Name of the Examination: First Semester End Semester Examination
Name of the Subject: Mechanics
Subject Code: AM1101
Date of Examination: 3rd April, 2021.
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Examination Roll Number: 2020ITB065
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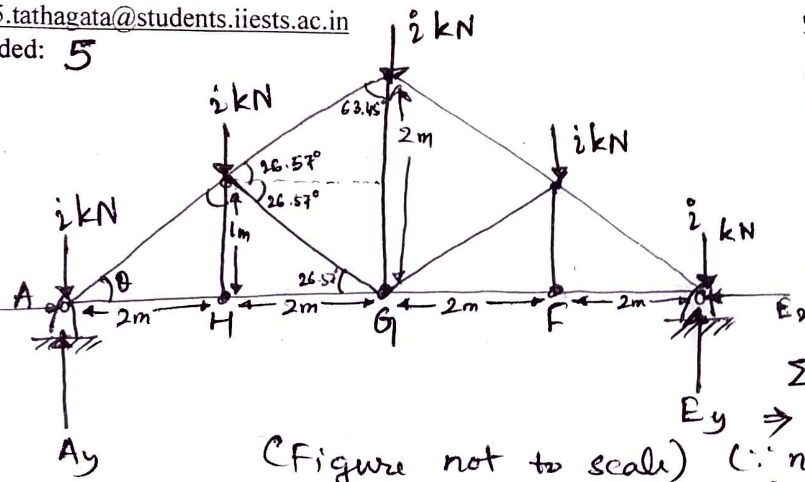
$\boxed{i = 0+6+5 = 11}$

Ans 1)

Assuming all forces to be tensile.



(Figure not to scale)

$\tan\theta = \frac{2}{4} = \frac{1}{2}$

$\Rightarrow \theta = 26.57°$

$\Sigma F_x = 0$

$\Rightarrow A_x - E_x = 0$

($\because$ no horizontal force present) $\therefore A_x = E_x = 0$ kN

For the complete truss,

$\Sigma F_y = 0 \Rightarrow A_y + E_y - i - i - i - i - i = 0$

$\Rightarrow A_y + E_y = 5i$

Putting $E_y = 2.5i$,

$\Rightarrow \boxed{A_y = 2.5i = 27.5 \text{ kN}}$

$\Sigma M_A = 0$ (+ve)

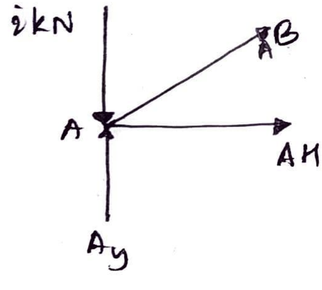
$\Rightarrow (E_y \times 8) - (i \times 2) - (i \times 4) - (i \times 6) - (i \times 8) = 0$

$\Rightarrow 8E_y = 20i$

$\Rightarrow E_y = 2.5i$

$\Rightarrow \boxed{E_y = 27.5 \text{ kN}}$

FBD of A,



Applying conditions of equilibrium,

$\Sigma F_x = 0 \Rightarrow AB\cos\theta + AH = 0$

$\Sigma F_y = 0$

$\Rightarrow A_y - i \text{ kN} + AB\sin\theta = 0$

$\Rightarrow A_y + AB\sin\theta = i$ kN

$\Rightarrow AB\sin\theta = -1.5i$ kN

$\Rightarrow AB = -3.35i$ kN

$\Rightarrow \boxed{AB = -36.85 \text{ kN}}$

$\therefore AH = 3i$ kN

$\Rightarrow \boxed{AH = 33 \text{ kN}}$

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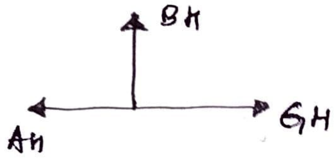
FBD of H,



$\Sigma F_x = 0 \Rightarrow GH - AH = 0 \Rightarrow GH = AH = 3i\,kN$

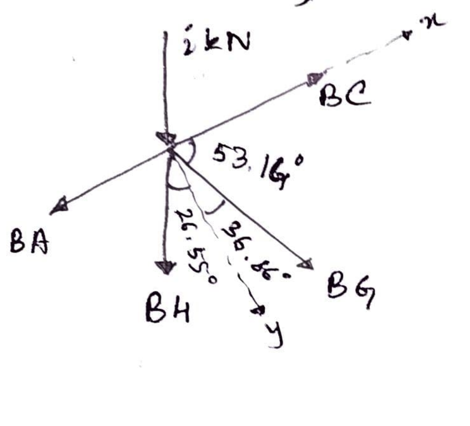
$\Rightarrow \boxed{GH = AH = 33\,kN}$

$\Sigma F_y = 0$

$\Rightarrow \boxed{BH = 0\,kN}$

$\therefore$ AH = EF ; GF = HG ; FD = BH ; ED = AB
[Since the system is symmetrical]

FBD of B,



$\Sigma F_y = 0$

$\Rightarrow BG \cos 36.86^\circ + i \cos 26.57^\circ = 0$

$\Rightarrow BG = -1.1178i\ kN$

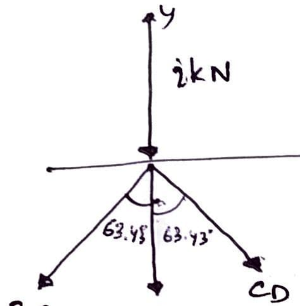
$\Rightarrow \boxed{BG = -12.3\,kN}$

$\Sigma F_x = 0 \Rightarrow BC + BG \cos 53.14^\circ - AB - i \sin 26.57^\circ = 0$

$\Rightarrow BC = -2.232i\,kN$

$\Rightarrow \boxed{BC = -24.552\,kN}$

FBD of C,



$\Sigma F_y = 0$

$\Rightarrow BC \cos 63.48^\circ + CD \cos 63.43^\circ + CG \cos 43.45^\circ + 1 = 0$

$\Rightarrow CG = -1.1i\,kN$

$\Rightarrow \boxed{CG = -12.1\,kN}$

Members	Force	Nature	
1) AB = DE	+ 36.85 kN	C	
2) BC = CD	+ 24.552 kN	C	
3) BH = DF	0	–	Zero force Members
4) AH = EF	33 kN	T	
5) GH = FG	33 kN	T	(Ans)
6) BG = DG	12.3 kN	C	

(-)ve sign depicts that the force is compressive since we assumed all to be tensile.

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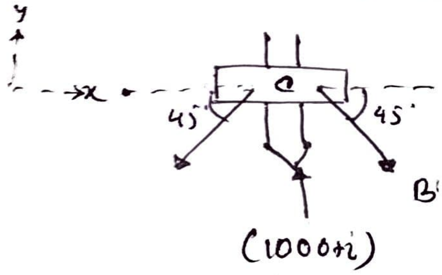
Ans 2) FBD of upper bar screw:



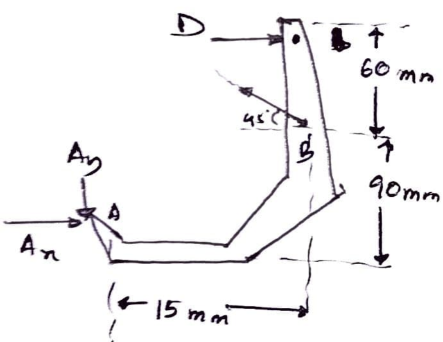
$$\Sigma F_y = 0$$

$$\Rightarrow 2B \sin 45^\circ = (1000+i)$$

$$\Rightarrow B = \frac{(1000+i)}{2\sin 45^\circ} = \frac{(1000+11)}{2\sin 45^\circ}$$

$$= 714.884 \text{ N}$$

FBD of ABD arm:-



$$\Sigma M_A = 0$$

$$\Rightarrow (90+60) \times D = (0.714 \cos 45^\circ \times 90) + (0.714 \sin 45^\circ \times 15)$$

$$\Rightarrow D = \frac{53.01}{150}$$

$$\Rightarrow D = 0.353 \text{ kN}$$

$$\Sigma F_x = 0 \Rightarrow A_x + 0.353 = 0.714 \cos 45^\circ$$

$$\Rightarrow A_x = 0.151 \text{ kN}$$

$$\Sigma F_y = 0 \Rightarrow A_y = 0.714 \cos 45^\circ$$

$$\Rightarrow A_y = 0.504 \text{ kN}$$

$$A = \sqrt{A_x^2 + A_y^2} = \sqrt{(0.151)^2 + (0.504)^2} = \sqrt{0.2768}$$

$$= 0.526 \text{ kN}$$

(Ans)

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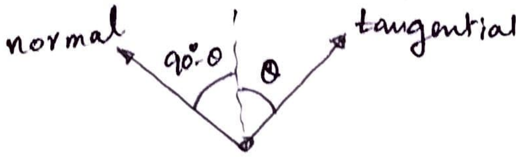
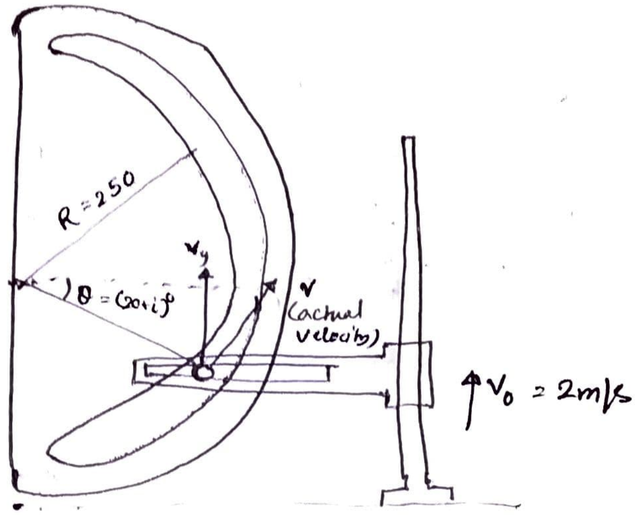
Ans 5)





$\theta = 20+i$

$\Rightarrow \theta = 31°$ [i = 11]

So, $v_y = v_0 = v\cos\theta$

$\Rightarrow v = \dfrac{v_0}{\cos\theta} = v_0 \sec\theta$

$\Rightarrow v = 2\sec(31°)$ m/s

$\Rightarrow v = 2.33$ m/s

Centripetal acceleration, $a_n = \dfrac{v^2}{R}$

$a_n = \dfrac{4\sec^2(31°)}{0.25}$ m/s² [R = 250 mm = 0.25 m]

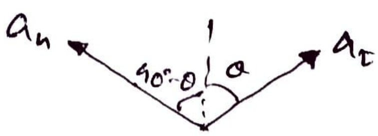
$\Rightarrow a_n = 21.78$ m/s

Since velocity in vertical direction is v_0, which is constant.

∴ acceleration $\left[a = \dfrac{dv_0}{dt} = 0\right]$ in vertical component is 0.

$\Rightarrow a_n \sin\theta + a_z \cos\theta = 0$

$\Rightarrow a_t = -\dfrac{a_n \sin\theta}{\cos\theta} = -a_n \tan\theta$



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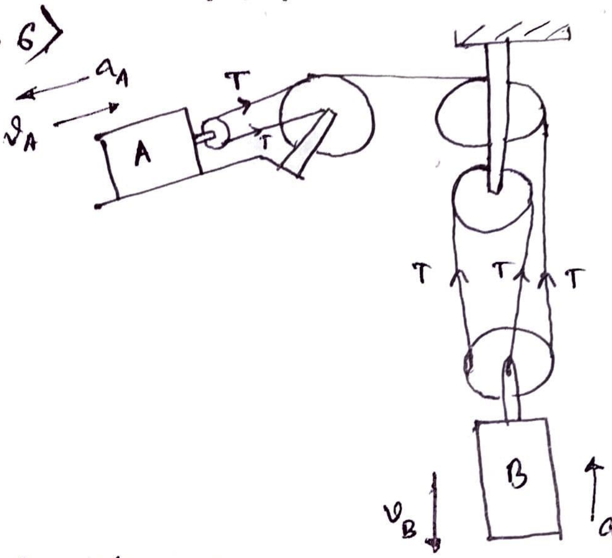
$\Rightarrow a_t = -21.78 \tan(31^\circ)\ m/s^2$

$\Rightarrow a_t = -13.08\ m/s^2$

. . .

$$\boxed{\begin{aligned} a_n &= 22.74\ m/s^2 \\ a_t &= -14.77\ m/s^2 \end{aligned}}\ \text{(Ans)}$$

Ans 6)



$v_B = 3\hat{i}\ m/s$

$= 33\ m/s$

$a_B = 5\hat{i}\ m/s^2$

$= 55\ m/s^2$

Using Virtual Work Theorem,

$\Sigma \vec{T}\cdot\vec{v} = 0$

$\Rightarrow -3Tv_B + 2Tv_A = 0$

$\Rightarrow v_A = \dfrac{3v_B}{2}$

$\Rightarrow v_A = \dfrac{3\times 33}{2}\ m/s$

$v_A = \boxed{49.5\ m/s}$ (Ans)

Using Virtual Work Theorem,

$\Sigma \vec{T}\cdot\vec{a} = 0$

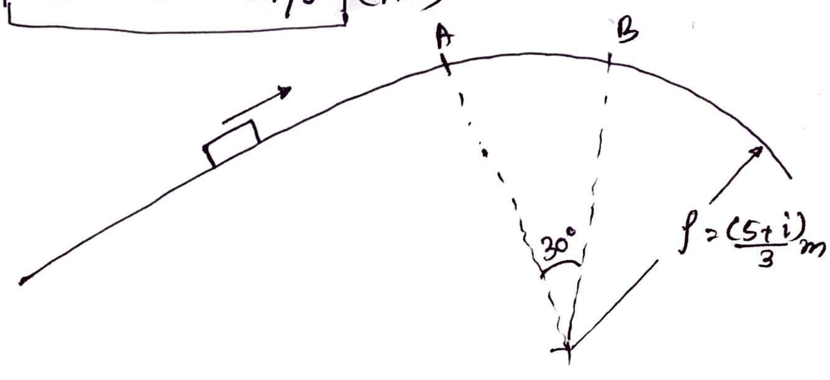
$\Rightarrow +3Ta_B - 2Ta_A = 0$

$\Rightarrow a_A = \dfrac{3a_B}{2}$

$\Rightarrow a_A = \dfrac{3\times 55}{2}\ m/s^2$

$\Rightarrow \boxed{a_A = 82.5\ m/s^2}$ (Ans)

Ans 7)



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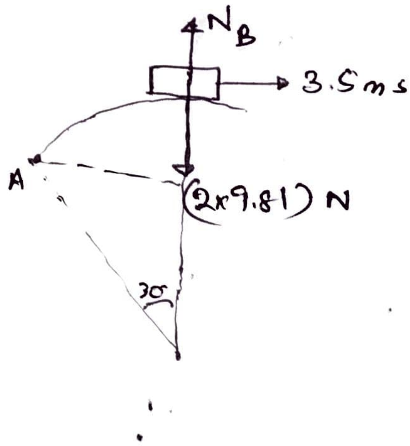
At B,



$$\Sigma F_{centripetal} = \frac{mv^2}{\rho}$$

(where $v_B = 3.5\, m/s$,

$\rho = \frac{5+11}{3} = 5.33\, m$)

$$\Rightarrow (2\times 9.81) - N_B = \frac{2\times 3.5^2}{5.33}$$

$$\Rightarrow 19.62 - N_B = 4.59$$

$$\Rightarrow \boxed{N_B = 15.02\ N.\ (Ans)}$$

By conservation of energy,

$K_A + U_A = K_B + U_B$ (where K : Kinetic Energy & U : Potential Energy)

$\Rightarrow \frac{1}{2} m v_A^2 + 0 = \frac{1}{2} m v_B^2 + mg\rho(1-\cos 30^\circ)$ [Taking A as reference point]

$$\Rightarrow \frac{1}{2}\times v_A^2 = \frac{1}{2}\times(3.5)^2 + 9.81\times\frac{16}{3}\times\left(1-\frac{\sqrt{3}}{2}\right)$$

$$\Rightarrow v_A^2 = (3.5)^2 + 2\times 9.81\times\frac{16}{3}\left(1-\frac{\sqrt{3}}{2}\right)$$

$$\Rightarrow v_A^2 = 133.07$$

$$\Rightarrow v_A = 11.53\, m/s\ (Ans)$$

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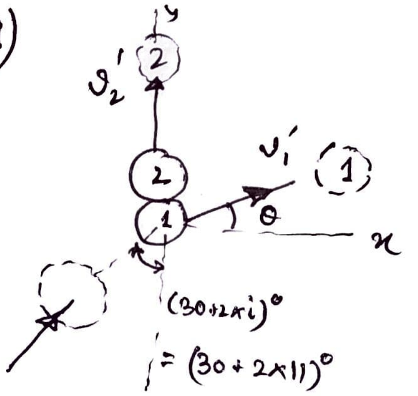
Ans 9)



$= (30+2\times 11)^\circ$
$= 52^\circ$

1 and 2 together:

$m v_1 \cos 52^\circ = m v_1' \sin\theta + m v_2'$

$\Rightarrow v_1'\sin\theta + v_2' = 0.62 v_1$ ...(1)

For 1 alone: $m v_1 \sin 52^\circ = m v_1' \cos\theta$

$\Rightarrow v_1'\cos\theta = v_1 (0.78)$ ...(2)

Restitution: $v_2' - v_1'\sin\theta = e v_1 \cos 52^\circ$

$\Rightarrow v_2' - v_1'\sin\theta = 0.9 \times v_1 \times (0.616)$ ...(3)

(1) & (3): $\cancel{v_1'\sin\theta =}$

$0.62 v_1 - v_1'\sin\theta = v_1'\sin\theta + 0.55 v_1$

$\Rightarrow 2 v_1' \sin\theta = 0.07 v_1$

$\Rightarrow \sin\theta = \dfrac{0.035 v_1}{v_1'}$

$\Rightarrow \sin\theta = \dfrac{0.035 v_1}{\dfrac{v_1 (0.78)}{\cos\theta}}$

$\Rightarrow \tan\theta = \dfrac{0.035}{0.78}$

$\Rightarrow \theta = \tan^{-1}(0.0448)$

$\Rightarrow \theta = 2.57^\circ$ (Ans)

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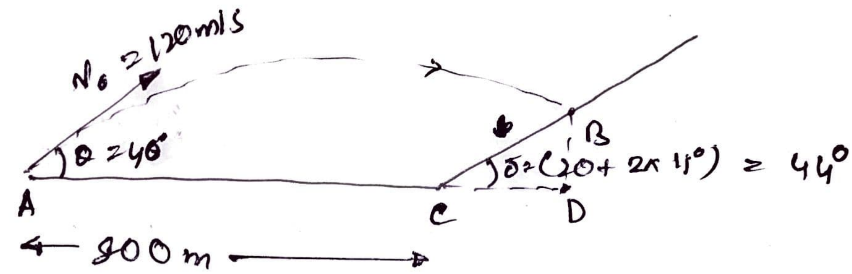
Ans4)



$(v_x)_0 = 120\cos 40^\circ$
$= 91.92\, m/s$

$(v_y)_0 = 120\sin 40^\circ$
$= 77.13\, m/s$

Considering uniformly accelerated horizontal motion,

$x = x_0 + (v_x)_0 t$

$\Rightarrow 800 + CD = 0 + 120\cos 40^\circ t$

$\Rightarrow \boxed{t = \dfrac{800 + CD}{91.92}}$ — (1)

$CD = 120\cos 40^\circ t - 800$
$\Rightarrow CD = 91.92t - 800$

From right angled triangle BDC,

$\tan\delta = \dfrac{BD}{CD}$

$\delta = 42^\circ$
$\tan\delta = 0.9$

$\Rightarrow \boxed{BD = CD\tan\delta}$ — (2)

Considering vertical motion,

$BD = y_0 + (v_y)_0 t - \frac{1}{2} g t^2$

from (1) & (2)

$CD\tan\delta = 0 + (77.13)t - \frac{1}{2} \times (9.81)t^2$

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$$\Rightarrow (91.92t - 800)\tan\delta = 77.13t - \frac{9.81}{2}t^2$$

$$\Rightarrow (91.92t - 800).0.9 = 77.13t - \frac{9.81}{2}t^2$$

$$\Rightarrow 82.73t - 720 = 77.13t - 4.9t^2$$

$$\Rightarrow 5.6t - 720 = -4.9t^2$$

$$\Rightarrow 49t^2 + 56t - 7200 = 0$$

$$\Rightarrow t = \frac{-56 \pm \sqrt{(56)^2 + 4\times 49\times 7200}}{2\times 49}$$

$$\Rightarrow t = \frac{1133.25}{2\times 49} \quad \text{(neglecting)}$$

$$\boxed{t = 11.56\ s}$$

Hence time of flight is 11.56 seconds.
(Ans)

T. Ghosh.