances along the post of points A, B and C are shown in Fig. 2.1.

(i) Calculate the horizontal component of the force exerted on the post by the wire connected to point C.

horizontal component of force = ... N [1]

(ii) By considering moments about end A, determine the tension *T*.

T = ... N [2]

(iii) Calculate the vertical component of the force exerted on the post at end A.

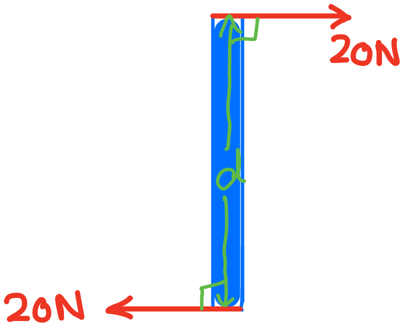
force = ... N [1]

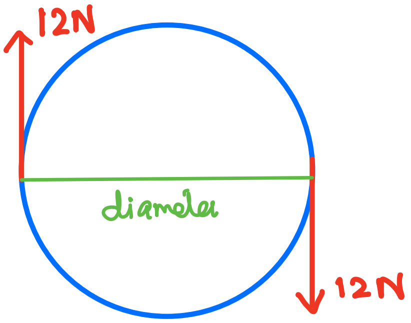
[Total: 6]

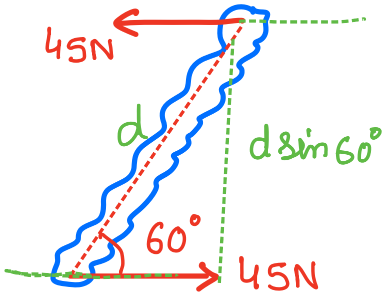
Couple of forces:

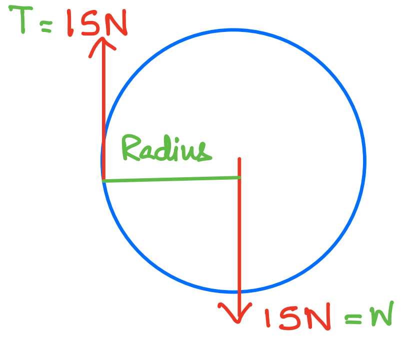
Identification: Two equal and opposite forces separated by a perpendicular distance form a couple and tends to produce rotation only.

Examples:-

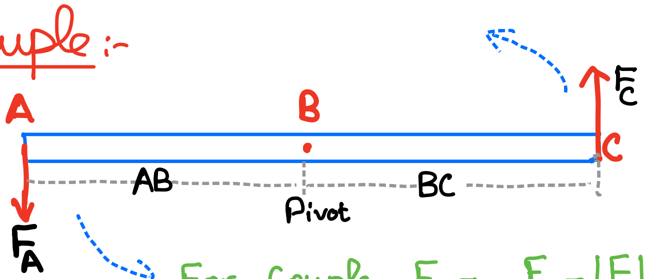








Torque of a Couple:-



For Couple, $F_A = -F_C = |F|$

A.C.W. Moment about Pivot B $= (F_A)(AB) + (F_C)(BC)$

For couple, $F_A = -F_C = F$

A.C.W. Torque $= (F)(AB) + (F)(BC)$

$\tau = F(AB + BC) = F(AC)$

$$\boxed{\text{Torque of couple} = \left(\text{Magnitude of a force that forms a couple}\right)\left(\text{Perpendicular separation between forces}\right)}$$

3 **(a)** Define the *moment* of a force.

Product of force and perpendicular distance from the point of application of force to the pivot. [2]

(b) State the two conditions necessary for a body to be in equilibrium.

1. Resultant force = 0

2. Σ C·W·M = Σ A·C·W·M

[2]

(c) Two parallel strings S_1 and S_2 are attached to a disc of diameter 12 cm, as shown in Fig. 3.1.

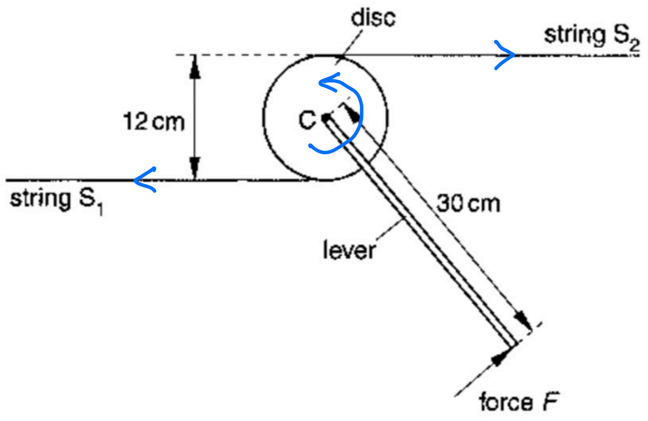


Fig. 3.1

The disc is free to rotate about an axis normal to its plane. The axis passes through the centre C of the disc.

A lever of length 30 cm is attached to the disc. When a force F is applied at right angles to the lever at its end, equal forces are produced in S_1 and S_2. The disc remains in equilibrium.

(i) On Fig. 3.1, show the direction of the force in each string that acts on the disc. [1]

(ii) For a force F of magnitude 150 N, determine

1. the moment of force F about the centre of the disc,

$A.C.W.\ M = (F)(d)$

$= (150)(30\times10^{-2})$

moment = 45 N m

2. the torque of the couple produced by the forces in the strings,

Torque of Couple in C.W = Moment due to 150N force in A.C.W

$= 45$

torque = 45 N m

3. the force in S_1.

Torque of couple $= (F_{S_1})(d)$

$45 = (F_{S_1})(12\times10^{-2})$

$F_{S_1} = \frac{4500}{12}$

force = 375 N

[4]

VECTORS

1. Which pair contains one vector and one scalar quantity?

A displacement : acceleration
B force : kinetic energy
C momentum : velocity
D power : speed

2. Which list contains only scalar quantities?

A mass, acceleration, temperature, kinetic energy
B mass, pressure, electric potential, kinetic energy
C acceleration, temperature, volume, electric charge
D moment, impulse, density, electric field

3. Which line in the table correctly identifies force, kinetic energy and momentum as scalar or vector quantities?

	Force	Kinetic energy	Momentum
A	scalar	vector	vector
B	vector	scalar	scalar
C	vector	scalar	vector
D	vector	vector	vector

4. Forces of 4N and 6N act at a point. Which of the following could **not** be the magnitude of their resultant?

A 1 N **B** 6 N **C** 8 N **D** 10 N

5. The following physical quantities can be either positive or negative.

s: displacement of a particle along a straight line
θ: temperature on the Celsius scale
q : electric charge
V: reading on a digital voltmeter

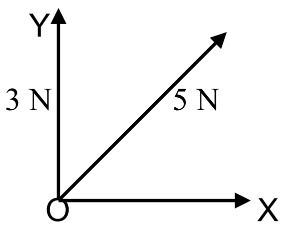
Which of these quantities are vectors?

A s, θ, q, V **B** s, q, V
C θ, V **D** s only

6. Find the angle between two equal forces F when their resultant is also equal to F.

A 120° **B** 135° **C** 45° **D** 60°

7. A force of 5 N may be represented by two perpendicular components OY snd OX as shown in the diagram, which is not drawn to scale.

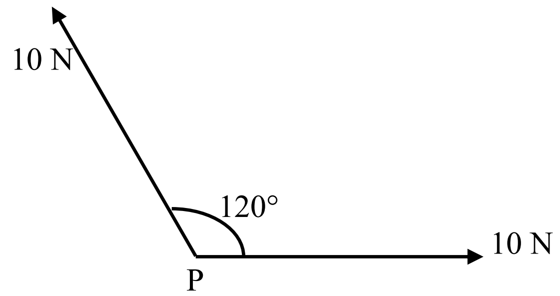


OY is of magnitude 3 N.

What is the magnitude of OX.

A 2 N **B** 3 N **C** 4 N **D** 5 N

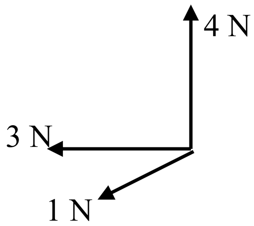
8. Two forces, each of 10 N, act at a point P as hown in the diagram. The angle between the directions of the forces is 120°.



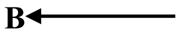
What is the magnitude of the resultant force?

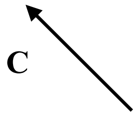
A 5 N **B** 10 N **C** 17 N **D** 20 N

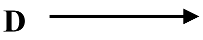
9. Figure shows three force vectors.



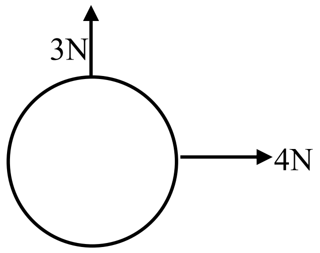
Which of the following vectors A, B, C, D would be most likely to represent their resultant.



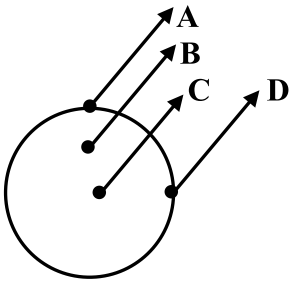




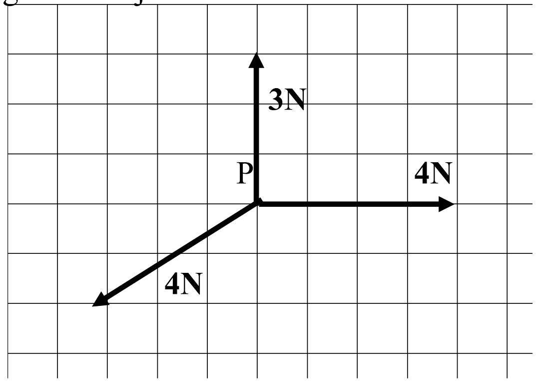
10. Two forces act on a circular disc as shown in the diagram.



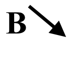
Which arrow best shows the line of action of the resultant forces.

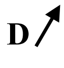


11. The vector diagram shows three coplanar forces acting on an object at P



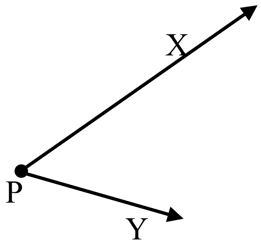
The magnitude of the resultant of these three forces is 1N. What is the direction of this resultant.





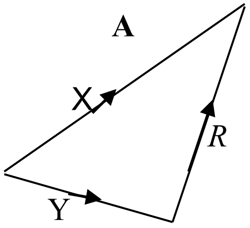
Theory section

12. Two forces *X* and *Y* act at a point P as shown. The lengths of the lines represent the magnitudes of the forces.

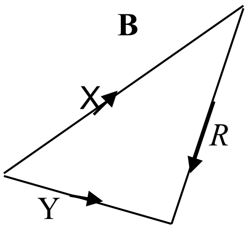


Which vector diagram shows the resultant *R* of these two forces?

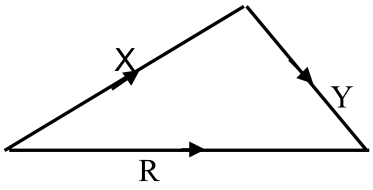
A



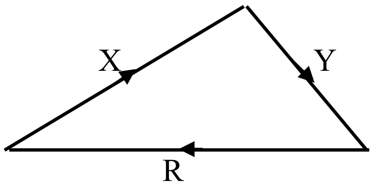
B



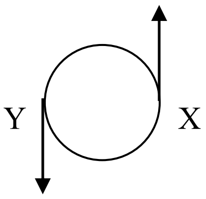
C



D

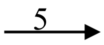


13. Figure shows the velocities 20 m s^{-1} and 25 m s^{-1} of two cars X and Y at one instant on a circular track.

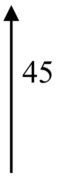


The velocity of Y relative to X in m s^{-1} is given by which vector.

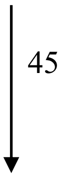
A



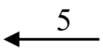
B



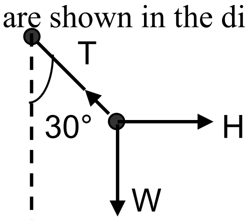
C



D



14. A pendulum bob is held stationary by a horizontal force *H*. The three forces acting on the bob are shown in the diagram.

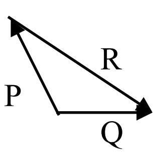


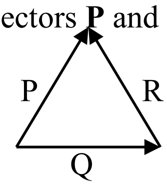
Which statement is correct?

A *H* = *T* cos 30° **B** *T* = *H* cos 30°

C *W* = *T* cos 30° **D** *W* = *Tsin* 30°

For each of the following figures, express the vector **R** in terms of vectors **P** and **Q**.





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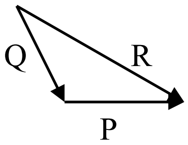

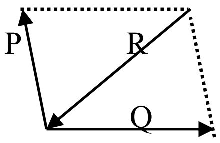

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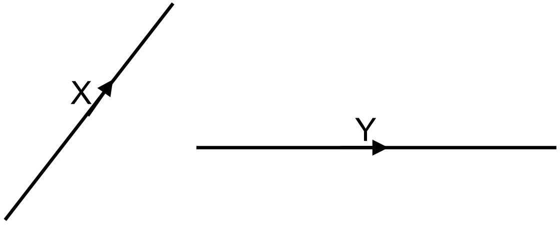
The diagram shows two vectors X and Y.



Draw the vector triangle in which the vector Z show

(a) the magnitude and direction of vector X + Y?

(b) the magnitude and direction of vector X – Y?

(c) the magnitude and direction of vector Y – X?

****

VECTORS

Q1. (a) State the difference between a scalar quantity and a vector quantity.

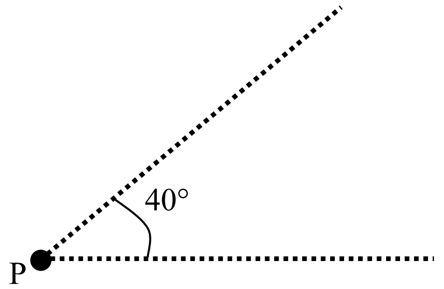
scalar: ……………………………………………………………………………………………......

……

vector: ……………………………………………………………………………………………......

……

(b) Two forces of magnitude 6.0 N and 8.0 N act at a point P. Both forces act away from point P and the angle between them is 40°. Figure below shows two lines at an angle of 40° to one another.



Draw a vector diagram to determine the magnitude of the resultant of two forces. [4]

{Q.1 / June 2004/9702-1}

Q.2 A picture of weight 5 N is suspended from a hook on a wall by a cord which has a breaking strength of 25 N. Initially (Fig. 2.1) the picture is found to be too low; the cord is shortened, with the intention of hanging the picture as in Fig. 2.2.

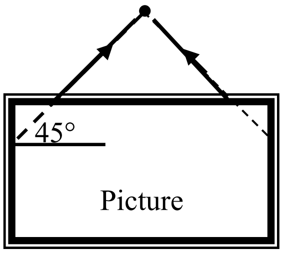


Fig. 2.1

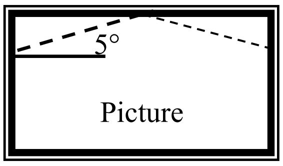


Fig. 2.2

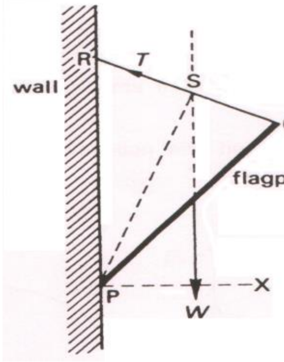
However, when the picture is replaced the chord breaks immediately. Explain why the cord broke when supporting a load so much less than its breaking strength.

……

……

VECTORS

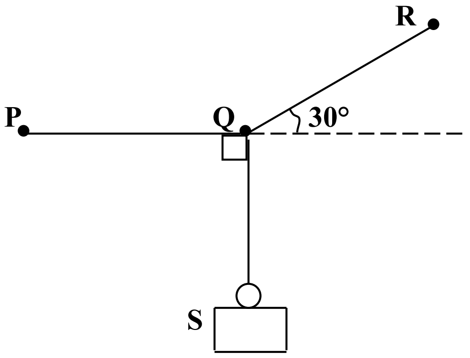
1. The diagram below shows a heavy flagpole PQ hinged at a vertical wall at end P and held by a wire connected between end Q and a point R on the wall. The weight of the flagpole is ***w*** and the tension in the wire is *T*.



What is the direction of the force exerted by the wall on the flagpole?

A $\overrightarrow{PQ}$ **B** $\overrightarrow{PS}$ **C** $\overrightarrow{PX}$ **D** $\overrightarrow{QP}$

2. In the diagram below, a body **S** of weight *W* hangs vertically by a thread tied at **Q** to the string **PQR**.



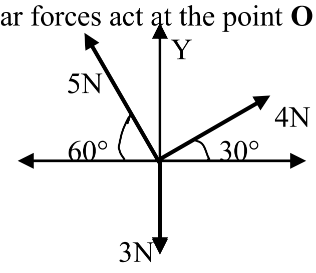
If the system is in equilibrium, what is the tension in the section PQ?

A *W cos 60°* **B** *W tan 30°*
C *W cos 30°* **D** *W tan 60°*

3. A body is acted on by three forces *X, Y* and *Z* that hold it in equilibrium.
If *X* = 5 N**,** *Y* = 4 N, and *Z* = 3 N, what is the angle between the directions of *X and* **Z**?

A 37° **B** 53° **C** 90° **D** 127°

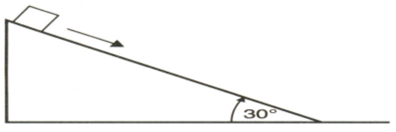
4. Three coplanar forces act at the point **O** as shown.



The component of the resultant force, in N, along **OX** is

A 0 **B** 0.96 **C** 2.33 **D** 3.33

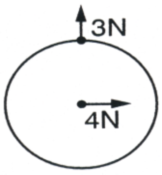
5. A body slides down a smooth slope inclined at 30° to the horizontal.



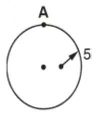
What is the acceleration?

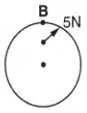
A 5.0 m s^{-2} **B** 5.8 m s^{-2}
C 8.7 m s^{-2} **D** 10 m s^{-2}

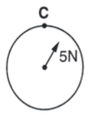
6. Two forces act on a circular disc as shown.



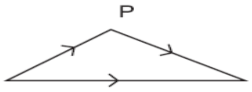
Which diagram shows the line of action of the resultant force?

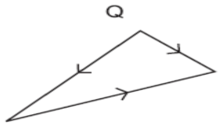


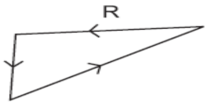


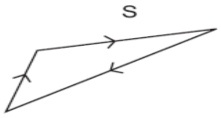


7. Which two vector diagrams represent forces in equilibrium?



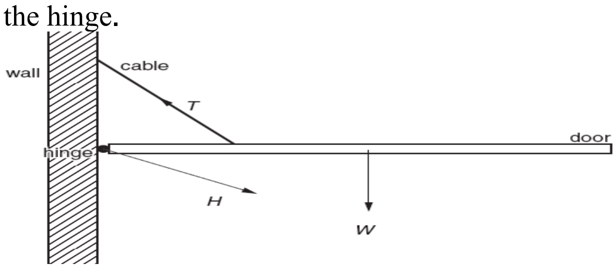






A P and Q **B** Q and R
C R and S **D** S and P

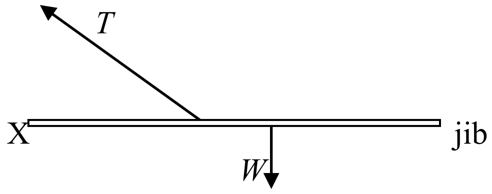
8. A hinged door is held closed in the horizontal position by a cable.
Three forces act on the door: the weight *W* of the door, the tension *T* in the cable, and the force *H* at the hinge.



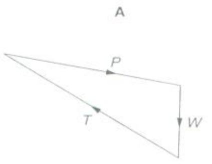
Which list gives the three forces in **increasing** order of magnitude

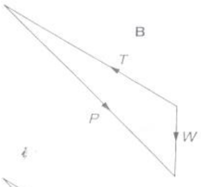
A *H,T,W* **B** *T,H,W*
C *W,H,T* **D** *W,T,H*

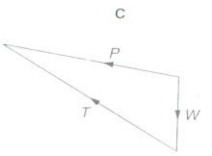
9. The diagram shows the jib of a tower crane. Only three forces act on the jib; the tension *T* provided by a supporting cable; the weight *W* of the jib; and a force *P* (not shown) acting at point **X.**

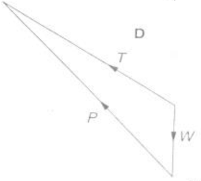


The jib is in equilibrium.
Which triangle of forces is correct?









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Surprise Test (Topic : Vectors)

Name :____

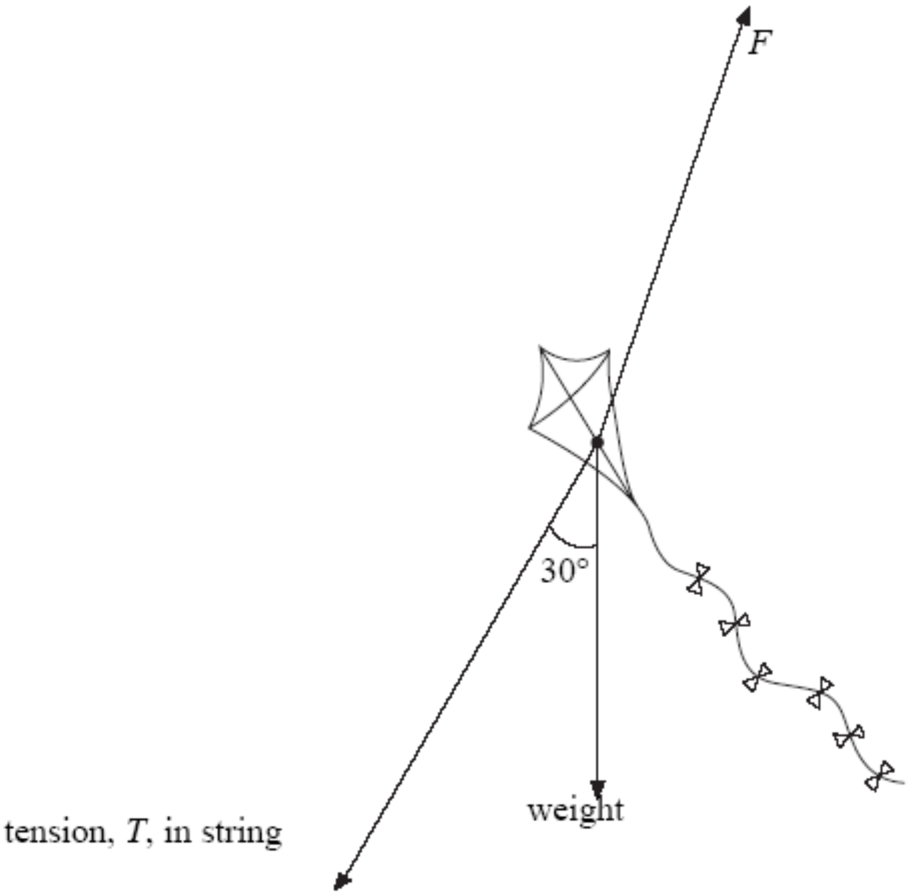
Contact No. _______________________ **School:**__________________________

Paper 1 (MCQ)

Q. No.	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**
Answer									

Paper 2 (AS Theory)

The diagram shows the forces acting on a stationary kite. The force *F* is the force that the air exerts on the kite. The weight of the kite is 2.5 N



(a) Show on the diagram how force *F* can be resolved into horizontal and vertical components. [1]

(b) The magnitude of the tension, *T*, is 25 N. [1]

Calculate

(i) the horizontal component of the tension,

....
...

(ii) the vertical component of the tension.

....

(c) (i) Calculate the magnitude of the vertical component of *F*.

....

(ii) State the magnitude of the horizontal component of *F*.

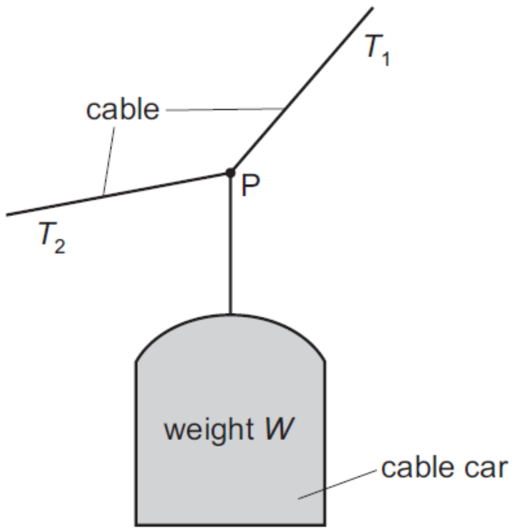
……………………..

(iii) Hence calculate the magnitude of *F*.

[4]

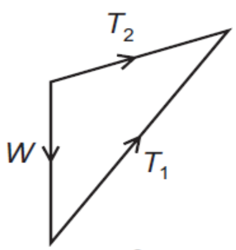
Name: ……………………………………………………………………………………………

1. A cable car of weight W hangs in equilibrium from its cable at point P.
The cable has tensions T_1 and T_2 as shown.

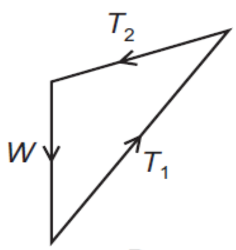


Which diagram correctly represents the forces acting at point P?

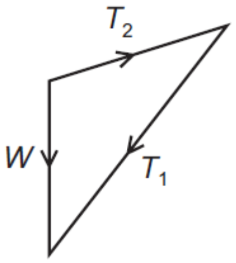
A



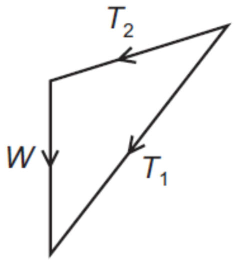
B



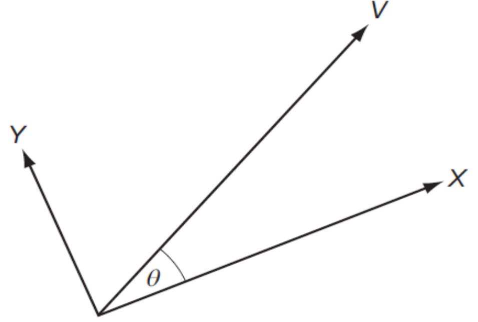
C



D



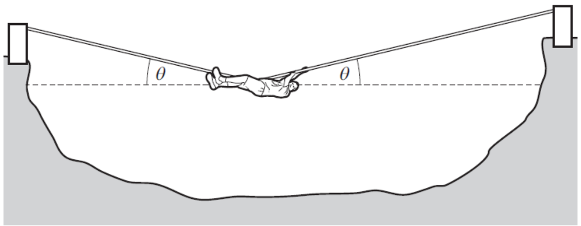
2 A vector quantity V is resolved into two perpendicular components X and Y. The angle between V and component X is θ.



The angle between component X and the vector V is increased from 0° to 90°.
How do the magnitudes of X and Y change as the angle θ is increased in this way?

	X	Y
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	Decrease

3. The diagram shows a rope bridge that a student makes on an adventure training course. The student has a weight W.



Which formula gives the tension T in the rope?

A $T = \dfrac{W}{2\cos\theta}$ **B** $T = \dfrac{W}{2\sin\theta}$

C $T = \dfrac{W}{\cos\theta}$ **D** $T = \dfrac{W}{\sin\theta}$

4. The diagrams show two ways of hanging the same picture.

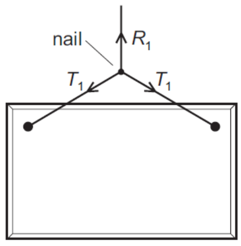


diagram 1

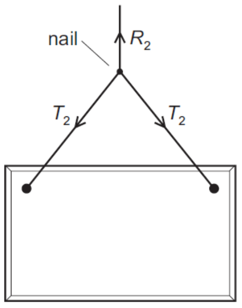


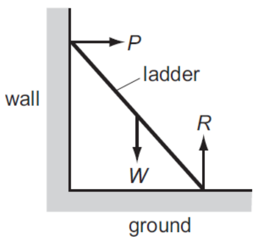
diagram 2

In both cases, a string is attached to the same points on the picture and looped symmetrically over a nail in a wall. The forces shown are those that act on the nail.
In diagram 1, the string loop is shorter than in diagram 2.
Which information about the magnitude of the forces is correct?

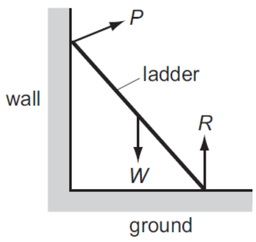
A $R_1 = R_2$ $T_1 = T_2$ **B** $R_1 = R_2$ $T_1 > T_2$
C $R_1 > R_2$ $T_1 < T_2$ **D** $R_1 < R_2$ $T_1 = T_2$

5. A ladder is positioned on icy (frictionless) ground and is leant against a rough wall. At the instant of release it begins to slide.
Which diagram correctly shows the directions of the forces P, W and R acting on the ladder as it begins to slide?

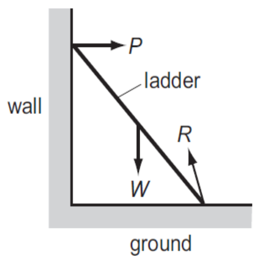
A



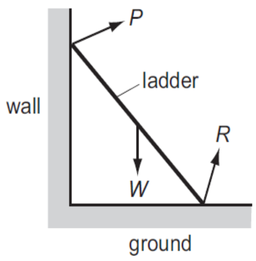
B



C



D



6. Vectors P and Q are drawn to scale.

Which diagram represents the vector (P – Q) ?

A

B

C

D

7. Vectors P and Q are drawn to scale.

Which diagram represents the vector (P + Q)?

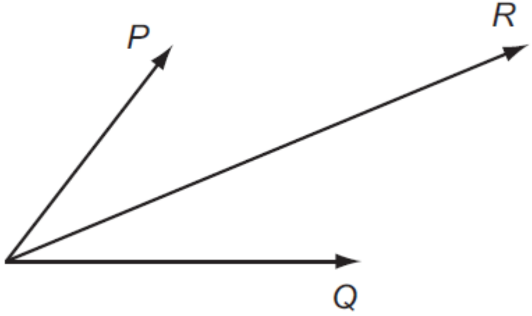
A

B

C

D

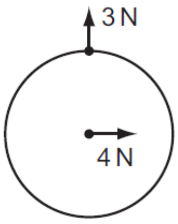
8. Two physical quantities P and Q are added. The sum of P and Q is R, as shown.



Which quantity could be represented by P and by Q?

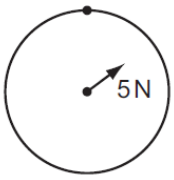
A kinetic energy
B power
C speed
D velocity

9. Two forces act on a circular disc as shown.

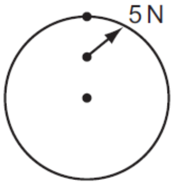


Which diagram shows the line of action of the resultant force?

A

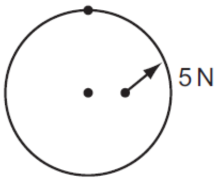


B



C

D

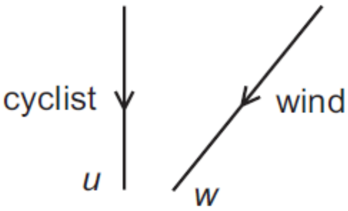


10. The diagram shows a displacement vector.

What is the vertical component of this displacement vector?

A 3.0km **B** 4.0km **C** 5.0km **D** 6.6km

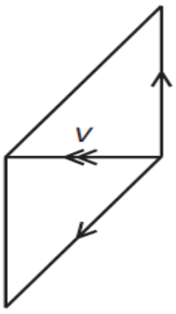
11. A cyclist is travelling due south with velocity *u*. The wind is blowing from the north-east with velocity *w*.



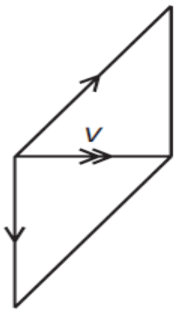
The wind has a velocity v relative to the cyclist, where v = w – u.

Which vector diagram shows the magnitude and direction of velocity v?

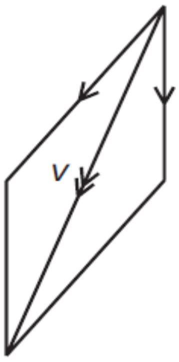
A



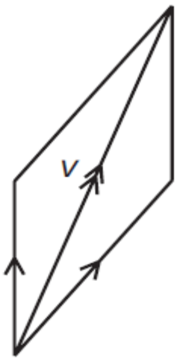
B



C



D



FORCE:

Def. Rate of change of momentum is force

Formula: $F = \frac{\Delta P}{\Delta t} \Rightarrow F = \frac{\Delta(mv)}{\Delta t}$

$$F = m\left(\frac{\Delta v}{\Delta t}\right) \Rightarrow \boxed{F = ma}$$

Types:

(a) Upthrust:

Def. Force excerted by fluid particles in upward direction caused as a resuelt of difference of pressure is upthrust.

Symbol:- U

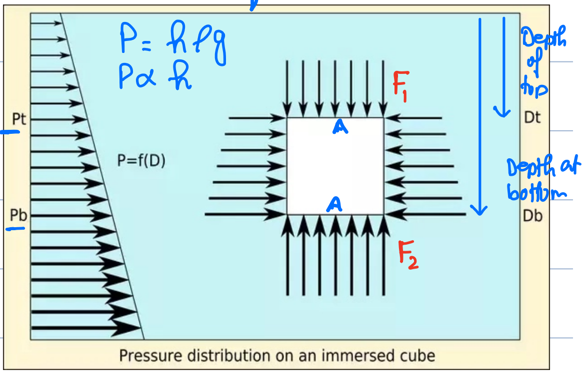
Formula:- $U = F_2 - F_1$

$$U = P_2A - P_1A$$

$$U = A(P_2 - P_1)$$

$$U \propto \Delta P$$

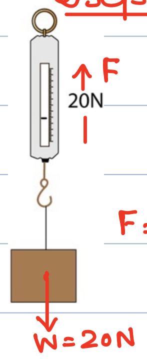
ie upthrust is caused due to pressure difference.



Pressure distribution on an immersed cube

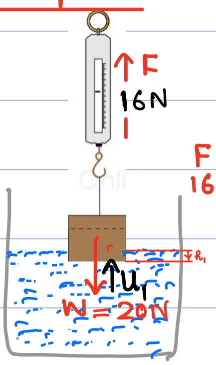
Dependance:-

Case 1:- upthrust increases with depth if top of object is excposed to atmosphere:-

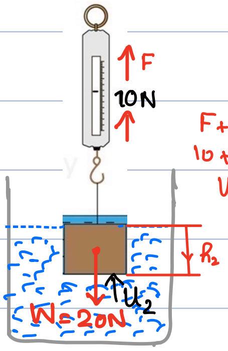


air

$F = W = 20N$



$F + U_1 = W$
$16 + U_1 = 20$
$U_1 = 4N$

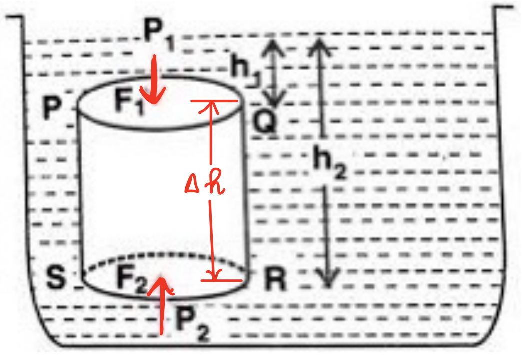


$F + U_2 = W$
$10 + U_2 = 20$
$U_2 = 10 N$

$U \propto \Delta P \Rightarrow U \propto (P_{bottom} - P_{top}) \Rightarrow U \propto h\rho g$ - Constant atmospheric Pressure

$U \propto h$ i.e. upthrust increases with depth if top of object is exposed to atmosphere.

Case 2 :- Upthrust remain constant on a totally immersed object:-

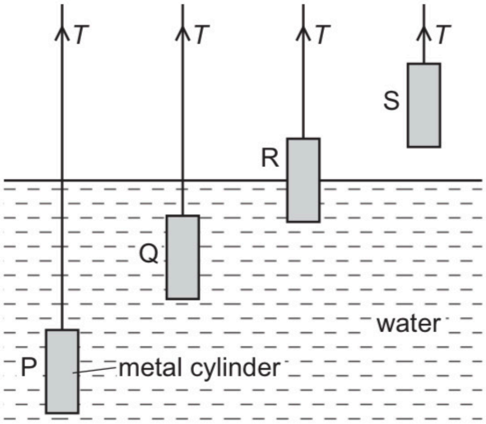


$$U = F_2 - F_1 = P_2 A - P_1 A$$
$$U = h_2 \rho g A - h_1 \rho g A$$
$$U = (h_2 - h_1) \rho g A$$
$$U = (h) \rho g A \Rightarrow U = \rho (hA) g$$
$$U = \rho V g \Rightarrow U = mg$$

i.e. upthrust is equal to the weight of displaced liquid. Therefore upthrust remain constant on a totally immersed object at all positions inside water / fluid.

10 A metal cylinder is suspended vertically in equilibrium by a cord. The diagram shows the cylinder in four different positions P, Q, R and S.

June 17/12



$$T + U = W$$
$$T + \text{Constant} = \text{Constant}$$
$$T = \text{Constant}$$

Which statement explains the variation of the tension *T* in the cord?

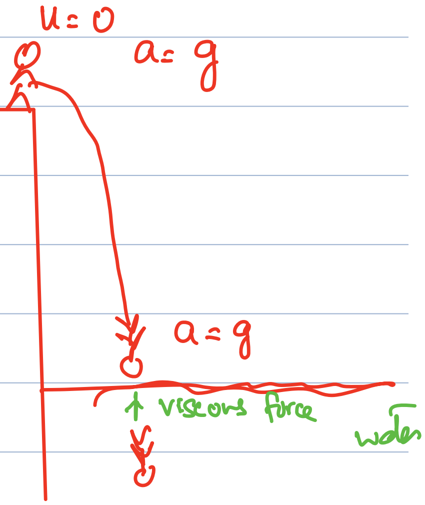
[✓ **A**] At P and at Q, the tension *T* in the cord is the same because the difference in pressure between the top and bottom of the cylinder is the same. ie Same upthrust at P and Q.

B At Q, the tension *T* in the cord is x less than at P because, at smaller depth, liquid pressure is smaller.

C At R, the tension *T* in the cord is greater less than at P because atmospheric pressure is less than water pressure.

D At S, the tension *T* in the cord is greater than at P because atmospheric pressure at S exerts x no force on the top or bottom of the cylinder.

(b) Viscous force:-



Def Force exerted by the fluid particle due to their collision on a moving object against its motion.

Dependance: Viscous force (ie air resistance) ↑ if

(i) Velocity of object increases

(ii) Surface area of object perpendicular to the motion increases.

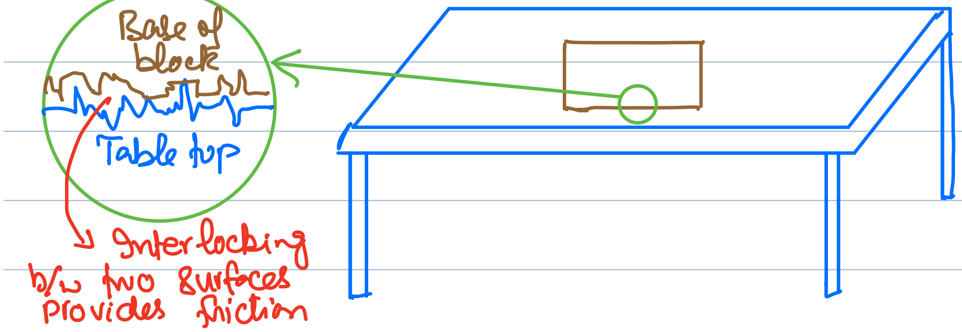
(iii) Viscosity of fluid increases.

Nature of force:- Resistive or Reactional force.

(c) Frictional force:-

Def. The force which resists the sliding motion of two objects in-contact with each other.

Source: Inter-locking b/w two surfaces incontact with each other.



Dependance:- Frictional force increases due to increase in interlocking b/w surfaces if
(i) Contact surfaces are rough.
(ii) Contact area increases.

(d) Gravitational force:-

Nature: Always attractive
Source: Mass of objects / particles

Difference b/w mass and weight

S.No.	Property	Mass	Weight
1.	Definition	Measure of Inertia	Gravitational pull of Earth / Planet.
2.	Conservation	Remain conserved every where in the Universe	weight varies as 'g' varies by $W = mg$
3.	Measuring device	Top pan balance	Newton meter / spring balance
4.	P.S.	Scalar	Vector
5.	Units	Kg	N

(e) Electric Force:

Nature: Either attractive or repulsive
Source: Charges on particles / objects
Note: Like charges repel and unlike charges attract each other.

PRESSURE:-

Def: Force acting perpendicularly per unit area is pressure.

Symbol: P

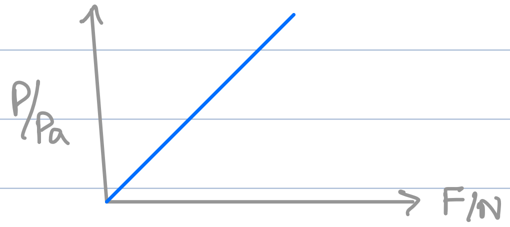
Formula $P = \frac{F}{A}$

Units Pascal (Pa) $= Nm^{-2} = Kg\,m^{-1}s^{-2}$

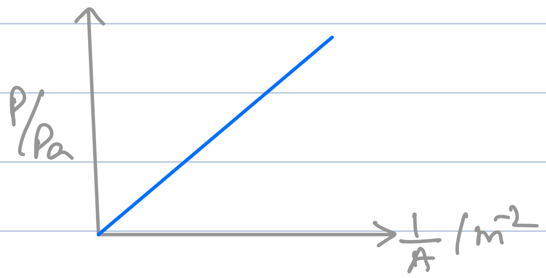
P.S. Scalar

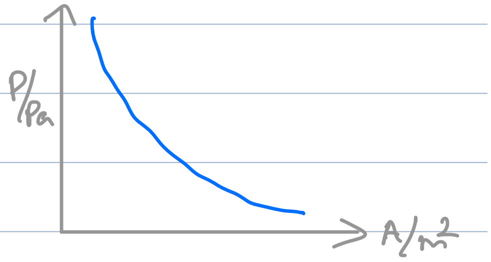
Dependance:

i) **Force:** $P \propto F$ for constant area.



(ii) **Area:** $P \propto \frac{1}{A}$ for constant force.





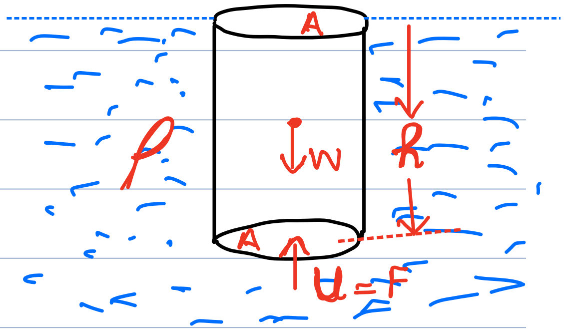
FLUID PRESSURE:-

Def: Force exerted by a column of fluid due to its weight per unit area is fluid pressure.

Formula: $P = h\rho g$

Here h - Depth of fluid column
ρ - Density of fluid
g - Gravitational field strength
$= 9.81\,\mathrm{N\,kg^{-1}}$

Proof of $P = h\rho g$:



$$P = \frac{F}{A} = \frac{U}{A}$$

$$P = \frac{mg}{A}$$

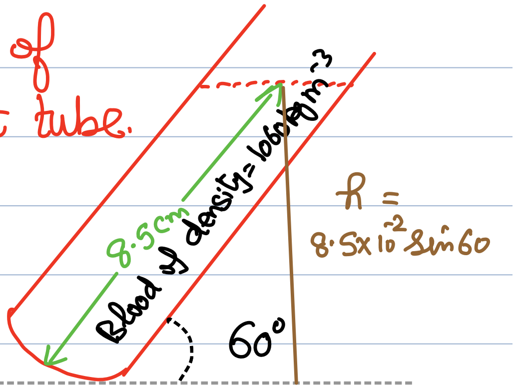
$$P = \frac{(\rho V)g}{A}$$

$$P = \frac{\rho(\cancel{A}h)g}{\cancel{A}}$$

$$\boxed{P = h\rho g}$$

Therefore, fluid pressure is independent of area of container.

Q) Calculate the pressure of blood at the base of test tube.



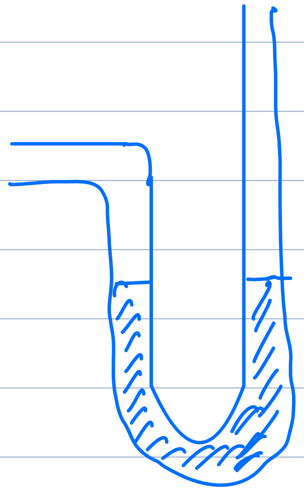
$P = h\rho g$

$= (8.5\times10^{-2}\sin 60)(1060)(9.81)$

$= \underline{765}$ Pa

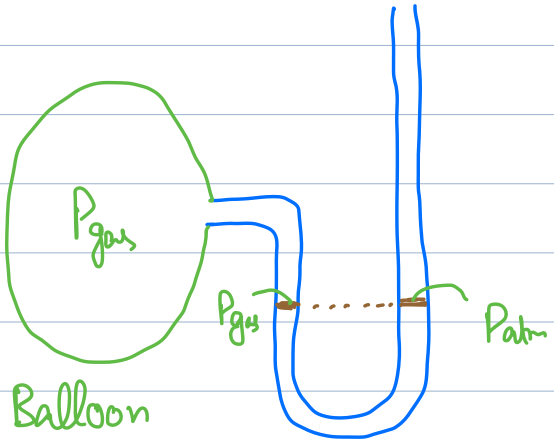
Manometer :- Device used to measure small gas pressure.

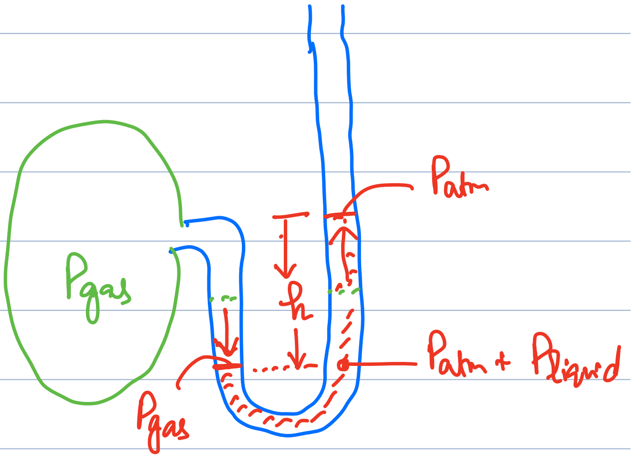
Principle :- Fluid exert equal pressure in all directions at the same depth / level.



Level of liquid in both limbs is same due to external atmospheric pressure acting at its surface

Case 1 :- If $P_{gas} > P_{atm}$:



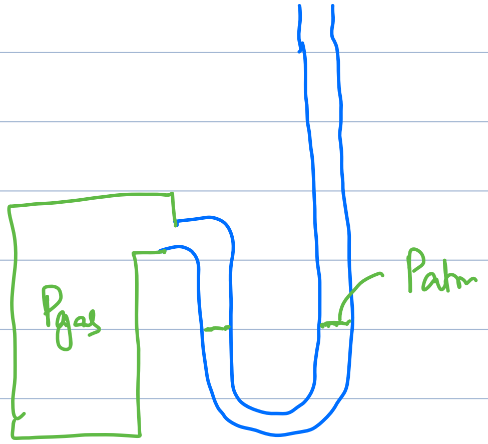


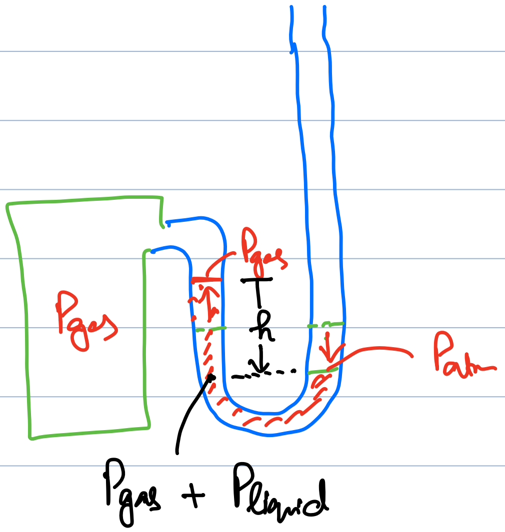
In equilibrium state

$$P_{gas} = P_{atm} + P_{liquid}.$$

$$\boxed{P_{gas} = P_{atm} + h\rho g}$$

Case 2: If $P_{gas} < P_{atm}$:





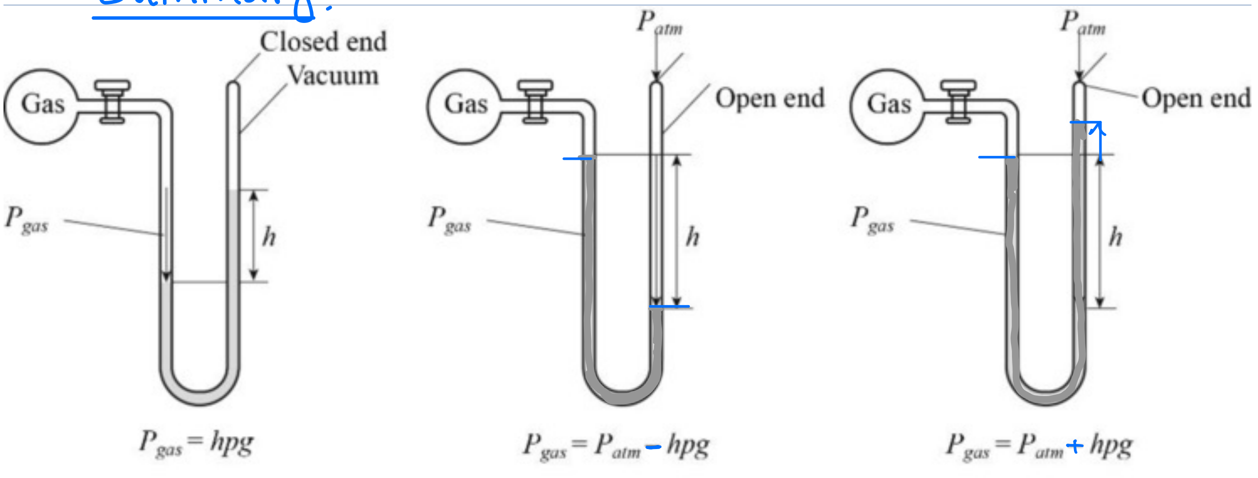
In equilibrium state

$$P_{gas} + P_{liquid} = P_{atm}$$

$$P_{gas} = P_{atm} - P_{liquid}$$

$$P_{gas} = P_{atm} - h\rho g$$

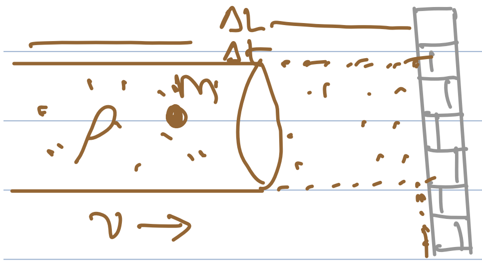
Summary:



$P_{gas} = h\rho g$ $P_{gas} = P_{atm} - h\rho g$ $P_{gas} = P_{atm} + h\rho g$

Figure 1

Pressure excerted by fluid particles on a perpendicular area due to their motion:



Assumption :- Fluid particles do not bounce back and move down along the wall. So their final horizontal momentum is zero.

Horizontal Initial momentum $= mv$

Final horizontal momentum $= 0$

change of momentum $= 0 - mv$

$$\Delta p = -mv$$

Rate of change of momentum $= \frac{\Delta p}{\Delta t} = \frac{-mv}{\Delta t}$

$$F = -\frac{mv}{\Delta t}$$

-ve sign shows that force is excerted by wall on fluid particles. So by Newton's third law, force excerted by fluid particles on wall is +ve.

$$F = \frac{mv}{\Delta t}$$

$$F = \frac{(\rho V)v}{\Delta t} \qquad \left\{ \begin{aligned} \rho &= \frac{m}{V} \\ m &= \rho V \end{aligned} \right\}$$

$$F = \rho\left(A\frac{\Delta L}{\Delta t}\right)v \Rightarrow F = \rho A(v)v$$

$$F = \rho A v^2$$

Pressure, $P = \frac{F}{A} = \frac{\rho A v^2}{A} \Rightarrow \boxed{P = \rho v^2}$

Density:

Def. Mass per unit volume is density.

Symbol: ρ

Formula: $$\rho = \frac{m}{V}$$

Units: $kg\,m^{-3}$

P.S: Scalar

Dependance:

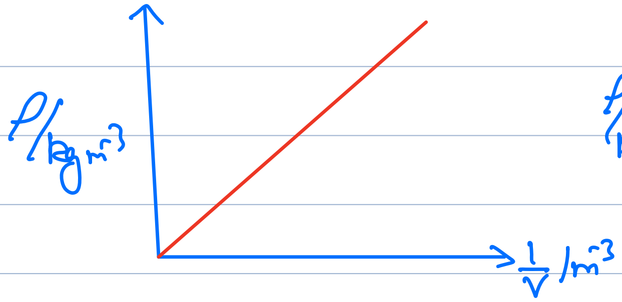
(i) Mass: – Measure of Inertia

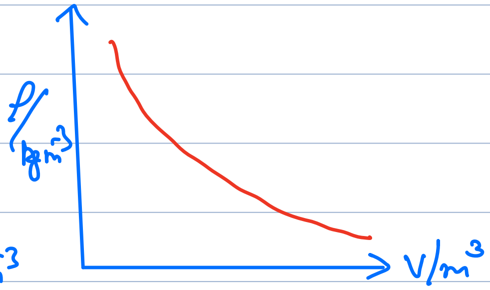
$\rho \propto m$ for constant volume

Gradient = $\frac{1}{V}$

(ii) Volume: – Space occupied by matter

$\rho \propto \frac{1}{V}$ for constant mass





June 2019
12

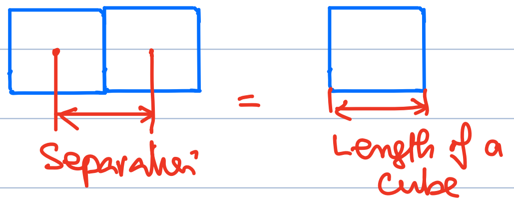
Q.NO.21

Concept

Relationship b/w volume and average separation b/w particles/molecules:-

Assumption:

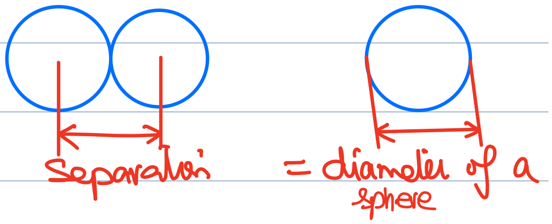
Consider particles as small cubes



$$V = L^3$$

$$\text{Volume} = (\text{separation})^3$$

Consider particles as small spheres:-



$$V = \frac{4}{3}\pi r^3$$

$$V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$$

$$V = \frac{4}{3}\pi\left(\frac{d^3}{8}\right)$$

$$V = \left(\frac{\pi}{6}\right)d^3$$

$$V = (\text{constant})\, d^3$$

$$V \propto d^3$$

$$\text{Volume} \propto (\text{separation})^3$$

Therefore,

$$\boxed{\begin{array}{l}\text{Volume} = (\text{separation})^3 \\ \text{Separation} = (\text{volume})^{1/3}\end{array}}$$

or

Relationship between density and separation

$$\rho = \frac{m}{V}$$

$$\rho = \frac{m}{(\text{separation})^3}$$

For constant mass, m

$$\boxed{\begin{gathered} \text{Density} \propto \frac{1}{(\text{separation})^3} \\ \text{or} \\ \text{Separation} \propto \frac{1}{(\text{Density})^{1/3}} \end{gathered}}$$