Indian Institute of Technology (Indian School of Mines) Dhanbad
NMEC101: ENGINEERING MECHANICS (2025-26)

Total: 30 marks (1 hour) **Mid-Semester Examination** **Date: 17-09-2025**

(All the questions are compulsory. Assume suitable data if it is found missing in the question. Sub-parts of a question should be solved in one place.)

1. For the bracket shown in ***Figure 1***, determine:

(a) the vector expression of the resultant force and moment of the wrench system at the origin of the coordinate system.

(b) the coordinate of the point P in the X-Y plane through which the resultant force of the wrench passes.

(c) pitch of the wrench system. **(10 marks)**

Note: The forces acting at O, A, and B are parallel to X,Y, and Z axes, respectively. Assume the thickness of the bracket to be negligible.

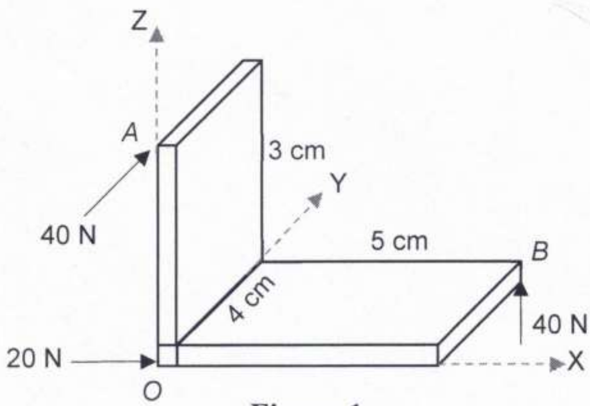


Figure 1

Solution.

(a) $\vec{R}_o = (20\hat{i} + 40\hat{j} + 40\hat{k})$ N (1 mark)

$(\vec{M}_o)_A = \vec{r}_{OA} \times 40\hat{j} = 3\hat{k} \times 40\hat{j} = -120\hat{i}$ N-cm

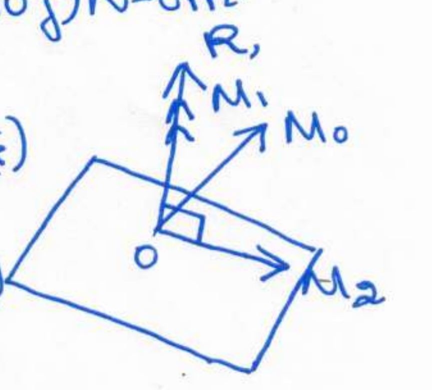
$(\vec{M}_o)_B = \vec{r}_{OB} \times 40\hat{k} = (5\hat{i} + 4\hat{j}) \times 40\hat{k} = (-200\hat{j} + 160\hat{i})$ N-cm

$\therefore \vec{M}_o = (\vec{M}_o)_A + (\vec{M}_o)_B = -120\hat{i} - 200\hat{j} + 160\hat{i}$ (2 marks)

$\Rightarrow \vec{M}_o = (40\hat{i} - 200\hat{j})$ N-cm

(b) $\vec{M}_1 = (\vec{M}_o \cdot \vec{\lambda}_R)\vec{\lambda}_R$

$\Rightarrow \vec{M}_1 = (40\hat{i} - 200\hat{j}) \cdot \dfrac{(20\hat{i} + 40\hat{j} + 40\hat{k})}{60} \cdot \dfrac{(20\hat{i} + 40\hat{j} + 40\hat{k})}{60}$



$\Rightarrow \vec{M}_1 = -(40\hat{i} + 80\hat{j} + 80\hat{k})$ N-cm.

(2 marks)

Let the resultant force of the wrench pass through the point (x, y) in the X-Y plane.

We know that,

$$\vec{M_1} + \vec{M_2} = \vec{M_0} \quad \text{(1 mark)}$$

$$\Rightarrow \vec{M_1} + (r \times \vec{R_0}) = \vec{M_0}$$

$$\Rightarrow -40\hat{i} - 80\hat{j} - 80\hat{k} + [(x\hat{i} + y\hat{j}) \times (20\hat{i} + 40\hat{j} + 40\hat{k})] = 40\hat{i} - 200\hat{j}$$

$$\Rightarrow (-40 + 40y)\hat{i} + (-80 - 40x)\hat{j} + (-80 + 40x - 20y) = 40\hat{i} - 200\hat{j} \quad \text{(1 mark)}$$

$$\therefore -40 + 40y = 40 \qquad -80 - 40x = -200$$

$$\Rightarrow \boxed{y = 2 \text{ cm}} \qquad \Rightarrow \boxed{x = 3 \text{ cm}}$$

(1 mark)

(c) Pitch of the wrench system (P) $= \left|\frac{M_1}{R_0}\right|$

$$= \frac{\sqrt{(40)^2 + (-80)^2 + (-80)^2}}{\sqrt{(20)^2 + (40)^2 + (40)^2}}$$

$$= \frac{120}{60} = 2 \text{ cm}$$

(2 marks)

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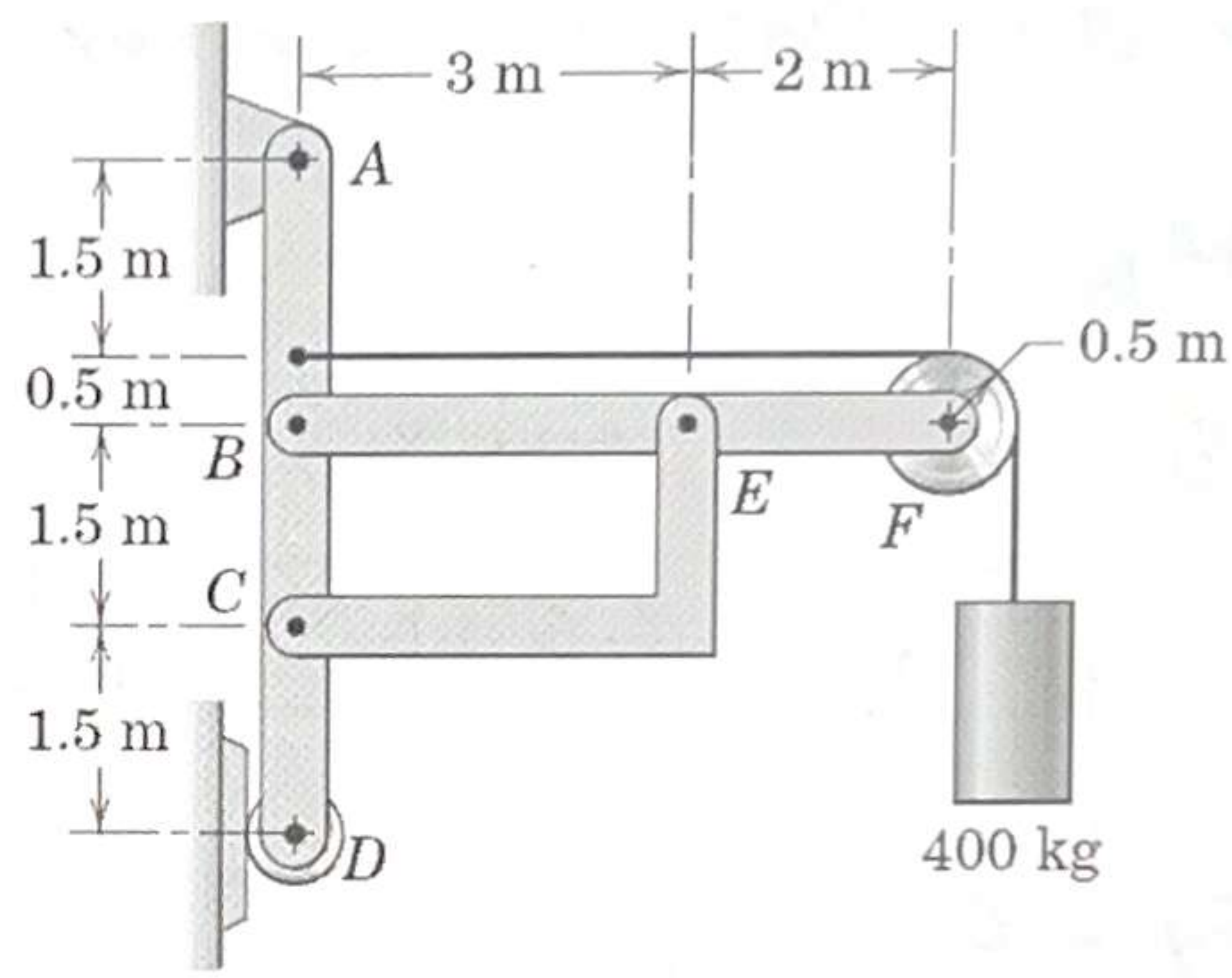
2. The frame in **Figure 3** supports the 400-kg load in the manner shown. Neglect the weights of the members compared with the forces induced by the load and determine the horizontal and vertical components of reaction at pins B and E. Take $g = 9.8\ m/s^2$.

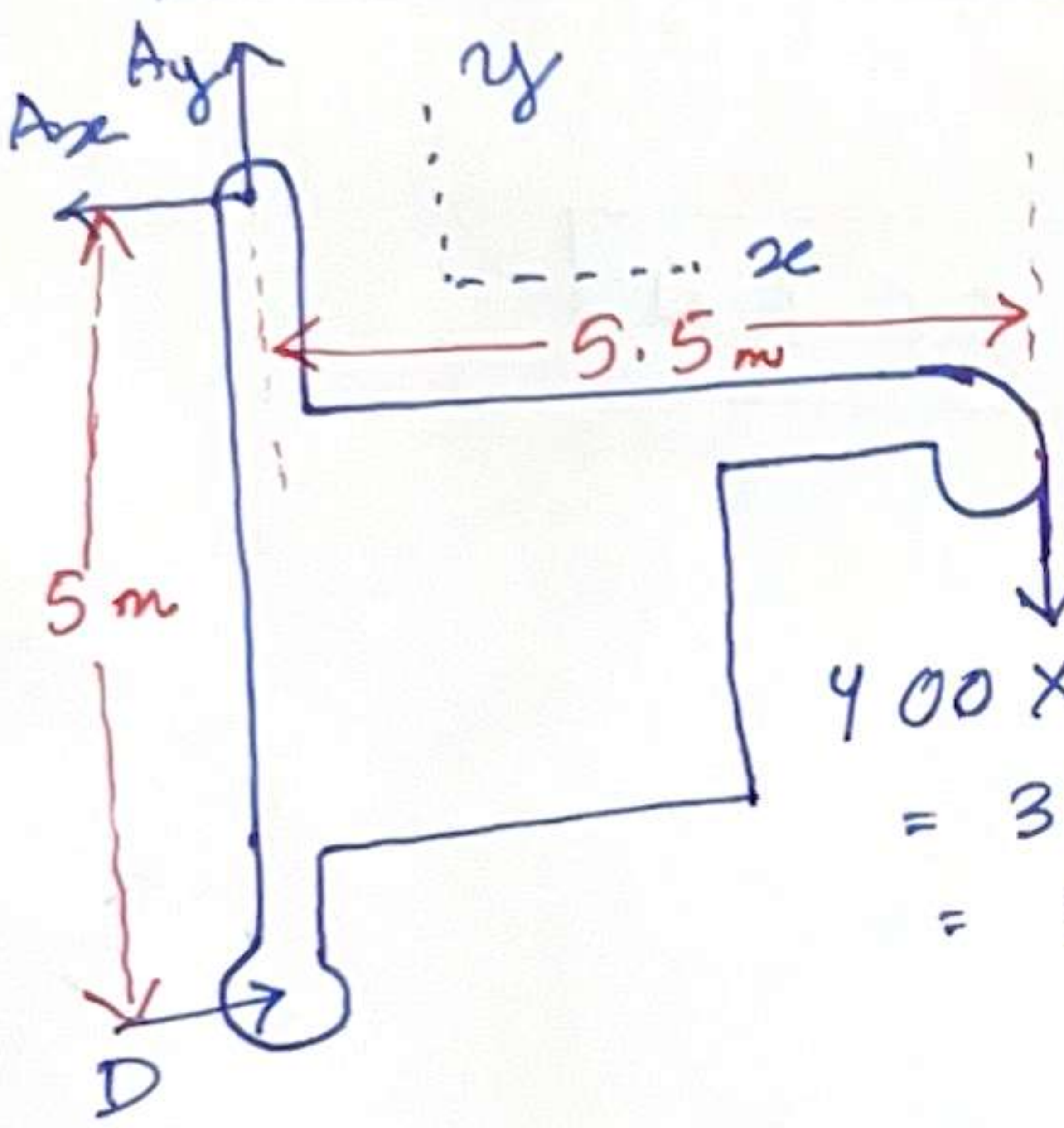
(10 marks)



(Figure 3)

Solution -

FBD of Entire Frame.



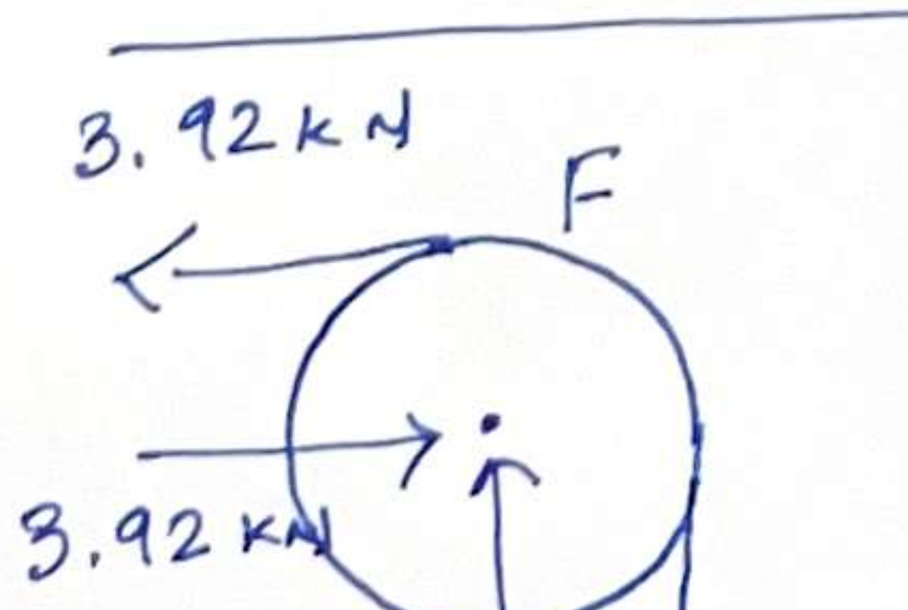
400×9.81
$= 3924\ N$
$= 3.92\ kN$

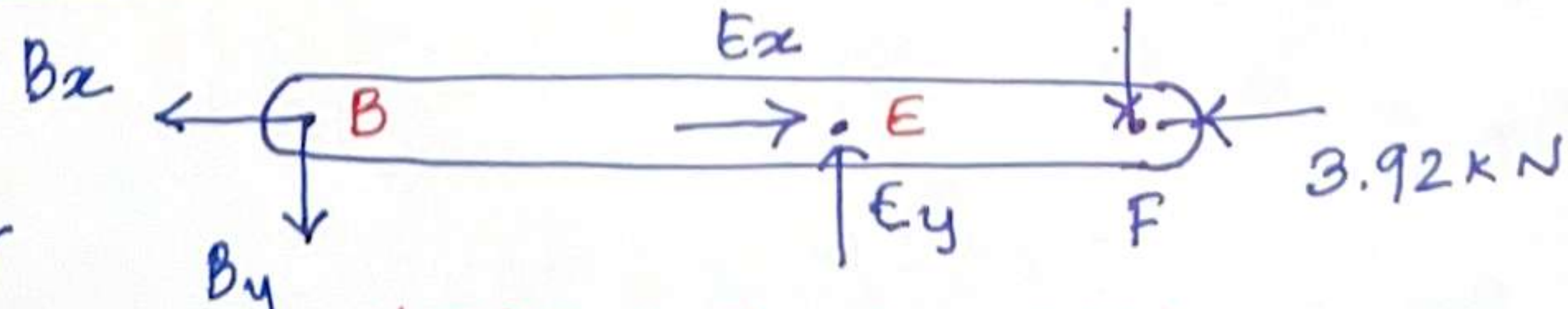
$\Sigma M_A = 0 \Rightarrow 3.92 \times 5.5 - 5 \times D = 0 \Rightarrow \boxed{D = 4.32\ kN}$

$\Sigma F_x = 0 \Rightarrow A_x - D = 0 \Rightarrow A_x - 4.32 = 0 \Rightarrow \boxed{A_x = 4.32\ kN}$

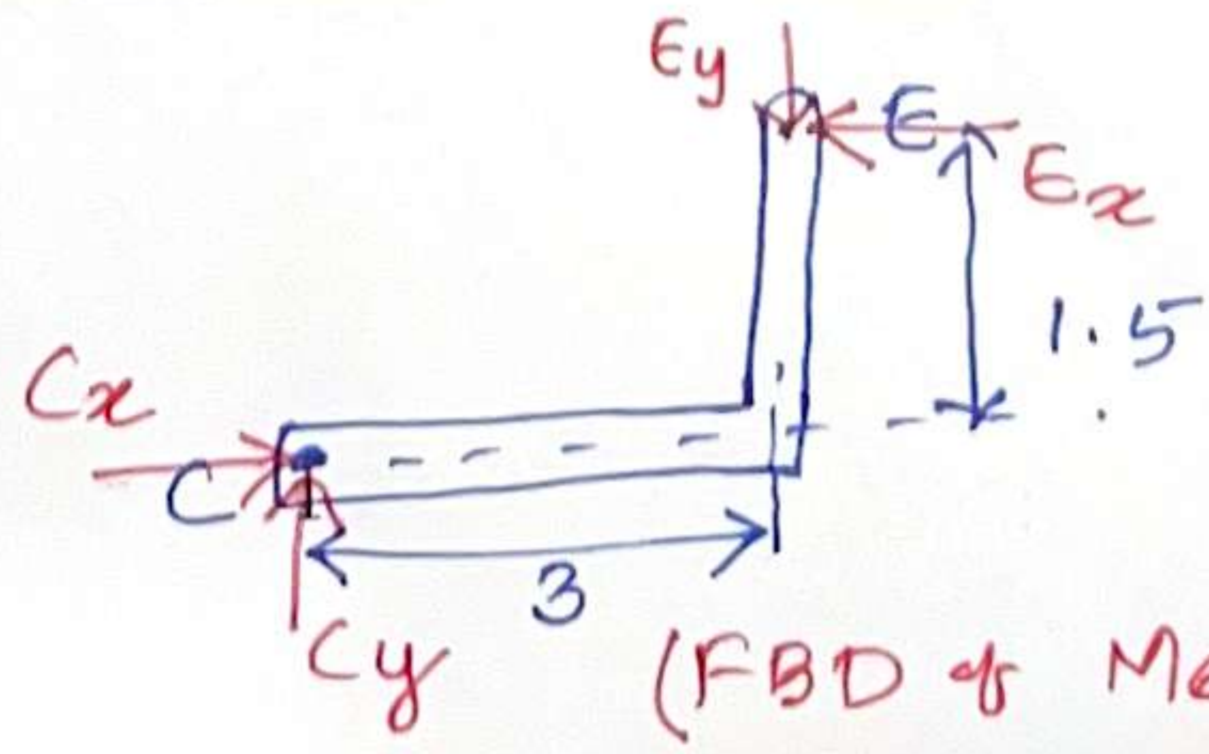
$\Sigma F_y = 0 \Rightarrow A_y - 3.92 = 0 \Rightarrow \boxed{A_y = 3.92\ kN}$

FBD of each member





(FBD of Member BF)



(FBD of Member CE)

From the FBD of member CE,

$$\Sigma M_C = 0$$

$$\Rightarrow E_x \times 1.5 - E_y \times 3 = 0$$

$$\Rightarrow E_x = 2E_y$$

$$\Rightarrow \boxed{E_y = \frac{1}{2} E_x}$$, Similarly, $\boxed{C_y = \frac{1}{2} C_x}$

From the FBD of member BF,

$$\Sigma M_B = 0$$

$$\Rightarrow 3.92 \times 5 - E_y \times 3 = 0$$

$$\Rightarrow \boxed{E_y = 6.53\,kN} \Rightarrow \boxed{E_x = 13.06\,kN}$$

$$\Sigma F_y = 0$$

$$\Rightarrow E_y - B_y - 3.92 = 0$$

$$\Rightarrow 6.53 - B_y - 3.92 = 0$$

$$\Rightarrow \boxed{B_y = 2.61\,kN}$$

$$\Sigma F_x = 0$$

$$\Rightarrow B_x + 3.92 - E_x = 0$$

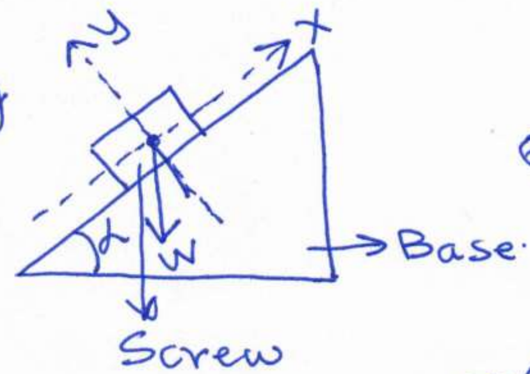
$$\Rightarrow B_x + 3.92 - 13.06 = 0$$

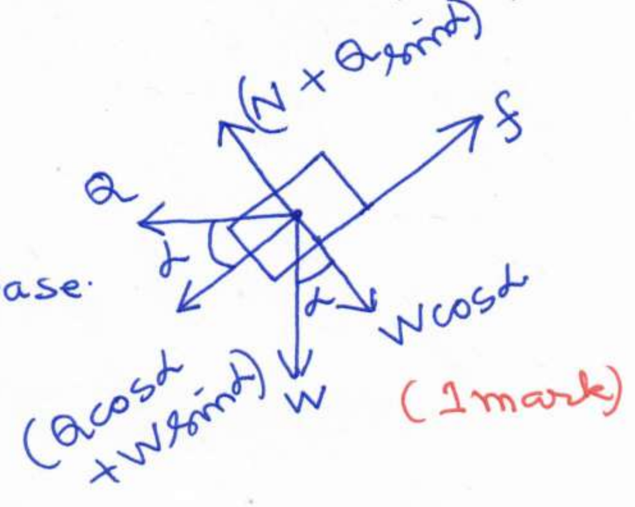
$$\Rightarrow \boxed{B_x = 9.14\,kN}$$

3. For a square threaded screw jack, derive the condition for the self-locking of the screw. Show the steps in details. **(5 marks)**

Solution

(Lowering of load)





(1 mark)

• $\sum F_x = 0$

$\Rightarrow f = \mu_s N = Q\cos\alpha + W\sin\alpha$ (1 mark)

$\Rightarrow \mu_s (W\cos\alpha - Q\sin\alpha) = Q\cos\alpha + W\sin\alpha$

• $\sum F_y = 0$

$\Rightarrow N + Q\sin\alpha = W\cos\alpha$

$\Rightarrow N = (W\cos\alpha - Q\sin\alpha)$ (1 mark)

$$\Rightarrow Q = W\frac{(\mu_s\cos\alpha - \sin\alpha)}{(\cos\alpha + \mu_s\sin\alpha)}$$

$$\Rightarrow Q = W\frac{(\tan\phi_s\cos\alpha - \sin\alpha)}{(\cos\alpha + \tan\phi_s\sin\alpha)}$$

$$\Rightarrow \boxed{Q = W\tan(\phi_s - \alpha)}$$ (1 mark)

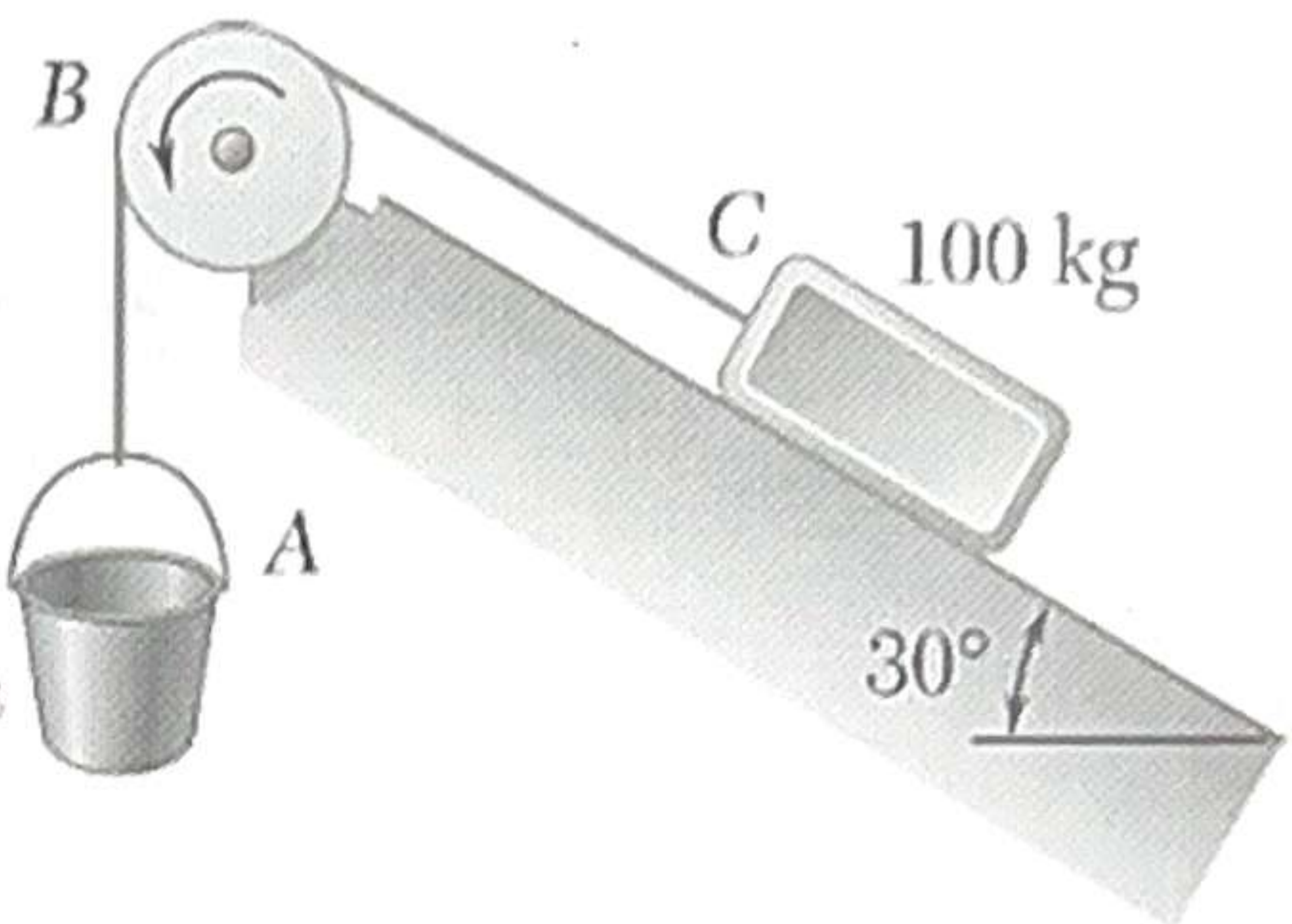
If $\phi_s > \alpha$ (1 mark).

$\Rightarrow Q = +ve$

$\Rightarrow$ Effort is reqd. to lower the load. Such a screw is called "Self-Locking Screw"

4. Bucket A and block C are connected by a cable that passes over drum B as shown in **Figure 4**. Knowing that drum B rotates slowly counter clockwise and that the coefficients of friction at all surfaces are $\mu_s = 0.35$ and $\mu_k = 0.25$, determine the smallest combined mass m of the bucket and its contents for which block C will start moving up the incline.

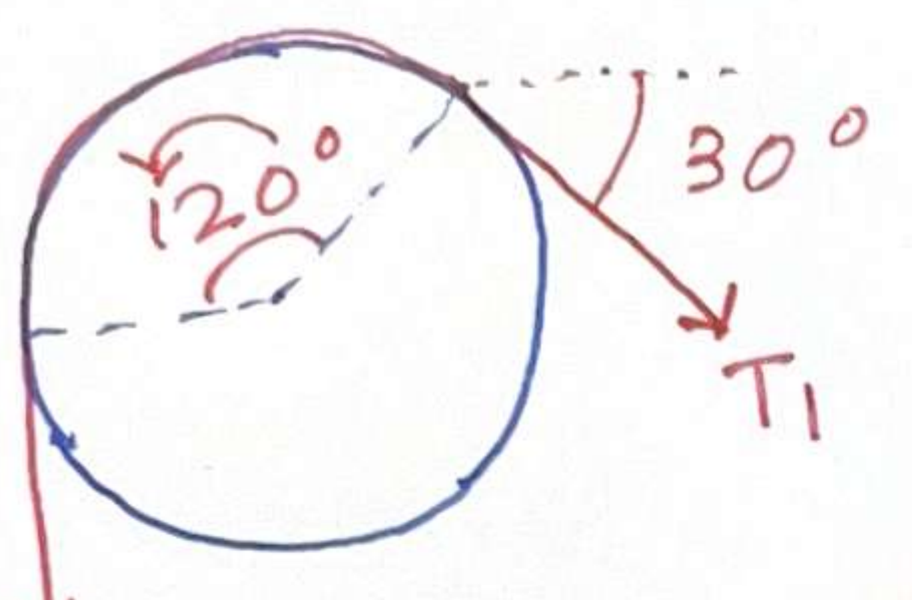
Sol:- (5 marks)



(Figure 4)

FBD of Drum

$\theta = 120^\circ = \frac{2}{3}\pi$ rad



$T_2 = mg$

Assuming
$T_1 = T_{max}$
$T_2 = T_{min}$

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$\Rightarrow T_1 = T_2 e^{\mu\theta}$$

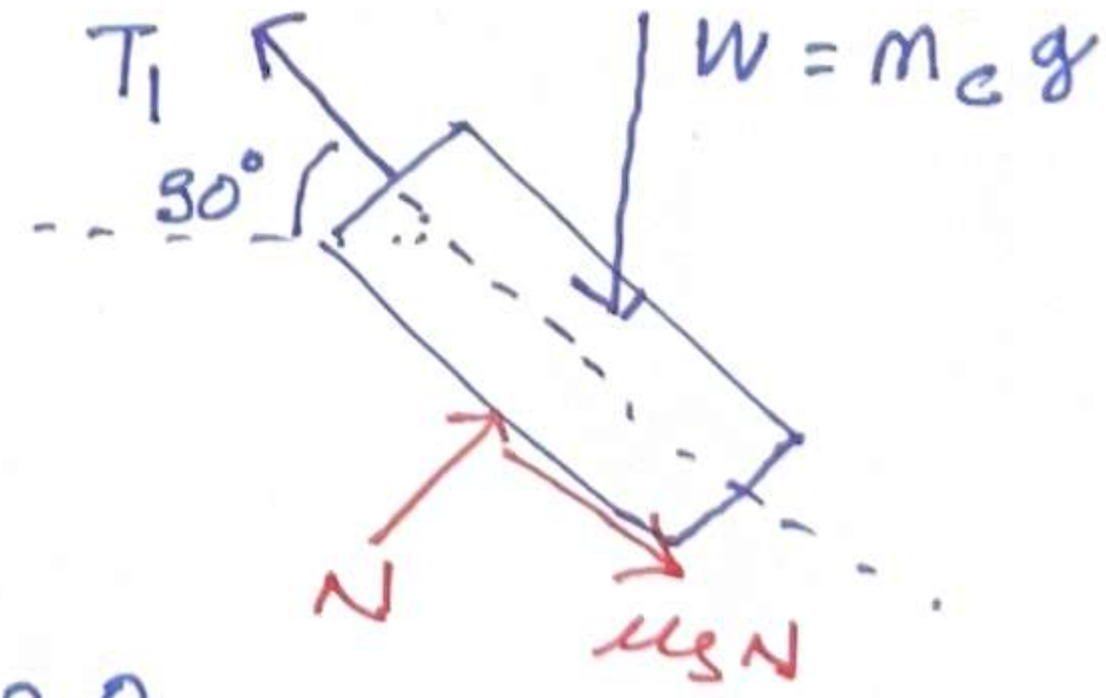
$$\Rightarrow \boxed{T_1 = mg e^{\frac{2\mu\pi}{3}}}$$

As $\mu = 0.35$, $\Rightarrow T_1 = mg e^{(2\times0.35\times\pi)/3}$

$$T_1 = 2.0814\, mg$$

Impending motion upward -

$m_c = 100$ kg



$+\nearrow \Sigma F = 0 \Rightarrow N - m_c g\cos 30 = 0$

$\Rightarrow N = m_c g \cos 30$

$\Rightarrow F = \mu_s N = 0.35 \times m_c g \cos 30$

$+\nwarrow \Sigma F = 0 \Rightarrow T_1 - \mu_s N - m_c g \sin 30 = 0$

$\Rightarrow 2.0814 mg - 0.35 \times m_c g \cos 30 - m_c g \sin 30 = 0$

$$2.0814\,m = 0.35\,m_c \cos 30 + m_c \sin 30$$

$$2.0814\,m = 0.8031\,m_c$$

$$m = 0.38585\,m_c$$

$$= 0.38585 \times 100\,kg$$

$$= 38.58\,kg$$

$$\boxed{m \simeq 38.6\,kg}$$

(Ans)