Model Question Paper-I with effect from 2022

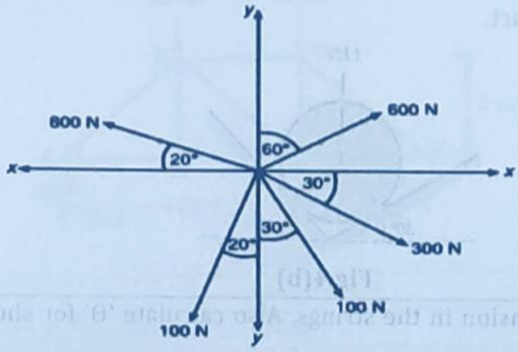
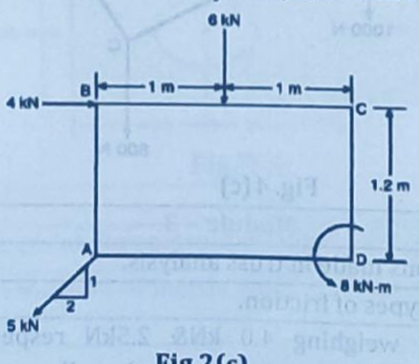
CBCS SCHEME

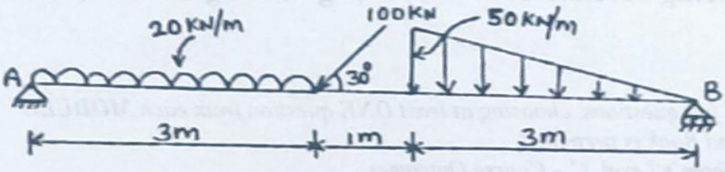
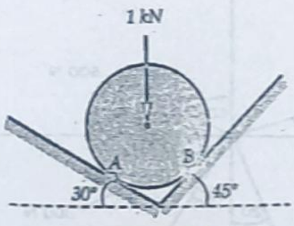
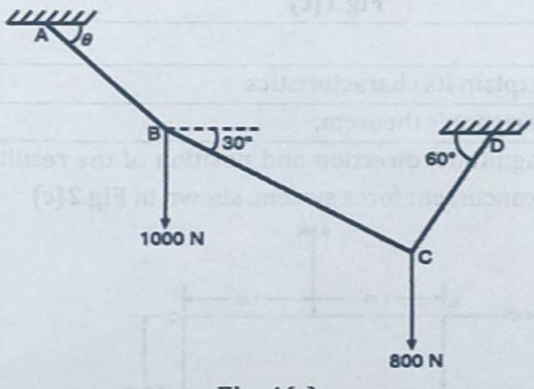
First Semester B.E Degree Examination, ____________/203

Engineering Mechanics for Civil Engineering Stream (BCIVC103)

TIME: 03Hours
Max.Marks:100
NOTES:

*1. Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE***
2. VTU Formula Hand Book is permitted.
3. M – Marks, L – Bloom's Level, C – Course Outcomes

		Module - 1	M	L	C
Q.1	a	Explain classifications of force system.	6	L2	CO1
	b	State and prove law of parallelogram of forces.	7	L2	CO1
	c	Determine the magnitude and direction of the resultant of the coplanar force system. shown in in **Fig. 1(c)**  Fig.1(c)	7	L3	CO1
		OR			
Q.2	a	Define force and explain its characteristics.	4	L2	CO1
	b	State and prove Varignon's theorem.	6	L2	CO1
	c	Determine the magnitude, direction and position of the resultant of the coplanar non concurrent force system, shown in **Fig.2(c)**  Fig.2(c)	10	L3	CO1
		Module - 2			

Q.3	a	State and prove Lami's theorem.	5	L2	CO2
	b	Explain different types of Beams.	5	L2	CO2
	c	Determine the reactions at the supports for the beam shown in **Fig. 3(c)**  Fig. 3(c)	10	L3	CO2
		OR			
Q.4	a	What is meant by equilibrium? State the conditions of static equilibrium for both coplanar concurrent and non-concurrent force system.	5	L2	CO2
	b	Draw the FBD of sphere shown in **Fig.4(b)** and find the reactions of the points of contact.  Fig.4(b)	7	L2	CO2
	c	Determine the tension in the strings. Also calculate 'θ' for shown in **Fig. 4(c)**  Fig. 4(c)	8	L3	CO2
		Module – 3			
Q5	a	Outline the assumptions made in truss analysis.	4	L2	CO3
	b	Explain the different types of friction.	4	L2	CO3
	c	Two blocks A & B weighing 4.0 kN& 2.5kN respectively are connected by a wire passing over a smooth pulley as shown in **Fig.5(c)** and determine the value of 'P'. Take μ between the contact	12	L3	CO3

surfaces is 0.2.

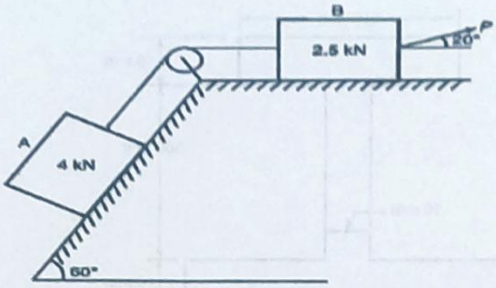


Fig.5(c)

OR

Q.6	a	Outline the laws of static friction.	5	L2	CO3
	b	Classify the different types of trusses.	5	L2	CO3
	c	Determine the support reactions and the forces in members EF, BF and BC for the truss shown in **Fig.6(c)** by method of Section.	10	L3	CO3

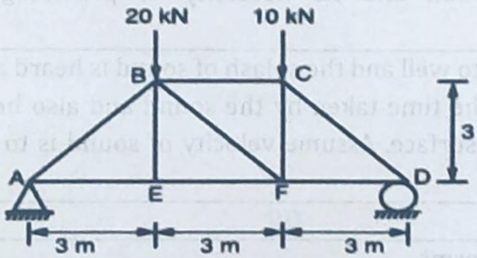


Fig.6(c)

Module – 4

Q.7	a	State and Prove Parallel axis theorem.	8	L2	CO4
	b	Determine the Centroid of the shaded area as shown in **Fig.7(b)**	12	L3	CO4

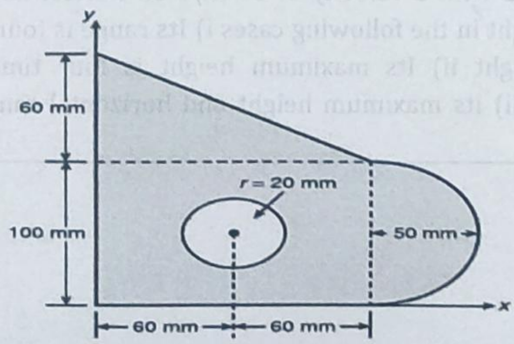
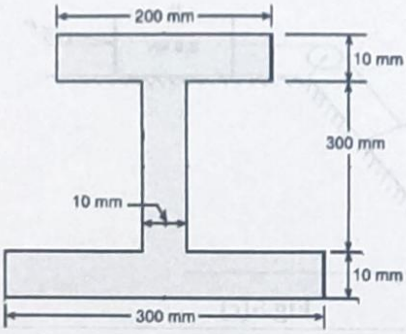


Fig.7(b)

OR

Q.8	a	Derive the expression for centroid of a triangle from first principle.	8	L2	CO4
	b	Determine the Moment of Inertia about its Centroidal axes as shown in **Fig.8(b)**	12	L3	CO4

		 **Fig.8(b)**			
		Module – 5			
Q.9	a	Define the following terms i) Acceleration ii) Displacement iii) Speed iv) Velocity	4	L1	CO5
	b	Explain Super elevation and its necessity of providing super elevation.	6	L2	CO5
	c	A Stone is dropped into well and the splash of sound is heard after 09 seconds. Determine the time taken by the sound and also height of drop from the water surface. Assume velocity of sound is to be 330 m/sec.	10	L3	CO5
		OR			
Q.10	a	Define the following terms i) Kinetics ii) Kinematics iii) Projectile motion.	6	L1	CO5
	b	State D Alembert's Principle and mentions its applications in plane motion	6	L2	CO5
	c	A projectile is fired with a velocity of 60 m/s on horizontal plane. Find its time of flight in the following cases i) Its range is four times the maximum height ii) Its maximum height is four times the horizontal range iii) Its maximum height and horizontal range are equal.	8	L3	CO5

Model Question Paper - Solution.

BCIVC - 203

Module 1

Q. 1) a) Classification of force system

1) Coplanar force system
2) Non-coplanar force system
3) Collinear force system.

1) Coplanar force system :- If two or more forces are acting in a single plane, then it is called Coplanar force system. The types of coplanar force system are

i) Coplanar concurrent force system.
ii) Coplanar non-concurrent force system.
iii) Coplanar parallel force system.

If two or more forces are acting in a single plane and their lines of action pass through a single point, then it is called coplanar concurrent force system. (as shown in fig. a)

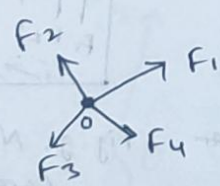


Fig. a. Coplanar concurrent force system.

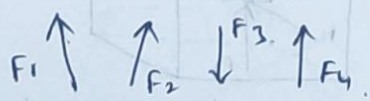


Fig. b. Coplanar non-concurrent force system.

If two or more forces are acting in a single plane and their lines of action do not meet at a common point, then the forces constitute a coplanar non-concurrent force system.

If two or more forces are acting in a plane with their lines of action parallel to one another, then it is called coplanar parallel force system.

The coplanar parallel force system is of two types.

i) Like parallel forces :- Parallel forces act in same directions as shown in fig c.

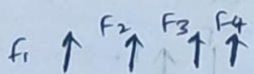


Fig. C Like Parallel forces

ii) Unlike parallel forces :- The forces are parallel to one another, but some forces have their line of action in opposite direction. as shown in fig. d.

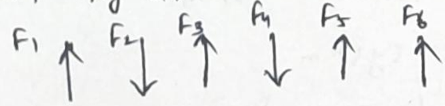


fig. d. Unlike parallel forces

Non-coplanar force system :-

If two or more forces are acting in a different plane, the forces constitute a non-coplanar force system. Such a system of forces can be

i) Non-coplanar concurrent force system
ii) Non-coplanar non-concurrent force system.
iii) Non-coplanar parallel force system.

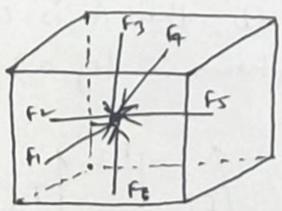


Fig. e. Non-coplanar Concurrent

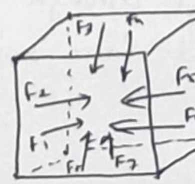


Fig. f. Non-coplanar Non-concurrent

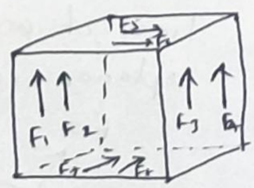


Fig. g. Non coplanar parallel forces

Collinear force system.

If the lines of action of two or more forces coincide with one another, it is called Collinear force system. as shown in (fig. h)

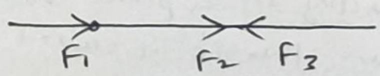


Fig. h.

Non-collinear force system :- If the lines of action of forces donot coincide with each other, it is called non-collinear. as shown in fig. g.

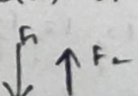


Fig. g. Non-collinear force system.

1) b) Parallelogram Law of forces.

"If two forces acting simultaneously on a body at a point are represented by the two adjacent sides of a parallelogram (in magnitude & direction), their resultant is represented in magnitude and direction by the diagonal of the parallelogram which passes through the point of intersection of the two sides representing the forces."

Consider two forces F_1 & F_2 acting on a particle as shown in fig I. Let the angle b/w two forces be θ. If parallelogram ABCD is constructed as shown in fig. ii. with AB representing F_1 & AD representing F_2 to same scale, according to parallelogram law of forces AC represents the resultant R. Drop perpendicular CE to AB.

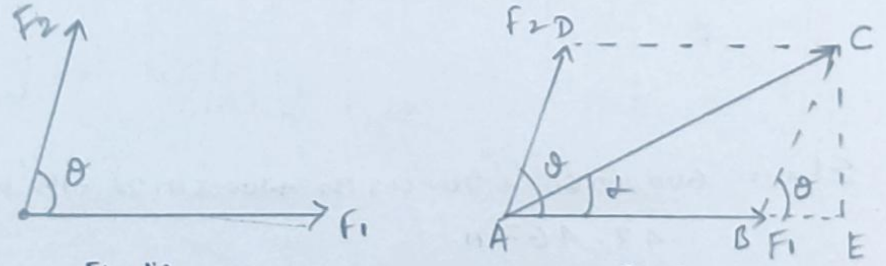


Fig.(i) Fig.(ii)

Now the resultant R of F_1 & F_2 is given by

$$R = AC$$
$$= \sqrt{AE^2 + CE^2}$$
$$= \sqrt{(AB+BE)^2 + (CE)^2}$$

But $AB = F_1$ & $BE = BC\cos\theta = F_2\cos\theta$

$CE = BC\sin\theta = F_2\sin\theta$.

$$R = \sqrt{(F_1 + F_2\cos\theta)^2 + (F_2\sin\theta)^2}$$

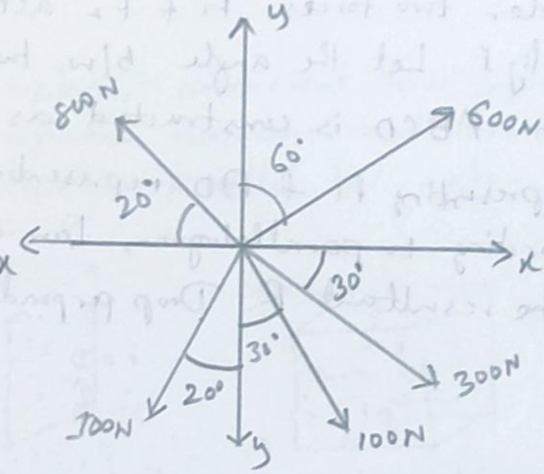
$$= \sqrt{F_1^2 + 2F_1F_2\cos\theta + F_2^2\cos^2\theta + F_2^2\sin^2\theta}$$

$$= \sqrt{F_1^2 + 2F_1F_2\cos\theta + F_2^2}$$

The inclination of the resultant to force F_1 is given by

$$\alpha = \tan^{-1}\left(\frac{F_2\sin\theta}{F_1+F_2\cos\theta}\right).$$

1) c).



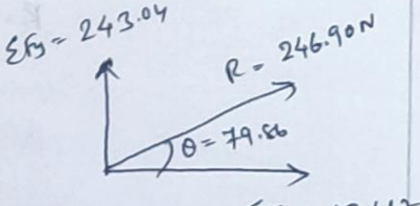
$$\Sigma F_x = 600\sin 60° + 300\cos 30° + 100\sin 30° - 100\sin 20° - 800\cos 20°$$
$$= 43.467\,N.$$

$$\Sigma F_y = 600\cos 60° - 300\sin 30° - 100\cos 30° - 100\cos 20° + 800\sin 20°$$
$$= 243.04\,N.$$

$$R = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$$

$$= \sqrt{(43.46)^2 + (243.04)^2}$$

$$\therefore R = 246.90\,N.$$



$$\theta = \tan^{-1}\left(\frac{\Sigma F_y}{\Sigma F_x}\right) \Rightarrow \theta = 79.86°$$

OR

Q. 2) a) Force is defined as an agency which tries to change state of rest or uniform motion.

Characteristics of force are

i) Magnitude

ii) Direction.

iii) Line of action.

iv) Point of application.

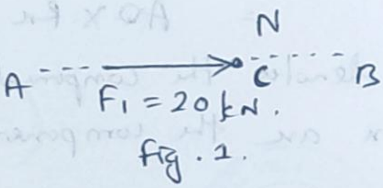
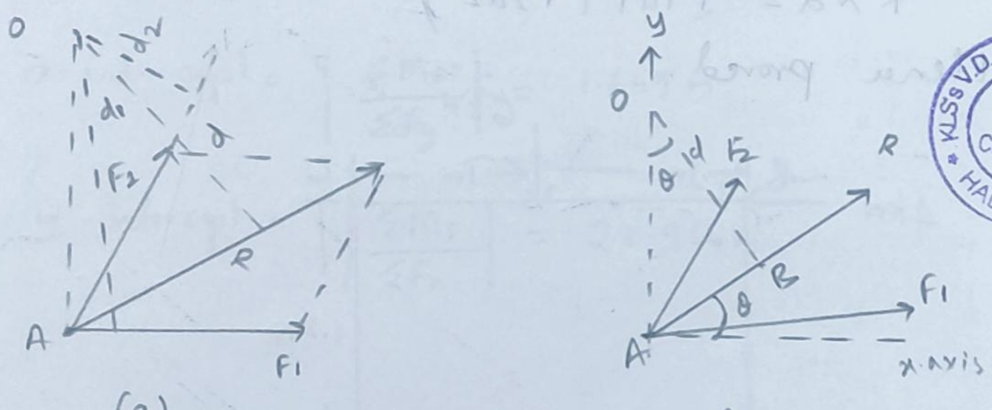


fig. 1.

In figure 1, F_1 is the force having a magnitude 20kN acting in +ve x direction towards north and 'C' is the point of application & AB is the line of action.

b) Varignon's theorem :-

" The algebraic sum of moments of a system of coplanar forces about a moment centre is equal to the moment of their resultant force about the same moment centre".



(a)

(b)

Referring to above Fig. (a), Let R be the resultant of forces F_1 & F_2 and 'O' be the moment centre. Let d, d_1 & d_2 be the moment arms of the forces R, F_1 & F_2 resp. Then we have to prove

$$R \times d = F_1 d_1 + F_2 d_2 \longrightarrow (1)$$

Join OA and consider it as y-axis. Draw x-axis ⊥ to it with A as origin. Let resultant make an angle 'θ' w.r.t x-axis. Noting the angle AOB is also θ, we can write

$$R \times d = R \times AO \cos\theta$$
$$= AO \times R\cos\theta$$
$$= AO \times R_x$$

Where R_x denotes the component of R in x-direction. Similarly F_{1x} & F_{2x} are the components of F_1 & F_2 in x direction then,

$$F_1 d_1 = AO \times F_{1x} \rightarrow ②$$
$$F_2 d_2 = AO \times F_{2x} \rightarrow ③$$

From eqn ② & ③

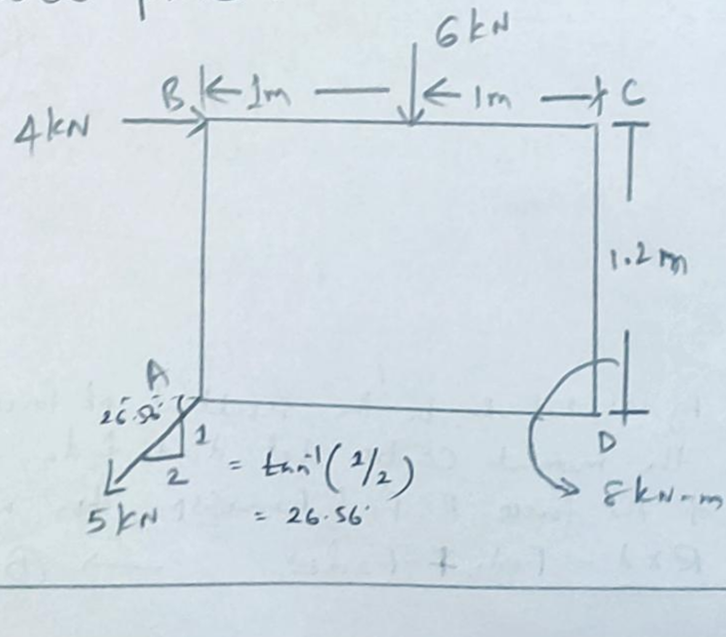
$$F_1 d_1 + F_2 d_2 = (F_{1x} + F_{2x}) \times AO$$
$$= R_x \times AO \rightarrow ④$$

From eqn ① & ④ we have

$$R \times d = F_1 d_1 + F_2 d_2,$$

Hence proved.

2) c)



$= \tan^{-1}(1/2)$

$= 26.56°$

Magnitude of resultant (R)

$\Sigma F_x = 4 - 5\cos 26.56^\circ = -0.472\text{ kN}$

$\Sigma F_y = -6 - 5\sin 26.56^\circ = -8.236\text{ kN}$

$R = \sqrt{(-0.472)^2 + (-8.236)^2}$

$\therefore R = \underline{8.249\text{ kN}}$

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

$= 86.72^\circ$

Position of resultant (d).

$d = \left(\frac{\Sigma M_D}{R}\right)$

$\Sigma M_D = 4 \times 1.2 - 5\sin 26.56 \times 2 - 8 - 6 \times 1$

$= -13.671\text{ kN-m}$

$d = \left|\frac{-13.671}{8.249}\right| = 1.657\text{ m}$

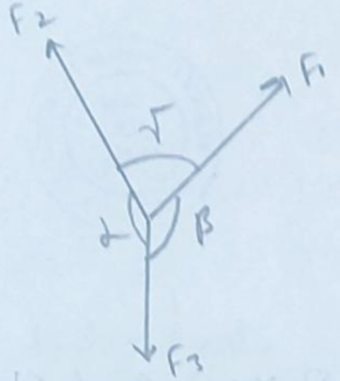
$x\text{-intercept} = \left|\frac{\Sigma M_D}{\Sigma F_y}\right| = 1.659\text{ m}$

$y\text{-intercept} = \left|\frac{\Sigma M_D}{\Sigma F_x}\right| = 28.964\text{ m}$

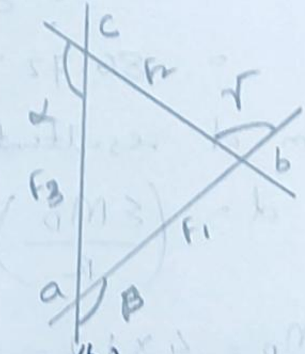
Module 2

Q.3) a) "If a body is in equilibrium under the action of only three forces, each forces is proportional to the sine of angle between the other two forces."

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$



(a)



(b)

<u>Proof</u>:- Draw the three forces F_1, F_2 and F_3 one after the other in direction and magnitude starting from point 'a'. Since the body is in equilibrium the resultant should be zero, which means, the last point of force diagram should coincide with 'a'. Thus, it results in a Δ^{le} of forces abc shown in fig. b.

Now the external angles at a, b & c are equal to β, γ & α, since ab, bc and ca are $\parallel^{le}$ to F_1, F_2 and F_3 resp.

In the triangle of forces abc,

$$ab = F_1, \quad bc = F_2 \quad \& \quad ca = F_3$$

Applying sine rule for the Δ^{le} abc.

$$\frac{ab}{\sin(180^\circ-\alpha)} = \frac{bc}{\sin(180^\circ-\beta)} = \frac{ca}{\sin(180-\gamma)}$$

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

3) b) Types of beams :-

i) <u>Cantilever</u> :- If a beam is fixed at one end and other end is free it is called cantilever beam

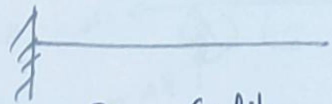


Fig. Cantilever beam

ii) <u>Simply supported beam</u> :- In this type of beam both ends are simply supported. There is only one reaction component at each support.

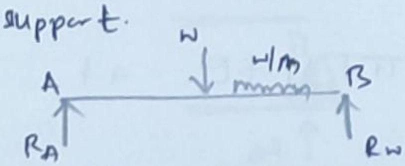


Fig. Simply supported beam

iii). <u>One end hinged and other end on roller</u> :- As name itself suggests, in this type of beam one end is hinged and other is on roller.

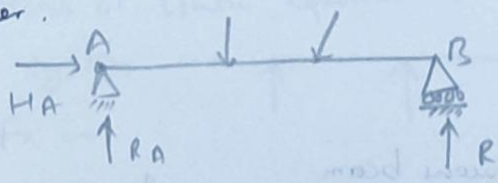


Fig. One end hinged and other on roller.

iv) <u>Overhanging beam</u> :- If a beam is projected beyond the supports, it is called overhanging beam.

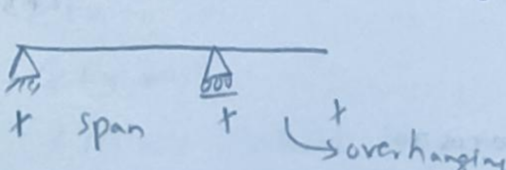


Fig. Overhanging beam.

v) Both ends hinged :- As name itself suggests, both the ends of the beam are hinged. There are two reaction components at each end.

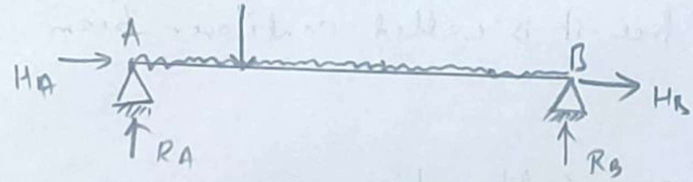


Fig. Both ends hinged beam.

vi) Propped Cantilever :- In this type of beam one end of beam is fixed and other end is simply supported.

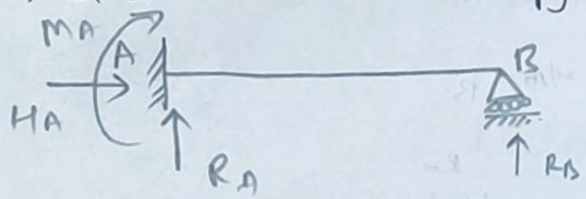
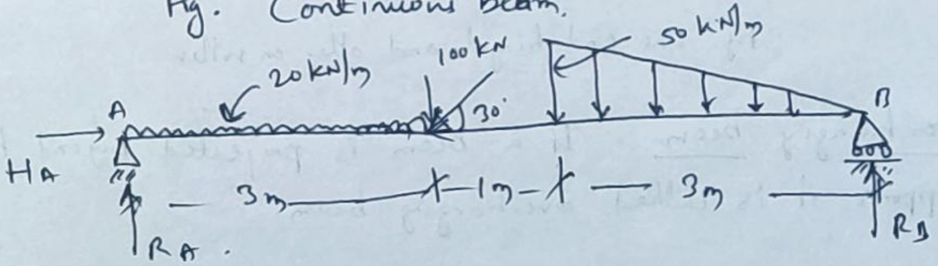


Fig. Propped Cantilever beam.

vii) Continuous beam :- A beam having three or more supports is called Continuous beam.

Fig. Continuous beam.

Q. 3) c)



$\Sigma F_x = 0.$

$0 = +H_A - 100\cos 30^\circ$

$\Rightarrow H_A = \underline{86.60\ kN}.$

$\Sigma F_y = 0.$

$0 = R_A + R_B - 20 \times 3 - 100 \sin 30^\circ - \frac{1}{2} \times 50 \times 3$

$\Rightarrow R_A + R_B = 185 \text{ kN} \rightarrow (1)$

$\Sigma M_A = 0.$ $+\circlearrowright$

$0 = -R_B \times 7 + 20 \times 3 \times 1.5 + 100 \sin 30^\circ \times 3$
$+ \frac{1}{2} \times 50 \times 3 \times \left(4 + 2/3 \times 3\right)$

$\Rightarrow R_B = \underline{87.86 \text{ kN}}.$

$\Rightarrow R_A = \underline{97.14 \text{ kN}}.$

Q.4) a) A body is said to be in equilibrium when its static position or its motion with uniform velocity is not altered by the system of forces acting on it.

→ Conditions of static equilibrium for coplanar concurrent force system are –

$\Sigma F_x = 0$

$\Sigma F_y = 0.$

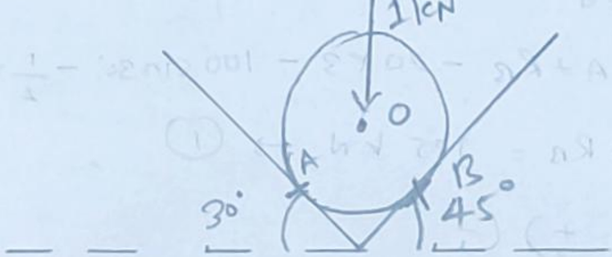
→ Conditions of static equilibrium for coplanar non-concurrent force system are –

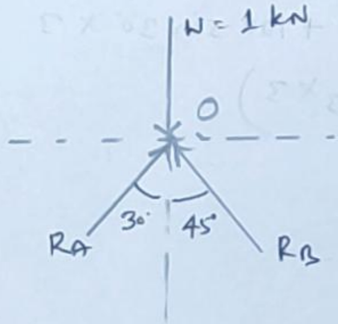
$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma M = 0$ about any moment centre.

Q.4) b).





FBD @ O.

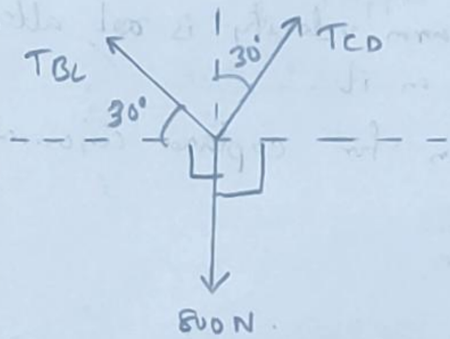
Applying Lami's theorem.

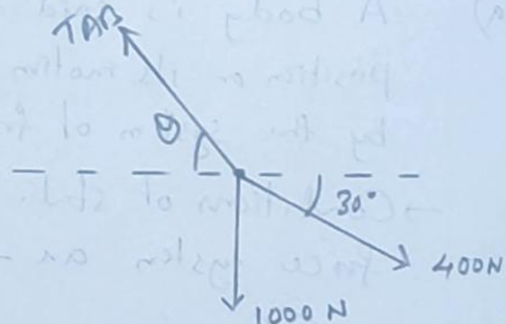
$$\frac{R_A}{\sin \cancel{135}^\circ} = \frac{R_B}{\sin 150^\circ} = \frac{W}{\sin 75^\circ}$$

$\Rightarrow R_A = 732.05$ ~~kN~~ N $= 0.732$ kN.

$\Rightarrow R_B = 517.63$ N $= 0.517$ kN.

Q.4) c)





FBD @ C.

FBD @ B

Consider FBD @ C, Using Lami's thm

$T_{CD}/\sin 120^\circ = T_{BC}/\sin 150^\circ = 800/\sin 90^\circ$

$\Rightarrow T_{BC} = 400$ N & $T_{CD} = 692.82$ N.

Consider FBD @ B, using eqn's of equilibrium.

$\Sigma F_x = 0 \Rightarrow -T_{AB}\cos\theta + 400\cos 30^\circ = 0$

$\Rightarrow T_{AB}\cos\theta = 346.41 \rightarrow (1)$

$\Sigma F_y = 0 \Rightarrow T_{AB}\sin\theta - 400\sin 30^\circ - 1000 = 0.$

$T_{AB}\sin\theta = 1200 \longrightarrow (2).$

Dividing (ii) by (i)

$$\frac{T_{AB}\sin\theta}{T_{AB}\cos\theta} = \frac{1200}{346.41}$$

$\therefore \theta = 73.90'$

Substituting 'θ' in eqn ① we get

$\therefore T_{AB} = 1249.15 \, N$

Module-3

Q.5) a) Assumption made in truss analysis.

1. The members of trusses are straight.
2. The c/s of members is uniform.
3. The forces are acting only on joints.
4. All members are pin-jointed members.
5. All members are rigid.
6. All members of truss are two force members.

5). b) Types of friction :-

1) Static friction :- It is a friction experienced b/w two bodies when both bodies are at rest.

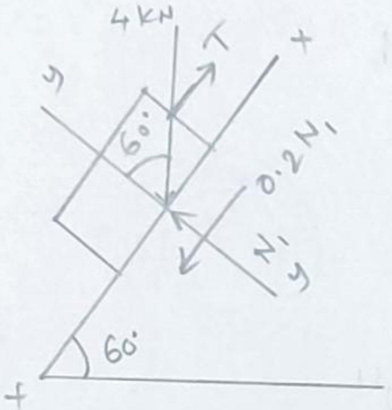
2) Dynamic friction :- It is a friction experienced between two bodies when one body moves over the other.
It is of two types.
a) Sliding friction   b) Rolling friction.

Based on the surface of contact, there are two types of friction.

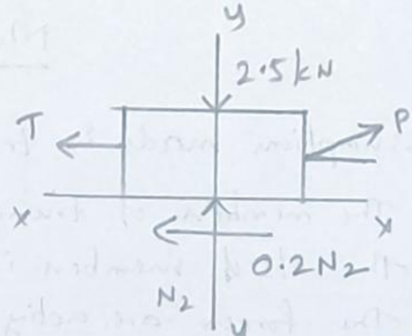
i) Dry friction:- If the contact surfaces b/w two bodies are dry, then it is called dry friction

ii) Fluid friction :- The friction b/w two fluid layers or the friction b/w a solid and fluid is called fluid friction

5) c)



FBD of 4kN block



FBD of 2.5kN block

Consider the FBD of 4 kN block

$\Sigma F_y = 0$

$N_1 - 4\cos 60° = 0$

$N_1 = 2$ kN

$\Sigma F_x = 0$

$T - 0.2 \times 2 - 4\sin 60° = 0$

$T = 3.864$ kN

Consider the FBD of 2.5kN block

$\Sigma F_y = 0$

$N_2 - 2.5 + P\sin 20° = 0$

$N_2 = 2.5 - P\sin 20°$

$\Sigma F_x = 0$

$P\cos 20° - 0.2(2.5 - P\sin 20°) - 3.864 = 0$

$1.008\,P = 4.364$

$\therefore P = 4.329$ kN

OR

Q.6)a) i) The frictional force always acts in a direction opposite to that in which the body tends to move

ii) Till the limiting value is reached, magnitude of frictional force is exactly equal to the tangential force which tends to move the body.

iii) The magnitude of limiting friction bears a constant ratio to the normal reaction b/w the two contacting surfaces.

iv) The force of friction depends on the roughness / smoothness of surfaces.

v) The force of friction is independent of the area of contact b/w the two surfaces.

vi) After the body starts moving, dynamic friction comes into play, the magnitude of which is less than the limiting friction.

6) b) Trusses are classified as -

i) Perfect truss / Rigid truss.

ii) Non-rigid truss / deficient truss.

iii) Over rigid / redundant truss

i) Perfect truss :- It is a truss in which the members are sufficient to resist external loads and in which deformation is very small.

$$m = 2j - 3$$

ii) Non-rigid truss or deficient truss :-

It is a truss in which the number of members are less than that required for a perfect truss

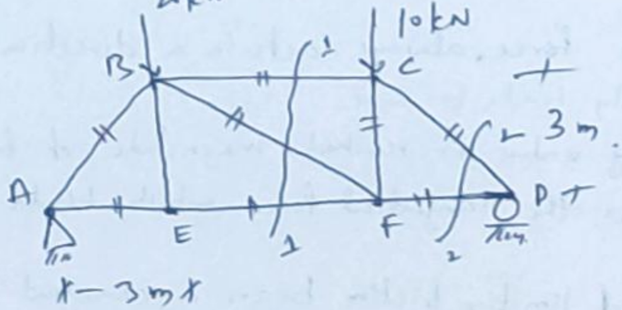
$$m < 2j - 3$$

iii) Over rigid or redundant truss :-

It is a truss in which the no. of members are more than that of required for a truss.

$$m > 2j - 3$$

6) c.



$\Sigma F_x = 0 \Rightarrow R_{Ax} = 0.$

$R_{Ay} + R_{Dy} = 30$

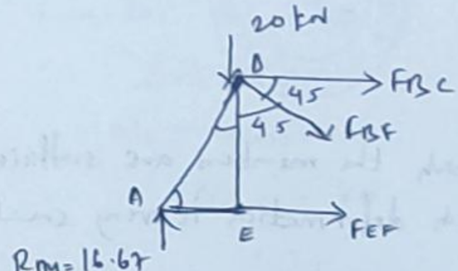
$\Sigma M_A = 0.$

$0 = -R_D \times 9 + 20 \times 3 + 10 \times 3$

$\Rightarrow R_D = 13.33$ kN

$R_{Ay} = 16.67$ kN.

Using the method of sections. (Chose a section line passes through the members BC, BF and EF in which internal forces need to be determined.



$\Sigma F_y = 0$

$0 = -20 + 16.67 - F_{BF} \cos 45°$

$\Rightarrow F_{BF} = -4.709$ kN. (C)

$\Sigma F_x = 0.$

$0 = -F_{BC} - F_{EF} - F_{BF} \sin 45°$

$\Rightarrow F_{BC} + F_{EF} = +3.33$

$\Sigma M_E = 0.$

$+16.67 \times 3 + F_{BC} \times 3 + F_{BF} \times \sin 45° \times 3 = 0.$

$\Rightarrow F_{BC} = -13.33$ kN (C)

Consider right of section 2 2

$F_{DF} = 13.33$ kN, $F_{DC} = -18.85$ kN

$F_{FR} = 0.$ kN

Module 4

Q.7) a) Parallel axis theorem :-

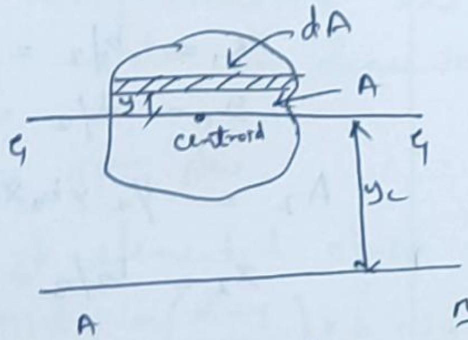
" Moment of inertia about any axis in the plane of an area is equal to the sum of inertia about $\parallel^{el}$ axes and product of area and square of the distance between the two parallel axes."

$$I_{AB} = I_{GG} + Ay_c^2$$

where I_{AB} - moment of inertia about AB.

I_{GG} - MI about centroidal axis $\parallel^{el}$ to AB

A - Total area of given figure



y_c - The distance b/w the axis AB and $\parallel^{el}$ centroidal axis GG.

Proof:- Consider an elemental strip dA at a distance 'y' from centroidal axis.

$$I_{AB} = \Sigma (y + y_c)^2 \, dA$$

$$= \Sigma (y^2 + y_c^2 + 2yy_c) \, dA$$

$$= \Sigma y^2 dA + \Sigma y_c^2 dA + \Sigma yy_c dA$$

Now, $\Sigma y^2 dA$ = MI about the axis GG. $= I_{GG}$

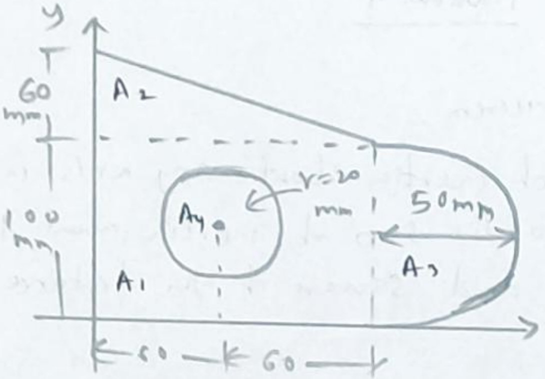
$$\Sigma 2yy_c dA = 2y_c \Sigma y \, dA$$

$$= 2y_c \times A \, \frac{\Sigma y \, dA}{A}$$

$y \, dA/A = 0 \Rightarrow \Sigma y_c^2 dA = y_c^2 \Sigma dA$

$= Ay_c^2 \Rightarrow I_{AB} = I_{GG} + Ay_c^2$

b)



$A_1 = b_1 \times d_1 = 120 \times 100 = 12{,}000 \, mm^2$

$x_1 = b_1/2 = 120/2 = 60 \, mm$

$y_1 = d_1/2 = 100/2 = 50 \, mm$

$A_2 = 1/2 \times b_2 \times h_2 = \frac{1}{2} \times 120 \times 60 = 3600 \, mm^2$

$x_2 = b_2/3 = \frac{120}{3} = 40 \, mm \qquad y_2 = 100 + h/3$

$= 100 + 60/3$

$= 120 \, mm.$

$A_3 = \frac{\pi R_3^2}{2} = \frac{\pi \times 50^2}{2} = 3926.9 \, mm^2$

$y_3 = r = 50 \, mm. \qquad x_3 = 120 + \frac{4R}{3\pi} = 141.22 \, mm$

$A_4 = \pi R_4^2 = \pi \times 20^2 = 1256.63 \, mm^2$

$x_4 = 60 \, mm, \quad y_4 = 50 \, mm.$

$\Rightarrow \quad \bar{y} = \frac{\Sigma A_i y_i}{\Sigma A_i} = \frac{12000 \times 50 + 3600 \times 120 + 3926.9 \times 50 - 1256.63 \times 50}{12000 + 3600 + 3926.9 - 1256.63}$

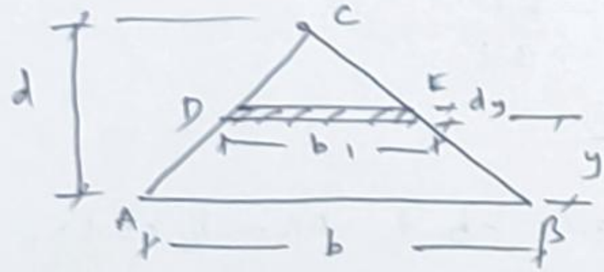
$\therefore \bar{y} = 63.79 \, mm.$

$\bar{x} = \Sigma A_i x_i / \Sigma A_i = \frac{12000 \times 60 + 3600 \times 40 + 3926.9 \times 141.22 - 1256.63 \times 60}{12000 + 3600 + 3926.9 - 1256.63}$

$= 73.52 \, mm \Rightarrow (\bar{x}, \bar{y}) \equiv (63.79 \, mm, 73.52 \, mm)$

OR

Q.5) a) Centroid of Δ^{le} from 1st principles.



Consider a Δ^{le} ABC having breadth 'b' and depth 'd'. Area = $\frac{1}{2} \times b \times d$. Now consider an elementary strip of an area $dA = b_1 dy$.

Δ^{le} ABC & Δ^{le} CDE are $\parallel^{lar}$ Δ^{les}.

$$\Rightarrow \frac{b_1}{b} = \frac{d-y}{d}$$

$$b_1 = \frac{(d-y)}{d} \times b$$

Area of elemental strip

$$= b_1 dy = \left(\frac{d-y}{d}\right) \times b \times dy.$$

Moment of area of elementary strip about AB

$$= \text{area} \times y$$

$$= \frac{(d-y)}{d} \times b \, dy \cdot y.$$

$$= by \, dy - \frac{by^2}{d} dy.$$

Sum of such elementary strips is given by

$$\int_0^d by \, dy - \int_0^d \frac{by^2}{d} dy.$$

$$= b \times \left[\frac{y^2}{2}\right]_0^d - b/d \left[\frac{y^3}{3}\right]_0^d$$

$$= \frac{bd^2}{2} - \frac{bd^3}{3d}.$$

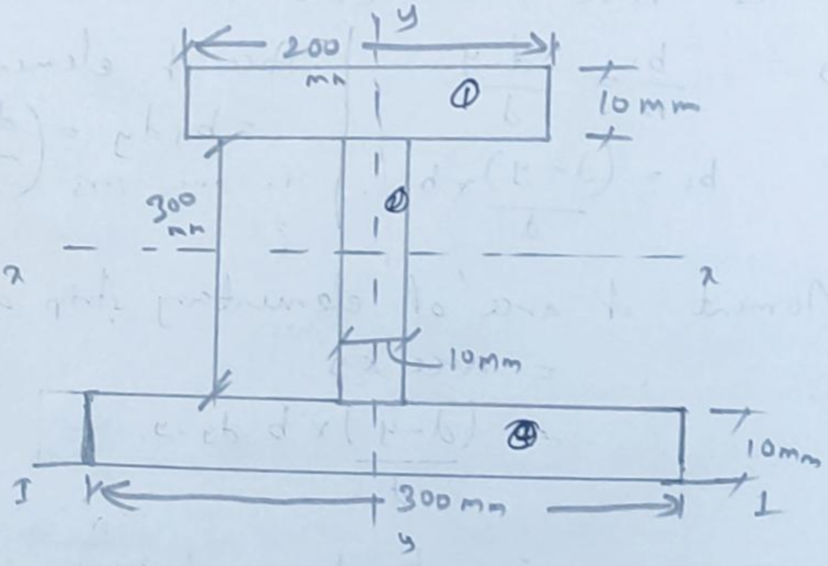
$$= \frac{bd^2}{6}.$$

Moment of total area about $AB = 1/2 \times b d \times \bar{y}$

$$\Rightarrow \bar{y} = \frac{bd^2/6}{1/2 \times bd}$$

$$\Rightarrow \bar{y} = d/3.$$

Q.8) b)



The composite section is divided into three simple rectangles.

$A_1 = 200 \times 10 = 2000\ mm^2$

$A_2 = 10 \times 300 = 3000\ mm^2$

$A_3 = 300 \times 10 = 3000\ mm^2$

Total area $= A = A_1 + A_2 + A_3 = 8000\ mm^2$

$y_1 = 310 + 10/2 = 315\ mm$

$y_2 = 10 + 300/2 = 160\ mm$.

$y_3 = \frac{10}{2} = 5\ mm$

$x_1 = 50 + \frac{200}{2} = 150\ mm$.

$x_2 = 145 + \frac{10}{2} = 150\ mm$.

$x_3 = \frac{300}{2} = 150\ mm$

Symmetric about y axis.
Hence $\bar{x} = \frac{300}{2} = 150\ mm$.

$$\bar{y} = \frac{\Sigma A_i y_i}{\Sigma A_i} = \frac{2000 \times 315 + 3000 \times 160 + 3000 \times 5}{8000}$$

$= \cancel{130.924}\ mm$ from ① – ①.

$= 140.625\ mm$.

$$I_{xx} = (I_{GG})_1 + A_1 y_{c_1}^2 + (I_{GG})_2 + A_2 y_c^2 + (I_{GG_3}) + A_3 y_c^3$$

$$\Rightarrow I_{xx} = \frac{200 \times 10^3}{12} + 200 \times 10 \times 174.375^2 + \frac{10 \times 300^3}{12}$$

$$+ 10 \times 300 \times 19.375^2 + \frac{300 \times 10^3}{12} + 300 \times 10 \times 135.625^2$$

$I_{xx} = 139.663 \times 10^6\ mm^4$.

$|||^{rly}$ $I_{yy} = (I_{GG_1}) + A_1 x_{c_1}^2 + (I_{GG_2}) + A_2 x_{c_2}^2 + (I_{GG_3}) + A_3 \times x_{c_3}^2$.

However $x_{c_1} = x_{c_2} = x_{c_3} = 0$.

$$\Rightarrow I_{yy} = \frac{10 \times 200^3}{12} + \frac{300 \times 10^3}{12} + \frac{10 \times 300^3}{12}$$

$= 29.9167 \times 10^6\ mm^4 \simeq 29.912 \times 10^6\ mm^4$

Module 5

Q.9) a) i) Acceleration :- Rate of change of velocity w.r.t time is called acceleration.

$$'a' = dv/dt \quad \text{unit is } m/s^2$$

ii) Displacement :- It is the vector quantity. It is a measure of the interval b/w two locations or two points measured along the shortest connecting path. Displacement unit is m, cm, ft.

iii) Speed :- Rate of change of distance travelled by the particle w.r.t time is called speed. unit is m/s. Scaler quantity.

iv) Velocity :- Rate of change of displacement w.r.t time is called velocity. denoted by v.

$$v = dx/dt \quad \text{unit is 'm/s'}.$$

9) b) Super elevation and its necessity :-

If the road surface is horizontal, then the centrifugal force acting radially outwards will draw the vehicle away from the centre effecting lateral slipping of the vehicle. If this is to prevented, then the frictional force offered at the wheel & road has to balance this centrifugal force

To prevent lateral slipping of the vehicle due to centrifugal force, the road edge away from the centre (outer edge) will be slightly raised above the inner edge by vertical height e.

Consider a vehicle of mass 'm' negotiate a circular curve of radius 'r' with velocity 'v'. Let the angle with which the road surfaced to be inclined at an angle θ w.r.t horizontal surface

$$mg\sin\theta = \frac{mv^2}{r}\cos\theta$$

$$\Rightarrow \tan\theta = \frac{v^2}{gr}$$

where θ is the banking angle known as super elevation

9) c). Let 'h' be the depth of the well. we have

$$t_1 + t_2 = 9s. \rightarrow (1)$$

Let t_1 → time taken by the stone to reach bottom of the well

t_2 → Time taken by sound to reach top of the well

Consider motion of stone.

using eq 2 $= h = ut + \frac{1}{2}gt^2$

$$h = ut + \frac{1}{2}gt^2$$

$u = 0,\ t = t_1,\ g = 9.81\,m/s^2$

$$h = 4.905\,t_1^2$$

Consider motion of the sound.

Let 'v' be the velocity of sound

't_2' be the time

$$v = h/t_2$$

$$t_2 = \frac{h}{v}$$

$$t_2 = \frac{4.905 t_1^2}{330} = 0.01486 t_1^2$$

Substituting in eqn ① we get-

$$t_1 + 0.01486 t_1^2 = 9.$$

$$t_1^2 + 62.278 t_1 - 605.50 = 0.$$

$$t_1 = 8.55 \text{ seconds.}$$

$$h = 4.905 \times (8.55)^2$$

$$\therefore h = 358.56 \text{ m}$$ //

OR

Q.10) a) i) Kinetics :- It is the branch of dynamics which deals with the study of properties of motion of the body or particle in such way that the forces which cause the motion of body are mainly taken into consideration.

ii). Kinematics :- It is the branch of dynamics which deals with the study of properties of motion of the body or particle under the system of forces without considering the effect of forces

iii) Projectile motion :- Whenever a particle is projected upwards with some inclination to the horizontal it travels in the air and traces parabolic path and falls to ground.

10) b). D'Alember's Principle

" The Newton's second law of motion is applicable not only to the motion of a particle but also to the motion of the body".

or

" System of forces acting on a moving body is in dynamic equilibrium with the inertia force of the body".

The application of plane motion are

i) Man falling under gravity.

ii) Bead on frictionless vertical hoop.

iii) Atwood's machine.

10) c). $u = 60\,m/s$.

Time of flight = $t = \frac{2u\sin\alpha}{g}$

$R = 4h$.

$$\Rightarrow \frac{\cancel{u^2}\sin 2\alpha}{\cancel{g}} = \frac{\cancel{4}^{2}}{}\times\frac{\cancel{u^2}\sin^2\alpha}{{}_{1}\cancel{2g}}$$

$$\Rightarrow \sin 2\alpha = 2\sin^2\alpha.$$

$$2\sin^2\alpha - 2\sin\alpha\cos\alpha = 0.$$

$$\Rightarrow \sin^2\alpha = \sin\alpha\cos\alpha$$

$$1\ \frac{\cancel{\sin^2\alpha}}{\cancel{\sin^2\alpha}} = \frac{\cos\alpha}{\sin\alpha} \Rightarrow \cot\alpha = 1$$

$$\therefore \alpha = 45^\circ$$

$$t = \frac{2 \times 60 \times \sin 45^\circ}{9.81}$$

$\therefore t_1 = \underline{8.649 \text{ seconds}}$

ii). $4R = h$

$\Rightarrow R = h/4$

$$\Rightarrow \frac{\cancel{u^2} \sin 2\alpha}{\cancel{g}} = \frac{\cancel{u^2} \sin^2\alpha}{8\cancel{g}}$$

$\Rightarrow 16 \sin\alpha \cos\alpha = \sin^2\alpha$

$\Rightarrow \cot\alpha = 1/16$

$\Rightarrow \alpha = \tan^{-1}(16)$

$\alpha = 86.423^\circ$

$$t_2 = \frac{2 \times 60 \times \sin 86.423^\circ}{9.81}$$

$\therefore t_2 = 12.20$ seconds

iii). $R = h$.

$$\Rightarrow \frac{\cancel{u^2} \sin 2\alpha}{\cancel{g}} = \frac{\cancel{u^2} \sin^2\alpha}{2\cancel{g}}$$

$\Rightarrow 4 \sin\alpha \cos\alpha = \sin^2\alpha$

$\cot\alpha = 1/4$

$\alpha = \tan^{-1}(4)$

$\therefore \alpha = 75.96^\circ$

$$t = \frac{2u \times \sin \alpha}{g}$$

$$= \frac{2 \times 60 \times \sin 75.96}{9.81}$$

$\therefore t_3 = 11.86$ seconds

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