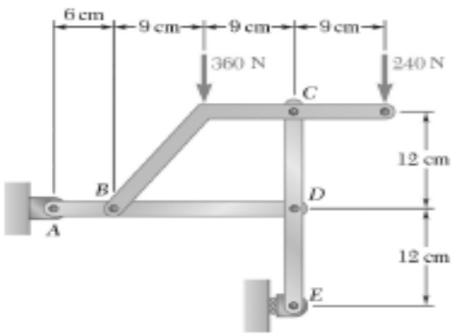
**Set 11 A**

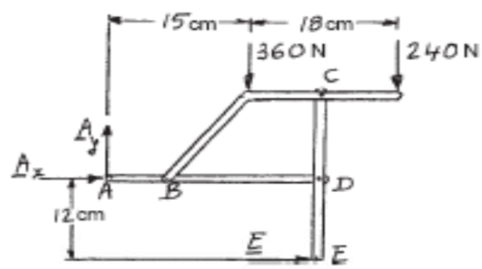



## PROBLEM 6.101

For the frame and loading shown, determine the components of all forces acting on member *ABD*.

## SOLUTION

Free body: Entire frame:




$$+\circlearrowleft \Sigma M_A = 0: \quad E(12 \text{ cm}) - (360 \text{ N})(15 \text{ cm}) - (240 \text{ N})(33 \text{ cm}) = 0$$

$$E = +1110 \text{ N} \qquad \mathbf{E} = +1.11 \text{ kN} \rightarrow$$

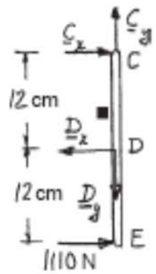
$$\xrightarrow{+} \Sigma F_x = 0: \quad A_x + 1110 \text{ N} = 0$$

$$A_x = -1110 \text{ N} \qquad \mathbf{A}_x = 1.11 \text{ kN} \leftarrow \blacktriangleleft$$

$$+\uparrow \Sigma F_y = 0: \quad A_y - 360 \text{ N} - 240 \text{ N} = 0$$

$$A_y = +600 \text{ N} \qquad \mathbf{A}_y = 600 \text{ N} \uparrow \blacktriangleleft$$

Free body: Member *CDE*:



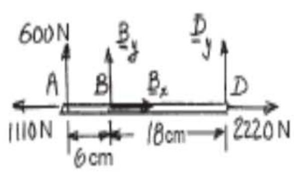

$$+\circlearrowleft \Sigma M_C = 0: \quad (1110\text{ N})(24\text{ cm}) - D_x\ (12\text{ cm}) = 0$$

$$D_x = +2220\text{ N}$$

**PROBLEM 6.101 (Continued)**

Free body: Member *ABD*:

From above: $\mathbf{D}_x = 2.22\text{ kN} \longrightarrow$ ◀




$$+\circlearrowleft \Sigma M_B = 0: \quad D_y(18\text{ cm}) - (600\text{ N})(6\text{ cm}) = 0$$

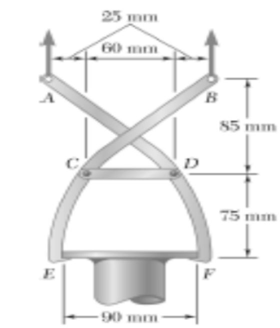
$$D_y = +200\text{ N} \qquad \mathbf{D}_y = 200\text{ N}\uparrow \blacktriangleleft$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad B_x + 2220\text{ N} - 1110\text{ N} = 0$$

$$B_x = -1110\text{ N} \qquad \mathbf{B}_x = 1.11\text{ kN} \longleftarrow \blacktriangleleft$$

$$+\uparrow \Sigma F_y = 0: \quad B_y + 200\text{ N} + 600\text{ N} = 0$$

$$B_y = -800\text{ N} \qquad \mathbf{B}_y = 800\text{ N}\downarrow \blacktriangleleft$$

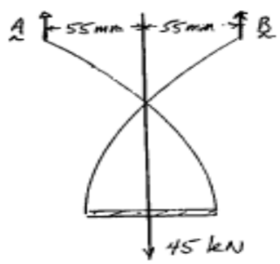



## PROBLEM 6.141

The tongs shown are used to apply a total upward force of 45 kN on a pipe cap. Determine the forces exerted at $D$ and $F$ on tong $ADF$.

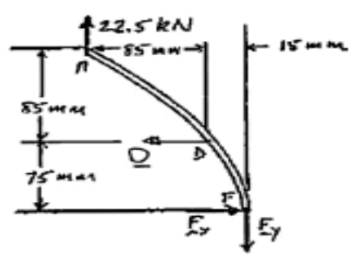
## SOLUTION

**FBD whole:**




By symmetry, $\mathbf{A} = \mathbf{B} = 22.5 \text{ kN} \uparrow$

**FBD $ADF$:**




$$\circlearrowleft \Sigma M_F = 0: \quad (75 \text{ mm})D - (100 \text{ mm})(22.5 \text{ kN}) = 0$$

$$\mathbf{D} = 30.0 \text{ kN} \longleftarrow \blacktriangleleft$$

$$\xrightarrow{\quad} \Sigma F_x = 0: \quad F_x - D = 0$$

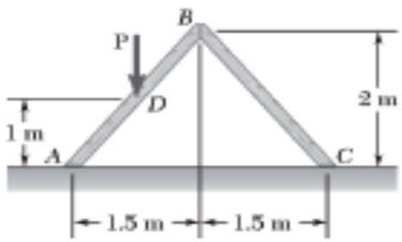
$$F_x = D = 30 \text{ kN}$$

$$\uparrow \Sigma F_y = 0: \quad 22.5 \text{ kN} - F_y = 0$$

$$F_y = 22.5 \text{ kN}$$

so

$$\mathbf{F} = 37.5 \text{ kN} \measuredangle 36.9^\circ \blacktriangleleft$$

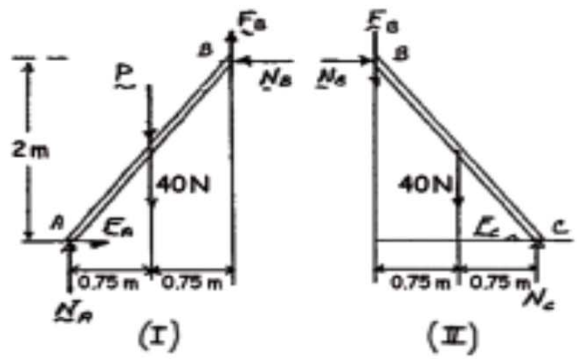



## PROBLEM 8.38

Two identical uniform boards, each of weight 40 N, are temporarily leaned against each other as shown. Knowing that the coefficient of static friction between all surfaces is 0.40, determine (*a*) the largest magnitude of the force **P** for which equilibrium will be maintained, (*b*) the surface at which motion will impend.

## SOLUTION

**Board FBDs:**




Assume impending motion at $C$, so

$$F_C = \mu_s N_C = 0.4 N_C$$

**FBD II:** $\circlearrowleft \Sigma M_B = 0$: $(1.5\text{ m})N_C - (2\text{ m})F_C - (0.75\text{ m})(40\text{ N}) = 0$

$$[1.5\text{ m} - 0.4(2\text{ m})]N_C = (0.75\text{ m})(40\text{ N})$$

or

$$N_C = 42.857\text{ N}$$

and

$$F_C = 0.4 N_C = 17.143\text{ N}$$

$$\xrightarrow{+} \Sigma F_x = 0: \quad N_B - F_C = 0$$

$$N_B = F_C = 17.143 \text{ N}$$

$$+\!\uparrow \Sigma F_y = 0: \quad -F_B - 40 \text{ N} + N_C = 0$$

$$F_B = N_C - 40 \text{ N} = 2.857 \text{ N}$$

Check for motion at $B$: $$\frac{F_B}{N_B} = \frac{2.857 \text{ N}}{17.143 \text{ N}} = 0.167 < \mu_s, \text{ OK, no motion.}$$

**FBD I:** $$\circlearrowleft \Sigma M_A = 0: \quad (2 \text{ m})N_B + (1.5 \text{ m})F_B - (0.75 \text{ m})(P + 40 \text{ N}) = 0$$

$$P = \frac{(2 \text{ m})(17.143 \text{ N}) + (1.5 \text{ m})(2.857 \text{ N})}{0.75 \text{ m}} - 40 \text{ N}$$

$$= 11.429 \text{ N}$$

## PROBLEM 8.38 (Continued)

Check for slip at $A$ (unlikely because of $P$):

$$\xrightarrow{} \Sigma F_x = 0: \quad F_A - N_B = 0 \quad \text{or} \quad F_A = N_B = 17.143 \text{ N}$$

$$+\!\uparrow \Sigma F_y = 0: \quad N_A - P - 40 \text{ N} + F_B = 0$$

or

$$N_A = 11.429 \text{ N} + 40 \text{ N} - 2.857 \text{ N}$$
$$= 48.572 \text{ N}$$

Then

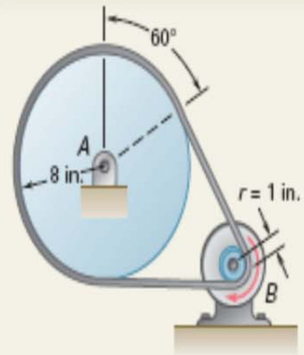
$$\frac{F_A}{N_A} = \frac{17.143 \text{ N}}{48.572 \text{ N}} = 0.353 < \mu_s$$

OK, no slip $\Rightarrow$ assumption is correct.

Therefore

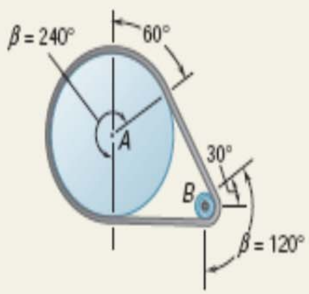
(*a*) $P_{\max} = 11.43 \text{ N}$ ◀

(*b*) Motion impends at $C$ ◀



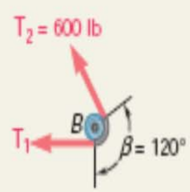

## SAMPLE PROBLEM 8.8

A flat belt connects pulley *A*, which drives a machine tool, to pulley *B*, which is attached to the shaft of an electric motor. The coefficients of friction are $m_s = 0.25$ and $m_k = 0.20$ between both pulleys and the belt. Knowing that the maximum allowable tension in the belt is 600 lb, determine the largest torque which can be exerted by the belt on pulley *A*.




## SOLUTION

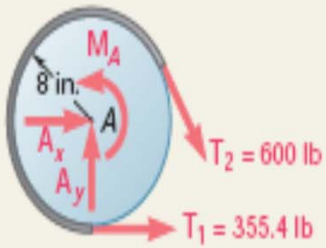
Since the resistance to slippage depends upon the angle of contact b between pulley and belt, as well as upon the coefficient of static friction $m_s$, and since $m_s$ is the same for both pulleys, slippage will occur first on pulley *B*, for which b is smaller.




**Pulley *B*.** Using Eq. (8.14) with $T_2 = 600$ lb, $m_s = 0.25$, and b = 120° = 2p/3 rad, we write

$$\frac{T_2}{T_1} = e^{m_s b} \qquad \frac{600 \text{ lb}}{T_1} = e^{0.25(2p/3)} = 1.688$$

$$T_1 = \frac{600 \text{ lb}}{1.688} = 355.4 \text{ lb}$$




**Pulley *A*.** We draw the free-body diagram of pulley *A*. The couple $\mathbf{M}_A$ is applied to the pulley by the machine tool to which it is attached and is equal and opposite to the torque exerted by the belt. We write

$$+1\ \Sigma M_A = 0: \qquad M_A - (600\ \text{lb})(8\ \text{in.}) + (355.4\ \text{lb})(8\ \text{in.}) = 0$$

$$M_A = 1957\ \text{lb} \cdot \text{in.} \qquad\qquad M_A = 163.1\ \text{lb} \cdot \text{ft} \quad \blacktriangleleft$$

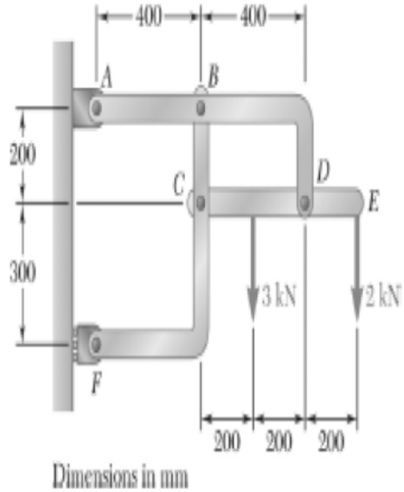
***Note.*** We may check that the belt does not slip on pulley *A* by computing the value of $m_s$ required to prevent slipping at *A* and verifying that it is smaller than the actual value of $m_s$. From Eq. (8.13) we have

$$m_s b = \ln \frac{T_2}{T_1} = \ln \frac{600\ \text{lb}}{355.4\ \text{lb}} = 0.524$$

and, since $b = 240° = 4p/3$ rad,

$$\frac{4p}{3} m_s = 0.524 \qquad m_s = 0.125 < 0.25$$

**Set 11 B (No submission required)**




## PROBLEM 6.105

For the frame and loading shown, determine the components of all forces acting on member *ABD*.

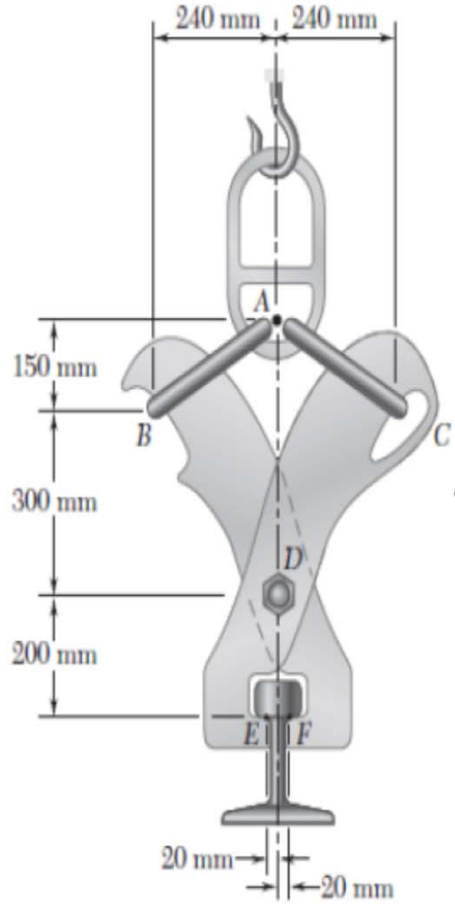
Force on ABD at A $= (-7.6\,\hat{i} + 5\hat{j})$ kN

" " " at B $= (-11.40\hat{i} - .5\hat{j})$ kN

" " " at B $= (19\hat{i} - 4.5\hat{j})$ kN.

**PROBLEM 6.144**

A 12-m length of railroad rail of weight 660 N/m is lifted by the tongs shown. Determine the forces exerted at D and F on tong BDF.

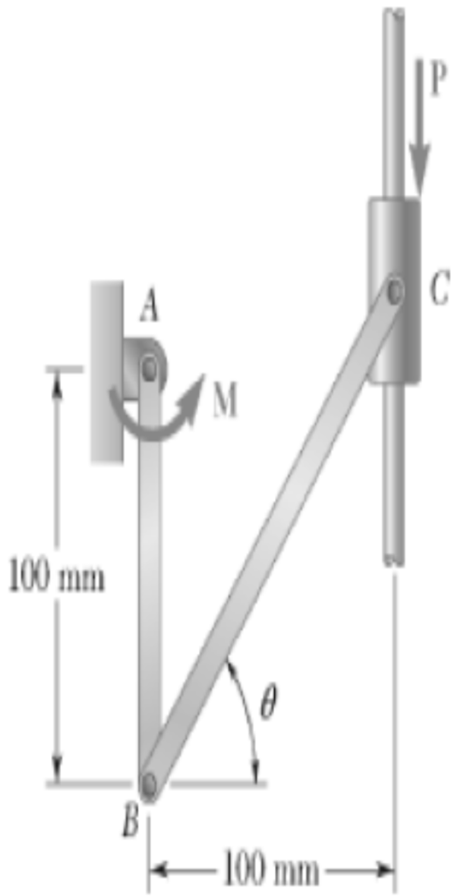



force on BDF at F is

$15.2\cos(15.1)\hat{i} - 15.2\sin(15.1)\hat{j}$ (kN)

force on BDF at D is

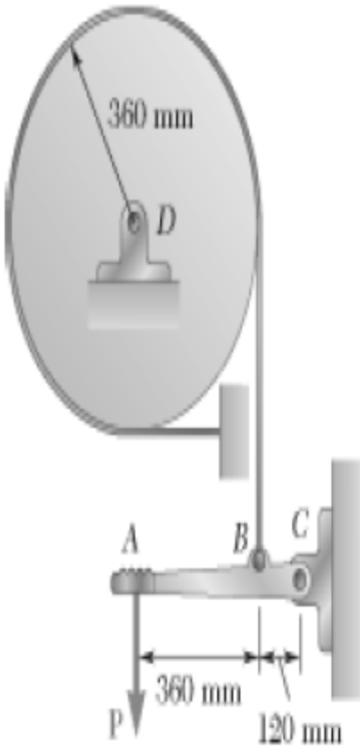
$-21$ kN$\hat{i}$




## PROBLEM 8.39

Knowing that the coefficient of static friction between the collar and the rod is 0.35, determine the range of values of $P$ for which equilibrium is maintained when $\theta = 50°$ and $M = 20\ \text{N}\cdot\text{m}$.

$$168.4\ \text{N} \leq P \leq 308\ \text{N}$$ ◀




# PROBLEM 8.109

A band brake is used to control the speed of a flywheel (which is driven by a motor not shown in the figure) [redacted]. The coefficients of friction are $\mu_s = 0.30$ and $\mu_k = 0.25$. ~~Determine the magnitude~~ [redacted] Knowing that $P = 45$ N and that the flywheel is rotating counterclockwise at a constant speed:

(i) Which side of belt experiences higher tension?

(ii) Find numerical values of tension on two sides of the belt.

[redacted]

180 N, 55.4 N Answer.