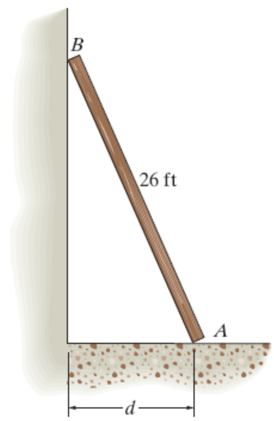
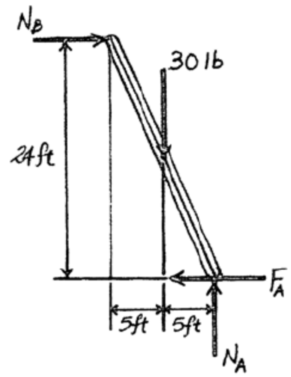
HW11 SOLUTIONS

8–7. The uniform thin pole has a weight of 30 lb and a length of 26 ft. If it is placed against the smooth wall and on the rough floor in the position $d = 10$ ft, will it remain in this position when it is released? The coefficient of static friction is $\mu_s = 0.3$.





$\curvearrowleft + \Sigma M_A = 0; \quad 30(5) - N_B(24) = 0$

$N_B = 6.25 \text{ lb}$

$\xrightarrow{+} \Sigma F_x = 0; \quad 6.25 - F_A = 0$

$F_A = 6.25 \text{ lb}$

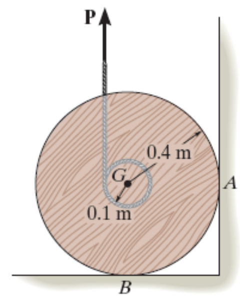
$+\uparrow \Sigma F_y = 0; \quad N_A - 30 = 0$

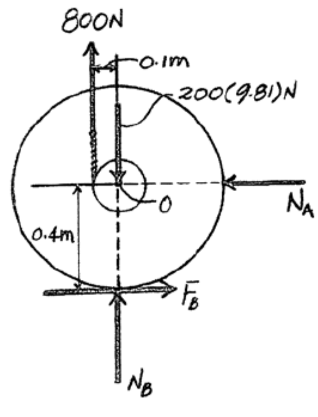
$N_A = 30 \text{ lb}$

$(F_A)_{max} = 0.3(30) = 9 \text{ lb} > 6.25 \text{ lb}$

Yes, the pole will remain stationary. **Ans**

8–15. The spool has a mass of 200 kg and rests against the wall and on the floor. If the coefficient of static friction at B is $(\mu_s)_B = 0.3$, the coefficient of kinetic friction is $(\mu_k)_B = 0.2$, and the wall is smooth, determine the friction force developed at B when the vertical force applied to the cable is $P = 800$ N.





$\xrightarrow{+} \Sigma F_x = 0;\qquad F_B - N_A = 0$

$+\uparrow \Sigma F_y = 0;\qquad 800 - 200(9.81) + N_B = 0$

$\circlearrowleft + \Sigma M_O = 0;\qquad -800(0.1) + F_B(0.4) = 0$

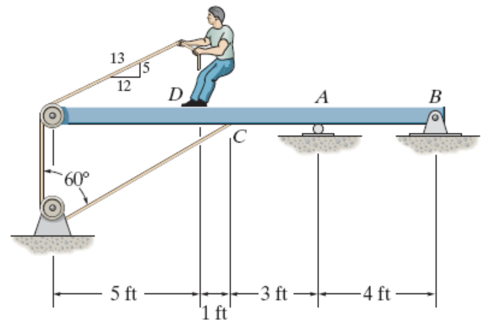
$F_B = 200\text{ N}$

$N_B = 1162\text{ N}$

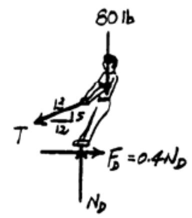
$(F_B)_{max} = 0.3(1162) = 348.6\text{ N} > 200\text{ N}$

Thus, $F_B = 200\text{ N}$ **Ans**

*8–16. The 80-lb boy stands on the beam and pulls on the cord with a force large enough to just cause him to slip. If the coefficient of static friction between his shoes and the beam is $(\mu_s)_D = 0.4$, determine the reactions at A and B. The beam is uniform and has a weight of 100 lb. Neglect the size of the pulleys and the thickness of the beam.



***Equations of Equilibrium and Friction*:** When the boy is on the verge to slipping, then $F_D = (\mu_s)_D N_D = 0.4N_D$. From FBD (a),



(a)

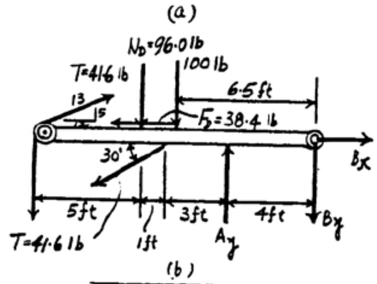
$$+\uparrow \Sigma F_y = 0; \quad N_D - T\left(\frac{5}{13}\right) - 80 = 0 \qquad [1]$$

$$\xrightarrow{+} \Sigma F_x = 0; \quad 0.4N_D - T\left(\frac{12}{13}\right) = 0 \qquad [2]$$

Solving Eqs. [1] and [2] yields

$$T = 41.6 \text{ lb} \qquad N_D = 96.0 \text{ lb}$$

Hence, $F_D = 0.4(96.0) = 38.4$ lb. From FBD (b),



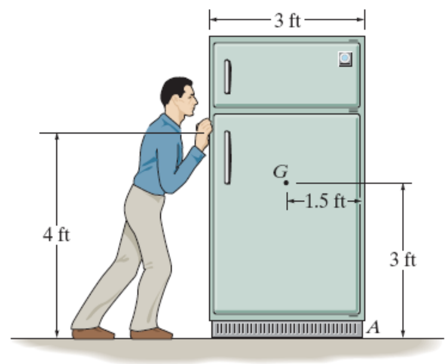
(b)

$$\curvearrowleft + \Sigma M_B = 0; \quad 100(6.5) + 96.0(8) - 41.6\left(\frac{5}{13}\right)(13)$$
$$+41.6(13) + 41.6\sin 30°(7) - A_y(4) = 0$$
$$A_y = 474.1 \text{ lb} = 474 \text{ lb} \qquad \textbf{Ans}$$

$$\xrightarrow{+} \Sigma F_x = 0; \quad B_x + 41.6\left(\frac{12}{13}\right) - 38.4 - 41.6\cos 30° = 0$$
$$B_x = 36.0 \text{ lb} \qquad \textbf{Ans}$$

$$+\uparrow \Sigma F_y = 0; \quad 474.1 + 41.6\left(\frac{5}{13}\right) - 41.6$$
$$-41.6\sin 30° - 96.0 - 100 - B_y = 0$$
$$B_y = 231.7 \text{ lb} = 232 \text{ lb} \qquad \textbf{Ans}$$

8–27. The refrigerator has a weight of 180 lb and rests on a tile floor for which $\mu_s = 0.25$. Also, the man has a weight of 150 lb and the coefficient of static friction between the floor and his shoes is $\mu_s = 0.6$. If he pushes horizontally on the refrigerator, determine if he can move it. If so, does the refrigerator slip or tip?



Equations of Equilibrium : From FBD (a),

$$+\uparrow \Sigma F_y = 0; \quad N - 180 = 0 \quad N = 180 \text{ lb}$$

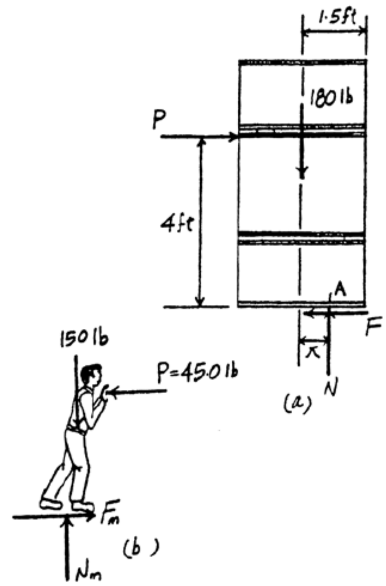
$$\xrightarrow{+} \Sigma F_x = 0; \quad P - F = 0 \qquad [1]$$

$$\curvearrowleft + \Sigma M_A = 0; \quad 180(x) - P(4) = 0 \qquad [2]$$

Friction : Assuming the refrigerator is on the verge of slipping, then $F = \mu N = 0.25(180) = 45$ lb. Substituting this value into Eqs.[1], and [2] and solving yields

$$P = 45.0 \text{ lb} \qquad x = 1.00 \text{ ft}$$

Since $x < 1.5$ ft, the refrigerator does not tip. Therefore, the above assumption is correct. Thus, **the refrigerator slips.** **Ans**



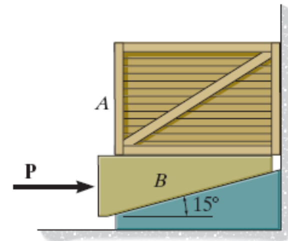
From FBD (b),

$$+\uparrow \Sigma F_y = 0; \quad N_m - 150 = 0 \quad N_m = 150 \text{ lb}$$

$$\xrightarrow{+} \Sigma F_x = 0; \quad F_m - 45.0 = 0 \quad F_m = 45.0 \text{ lb}$$

Since $(F_m)_{max} = \mu_s' N_m = 0.6(150) = 90.0 \text{ lb} > F_m$, then the man does not slip. Thus, **The man is capable of moving the refrigerator.** **Ans**

8–66. Determine the smallest horizontal force P required to lift the 200-kg crate. The coefficient of static friction at all contacting surfaces is $\mu_s = 0.3$. Neglect the mass of the wedge.



Free - Body Diagram. Since the crate is on the verge of sliding up and the wedge is on the verge of sliding to the right, the frictional force $\mathbf{F}_A$ on the crate must act downward and forces $\mathbf{F}_B$ and $\mathbf{F}_C$ on the wedge must act to the left as indicated on the free - body diagrams as shown in Figs. a and b. Also, $F_A = \mu_s N_A = 0.3N_A$, $F_B = \mu_s N_B = 0.3N_B$, and $F_C = \mu_s N_C = 0.3N_C$.

Equations of Equilibrium. Referring to Fig. a,

$\overset{+}{\rightarrow}\Sigma F_x = 0;$ $\quad 0.3N_B - N_A = 0$

$+\uparrow \Sigma F_y = 0;$ $\quad N_B - 0.3N_A - 200(9.81) = 0$

Solving,

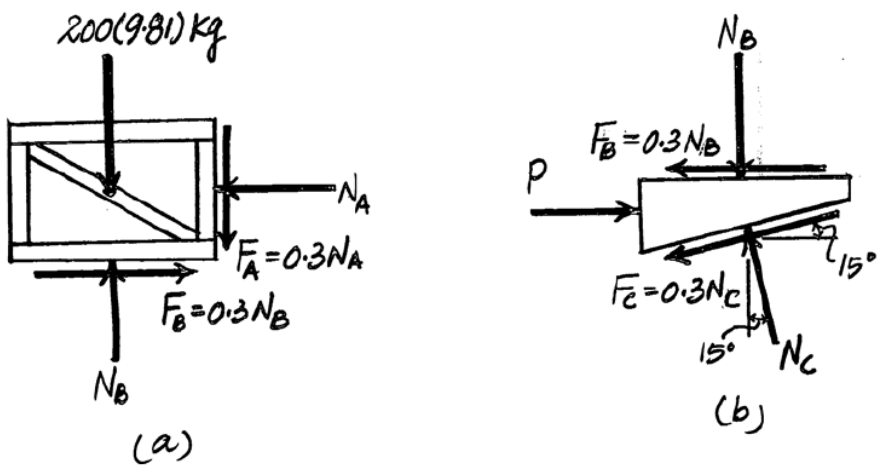
$$N_A = 646.81 \text{ N} \quad N_B = 2156.04 \text{ N}$$

Referring to Fig. b,

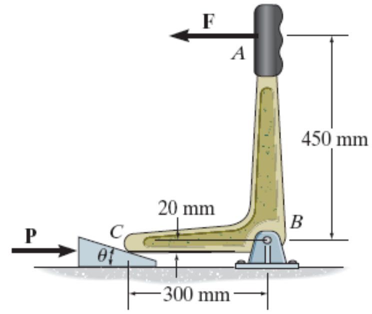
$+\uparrow \Sigma F_y = 0;$ $\quad N_C \cos 15° - 0.3N_C \sin 15° - 2156.04 = 0 \quad N_C = 2427.21 \text{ N}$

$\overset{+}{\rightarrow}\Sigma F_x = 0;$ $\quad P - 0.3(2156.04) - 2427.21 \sin 15° - 0.3(2427.21)\cos 15° = 0$

$P = 1978.37 \text{ N} = 1.98 \text{ N}$ **Ans.**



***8–72.** If the horizontal force **P** is removed, determine the largest angle θ that will cause the wedge to be self-locking regardless of the magnitude of force **F** applied to the handle. The coefficient of static friction at all contacting surfaces is $\mu_s = 0.3$.



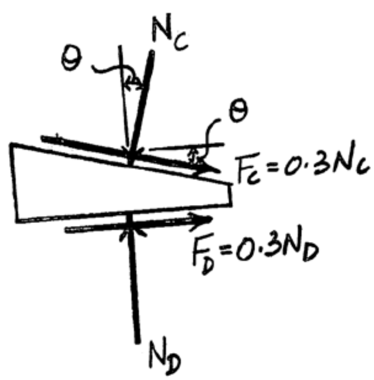
Free - Body Diagram. Since the wedge is required to be on the verge of sliding to the left (just self locking), the frictional forces $\mathbf{F}_C$ and $\mathbf{F}_D$ must act to the right such that $F_C = \mu_s N_C = 0.3N_C$ and $F_D = \mu_s N_D = 0.3N_D$ as indicated on the free-body diagram of the wedge shown in Fig. *a*.

Equations of Equilibrium. Referring to Fig. *a*,

$+\uparrow \Sigma F_y = 0;$ $\quad N_D - 0.3N_C \sin\theta - N_C \cos\theta = 0 \qquad N_D = N_C(0.3\sin\theta + \cos\theta)$

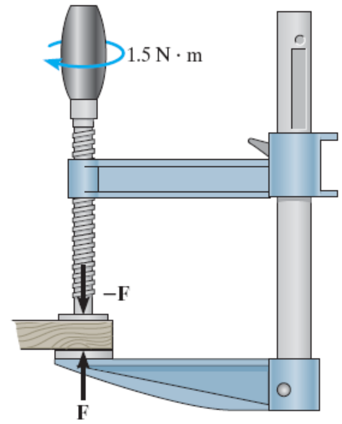
$\overset{+}{\rightarrow}\Sigma F_x = 0;$ $\quad 0.3N_C \cos\theta + 0.3[N_C(0.3\sin\theta + \cos\theta)] - N_C \sin\theta = 0$

$\theta = 33.4°$ **Ans.**



(a)

•**8–77.** The square threaded screw of the clamp has a mean diameter of 14 mm and a lead of 6 mm. If $\mu_s = 0.2$ for the threads, and the torque applied to the handle is 1.5 N · m, determine the compressive force F on the block.



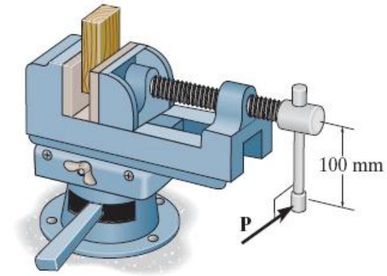
Frictional Forces on Screw : Here, $\theta = \tan^{-1}\left(\frac{l}{2\pi r}\right) = \tan^{-1}\left[\frac{6}{2\pi(7)}\right] = 7.768°$, $W = F$ and $\phi_s = \tan^{-1}\mu_s = \tan^{-1}(0.2) = 11.310°$. Applying Eq. 8 – 3, we have

$$M = Wr\tan(\theta + \phi)$$
$$1.5 = F(0.007)\tan(7.768° + 11.310°)$$

$$F = 620\text{ N} \qquad \textbf{Ans}$$

Note : Since $\phi_s > \theta$, the screw is self - locking. It will not unscrew even if the moment is removed.

***8–80.** Determine the magnitude of the horizontal force **P** that must be applied to the handle of the bench vise in order to produce a clamping force of 600 N on the block. The single square-threaded screw has a mean diameter of 25 mm and a lead of 7.5 mm. The coefficient of static friction is $\mu_s = 0.25$.



Here, $M = P(0.1)$

$$\theta = \tan^{-1}\left(\frac{L}{2\pi r}\right) = \tan^{-1}\left[\frac{7.5}{2\pi(12.5)}\right] = 5.455°$$

$\phi_s = \tan^{-1}\mu_s = \tan^{-1}(0.25) = 14.036°$

$W = 600\text{ N}$

Thus

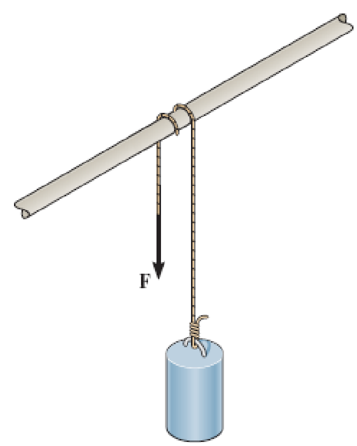
$$M = Wr\tan(\phi_s + \theta)$$

$$P(0.1) = 600(0.0125)\tan(14.036° + 5.455°)$$

$$P = 26.5\text{ N}$$ **Ans.**

Note: Since $\phi_s > \theta$, the screw is self-locking.

8–90. A cylinder having a mass of 250 kg is to be supported by the cord which wraps over the pipe. Determine the smallest vertical force F needed to support the load if the cord passes (a) once over the pipe, $\beta = 180°$, and (b) two times over the pipe, $\beta = 540°$. Take $\mu_s = 0.2$.



Frictional Force on Flat Belt : Here, $T_1 = F$ and $T_2 = 250(9.81) = 2452.5$ N. Applying Eq. 8 – 6, we have

a) If $\beta = 180° = \pi$ rad

$$T_2 = T_1 e^{\mu\beta}$$

$$2452.5 = Fe^{0.2\pi}$$

$$F = 1308.38\text{ N} = 1.31\text{ kN}$$ **Ans**

b) If $\beta = 540° = 3\pi$ rad

$$T_2 = T_1 e^{\mu\beta}$$

$$2452.5 = Fe^{0.2(3\pi)}$$

$$F = 372.38\text{ N} = 372\text{ N}$$ **Ans**

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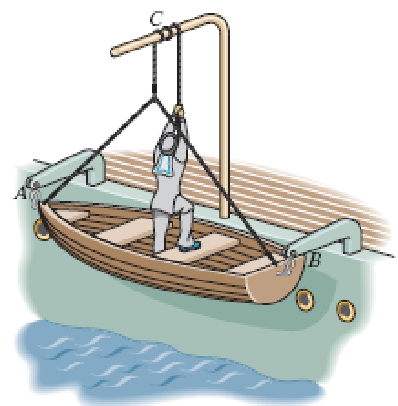
*8–92. The boat has a weight of 500 lb and is held in position off the side of a ship by the spars at A and B. A man having a weight of 130 lb gets in the boat, wraps a rope around an overhead boom at C, and ties it to the end of the boat as shown. If the boat is disconnected from the spars, determine the *minimum number of half turns* the rope must make around the boom so that the boat can be safely lowered into the water at constant velocity. Also, what is the normal force between the boat and the man? The coefficient of kinetic friction between the rope and the boom is $\mu_s = 0.15$. *Hint*: The problem requires that the normal force between the man's feet and the boat be as small as possible.

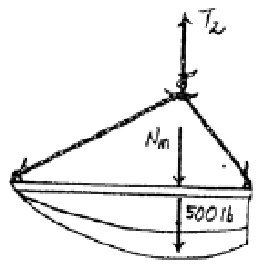


Frictional Force on Flat Belt : If the normal force between the man and the boat is equal to zero, then, $T_1 = 130$ lb and $T_2 = 500$ lb. Applying Eq. 8 – 6, we have

$$T_2 = T_1 e^{\mu\beta}$$
$$500 = 130e^{0.15\beta}$$
$$\beta = 8.980 \text{ rad}$$

The least number of half turns of the rope required is $\dfrac{8.980}{\pi} = 2.86$ turns. Thus

Use $\quad n = 3$ half turns **Ans**



(a)

(b)

Equations of Equilibrium : From FBD (a),

$$+\uparrow \Sigma F_y = 0; \quad T_2 - N_m - 500 = 0 \quad T_2 = N_m + 500$$

From FBD (b),

$$+\uparrow \Sigma F_y = 0; \quad T_1 + N_m - 130 = 0 \quad T_1 = 130 - N_m$$

Frictional Force on Flat Belts : Here, $\beta = 3\pi$ rad. Applying Eq. 8 – 6, we have

$$T_2 = T_1 e^{\mu\beta}$$
$$N_m + 500 = (130 - N_m)e^{0.15(3\pi)}$$
$$N_m = 6.74 \text{ lb} \qquad \textbf{Ans}$$