Department of Mechanical Engineering (NITC)

S1ME **ZZ1001D ENGINEERING MECHANICS** **Tutorial Test 4-Set5**

Time: One Hour **Answer Key** Maximum Marks: 20

1. Find the supporting force systems at *A* and *B* (Fig. 1). The length of *CB* is 8 m.

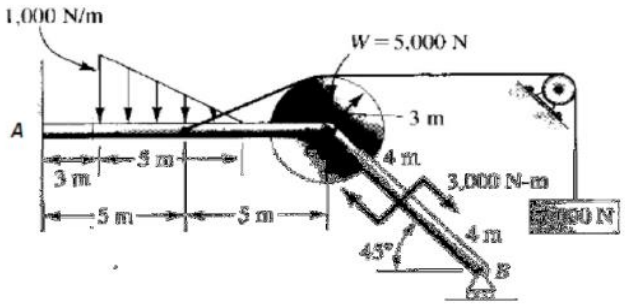
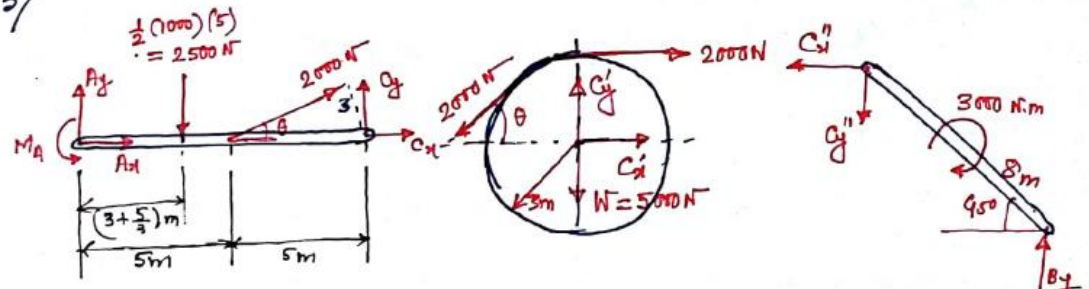


Figure 1

Solution:

5)



FBD I FBD II FBD III

$\theta = \sin^{-1}(\frac{3}{5}) = 36.87^\circ$

FBD I:

$\Sigma F_x = 0 \Rightarrow A_x + C_x = -2000\cos(\theta) = -16,000\ N$ (i)

$\Sigma F_y = 0 \Rightarrow A_y + C_y = 2500 - 2000\sin\theta = 1800\ N$ (ii)

$\Sigma M_A = 0 \Rightarrow M_A + 10\,C_y = (3+\frac{5}{3})(2500) - 5(2000\sin\theta) = 5666.67\ N$ (iii)

FBD II:

$\Sigma F_x = 0 \Rightarrow C_x' = 2000\cos\theta - 2000 = -400\ N$ (iv)

$\Sigma F_y = 0 \Rightarrow C_y' = 5000 + 2000\sin\theta = 6200\ N$ (v)

FBD III:

$\Sigma F_x = 0 \Rightarrow \quad C_x'' = 0 \quad$ (vi)

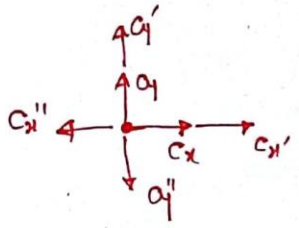
$\Sigma M_C = 0 \Rightarrow \quad (8\cos 45^\circ)\, B_y = 3000 \Rightarrow B_y = 530.33\ N \quad$ (vii)

$\Sigma F_y = 0 \Rightarrow \quad C_y'' = B_y = 530.33\ N \quad$ (viii)

At C $\Rightarrow$

$\Sigma F_x = 0 \Rightarrow C_x'' = C_x + C_x' = 0$ (from (vi))

$\Rightarrow C_x = -C_x' = 400\ N$ (from (iv))



$\Sigma F_y = 0 \Rightarrow C_y'' = C_y + C_y'$

$\Rightarrow C_y = 530.33 - 6200$ (from (viii) and (v))

$\Rightarrow C_y = -5669.67\ N \quad$ (ix)

(i) $\Rightarrow \quad A_x = -1600 - C_x = -1600 - 400$

$\Rightarrow A_x = -2000\ N$

(ii) $\Rightarrow \quad A_y = 1300 - C_y = 1300 + 5669.67 = 6969.67\ N$

(iii) $\Rightarrow \quad M_A = 5666.67 - 10C_y = 5666.67 - 10(-5669.67)$

$\Rightarrow M_A = 62363.34\ N.m$

Ans:

$A_x = -2000\ N$

$A_y = 6969.67\ N$

$B_y = 530.33\ N$

$M_A = 62363.34\ N.m$

2. Find the supporting force and couple-moment system for the cantilever beam (Fig. 2). What is the force and couple-moment system transmitted through a cross section of the beam at *B*?

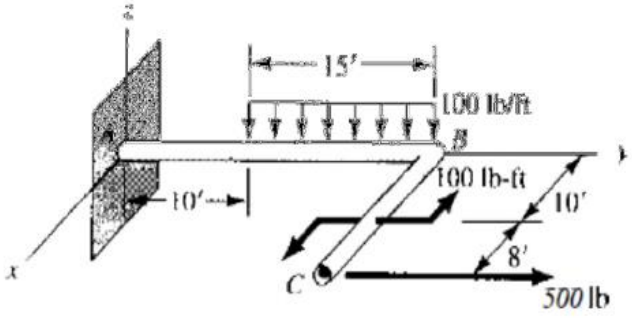


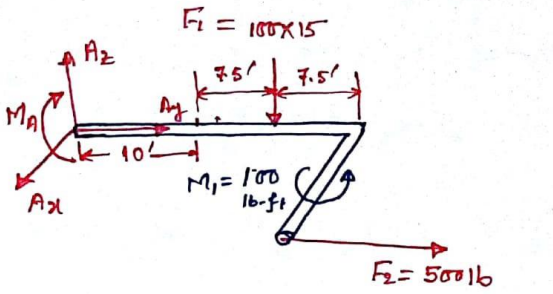
Figure 2

Solution:

10)

$\vec{F_1} = -1500\hat{k}$ lb, $\vec{r_1} = 17.5\hat{j}$ ft

$\vec{F_2} = 500\hat{j}$ lb, $\vec{r_2} = 18\hat{i} + 25\hat{j}$ ft



$\Sigma \vec{F} = 0$

$\Rightarrow \vec{A} + \vec{F_1} + \vec{F_2} = 0$

$\Rightarrow A_x\hat{i} + A_y\hat{j} + A_z\hat{k} - 1500\hat{k} + 500\hat{j} = 0$

$\vec{M_1} = 100\hat{k}$ lb-ft

$\therefore$ $A_x = 0$, $A_y = -500$ lb, $A_z = 1500$ lb $\Rightarrow \vec{A} = -500\hat{j} + 1500\hat{k}$ lb Ans

$\Sigma \vec{M_A} = 0$

$\Rightarrow \vec{M_A} + \vec{r_1} \times \vec{F_1} + \vec{r_2} \times \vec{F_2} + \vec{M_1} = 0$

$\Rightarrow \vec{M_A} = -17.5\hat{j} \times (-1500\hat{k}) - (18\hat{i} + 25\hat{j}) \times (500\hat{j}) - 100\hat{k}$

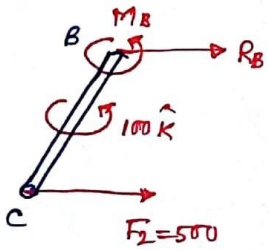
$= 26250\hat{i} - 9000\hat{k} - 100\hat{k}$

$\Rightarrow \vec{M_A} = 26250\hat{i} - 9100\hat{k}$ lb-ft Ans

Bc:

$\Sigma \vec{F} = 0 \Rightarrow \vec{R_B} + 500\hat{j} = 0$

$\Rightarrow \vec{R_B} = -500\hat{j}$ lb Ans



$\Sigma \vec{M_B} = 0 \Rightarrow \vec{M_B} + 100\hat{k} + 18 \times 500\hat{k} = 0$

$\Rightarrow \vec{M_B} = -9100\hat{k}$ lb-ft Ans

3. Determine the magnitude and direction ɵ of the minimum force *P* needed to pull the 50-kg roller over the smooth step (Fig. 3).

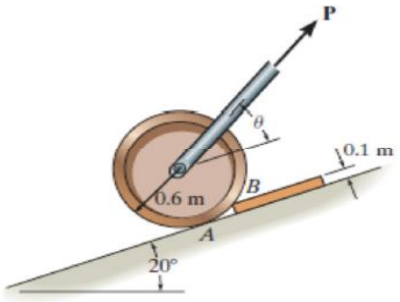


Figure 3

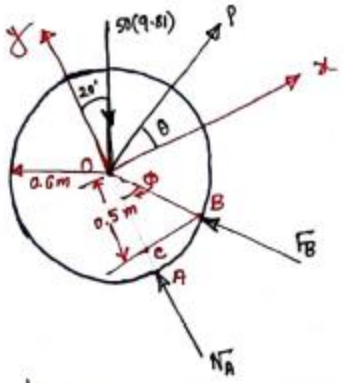
Figure 3

Solution:

15)

$$\phi = \cos^{-1}\left(\frac{OC}{OB}\right) = \cos^{-1}\left(\frac{0.5}{0.6}\right)$$

$$\Rightarrow \phi = 33.56^\circ.$$



For P_{min}, $N_A \to 0$.

$$\sum M_B = 0$$

$$\Rightarrow 0.5 \times (50 \times 9.81 \sin 20^\circ) + (\overset{BC}{0.3317}) \times (50 \times 9.81 \cos 20^\circ) - 0.5 \times (P\cos\theta) - (0.3317) \times (P\sin\theta) = 0$$

$BC = OB \sin\phi = 0.6 \sin(33.56^\circ)$

$\Rightarrow BC = 0.3317$ m

$$\Rightarrow 236.75 - P\cos\theta(0.5) - P\sin\theta(0.3317) = 0$$

$$\Rightarrow P = \frac{236.75}{0.5\cos\theta + 0.3317\sin\theta}$$

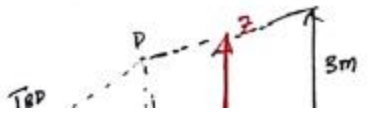
For P_{min}:

$$\frac{dP}{d\theta} = \frac{-236.75(-0.5\sin\theta + 0.3317\cos\theta)}{(0.5\cos\theta + 0.3317\sin\theta)^2} = 0$$

$$\Rightarrow \tan\theta = \frac{0.3317}{0.5} \Rightarrow \theta = \underline{33.56^\circ} \text{ Ans}$$

$$P_{min} = \frac{236.75}{0.5\cos(33.56^\circ) + 0.3317\sin(33.56^\circ)}$$

$$\Rightarrow P_{min} = \underline{394.57\ N} \text{ Ans}$$



4. Draw the free-body diagram of member *AB*, which is supported by a roller at *A* and a pin at *B*. Explain the significance of each force on the diagram. (See Fig. 4.)

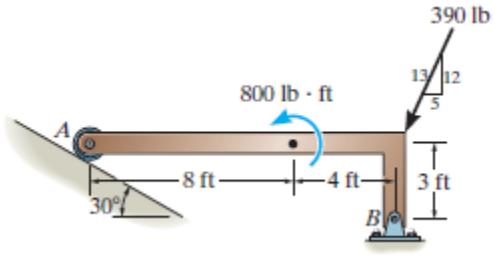


Figure 4

Solution:

5-2. Draw the free-body diagram of the hand punch, which is pinned at *A* and bears down on the smooth surface at *B*.