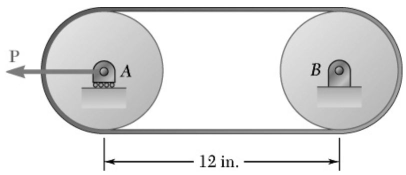
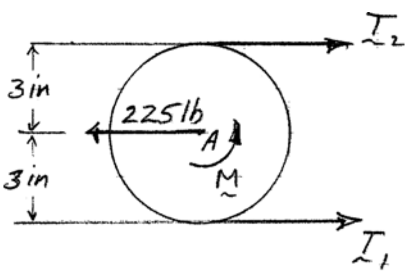
PROBLEM 8.131



Solve Problem 8.109 assuming that the flat belt and drums are replaced by a V belt and V pulleys with $\alpha = 36^{\circ}$. (The angle α is as shown in Figure 8.15*a*.)

SOLUTION

FBD pulley A:



Impending slipping: $$T_2 = T_1 e^{\mu_s \beta/\sin\frac{\alpha}{2}}$$

$$T_2 = T_1 e^{0.35\pi/\sin 18^{\circ}} = 35.1015 T_1$$

$$\rightarrow \Sigma F_x = 0: \quad T_1 + T_2 - 225 \text{ lb} = 0$$

$$T_1(1 + 35.1015) = 225 \text{ lb}$$

So $$T_1 = 6.2324 \text{ lb}$$

$$T_2 = 218.768 \text{ lb} = T_{max}$$

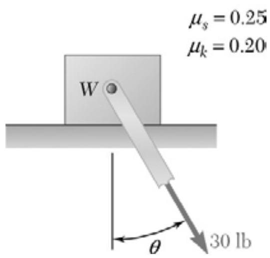
$$\circlearrowleft \Sigma M_A = 0: \quad M + (3 \text{ in.})(T_1 - T_2) = 0$$

$$M = (3 \text{ in.})(218.768 \text{ lb} - 6.232 \text{ lb})$$

(*a*) $$M = 638 \text{ lb}\cdot\text{in.} \blacktriangleleft$$

(Compare to 338 lb·in. with flat belt, Problem 8.109.)

(*b*) $$T_{max} = 219 \text{ lb} \blacktriangleleft$$

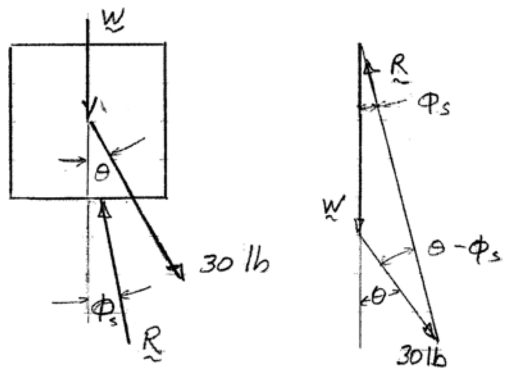


PROBLEM 8.132

Considering only values of θ less than $90°$, determine the smallest value of θ required to start the block moving to the right when (*a*) $W = 75$ lb, (*b*) $W = 100$ lb.

SOLUTION

FBD block: (motion impending)



$$\phi_s = \tan^{-1}\mu_s = 14.036°$$

$$\frac{30 \text{ lb}}{\sin\phi_s} = \frac{W}{\sin(\theta - \phi_s)}$$

$$\sin(\theta - \phi_s) = \frac{W \sin 14.036°}{30 \text{ lb}}$$

or $$\sin(\theta - 14.036°) = \frac{W}{123.695 \text{ lb}}$$

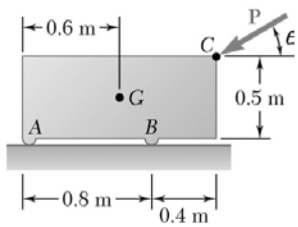
(*a*) $$W = 75 \text{ lb:} \quad \theta = 14.036° + \sin^{-1}\frac{75 \text{ lb}}{123.695 \text{ lb}}$$

$\theta = 51.4°$ ◀

(*b*) $$W = 100 \text{ lb:} \quad \theta = 14.036° + \sin^{-1}\frac{100 \text{ lb}}{123.695 \text{ lb}}$$

$\theta = 68.0°$ ◀

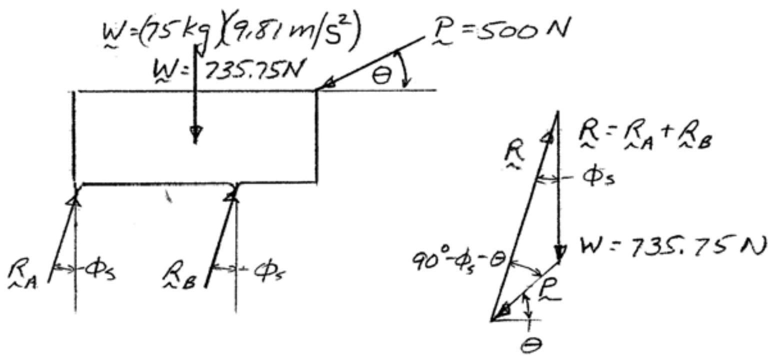
PROBLEM 8.133



The machine base shown has a mass of 75 kg and is fitted with skids at *A* and *B*. The coefficient of static friction between the skids and the floor is 0.30. If a force **P** of magnitude 500 N is applied at corner *C*, determine the range of values of θ for which the base will not move.

SOLUTION

FBD machine base (slip impending):



$$\phi_s = \tan^{-1}\mu_s = \tan^{-1}0.3 = 16.699°$$

$$\frac{W}{\sin(90° - \phi_s - \theta)} = \frac{P}{\sin\phi_s}$$

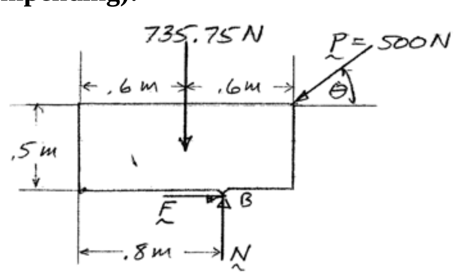
$$\sin(90° - \phi_s - \theta) = \frac{W\sin 16.699°}{P}$$

$$90° - 16.699° - \theta = \sin^{-1}\left[\frac{735.75\text{ lb}}{500\text{ lb}}(0.28734)\right]$$

$$\theta = 73.301° - 25.013°$$

$$\theta = 48.3°$$

FBD machine base (tip about B impending):



PROBLEM 8.133 CONTINUED

$$\circlearrowleft \Sigma M_B = 0: \quad (0.2\text{ m})(735.75\text{ N}) + (0.5\text{ m})\left[(500\text{ N})\cos\theta\right]$$

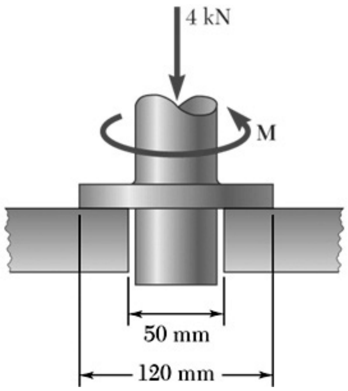
$$-(0.4\text{ m})\left[(500\text{ N})\sin\theta\right] = 0$$

$$0.8\sin\theta - \cos\theta = 0.5886$$

Solving numerically $\theta = 78.7°$

So, for equilibrium $48.3° \le \theta \le 78.7°$ ◀

PROBLEM 8.134



Knowing that a couple of magnitude $30\text{ N}\cdot\text{m}$ is required to start the vertical shaft rotating, determine the coefficient of static friction between the annular surfaces of contact.

SOLUTION

For annular contact regions, use Equation 8.8 with impending slipping:

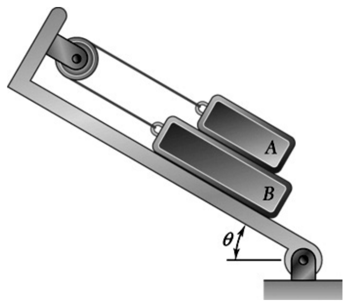
$$M = \frac{2}{3}\mu_s N \frac{R_2^3 - R_1^3}{R_2^2 - R_1^2}$$

So,

$$30\text{ N}\cdot\text{m} = \frac{2}{3}\mu_s(4000\text{ N})\frac{(0.06\text{ m})^3 - (0.025\text{ m})^3}{(0.06\text{ m})^2 - (0.025\text{ m})^2}$$

$$\mu_s = 0.1670 \blacktriangleleft$$

PROBLEM 8.135

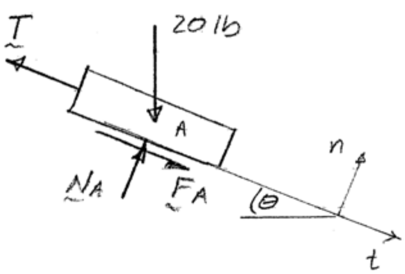


The 20-lb block *A* and the 30-lb block *B* are supported by an incline which is held in the position shown. Knowing that the coefficient of static friction is 0.15 between the two blocks and zero between block *B* and the incline, determine the value of θ for which motion is impending.

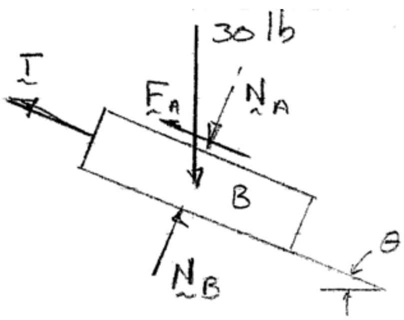
SOLUTION

FBD's

Block A:



Block B:



A: $\nearrow \Sigma F_n = 0$: $N_A - (20\text{ lb})\cos\theta = 0$ or $N_A = (20\text{ lb})\cos\theta$

B: $\nearrow \Sigma F_n = 0$: $N_B - N_A - (30\text{ lb})\cos\theta = 0$

or $$N_B = N_A + (30\text{ lb})\cos\theta = (50\text{ lb})\cos\theta$$

Impending motion at all surfaces:

$$F_A = \mu_s N_A$$

$$= 0.15(20\text{ lb})\cos\theta$$

$$= (3\text{ lb})\cos\theta$$

A: $\searrow \Sigma F_t = 0$: $F_A + (20\text{ lb})\sin\theta - T = 0$

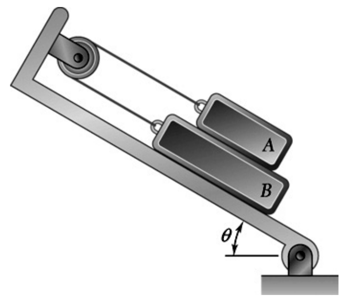
B: $\searrow \Sigma F_t = 0$: $-F_A + (30\text{ lb})\sin\theta - T = 0$

So $$(10\text{ lb})\sin\theta - 2F_A = 0$$

$$(10\text{ lb})\sin\theta = 2(3\text{ lb})\cos\theta$$

$$\theta = \tan^{-1}\frac{6\text{ lb}}{10\text{ lb}} = 30.96°$$

$\theta = 31.0°$ ◀

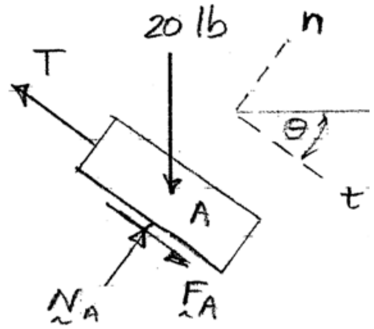


PROBLEM 8.136

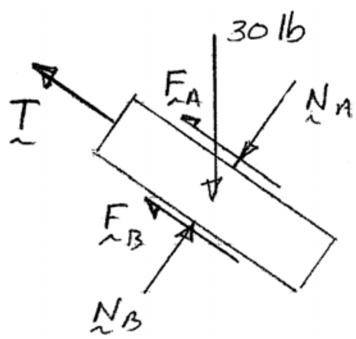
The 20-lb block A and the 30-lb block B are supported by an incline which is held in the position shown. Knowing that the coefficient of static friction is 0.15 between all surfaces of contact, determine the value of θ for which motion is impending.

SOLUTION

FBD's
Block A:



Block B:



A: $\nearrow \Sigma F_n = 0$: $N_A - (20\text{ lb})\cos\theta = 0$ or $N_A = (20\text{ lb})\cos\theta$

B: $\nearrow \Sigma F_n = 0$: $N_B - N_A - (30\text{ lb})\cos\theta = 0$

or $$N_B = N_A + (30\text{ lb})\cos\theta = (50\text{ lb})\cos\theta$$

Impending motion at all surfaces; B impends $\searrow$:

$$F_A = \mu_s N_A = (0.15)(20\text{ lb})\cos\theta = (3\text{ lb})\cos\theta$$

$$F_B = \mu_s N_B = (0.15)(50\text{ lb})\cos\theta = (7.5\text{ lb})\cos\theta$$

A: $\searrow \Sigma F_t = 0$: $(20\text{ lb})\sin\theta + F_A - T = 0$

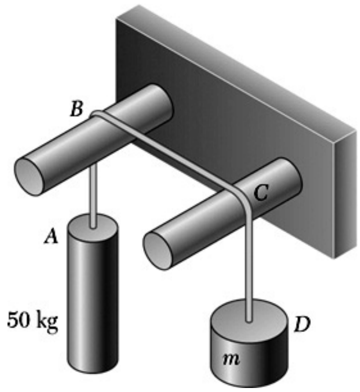
B: $\searrow \Sigma F_t = 0$: $(30\text{ lb})\sin\theta - F_A - F_B - T = 0$

So $$(10\text{ lb})\sin\theta - 2F_A - F_B = 0$$

$$(10\text{ lb})\sin\theta = 2(3\text{ lb})\cos\theta + (7.5\text{ lb})\cos\theta$$

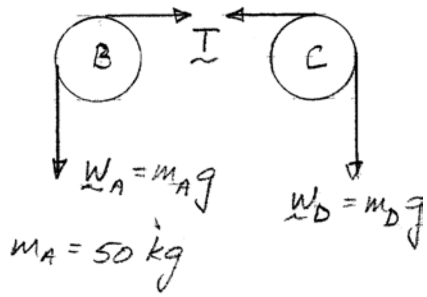
$$\tan\theta = \frac{13.5\text{ lb}}{10\text{ lb}} = 1.35; \qquad \theta = 53.5° \blacktriangleleft$$

PROBLEM 8.137



Two cylinders are connected by a rope that passes over two fixed rods as shown. Knowing that the coefficient of static friction between the rope and the rods is 0.40, determine the range of values of the mass *m* of cylinder *D* for which equilibrium is maintained.

SOLUTION



For impending motion of *A* up: $$T = W_A e^{\mu_s \beta_B}$$

and $$W_D = T e^{\mu_s \beta_C} = W_A e^{\mu_s(\beta_B + \beta_C)}$$

or $$m_D g = (50\text{ kg}) g e^{0.4\left(\frac{\pi}{2}+\frac{\pi}{2}\right)}$$

$$m_D = 175.7\text{ kg}$$

For impending motion of *A* down, the tension ratios are inverted, so

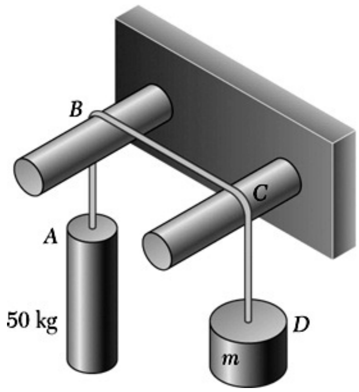
$$W_A = W_D e^{\mu_s(\beta_C + \beta_B)}$$

$$(50\text{ kg}) g = m_D g e^{0.4\left(\frac{\pi}{2}+\frac{\pi}{2}\right)}$$

$$m_D = 14.23\text{ kg}$$

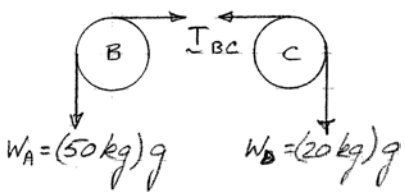
For equilibrium: $$14.23\text{ kg} \le m_D \le 175.7\text{ kg} \blacktriangleleft$$

PROBLEM 8.138



Two cylinders are connected by a rope that passes over two fixed rods as shown. Knowing that for cylinder D upward motion impends when $m = 20$ kg, determine (a) the coefficient of static friction between the rope and the rods, (b) the corresponding tension in portion BC of the rope.

SOLUTION



(a) Motion of D impends upward, so

$$T_{BC} = W_D e^{\mu_s \beta_C} \tag{1}$$

$$W_A = T_{BC} e^{\mu_s \beta_B} = W_D e^{\mu_s(\beta_C + \beta_B)}$$

So $$\mu_s \left(\frac{\pi}{2} + \frac{\pi}{2} \right) = \ln \frac{W_A}{W_D} = \ln \left(\frac{50 \text{ kg}}{20 \text{ kg}} \right)$$

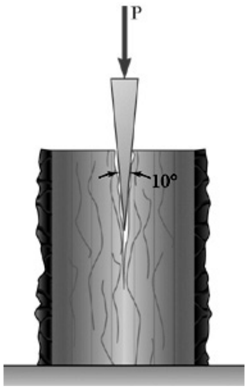
$$\mu_s = 0.29166$$

$$\mu_s = 0.292 \blacktriangleleft$$

(b) From Equation (1): $$T_{BC} = (20 \text{ kg})(9.81 \text{ m/s}^2) e^{0.29166\pi/2}$$

$$T_{BC} = 310 \text{ N} \blacktriangleleft$$

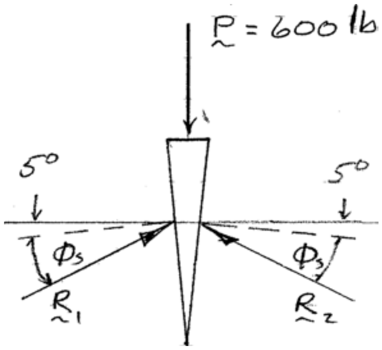
PROBLEM 8.139



A 10° wedge is used to split a section of a log. The coefficient of static friction between the wedge and the log is 0.35. Knowing that a force **P** of magnitude 600 lb was required to insert the wedge, determine the magnitude of the forces exerted on the wood by the wedge after insertion.

SOLUTION

FBD wedge (impending motion ↓):



$$\phi_s = \tan^{-1}\mu_s = \tan^{-1}0.35 = 19.29°$$

By symmetry: $R_1 = R_2$

$$\uparrow \Sigma F_y = 0: \quad 2R_1\sin(5° + \phi_s) - 600 \text{ lb} = 0$$

or $$R_1 = R_2 = \frac{300 \text{ lb}}{\sin(5° + 19.29°)} = 729.30 \text{ lb}$$

When P is removed, the vertical components of R_1 and R_2 vanish, leaving the horizontal components

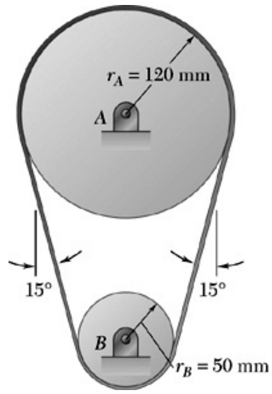
$$R_{1x} = R_{2x} = R_1\cos(5° + \phi_s)$$

$$= (729.30 \text{ lb})\cos(5° + 19.29°)$$

$$R_{1x} = R_{2x} = 665 \text{ lb} \blacktriangleleft$$

(Note that $\phi_s > 5°$, so wedge is self-locking.)

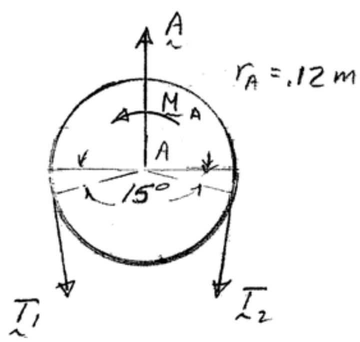
PROBLEM 8.140

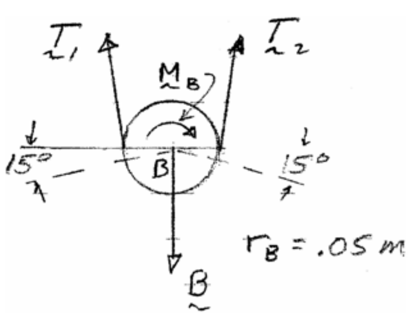


A flat belt is used to transmit a torque from drum B to drum A. Knowing that the coefficient of static friction is 0.40 and that the allowable belt tension is 450 N, determine the largest torque that can be exerted on drum A.

SOLUTION

FBD's drums:





$$\beta_A = 180° + 30° = \pi + \frac{\pi}{6} = \frac{7\pi}{6}$$

$$\beta_B = 180° - 30° = \pi - \frac{\pi}{6} = \frac{5\pi}{6}$$

Since $\beta_B < \beta_A$, slipping will impend first on B (friction coefficients being equal)

So $$T_2 = T_{\max} = T_1 e^{\mu_s \beta_B}$$

$$450\text{ N} = T_1 e^{(0.4)5\pi/6} \qquad \text{or} \qquad T_1 = 157.914\text{ N}$$

$$\circlearrowleft \Sigma M_A = 0: \quad M_A + (0.12\text{ m})(T_1 - T_2) = 0$$

$$M_A = (0.12\text{ m})(450\text{ N} - 157.914\text{ N}) = 35.05\text{ N}\cdot\text{m}$$

$$M_A = 35.1\text{ N}\cdot\text{m} \blacktriangleleft$$