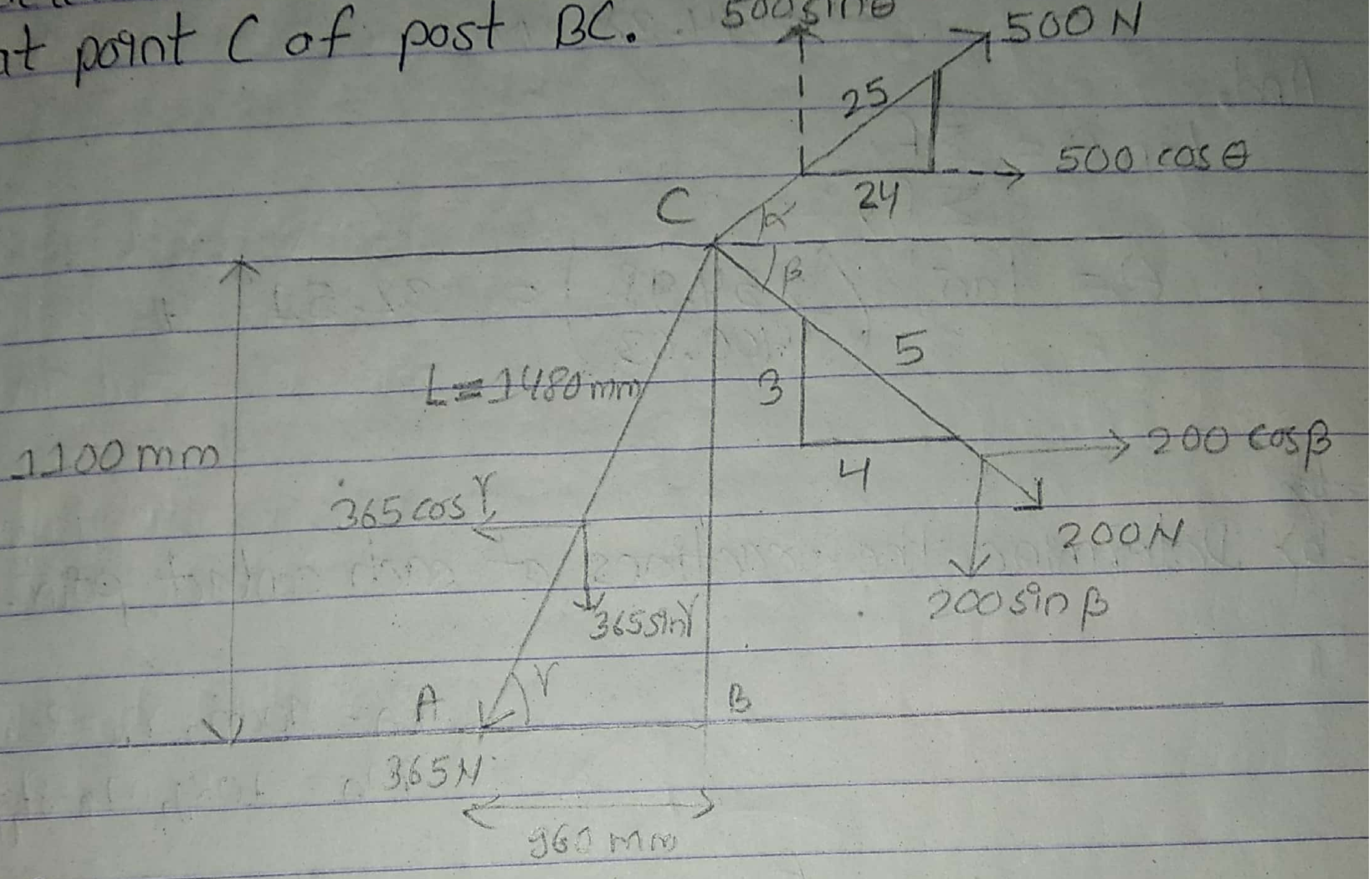
1. a) Knowing that the tension in rope AC is 365 N, determine the resultant of the three forces exerted at point C of post BC.



Sol^n →

$\sin\alpha = \frac{7}{25}$, $\sin\beta = \frac{3}{5}$, $\sin\gamma = \frac{1100}{1460}$

$\therefore \alpha = 16.26^\circ$ $\therefore \beta = 36.86^\circ$ $\therefore \gamma = 48.89^\circ$

Sum of X-component

$\rightarrow +;\ \Sigma F_x =$

$500\cos 16.26^\circ + 200\cos 36.86^\circ - 365\cos 48.89^\circ =$

$\therefore \Sigma F_x = 400.03\ N$

&

$\uparrow +;\ \Sigma F_y = 500\sin 16.26^\circ - 200\sin 36.86 - 365\sin 48.89 = 0$

$= -254.98\ N$

So, Resultant (R) $= \sqrt{(\Sigma f_x)^2 + (\Sigma f_y)^2}$
$= \sqrt{(400.03)^2 + (-254.98)^2}$
$= 474.38$ N

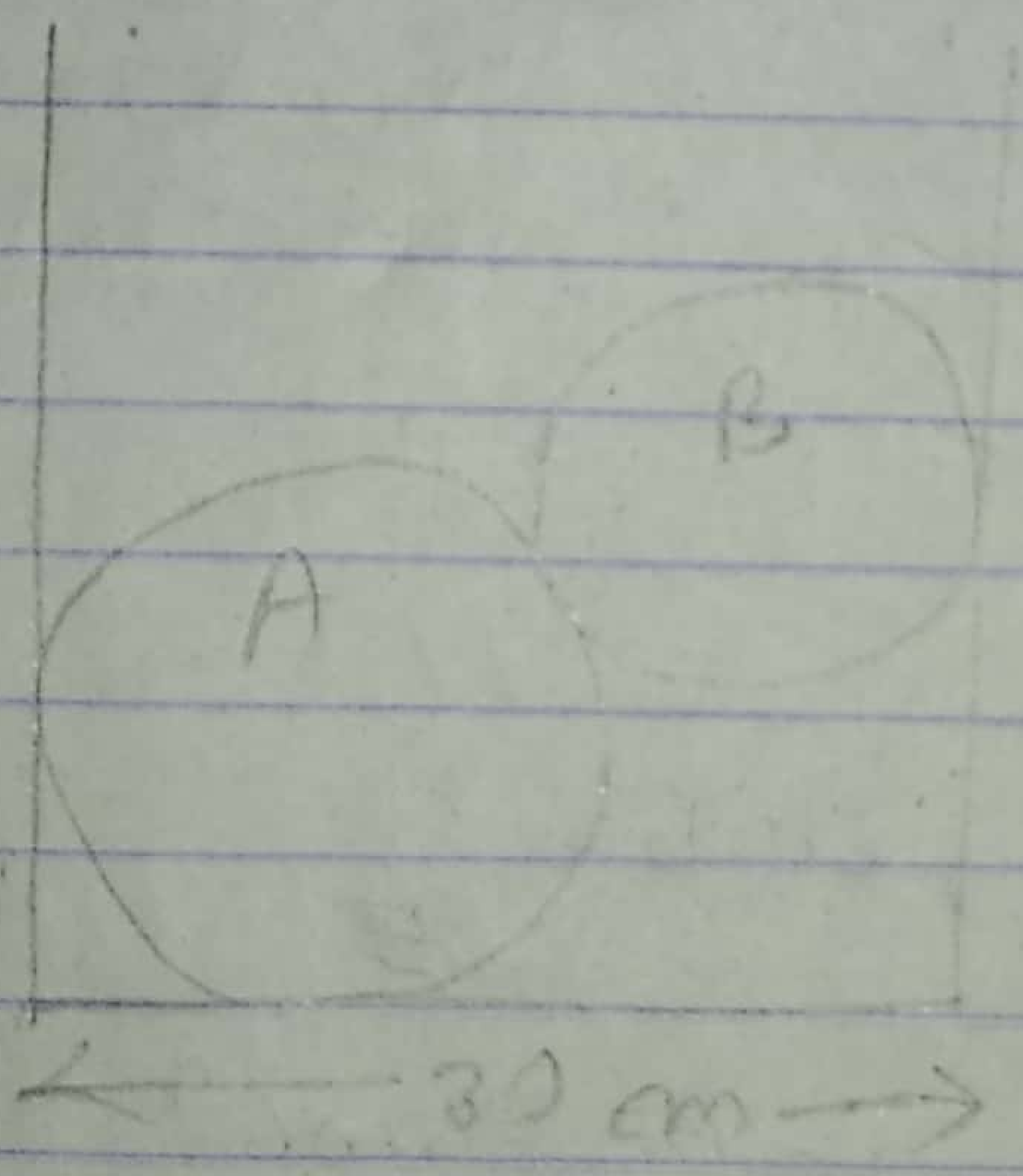
And,

$$\tan\theta = \frac{\Sigma f_x}{\Sigma f_y}$$

$$\therefore \theta = \tan^{-1}\left(\frac{254.98}{400.03}\right) = 32.51^\circ \quad \#$$

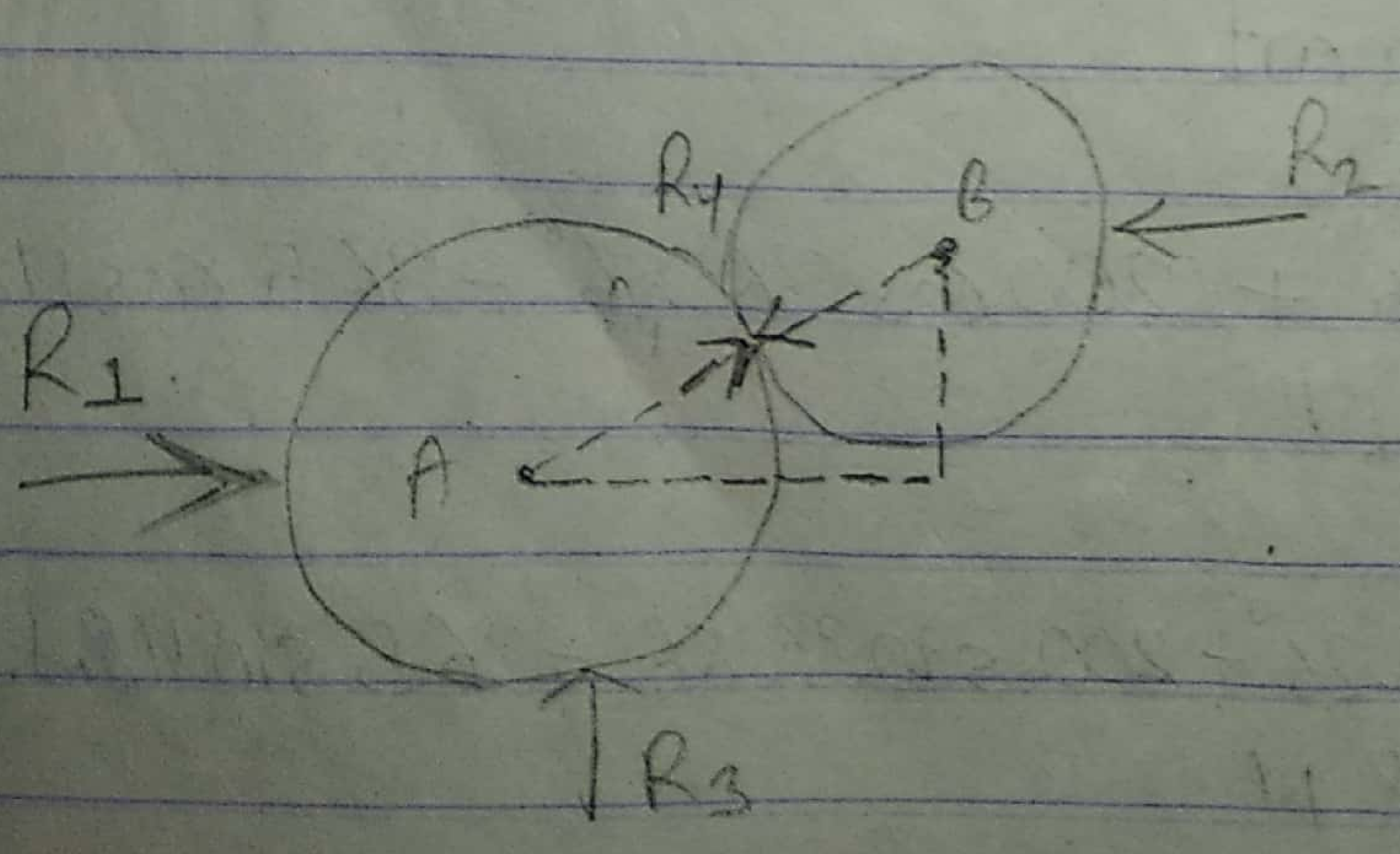
~~1. b)~~

1. b) Determine the reactions at each contact point.



$r_A = 10cm$, $r_B = 8cm$
$m_A = 10kg$, $m_B = 8kg$

Sol^n

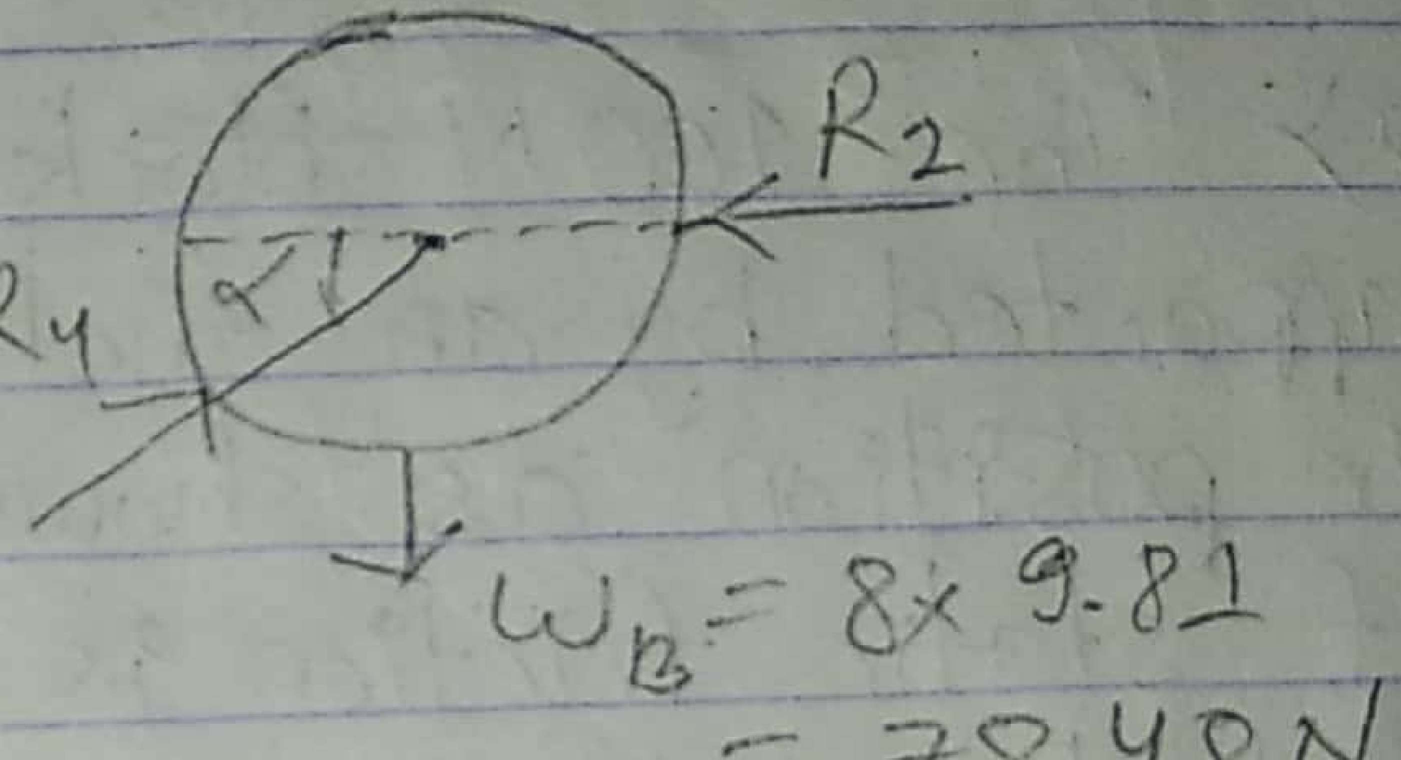


Let α be the angle made with horizontal axis.

$$\cos\alpha = \frac{30-10-8}{10+8}$$

$\therefore \alpha = 48.18°$

For sphere B,



FBD for sphere B

$\uparrow +;\ \Sigma F_y = 0$

$R_4 \sin\alpha - W_B = 0$

$R_4 \sin 48.18 = 78.48$

$\therefore R_4 = 105.30\,N$

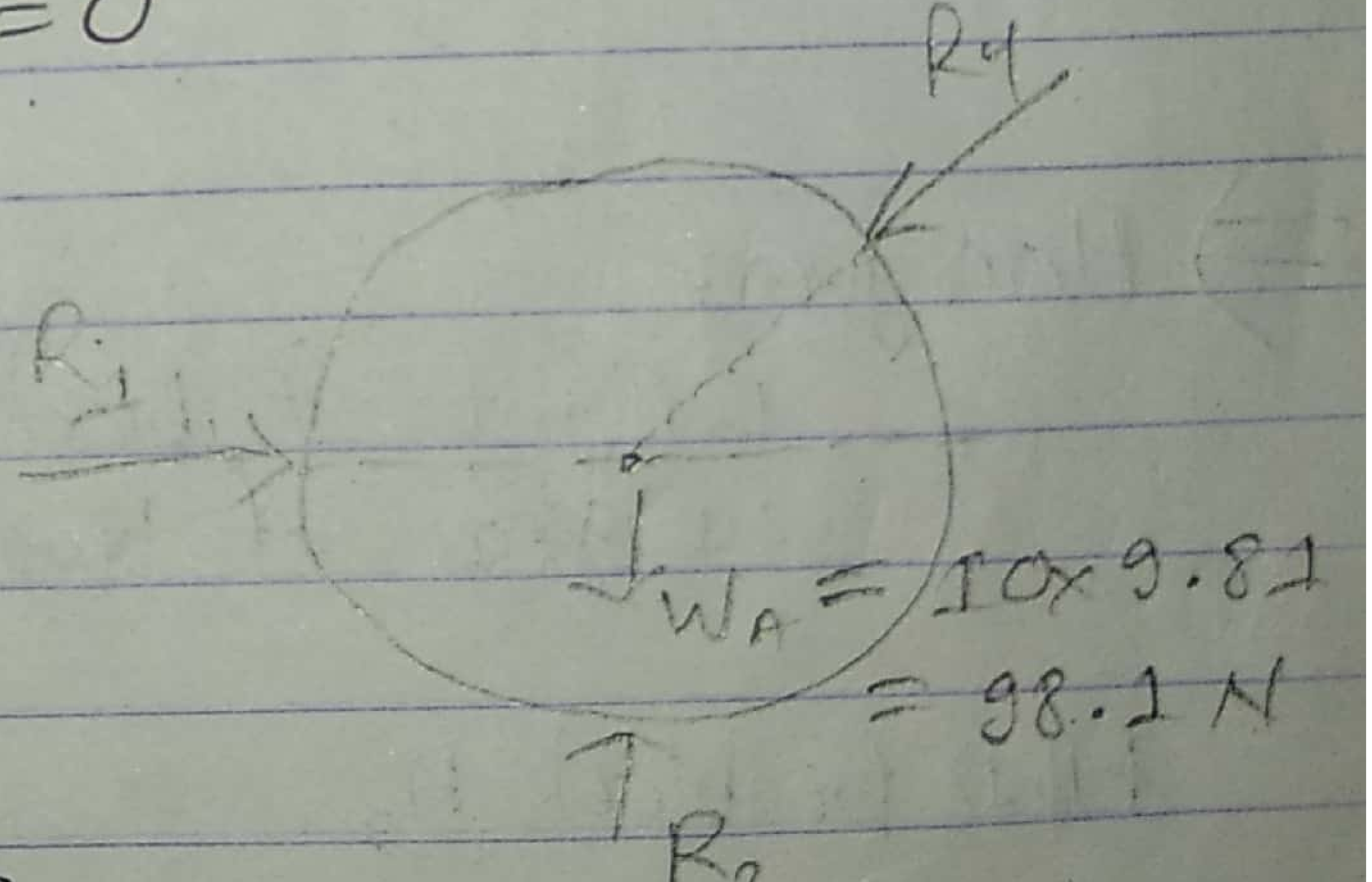
$\rightarrow +;\ \Sigma F_x = 0$

$R_4 \cos\alpha - R_2 = 0$

$105.30 \cos 48.18 - R_2 = 0$

$\therefore R_2 = 70.20\,N$

For sphere A,



FBD for sphere A

$\uparrow +;\ \Sigma F_y = 0$

$R_3 - W_A - R_4 \sin\alpha = 0$

$R_3 - 98.1 - 105.305 \sin 48.18 = 0$

$R_3 = 176.58\,N$

$\rightarrow +;\ \Sigma F_x = 0$

$R_1 - R_4 \cos\alpha = 0$

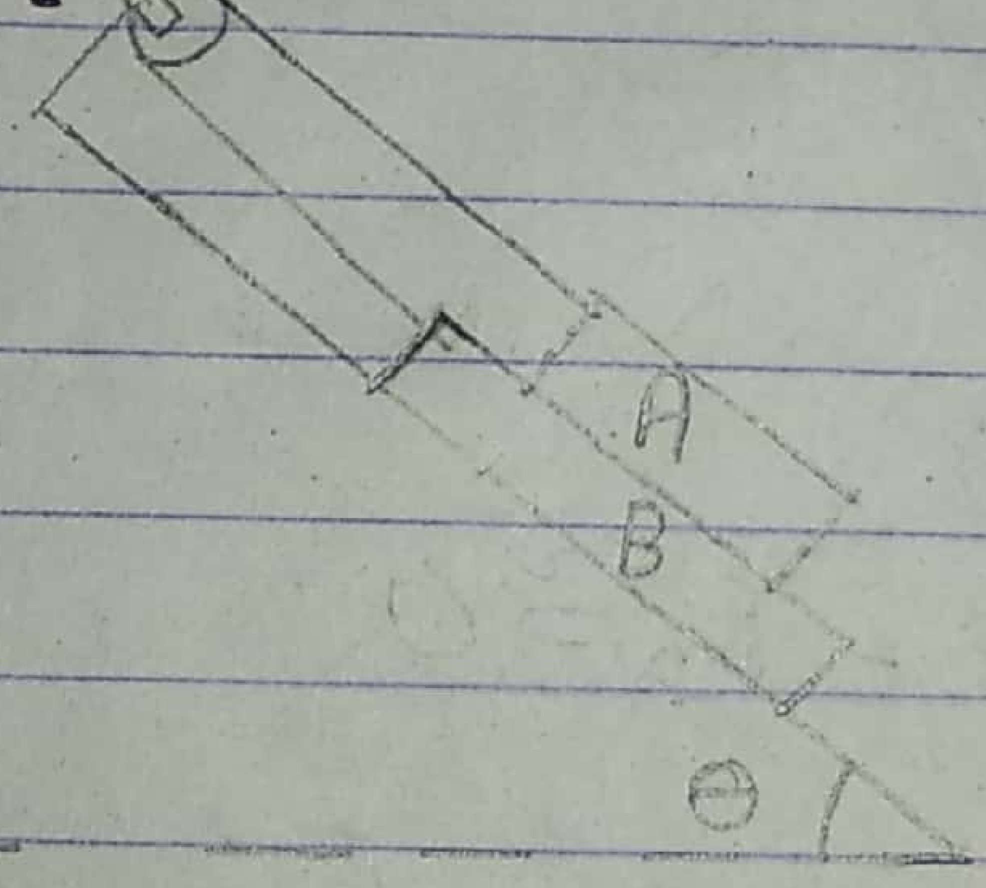
$R_1 - 105.30 \cos 48.18 = 0 \implies R_1 = 70.20\,N$

∴ Reaction components are :-

$R_4 = 105.30\,N$ & $R_2 = 70.20\,N$

& $R_3 = 176.58\,N$ & $R_1 = 70.20\,N$ #

2. a) The 100 N block A and 150 N block B are supported by an inclined surface that is held in the position as shown in fig. Knowing that the coeff. of static friction is 0.15 between all surfaces of contact, determine the value of θ for which motion is impending.

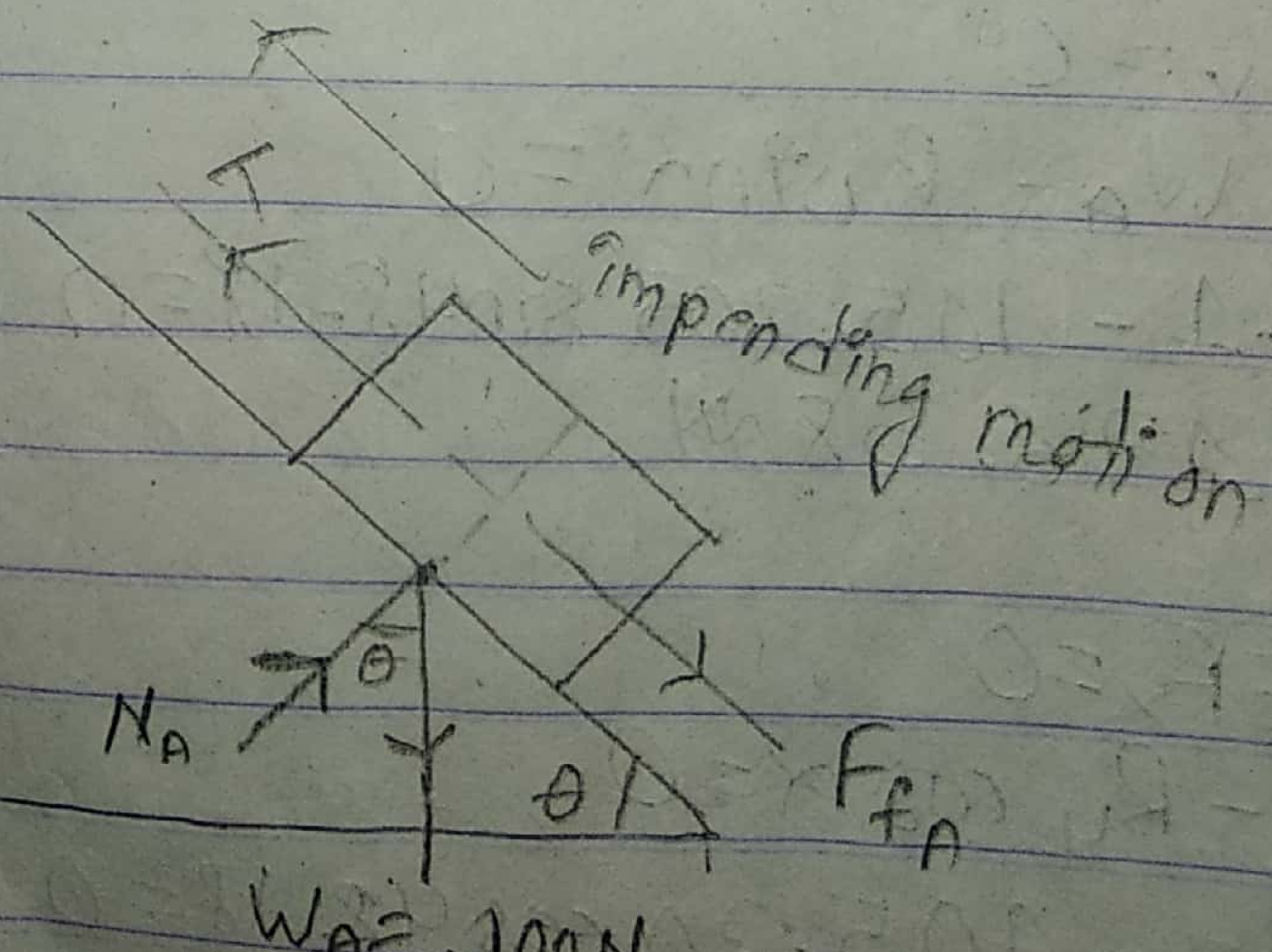


⇒ Here, given;

weight of block (A) $(W_A) = 100\,N$

weight of block B $(W_B) = 150$

FBD for block A,



$\nearrow +; \Sigma F_y = 0$

$N_A - W_A \cos\theta = 0$

$\therefore N_A = 100 \cos\theta$

&

$\therefore F_{fA} = \mu_s . N_A = 0.15 \times 100 \cos\theta = 15 \cos\theta$

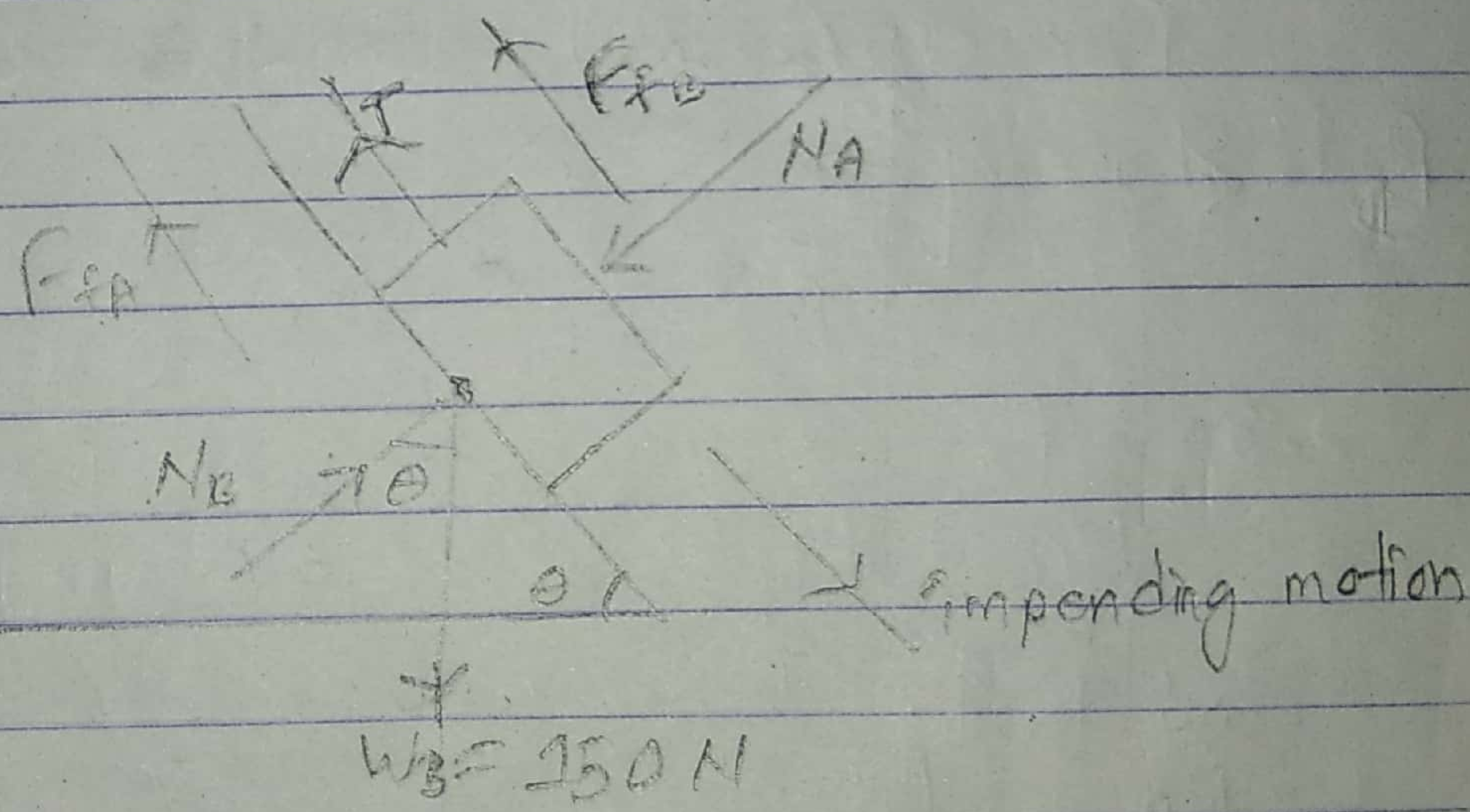
$\searrow +; \Sigma F_x = 0$

$F_{fA} - T + W_A \sin\theta = 0$

$15 \cos\theta - T + 100 \sin\theta = 0$

$\therefore T = 15 \cos\theta + 100 \sin\theta$

For block B,



$\nearrow +; \Sigma F_y = 0$

$N_B - N_A - 150 \cos\theta = 0$

$\therefore N_B = 150 \cos\theta + 100 \cos\theta$

$= 250 \cos\theta$

$\therefore F_{fB} = \mu_s . N_B$

$= 0.15 \times 250 \cos\theta$

$= 37.5 \cos\theta$

$\searrow +;\ \Sigma f_x = 0$

$-F_{fA} - T - F_{fB} + 150 \sin\theta = 0$

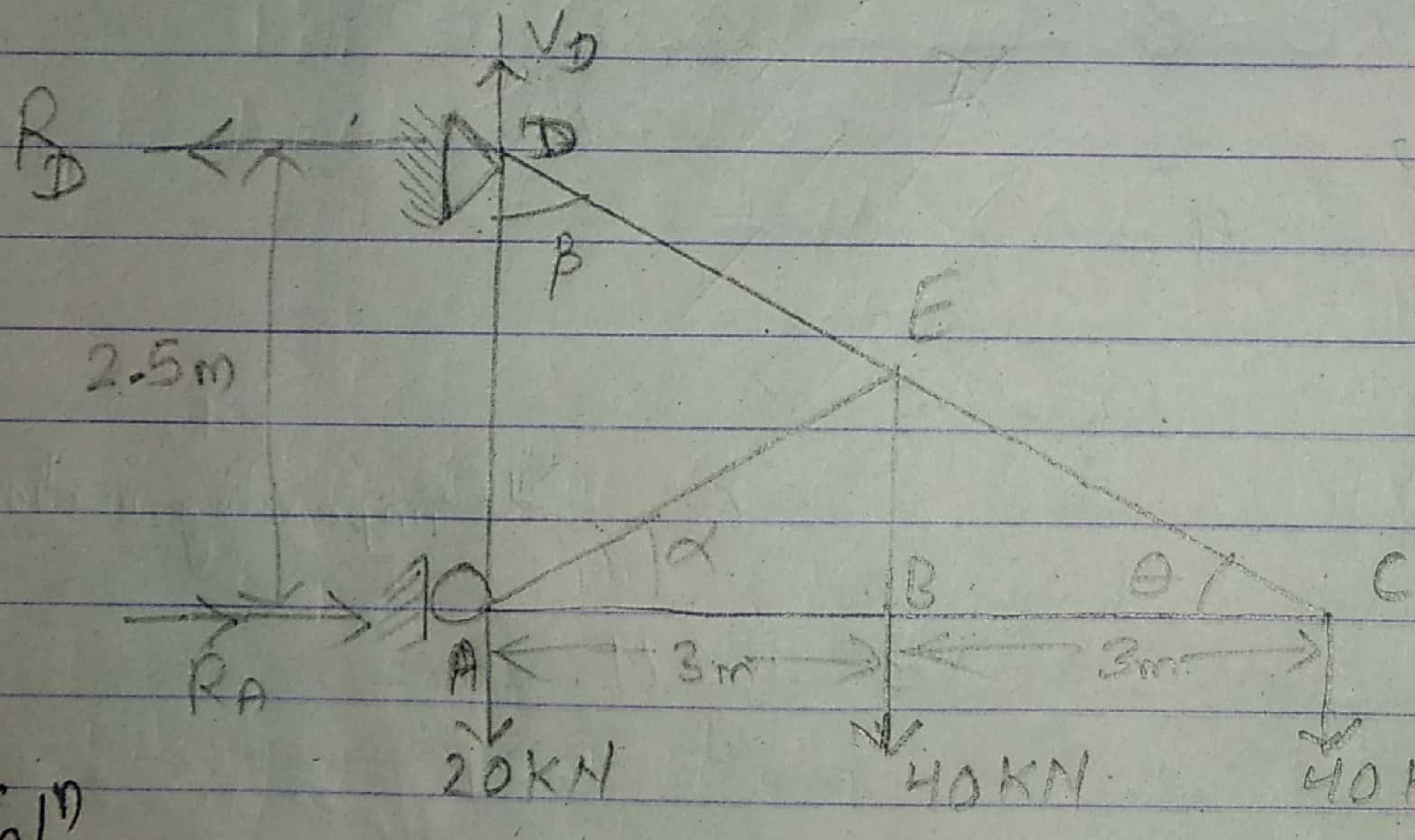
or, $-15\cos\theta - 15\cos\theta - 100\sin\theta - 37.5\cos\theta + 150\sin\theta = 0$

or, $-67.5\cos\theta + 50\sin\theta = 0$

or $\tan\theta = \dfrac{67.5}{50}$

$\therefore\ \theta = 53.47°$ #

2.b) Find the member forces of the given truss.



Solⁿ

$\uparrow +;\ \Sigma F_y = 0$

$V_D - 20 - 40 - 40 = 0$

$\therefore\ V_D = 100\ KN$

$+\circlearrowleft;\ \Sigma M_A = 0$

$-R_D \times 2.5 + 40 \times 3 + 40 \times 6 = 0$

$\therefore\ R_D = 144\ KN$

$\xrightarrow{+}$; $\Sigma f_x = 0$

$-R_D + R_A = 0$

$\therefore R_A = 144$ KN

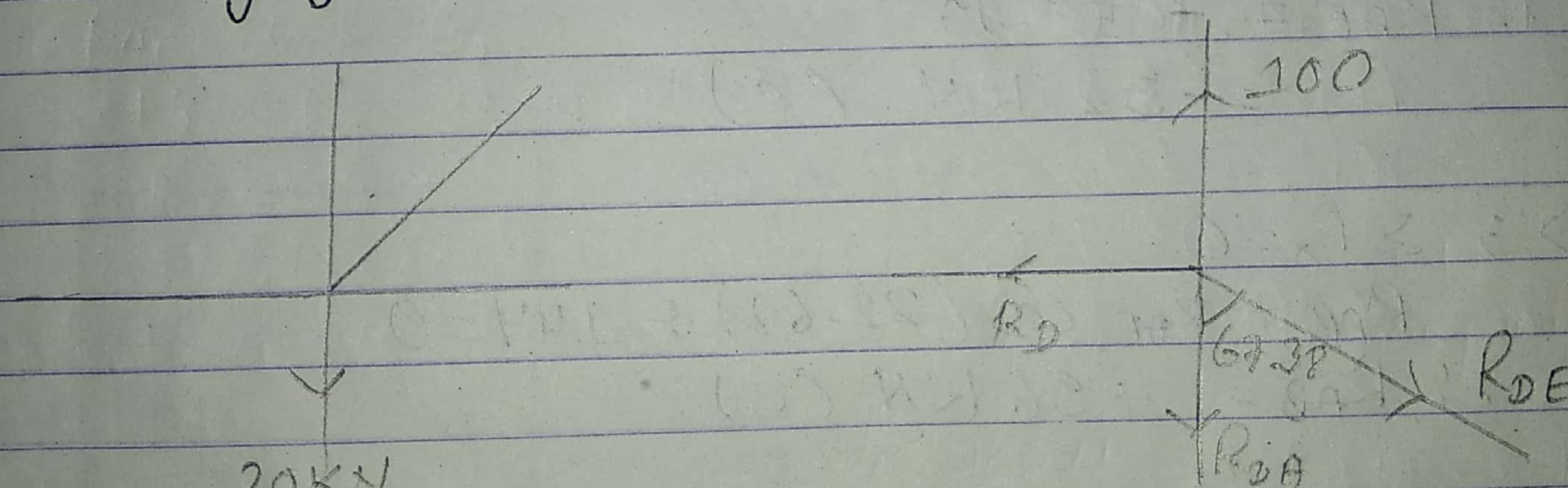
Let θ be the angle,

$\tan\theta = \frac{2.5}{6}$ & $\tan\beta = \left(\frac{6}{2.5}\right)$

$\therefore \theta = 22.62^\circ$ $\therefore \beta = 67.38^\circ$

& $\alpha = \theta = 22.62^\circ$

Taking joint at D



$\uparrow +$; $\Sigma f_y = 0$

$100 - R_{DA} - R_{DE} \cos 67.38 = 0$

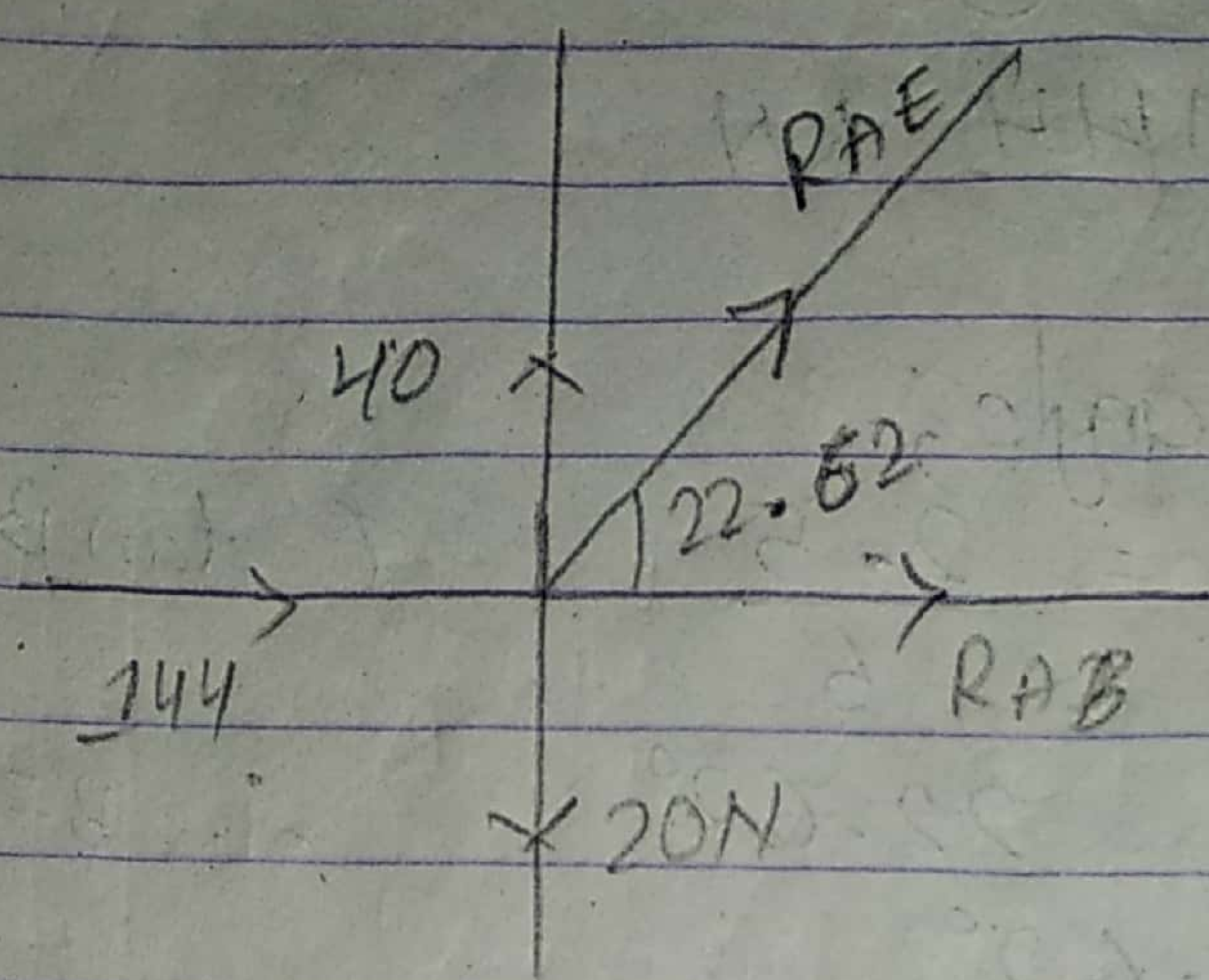
$\therefore R_{DA} = 40$ KN (T)

$\xrightarrow{+}$; $\Sigma f_x = 0$

$-144 + R_{DE} \sin 67.38 = 0$

$\therefore R_{DE} = 156$ (T)

Also, Taking joint at D,



$\uparrow +$; $\Sigma F_y = 0$

$R_{AE} \sin(22.62) + 40 - 20 = 0$

$\therefore R_{AE} = -51.99$

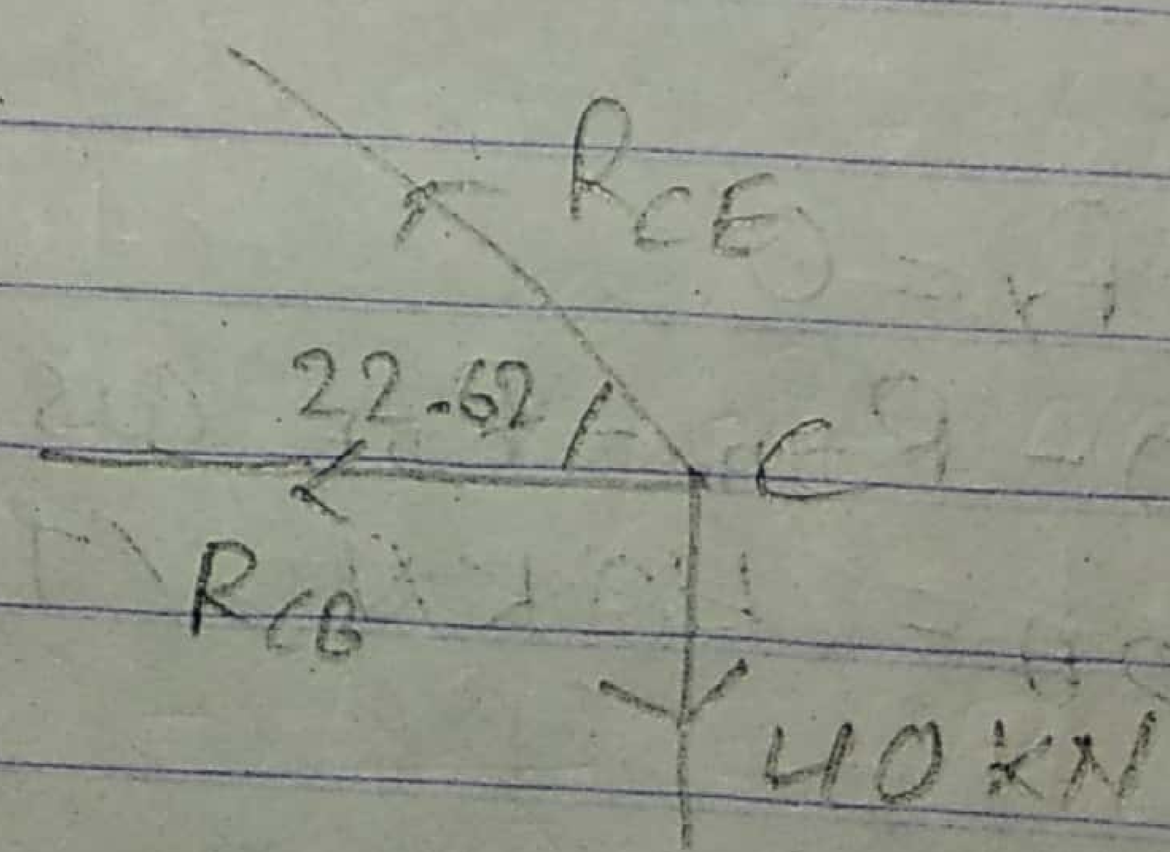
$= -52$ KN (C)

$\overset{+}{\Rightarrow}$; $\Sigma F_x = 0$

$R_{AB} + R_{AE} \cos(22.62) + 144 = 0$

$\therefore R_{AB} = -96$ KN (C)

Taking joint at C,



$\uparrow +$; $\Sigma F_y = 0$

$R_{CE} \sin 22.62 - 40 = 0$

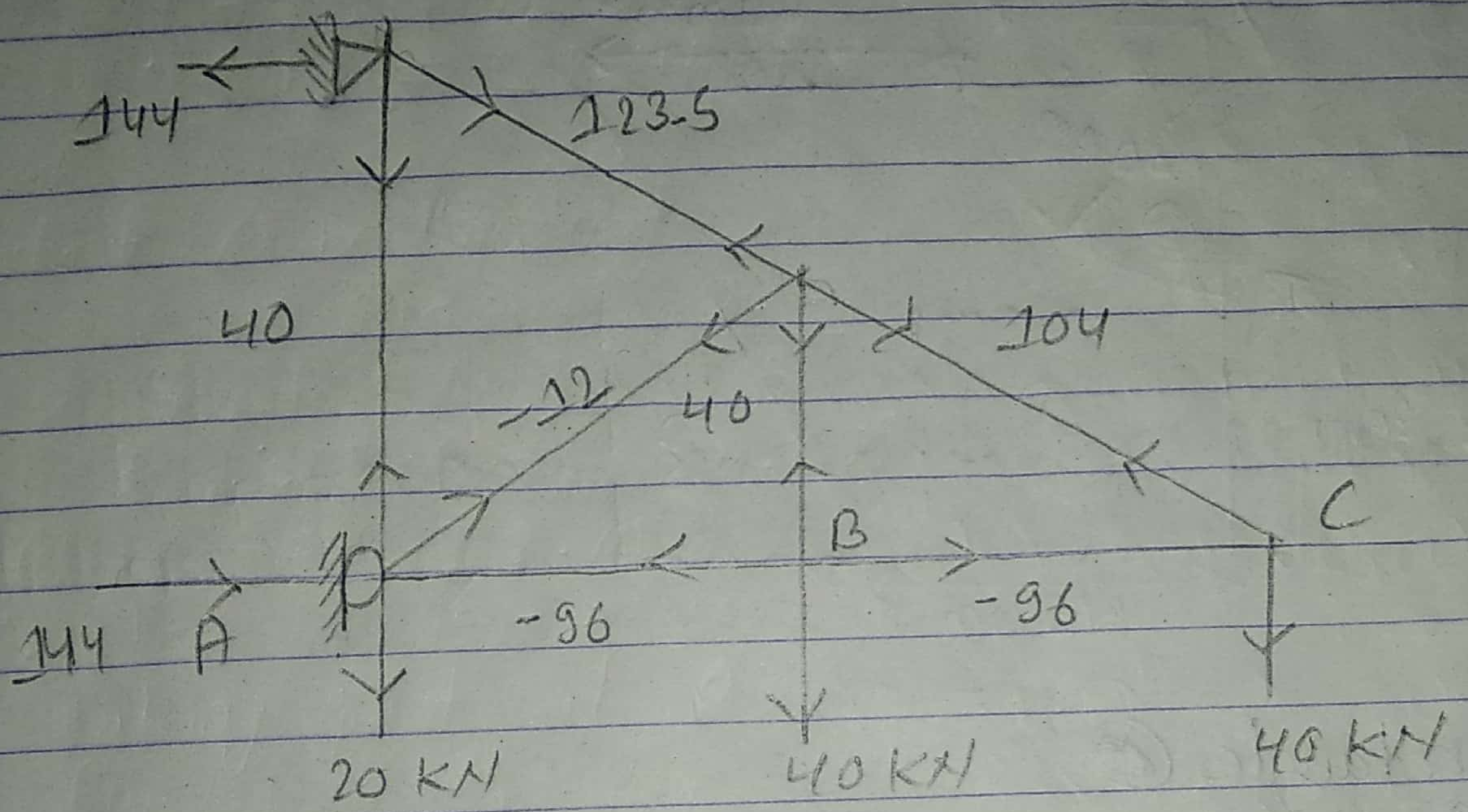
$\therefore R_{CE} = 103.995$

$= 104$ KN (T)

$\overset{+}{\Rightarrow}$; $\Sigma F_x = 0$

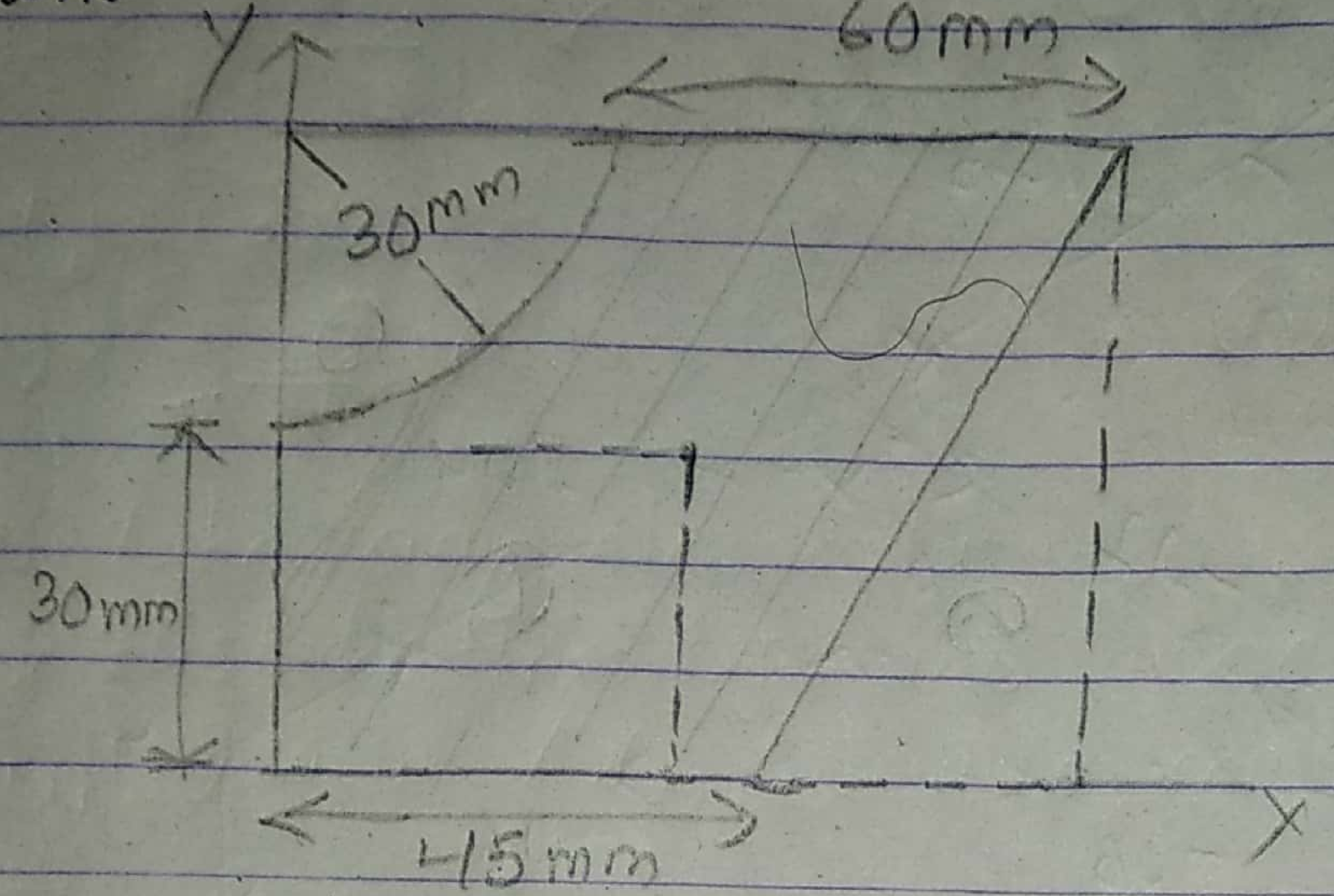
$-R_{CB} - R_{CE} \cos(22.62) = 0$

$\therefore R_{CB} = -96\ KN\ (C)$



Member of force	Magnitude	Nature
1) AB	96	C
2) CB	96	C
3) AD	40	T
4) BE	40	T
5) DE	156	T
6) AE	52	C
7) CE	104	T

3\. a) Find the centroid of the shaded area in fig. shown.



For rectangle ①.

$A_1 = 60 \times 90 = 5400\ mm^2$

$x_1 = \frac{90}{2} = 45\ mm$

$y_1 = \frac{60}{2} = 30\ mm$

For quarter,

$A_2 = \frac{\pi r^2}{4} = \frac{\pi \times (30)^2}{4} = 706.86\ mm^2$

$x_2 = \frac{4r}{3\pi} = \frac{4 \times 30}{3\pi} = 12.73\ mm$

$y_2 = 60 - \frac{4r}{3\pi} = 60 - \frac{4 \times 30}{3\pi} = 47.26\ mm$

For triangle,

$A_3 = \frac{1}{2} \times b \times h = \frac{1}{2} \times 45 \times 60 = 1350\ mm^2$

$$x_3 = 45 + \frac{2b}{3} = 45 + \frac{2}{3} \times 45 = 75$$

$$y_3 = \frac{1}{3} h = \frac{1}{3} \times 60 = 20$$

$$\therefore \quad \bar{x} = \frac{A_1 x_1 - A_2 x_2 - A_3 x_3}{A_1 - A_2 - A_3}$$

$$= \frac{5400 \times 45 - 706.86 \times 12.73 - 1350 \times 75}{5400 - 706.86 - 1350}$$

$$= 39.708 \text{ mm}$$

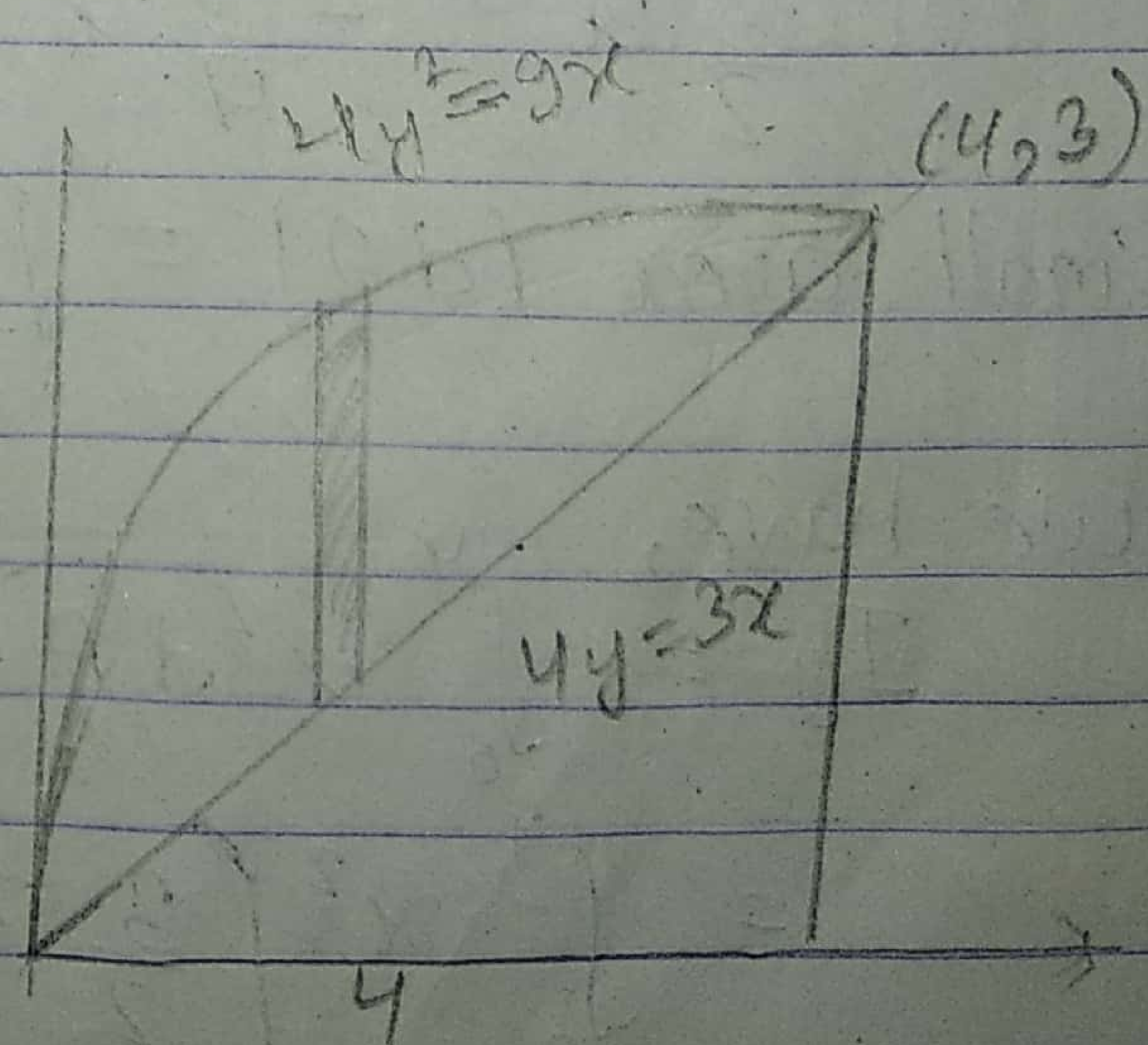
$$\bar{y} = \frac{A_1 y_1 - A_2 y_2 - A_3 y_3}{A_1 - A_2 - A_3}$$

$$= \frac{5400 \times 30 - 706.86 \times 47.26 - 1350 \times 20}{5400 - 706.86 - 1350}$$

$$= 30.387 \text{ mm}$$

$$\therefore (\bar{x}, \bar{y}) = (39.708, 30.387)$$

3.b) Find moment of inertia of geometry.



Solⁿ $4y^2 = 9x$

$y_1 = \frac{3}{2} x^{1/2}$ ------ (i)

& $4y = 3x$

$y_2 = \frac{3}{4} x$ ------ (ii)

Let us take an elementary strip dx which is at 'x' distance from y-axis where end points are (x_1, y_1) and (x_2, y_2) with centroid (x_{el}, y_{el})

$x_1 = x_2 = x_{el} = x$

$y_1 = \frac{3}{2} x^{1/2}$

$y_2 = \frac{3}{4} x$

$y_{el} = \frac{y_1 + y_2}{2} = \frac{\frac{3}{2} x^{1/2} + \frac{3}{4}x}{2} = \frac{3}{4}x^{1/2} + \frac{3}{8}x$

$y = y_1 - y_2$

$= \frac{3}{2} x^{1/2} - \frac{3}{4} x$

Small area $|dA| = \left(\frac{3}{2} x^{1/2} - \frac{3}{4} x\right) dx$

we have,

$I_y = \int_0^4 x^2 dA$

$= \int_0^4 x^2 \left(\frac{3}{2} x^{1/2} - \frac{3}{4} x\right) dx$

$$I_y = \int_0^4 \left(\frac{3}{2} x^{5/2} - \frac{3}{4} x^3\right) dx$$

$$= \left[\frac{3}{2} \frac{x^{7/2}}{7/2} - \frac{3}{4} \cdot \frac{x^4}{4}\right]_0^4$$

$$= \frac{3}{2} \times \frac{2}{7} \times [4]^{7/2} - \frac{3}{4} \times \frac{1}{4} \times (4)^4$$

$$= \frac{48}{7} \text{ linear unit}$$

4

$$I_x = \int_0^4 \frac{y_1^3\, dx}{3} - \int_0^4 \frac{y_2^3}{3} dx$$

$$= \frac{1}{3}\left[\int_0^4 y_1^3\, dx - \int_0^4 y_2^3\, dx\right]$$

$$= \frac{1}{3}\left[\int_0^4 \left(\frac{3}{2} x^{1/2}\right)^3 dx - \int_0^4 \left(\frac{3x}{4}\right)^3 dx\right]$$

$$= \frac{1}{3}\left[\int_0^4 \frac{27}{8} x^{3/2} dx - \int_0^4 \frac{27}{64} x^3\, dx\right]$$

$$= \frac{1}{3}\left[\frac{27}{8} \times \frac{x^{5/2}}{5/2} - \frac{27}{64} \frac{x^4}{4}\right]_0^4$$

$$= \frac{1}{3}\left[\frac{27}{8} \times \frac{2}{5} (4)^{5/2} - \frac{27}{64} \times \frac{1}{4} \times (4)^4\right]$$

$$= \frac{27}{5} \text{ linear unit.}$$

5. a) The motion of a particle is defined by the relation $x = t^3 - 9t^2 + 24t - 8$, where x and t are expressed in meter and second respectively. Determine

i) the time at which velocity is zero

ii) the position and the total distance travelled when acc^n is zero

⇒ Sol^n: Here,

$$x = t^3 - 9t^2 + 24t - 8 \quad \text{------ (1)}$$

$$\text{velocity, } v = \frac{dx}{dt} = 3t^2 - 18t + 24 \quad \text{------ (2)}$$

$$\text{acceleration, } a = \frac{dv}{dt} = 6t - 18 \quad \text{------ (3)}$$

i) ⇒

when $v = 0$, then, $0 = 3t^2 - 18t + 24$

Solving,

$t = 4 \text{ sec}, 2 \text{ sec}$

ii) ⇒ when $a = 0$, then, $0 = 6t - 18$

$\therefore t = 3 \text{ sec}$

When $t = 3$ sec, $x_3 = (3)^3 - 9(3)^2 + 24(3) - 8$

$= 10 \text{ m}$

When $t = 2$ sec, $x_2 = (2)^3 - 9(2)^2 + 24(2) - 8$

$= 12 \text{ m}$

When $t = 0$ sec, $x_0 = (0)^3 - 9(0)^2 + 24(0) - 8$

$= -8 \text{ m}$

∴ Total distance travelled,

$S = |x_3 - x_2| + |x_2 - x_1| + |x_1 - x_0|$

$S = |10 - 12| + |12 - 8| + |8 - (-8)|$

$S = 2 + 4 + 16$

∴ $S = 22$ m #

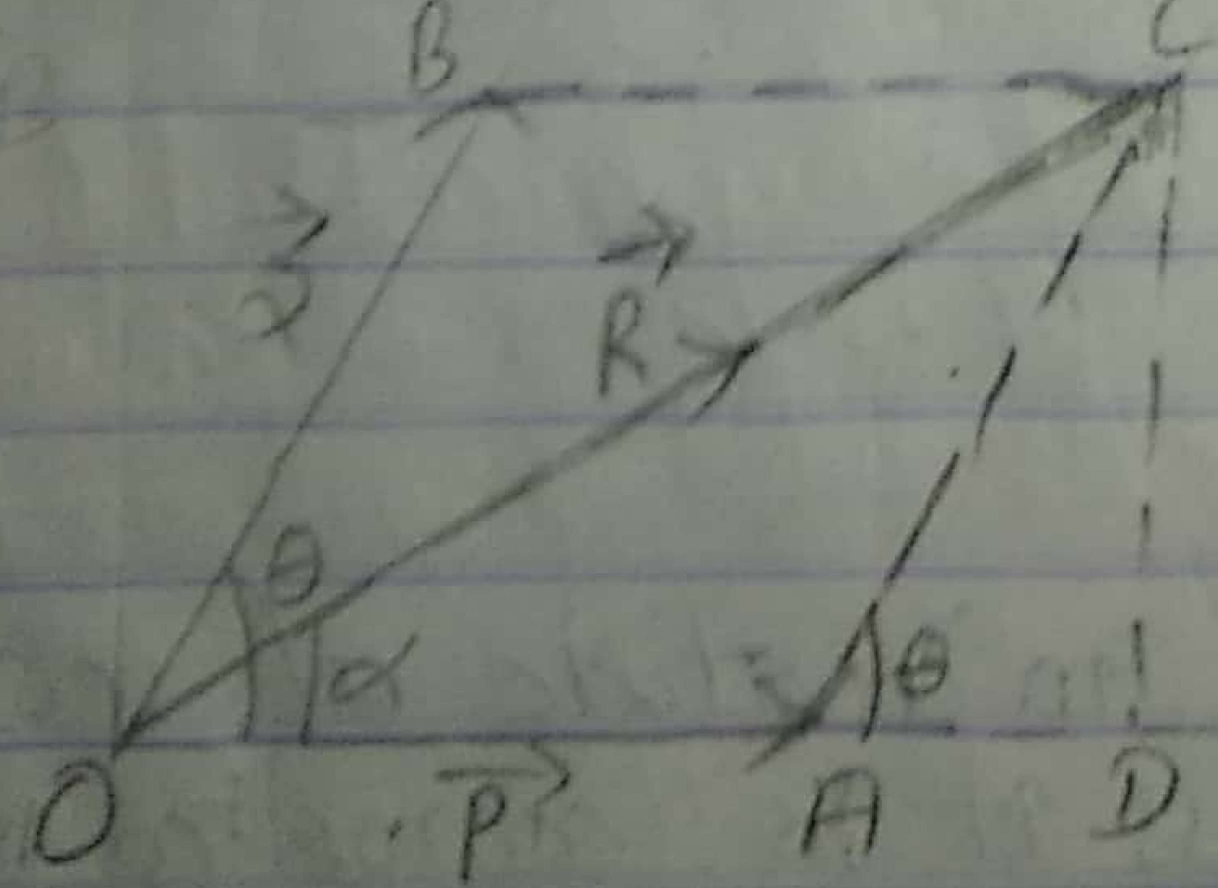
7) Write short notes on.

a) Fundamental Principles of applied mechanics.

⇒ The various principle of applied mechanics are given below:

i) Parallelogram law of vector addition :-

It states that "If two forces acting at a point be represented in magnitude and direction by the two adjacent sides of a parallelogram, then their resultantant is represented in magnitude and direction by the diagonal of the parallelogram, passing through the point.



Let $\vec{P}$ & $\vec{Q}$ be two forces acting on the body at O.

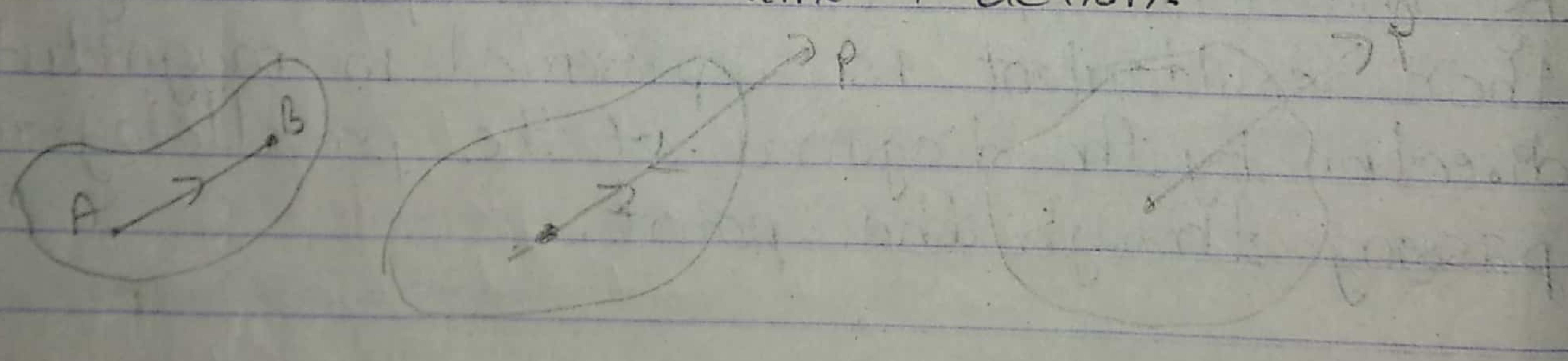
Let θ be the angle between $\vec{P}$ & $\vec{Q}$. If $\vec{R}$ be the resultant force along the diagonal OC which makes angle α with $\vec{P}$, then magnitude of $\vec{R}$ is

$$R = \sqrt{P^2+Q^2+2PQ\cos\theta}$$

$$\alpha = \tan^{-1}\left(\frac{Q\sin\theta}{P+Q\cos\theta}\right)$$

ii) Principle of transmissibility of force :-

It states that, " the condition of equilibrium or of motion of a rigid body will remain unchanged if force acting at a given point of the rigid body is replaced by a force of the same magnitude and same direction but acting at a different point, provided that the two forces have the same line of action."



iii) Newton's law of motion :-

First law :-

Every particle continues in a state of rest or uniform in a straight line unless it is compelled to change that state by force impressed on it.

Second law :-

~~The change of motion is~~ It states that, " Force is equal to the rate of change of momentum.".

Third law :-

It states that, " To every action, there is an equal and opposite reaction. "

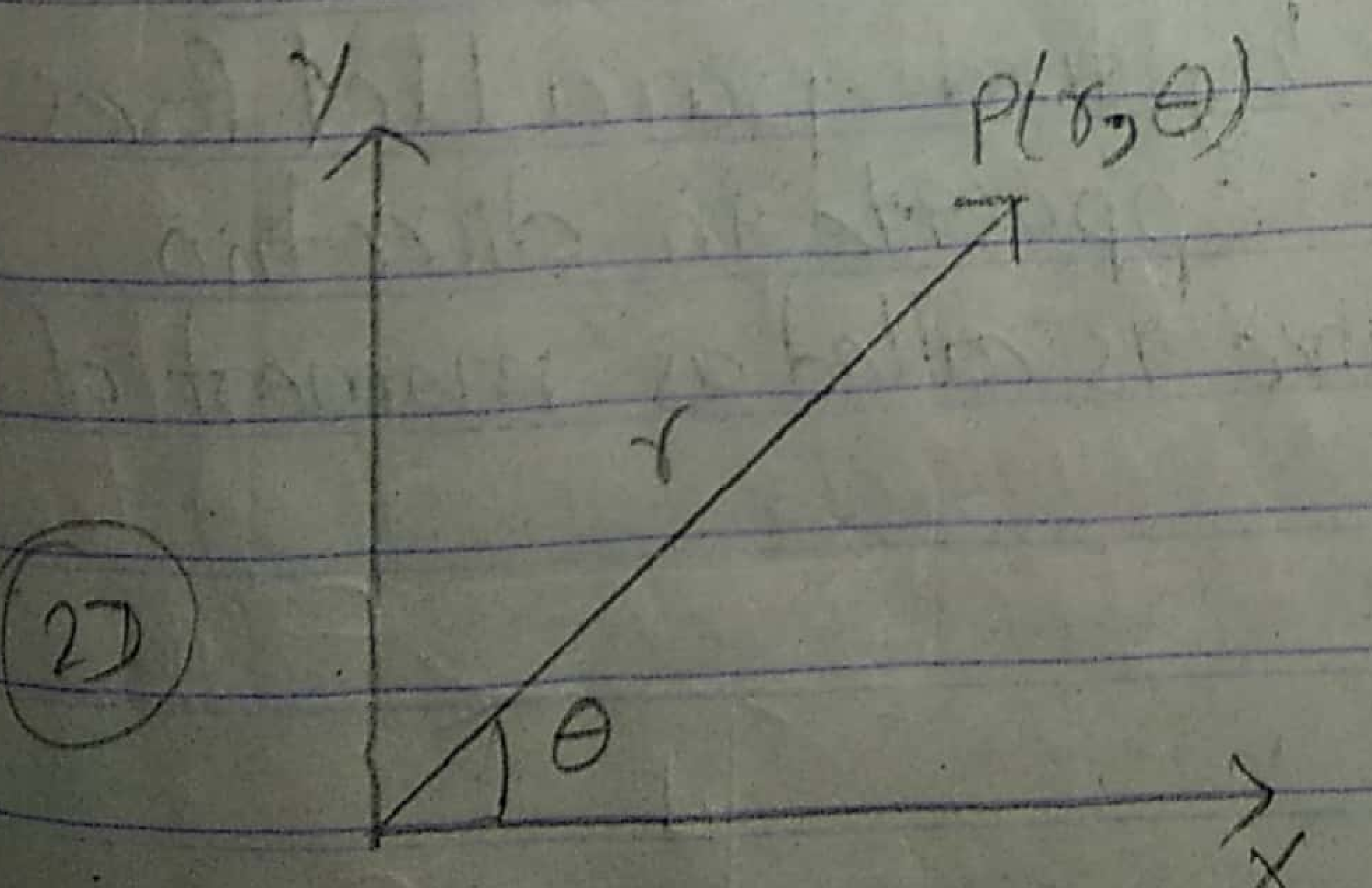
iv) Newton's law of Gravitation :-

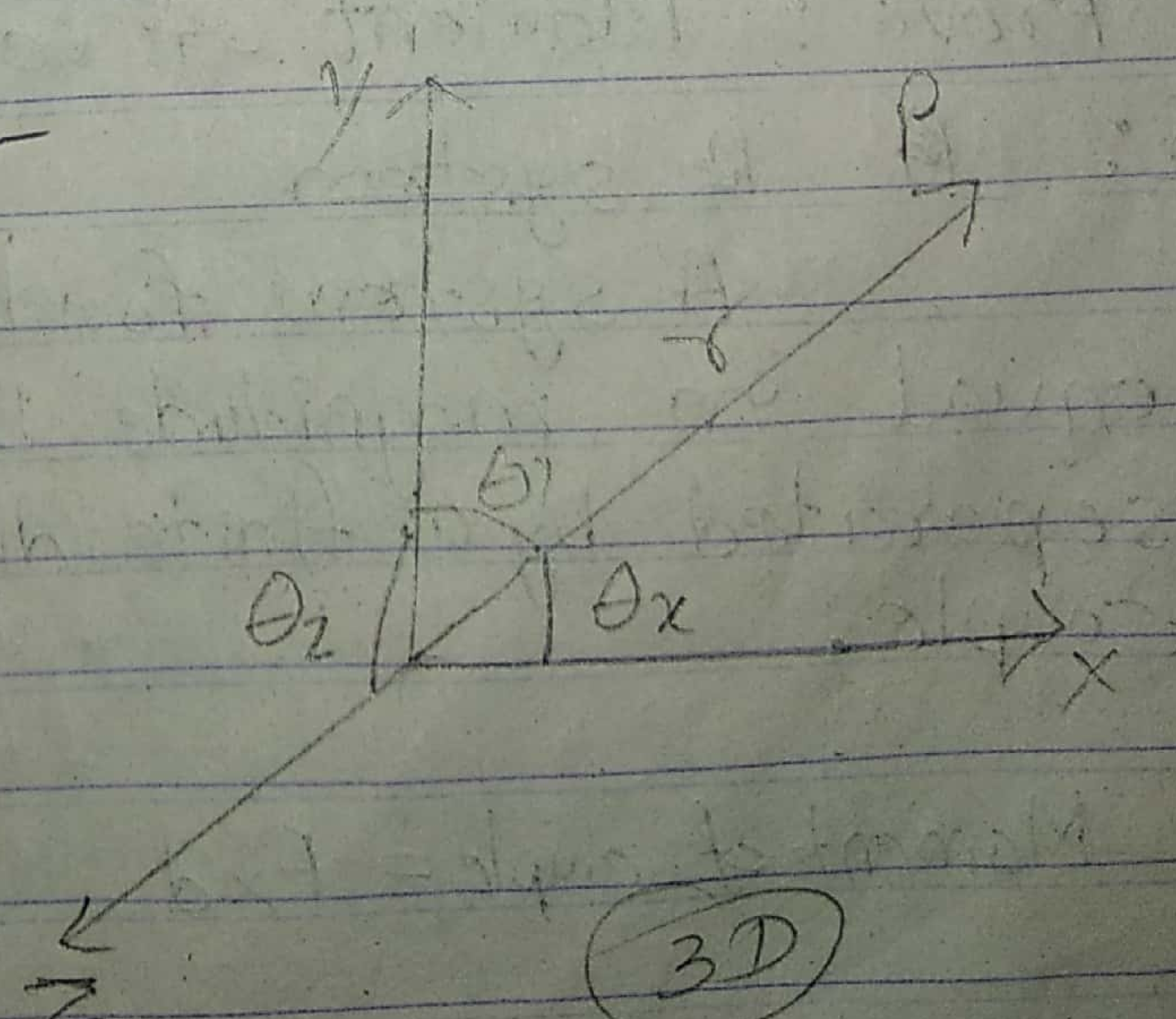
" Two particle are attracted towards each other along the line joining them with force whose magnitude is directly proportional to the product of the masses and inversly proportional to the square of the distance between the particles."

$$F = \frac{G m_1 m_2}{r^2}$$

b) Polar and cartesian coordinate system

• Polar coordinate system :-

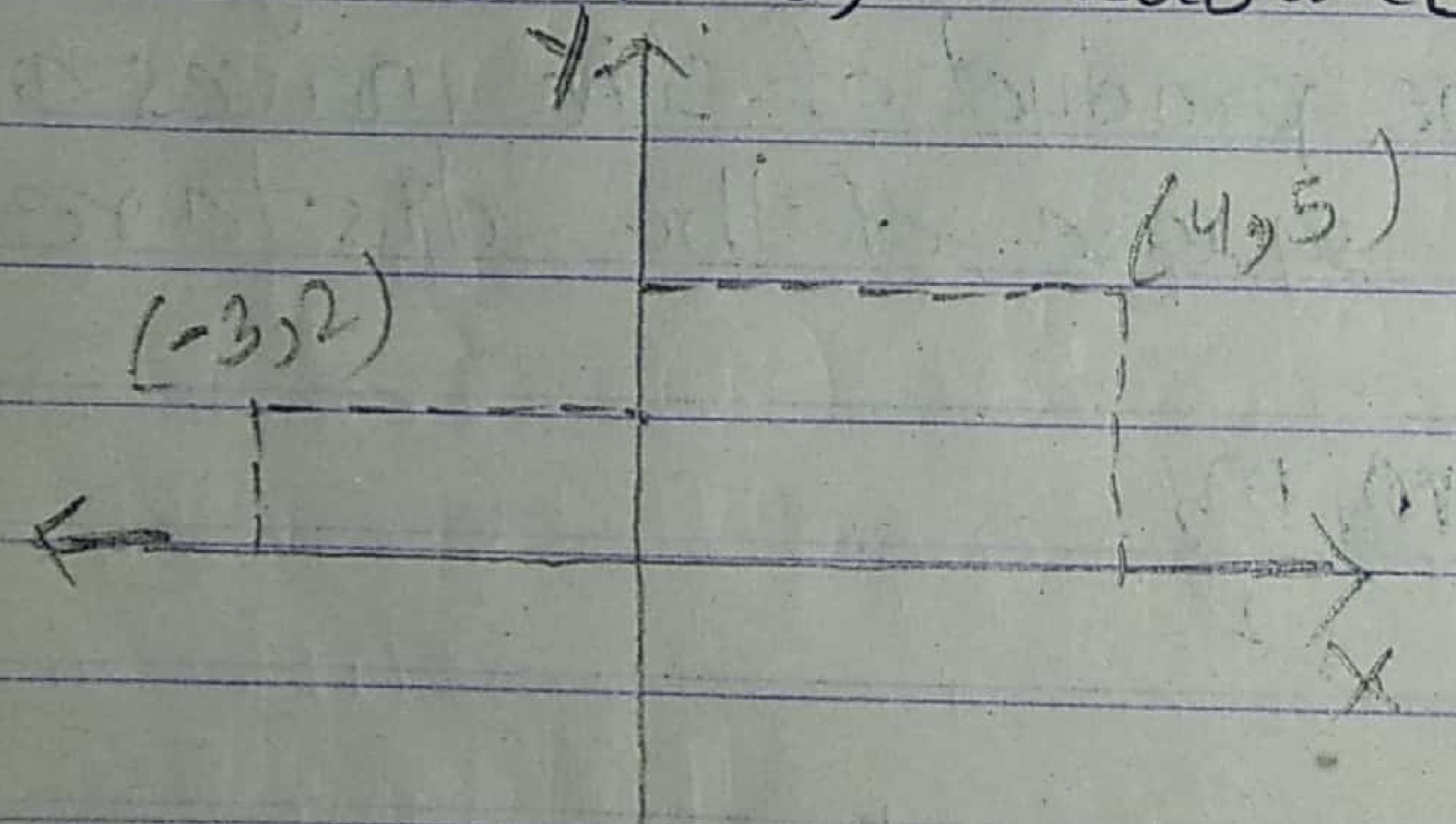




The polar coordinate system is a two dimensional coordinate system in which each point on a point is determined by a distance from a reference point and an angle from a reference direction.

- Cartesian coordinate system

A cartesian coordinate system in a plane is a coordinate system that specifies each point uniquely by a pair of numerical coordinates which are the signed distance to the point from two fixed ⊥r oriented lines, measured in the same unit of length.

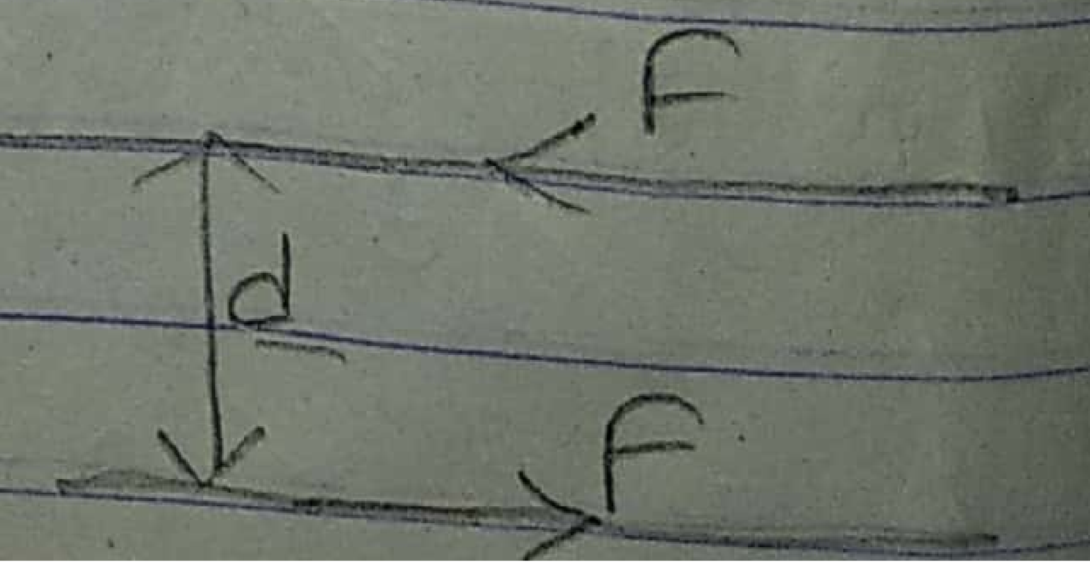


c) Prove: Moment of couple is a 'free vector'

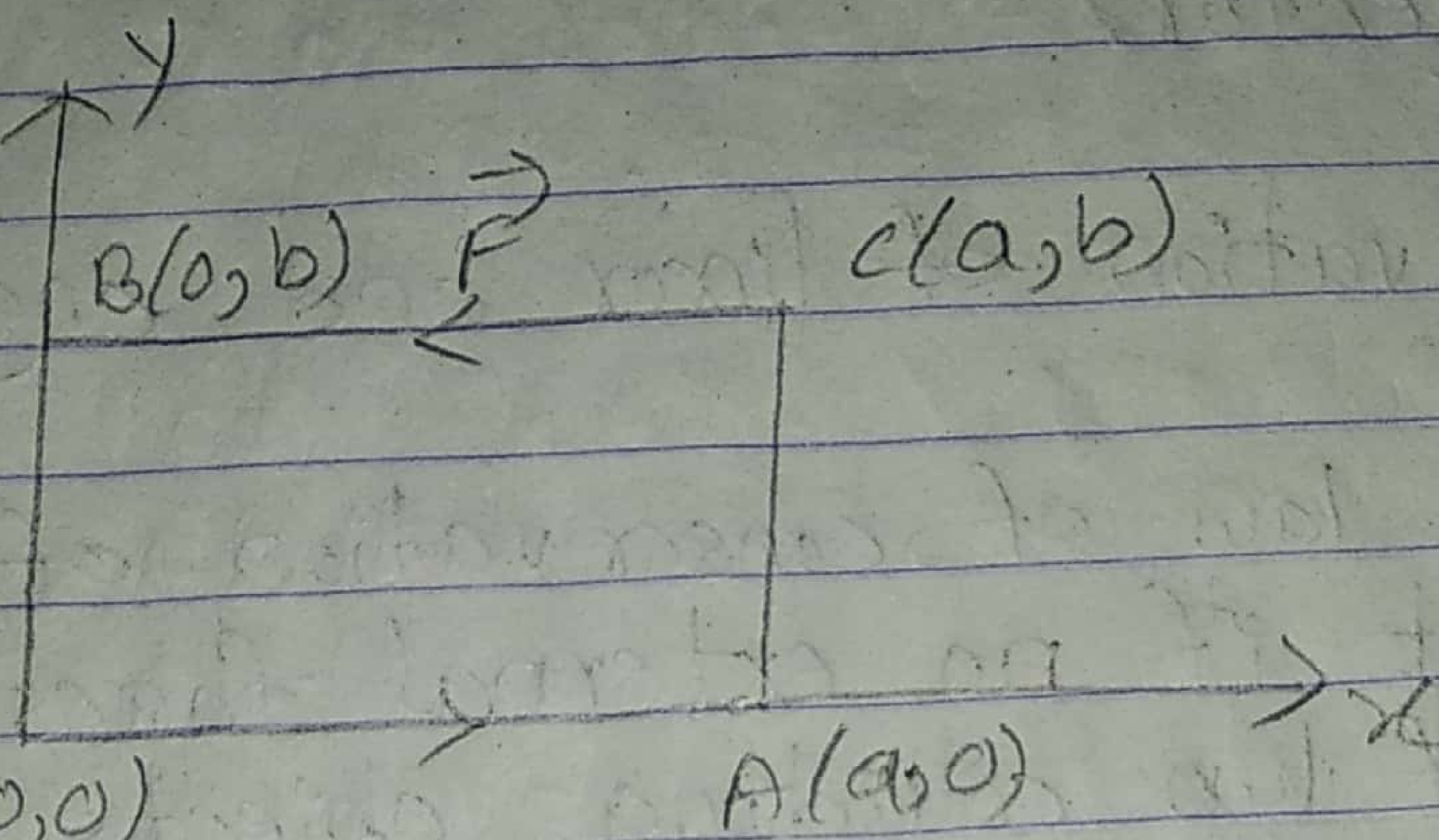
~~Ans~~: ~~A system~~

A system formed by two parallel forces equal in magnitude but opposite in direction separated by a finite distance is called as moment of couple.

Moment of couple = F×d



To show couple is a free vector, we have to show, moment of couple about any point will be same.



Consider a couple as shown in fig. acting on a xy-plane. The couple is acting on a rectangular element of length 'a' and breadth 'b'.

Taking moment about O,

$$\vec{M_o} = \vec{r_{OB}} \times -F\hat{i}$$
$$= [(0,b) - (0,0)] \times -F\hat{i}$$
$$= b\hat{j} \times -F\hat{i}$$
$$= bF\hat{k}$$

Taking moment about A,

$$\vec{M_A} = \vec{r_{AC}} \times \vec{F}$$
$$= \{(a,b) - (a,0)\} \times \{-F\hat{i}\}$$
$$= (a\hat{i} - b\hat{j}) \times (-F\hat{i})$$
$$= bF\hat{k}$$

Taking moment about B,

$$\vec{M_B} = \vec{r_{BO}} \times F\hat{i}$$
$$= \{(0,0) - (0,b)\} \times F\hat{i}$$
$$= -b\hat{j} \times F\hat{i} \Rightarrow bF\hat{k}$$

Since, $\vec{M_o} = \vec{M_A} = \vec{M_B}$
It is proved that moment of couple is a free vector.

d) Conservation of linear and angular momentum.
$\Rightarrow$

The law of conservation of linear momentum states that if no external forces act on the system of two colliding objects than the vector sum of the linear momentum of each body remains constant and is not affected by their mutual interaction.

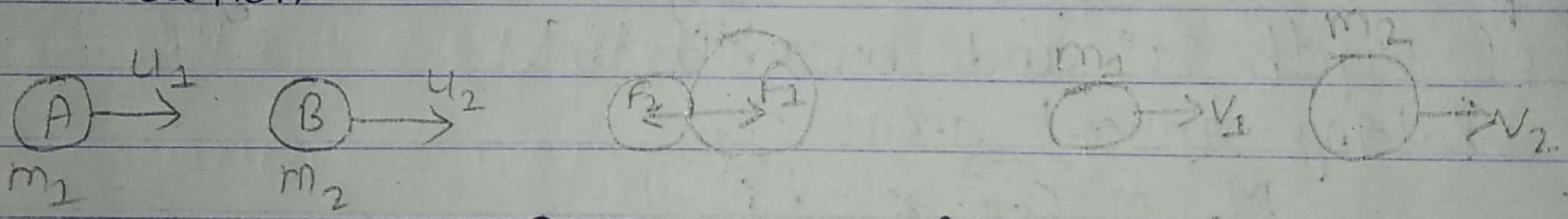


Fig. Collision of two spheres.

Mathematically,

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

which shows that total momentum before collision is equal to the total momentum after collision if no external forces ~~at~~ act on them.

The law of conservation of angular momentum states that if no external torque acts on a system, the total angular momentum of the system remains conserved.

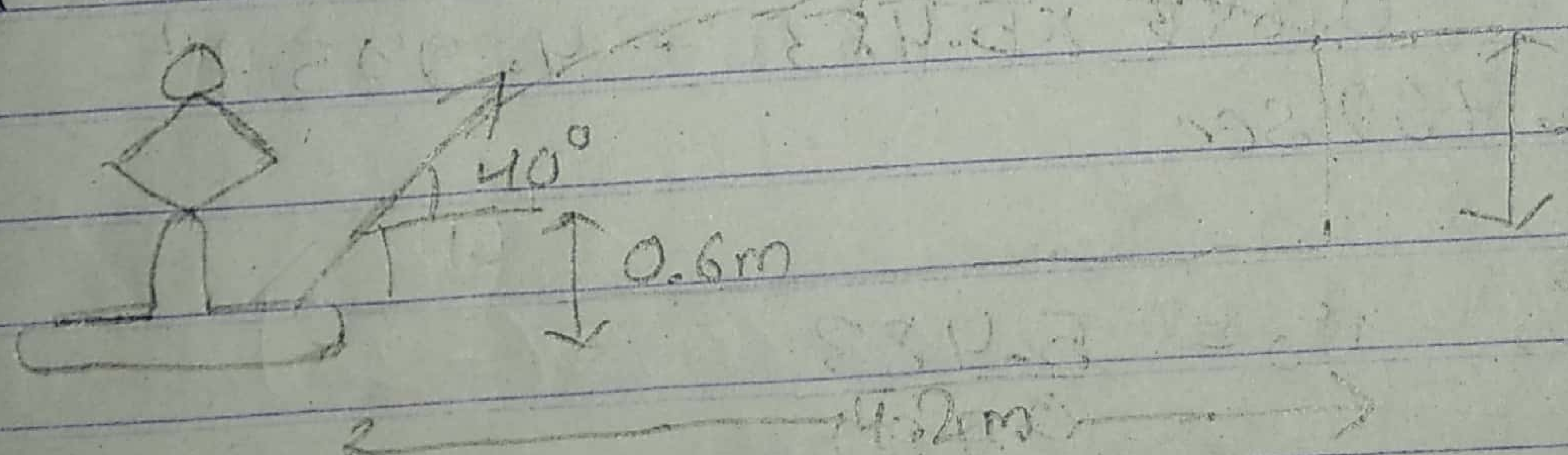
If I be the moment of inertia of a body about a given axis of rotation and ω, its angular velocity then,

$$I\omega = \text{constant}$$

which is the principle of conservation of angular momentum.

In general, $I_1\omega_1 = I_2\omega_2$

5. b) A homeowner uses a snowblower to clean his driveway. Knowing that the snow is dischaged at an average angle of 40° with the ~~ho~~ horizontal, determine the initial velocity v_0 of the snow.



Sol^n →

motion along x-axis $\xrightarrow{+}$

displacement, $S_x = 4.2\,m$

initial velocity, $u_x = u_0 \cos\theta$

$= 0.766$

acceleration $a_x = 0$

we have,

$$S_x = u_x t + \frac{1}{2} a_x t^2$$

b. We have,

$$S_x = u_x t + \frac{1}{2} a_x t^2$$

$$4.2 = 0.766\, u_o t$$

$$\therefore \quad u_o t = 5.483 \quad \text{------} \quad (i)$$

motion along Y-axis, $\uparrow +$;

displacement, $S_y = 1.05 - 0.6$

$$= 0.45\ m$$

initial velocity, $u_y = u_o \sin 40° = 0.643\, u_o$

acceleration $(a_y) = -9.81\ m/sec^2$

Now,

$$S_y = u_y t + \tfrac{1}{2} a_y t^2$$

$$0.45 = 0.643\, u_o t + \frac{1}{2}(-9.81) t^2$$

$$0.45 = 0.643 \times 5.483 - 4.905\, t^2$$

$$\therefore \quad t = 0.792\ sec$$

from eq^n (i), $\quad v_o = \dfrac{5.483}{0.792}$

$$\therefore \quad v_o = 6.922\ m/sec \quad \#$$

6. a) Rod OA rotates about O in horizontal plane. The motion of the 300 g collar B is defined by the relations $r_2 = [300 + 100 \cos(0.5\pi t)]$ and $\theta = \pi(t^2 - 3t)$ where r is expressed in mm, t in second and θ in radians. Determine the radial

and transverse component of the force exerted on the collar when (a) $t = 0$, (b) $t = 0.5$ sec.

Sol^n $\Rightarrow$ Given,

~~$r = [300 + 100 \cos($~~

$$\text{mass } (m) = 300\ g = 0.3\ kg$$
$$r = [300 + 100 \cos(0.5\pi t)]$$
$$\theta = \pi(t^2 - 3t)$$

we have,

	At $t = 0$ sec	At $t = 0.5$ sec
$r = 300 + 100\cos(0.5\pi t)$	400	370.71
$\dot{r} = -50\pi \sin(0.5\pi t)$	0	−111.07
$\ddot{r} = -25\pi^2 \cos(0.5\pi t)$	−246.74	−174.47
$\theta = \pi(t^2 - 3t)$	0	−1.25π
$\dot{\theta} = \pi(2t - 3)$	−3π	−2π
$\ddot{\theta} = 2\pi$	2π	2π

At $t = 0$,

$$a_r = \ddot{r} - r\dot{\theta}^2$$
$$= -246.74 - 400 \times (-3\pi)^2$$
$$= -35777.39\ mm\,s^{-2}$$
$$= -35.77\ m\,s^{-2}$$

$$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}$$
$$= 400(-2\pi) + 2\times(0)\cdot(-3\pi)$$
$$= 2513.27\ mm\,s^{-2}$$
$$= 2.513\ ms^{-2}$$

$$F_r = m\times a_r = 0.3\times(-35.777)$$
$$= -10.73\ N$$
$$F_\theta = m\times a_\theta = 0.3\times(2.513)$$
$$= 0.7539\ N$$

At $t = 0.5\,s$,

$$a_r = \ddot{r} - r\dot{\theta}^2$$
$$= -174.47 - 370.71\times(-2\pi^2)$$
$$= -14809.51\ mms^{-2}$$
$$= -14.809\ ms^{-2}$$

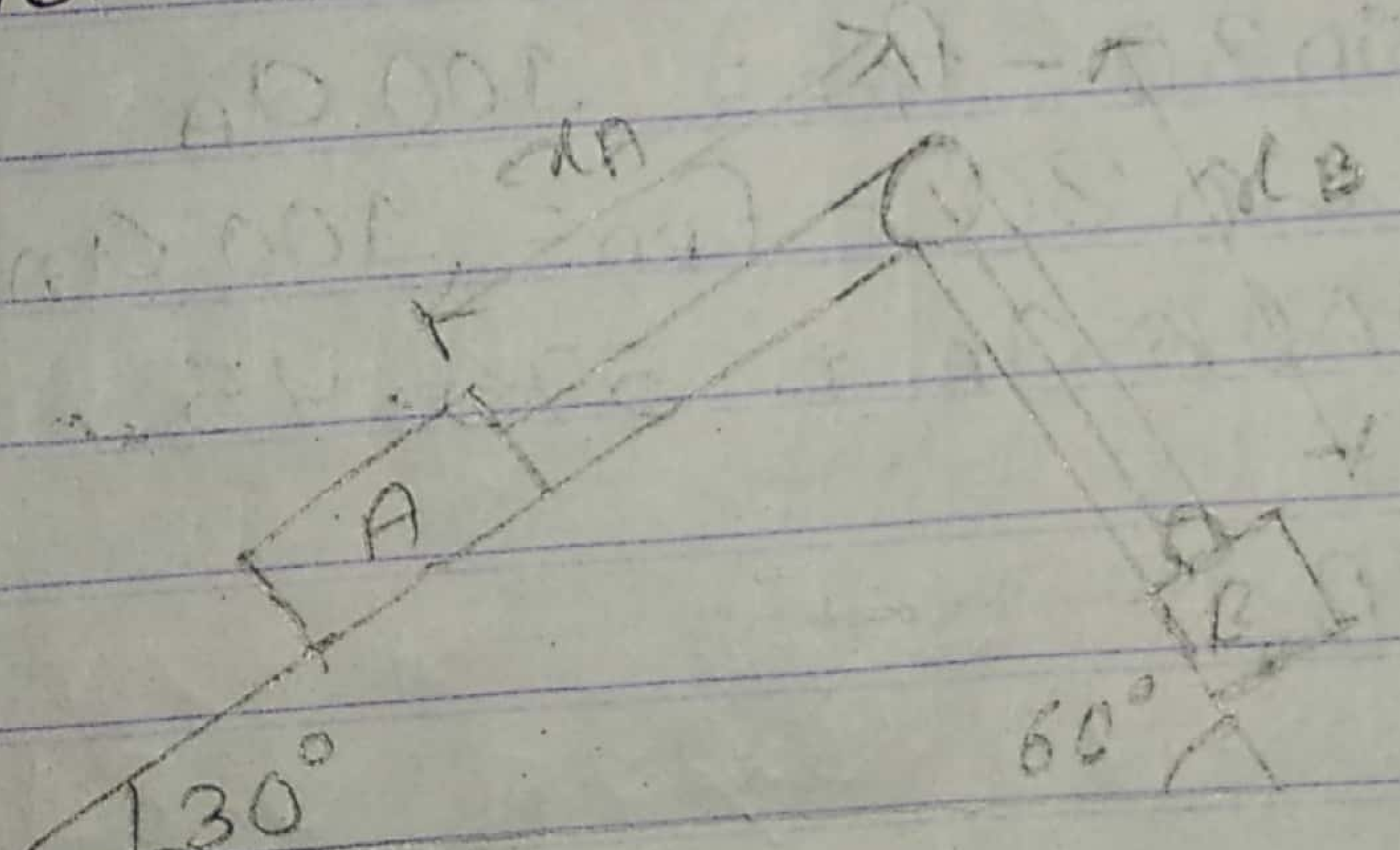
$$\cancel{a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}}$$
$$\cancel{= 400(-2\pi) + 2\times(0)\cdot(-3\pi)}$$
$$\cancel{= 2513.27\ mms^{-2}}$$
$$\cancel{= 2.513\ m\,s^{-2}}$$

$$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}$$
$$= 370.71(2\pi) + 2(-111.07)(-2\pi)$$
$$= 3724.98\ mms^{-2}$$
$$= 3.724\ ms^{-2}$$

$F_r = ma_r = 0.3 \times (-14.809)$
$= -4.442\,N$

$F_\theta = ma_\theta = 0.3 \times (3.724)$
$= 1.1172\,N$

6.b) The two block ($m_A = 100$ kg, $m_B = 150$ kg) shown are originally at rest. Assuming that the coefficient of friction between the blocks and the inclines are $\mu_s = 0.25$ and $\mu_k = 0.20$. determine:
i) acceleration of block A
ii) tension in the cord



Sol^n ⇒

From Kinematics,
length of rope is constant

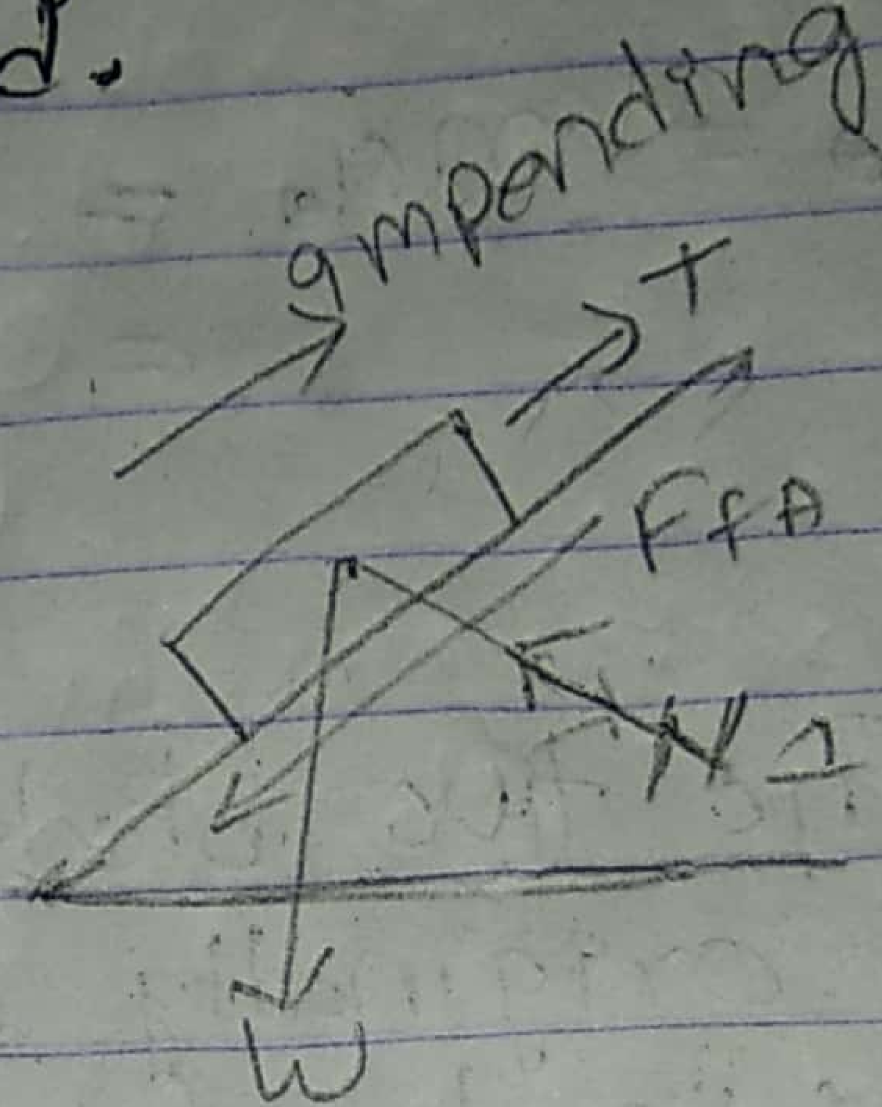
i.e.
$x_A + 2x_B = \text{constant}$
Diff. both sides twice w.r.to t,
$a_A + 2a_B = 0$

$a_A = -2a_B$

i.e. $a_A = 2a_B$ in magnitude opposite in direction in second.

Now,

FBD of block A,



$\uparrow +$; $\Sigma F_y = m a_y$

$N_1 - W \cos 30 = 0$

$\therefore N_1 = 849.57$ N

$F_{fA} = \mu_s . N_1 = 0.1 \times 849.57$ N $= 84.93$ N

Now,

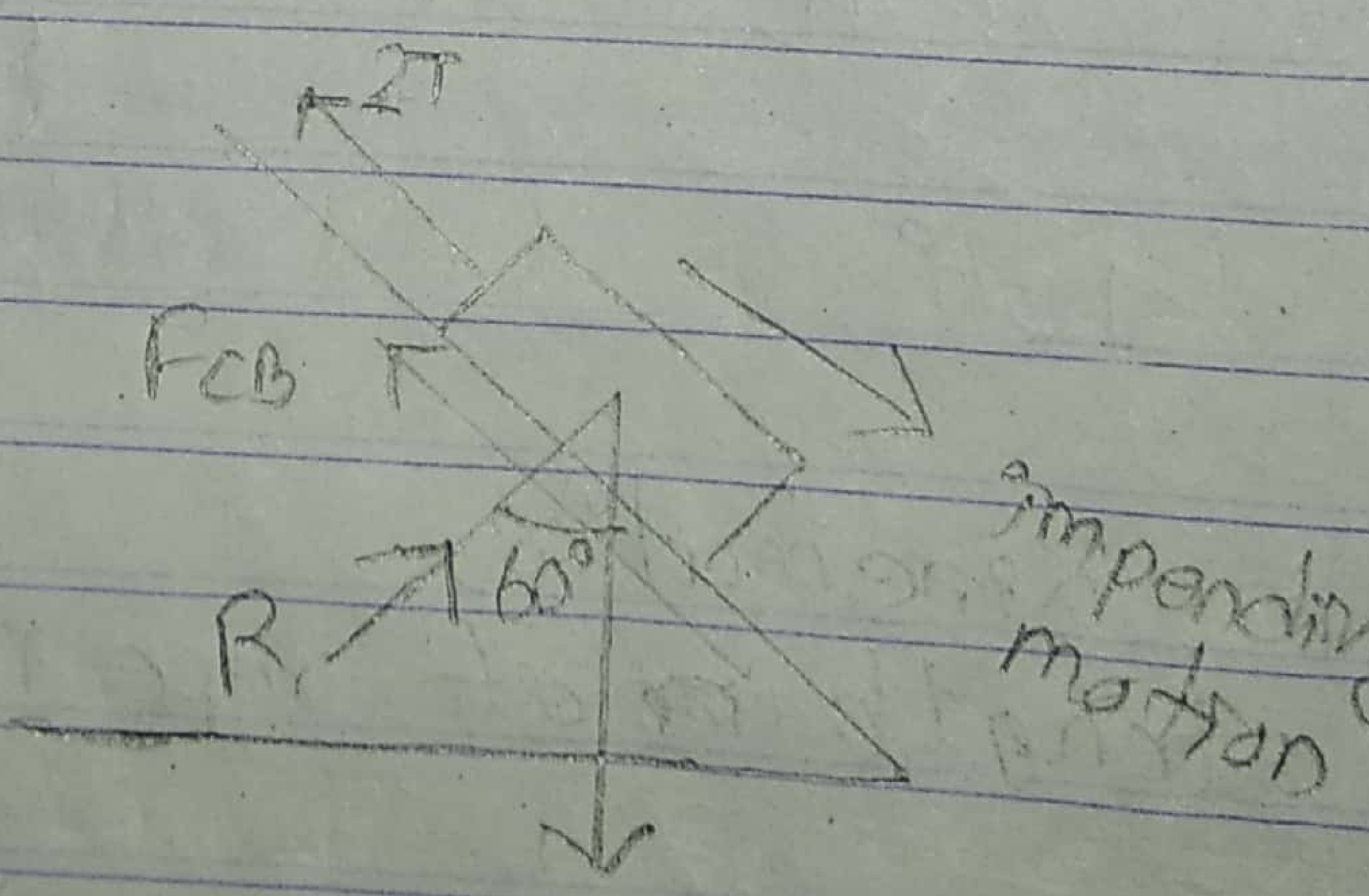
$+\nearrow$; $\Sigma F_x = m a_x$

$T - W \sin 30 - f_{fA} = 100 a_A$

$T - 981 \sin 30 - F_{fA} = 100 a_A$

$\therefore T = 100 a_A + 575.45$

FBD of block B,



$+\uparrow$; $\Sigma F_y = m a_y$ $\quad (\because a_y = 0)$

$R - W \cos 60 = 0$

$R = 735.75$ N

$F_{FB} = \mu_R R = 73.575 N$

$\overset{+}{\searrow}$; $\Sigma f_x = ma_x$

$W \sin 60° - 27 - F_{FB} = ma_B$

$2T = 1200.78 - 150 a_B$

$T = 600.39 - 75 a_B$

Now,

$600.39 - 75 a_B = 100 a_A + 573.45$

$600.39 - 575.45 = 100 a_A + 175 a_B$

$24.94 = 275 a_B$

$\therefore a_B = 0.0906 m/s^2$

and

$a_A = 0.1813 m/s^2$

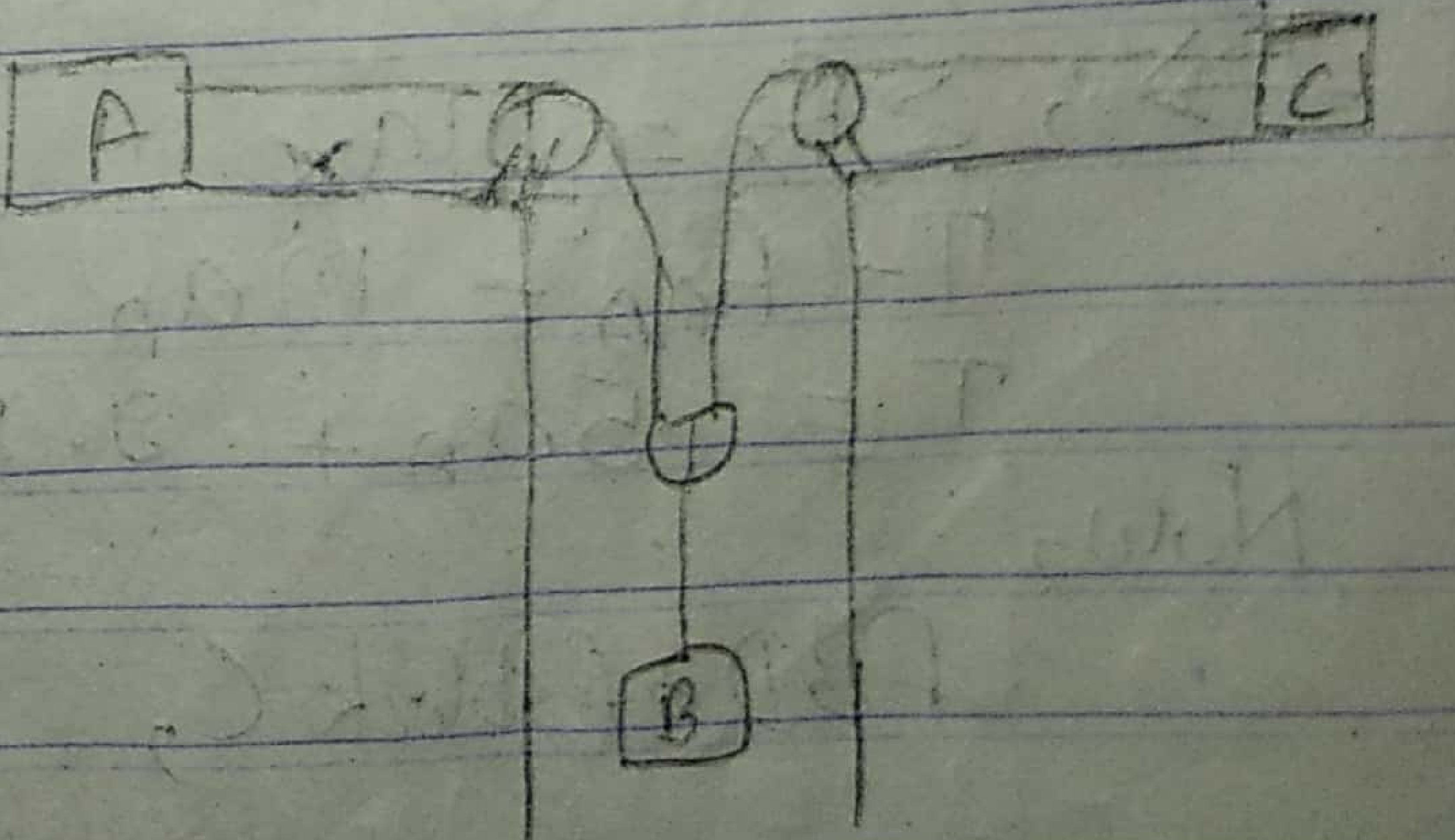
Hence, $T = 593.58 N$ #

6.6) OR

The coefficient of friction between block A and C and horizontal surfaces are $\mu_s = 0.24$ and $\mu_k = 0.2$. Knowing that $m_A = 5kg$, $m_B = 10kg$ and $m_C = 10 kg$. Determine.

i) The tension in the cord

ii) The acc^n of each block.



Sol^n ⟹ From Kinematics, length of rope is constant.

$$x_A + 2x_B + x_C = \text{constant} \quad \text{---} \text{(i)}$$

Diff. eq^n (i) twice w.r.to t,

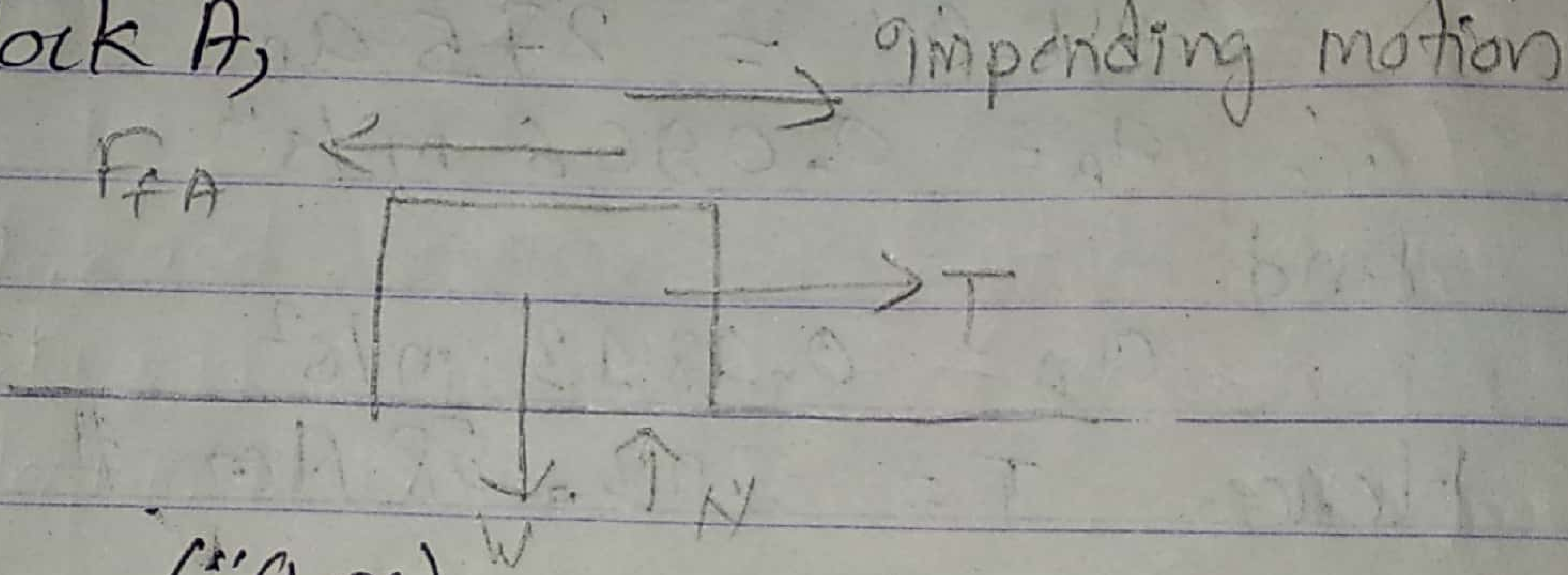
$$a_A + 2a_B + a_C = 0$$

$$2a_B = -(a_A + a_C)$$

Then, $2a_B = (a_A + a_C)$ in magnitude but opposite in dir^n in sense.

From kinetics,

FBD of block A,



$\uparrow +$; $\Sigma F_y = ma_y \quad (\because a_y = 0)$

$$-W + N_2 = 0$$

$$N_1 = W$$

$$N_1 = 49.05$$

$$F_{fA} = \mu \times N_1 = 0.2 \times 49.05 = 9.81\ N$$

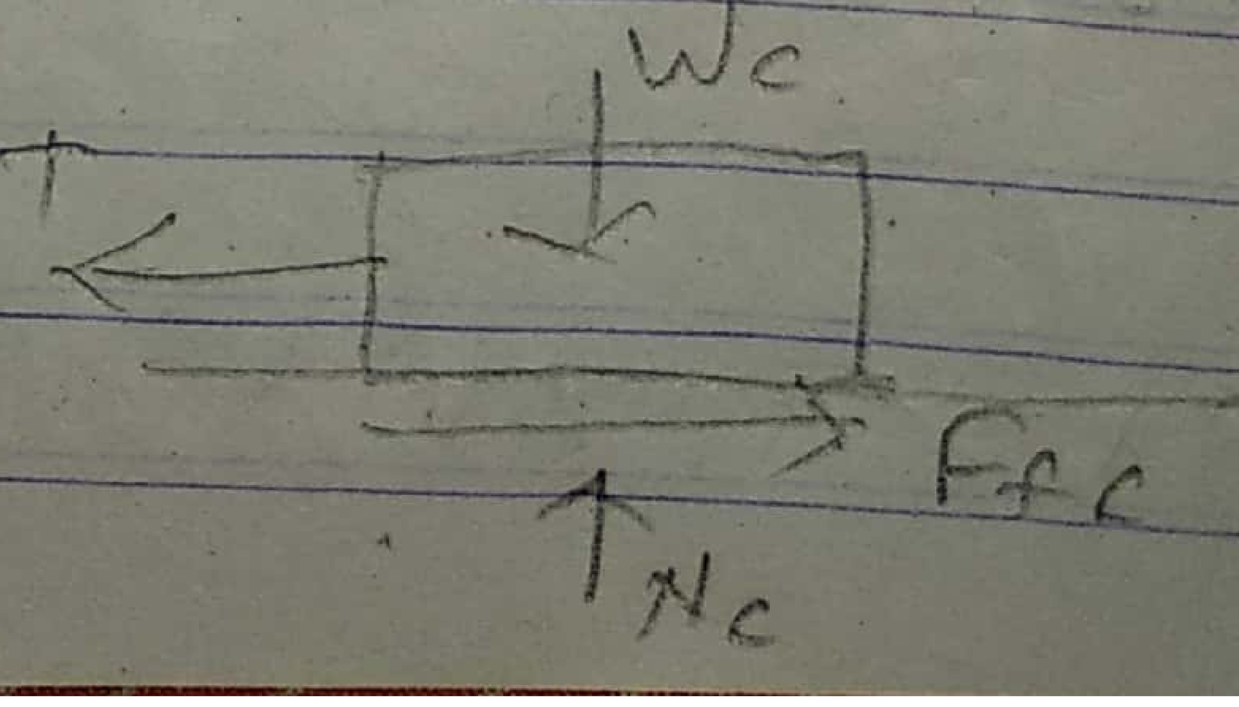
$\overset{+}{\rightarrow}$; $\Sigma F_x = ma_x$

$$T - F_{fA} = ma_A$$

$$T = 5a_A + 9.81 \quad \text{---} \text{(ii)}$$

Now,

FBD of block C,



$\uparrow +;\ \Sigma F_y = m a_y$

$N_c - W_c = 0$

$N_c = W_c$

$N_c = 98.1\ N$

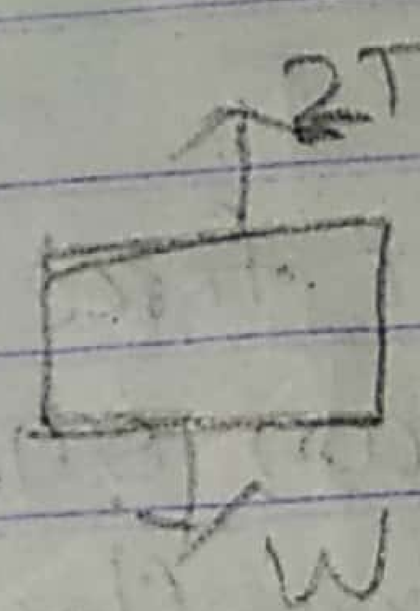
$F_{fc} = \mu_k \times N_c = 19.62\ N$

$\overset{+}{\leftarrow};\ \Sigma F_x = m a_x$

$T - F_{fc} = m a_c$

$T = 10 a_c + 19.62$ ——— (iii)

FBD of block B,



$\uparrow +;\ \Sigma F_y = m a_y$

$-2T + W_B = m a_y$

$2T = 98.1 - 10 a_B$

$T = 49.05 - 5 a_B$ ——— (iv)

solving (iii) & (iv)

$10 a_c + 19.62 = 49.05 - 5 a_B$

$10 a_c + 5 a_B = 29.43$

$a_B = 5.886 - 2 a_c$

Again, from (ii) and (iii)

$5 a_A + 9.81 = 10 a_c + 19.62$

$5 a_A - 10 a_c = 9.81$

$a_A = 1.962 + 2 a_c$

Then from eqn (1)

$$2(5.886 - 2a_c) = \cancel{19.62}\ 1.962 + 2a_c + a_c$$

$$11.772 - 4a_c = 1.962 + 3a_c$$

$$a_c = 1.40\ m/s^2$$

Hence,

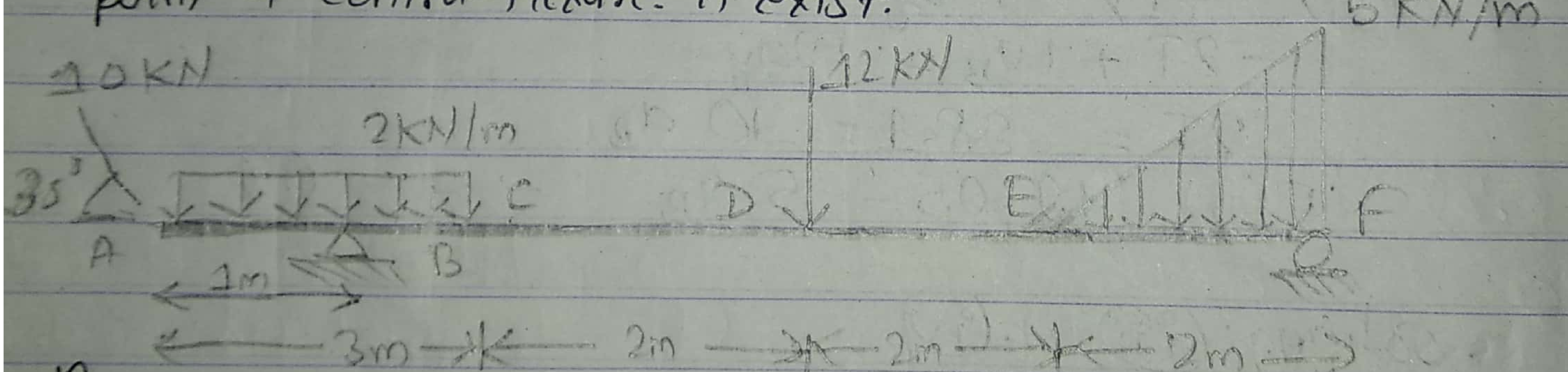
$$a_B = 3.08\ m/s^2$$

$$a_A = 4.762\ m/s^2$$

$$T = 10\,a_c + 19.62$$

$$= 33.62\ N$$

4. Draw shear force and bending moment diagram of the given beam shown. Also find point of zero shear and point of contra-flexure if exist.



Soln

Calculation of support reaction,

$\xrightarrow{+}$; $\Sigma f_x = 0$

$$10\cos 30^\circ - H_B = 0$$

$\therefore$ $H_B = 10 \times 0.866 = 8.66\ kN$ ($\leftarrow$)

$\circlearrowleft +$; $\Sigma M_B = 0$

$$-10\sin 30^\circ \times 1 - (2\times 1)\times \tfrac{1}{2} + (2\times 2) + (12\times 4) + \left(\tfrac{1}{2}\times 2\times 5\right)\times\left(6 + \tfrac{2}{3}\times 2\right) - V_F \times 8 = 0$$

or, $-5-1+4+48+\frac{110}{3}-8V_F=0$
$\therefore V_F = 10.33\ KN$

$\uparrow +;\ \Sigma F_y = 0$
$V_B + V_F - (10\sin 30°) - (2\times3) - 12 - (\frac{1}{2}\times2\times5) = 0$
$V_B + 10.33 - (10\sin 30) - (2\times3) - 12 - (\frac{1}{2}\times2\times5) = 0$
$\therefore V_B = 17.67\ KN$

Calculation of SF ($\uparrow + \downarrow$)
($\uparrow +$; calculate from left)
Let us take an arbitrary section X_1X_2 at a distance 'x' rightward from E.
intensity of load at X_1X_2 be h
from similar triangle, $\frac{h}{5} = \frac{x}{2}$

$\therefore h = 2.5x$

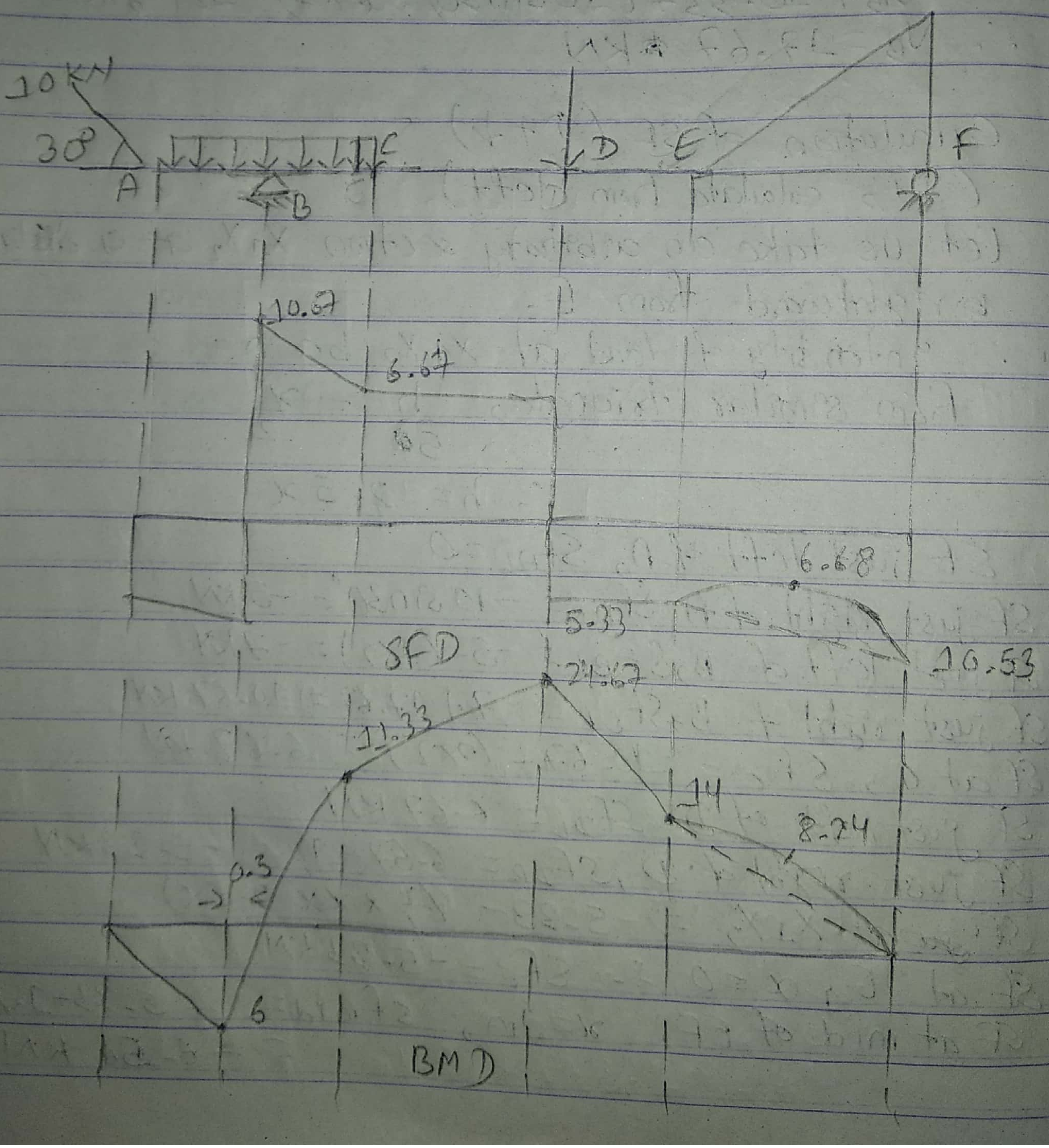
SF just left of A, $SF_{AL} = 0$
SF just right of A, $SF_{AR} = -10\sin 30° = -5\ KN$
SF just left of B, $SF_{BL} = -5-(1\times2) = -7\ KN$
SF just right of B, $SF_{BR} = -7+17.67 = 10.67\ KN$
SF just right of B, $= 10.67-(2\times2) = 6.67\ KN$
SF at C, $SF_C = 10.67-(2\times2) = 6.67\ KN$
SF just left of D, $SF_{DL} = 6.67\ KN$
SF just right of D, $SF_{DR} = 6.67-12 = -5.33\ KN$
SF at $X_1X_2 = -5.33 - (\frac{1}{2}\times x\times 2.5x)$
SF at E, $x=0$ $\therefore SF_E = -5.33\ KN$
SF at mid of EF, $x=1m$, $sf_{mid} = -5.33-1.25$
$= -6.58\ KN$

SF just left of F, $x = 2m$

$SF_{FL} = -5.33 - 5 = 10.33\ KN$

SF just right of F, $SF_{FR} = -10.33 + 10.33$

$= 0$



Calculation of BM

BM at A, $BM_A = 0$

BM at B, $BM_B = (-10 \sin 30 \times 1) - (2 \times 1) \times (\frac{1}{2})$

$= -6$ KNm

BM at C, $BM_C = -10 \sin 30^\circ \times 3 - (2 \times 1)(\frac{1}{2} + 2) + \frac{53}{3} \times (2) - (2 \times 2) \times (2/2)$

$= 11.33$ KNm

BM at D, $BM_D = -5 \times 5 - (2 \times 1)(\frac{1}{2} + 4) + \frac{53}{3} \times 4 - (2 \times 2) \times (2/2 + 2)$

$= 24.67$ KNm

BM at E, $BM_E = -5 \times 7 - (2 \times 1)(\frac{1}{2} + 6) + (53/3) \times 6 - (2 \times 2) \times (2/2 + 4) - 12 \times 2$

$= 14$ KNm

BM at F, $BM_F = -5 \times 9 - (2 \times 1)(\frac{1}{2} + 8) + 53/3 \times 8 - (2 \times 2)(2/2 + 6) - 12 \times 4 - (\frac{1}{2} \times 5 \times 2) \times 2/3$

$= 0$ KNm

BM at $Y_1 Y_2$, $= -10 \sin 30 (1 + y) - (2 \times 1)(y + \frac{1}{2}) + 17.67y - 2y \cdot y/2 = 0$

$0 = -5 - 5y - 2y - 1 + 17.67y - y^2$

$0 = y^2 - 17.67y + 7y + 6$

$0 = y^2 - 10.67y + 6$

Solving, $y = 0.59$ m.

BM at $X_1 X_2$, $x = 1$ m

BM centre $= -5 \times 8 - (2 \times 3) \times 6.5 + 17.67 \times 7 - 12 \times 3 - \frac{1}{2} \times 1 \times 2.5 \times \frac{1}{3}$

$= 8.27$ KNm. #