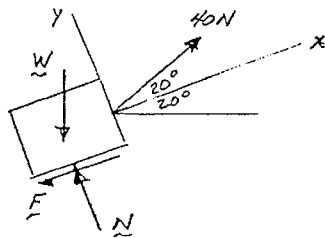


### PROBLEM 8.3

Determine whether the 10-kg block shown is in equilibrium, and find the magnitude and direction of the friction force when  $P = 40 \text{ N}$  and  $\theta = 20^\circ$ .

### SOLUTION

FBD Block:



Tension in cord is equal to  $P = 40 \text{ N}$ , from FBD of pulley.

$$W = (10 \text{ kg})(9.81 \text{ m/s}^2) = 98.1 \text{ N}$$

$$\sum F_y = 0: \quad N - (98.1 \text{ N})\cos 20^\circ + (40 \text{ N})\sin 20^\circ = 0$$

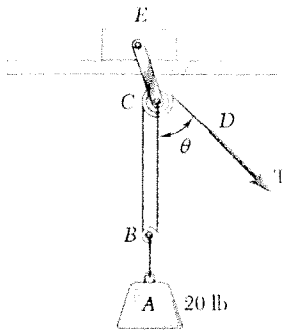
$$N = 78.503 \text{ N}$$

$$F_{\max} = \mu_s N = (0.30)(78.503 \text{ N}) = 23.551 \text{ N}$$

$$\text{For equilibrium: } \sum F_x = 0: \quad (40 \text{ N})\cos 20^\circ - (98.1 \text{ N})\sin 20^\circ - F = 0$$

$$F_{\text{eq}} = 4.0355 \text{ N} < F_{\max}, \quad \therefore \text{Equilibrium exists} \blacktriangleleft$$

$$F = F_{\text{eq}} \qquad F = 4.04 \text{ N} \nearrow 20^\circ \blacktriangleleft$$

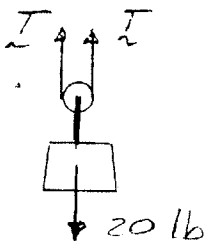


### PROBLEM 8.10

The 20-lb block *A* hangs from a cable as shown. Pulley *C* is connected by a short link to block *E* which rests on a horizontal rail. Knowing that the coefficient of static friction between block *E* and the rail is 0.35 and neglecting the weight of the block *E* and the friction in the pulleys, determine the maximum allowable value of  $\theta$  if the system is to remain in equilibrium.

### SOLUTION

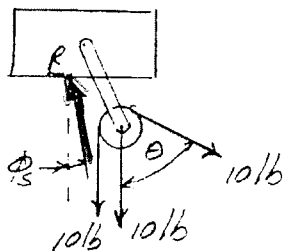
FBD A with pulley:



Tension in cord is *T* throughout from pulley FBD's

$$\uparrow \Sigma F_y = 0: \quad 2T - 20 \text{ lb} = 0, \quad T = 10 \text{ lb}$$

FBD E with pulley:



For  $\theta_{\max}$ , motion impends to right, and

$$\phi_s = \tan^{-1} \mu_s = \tan^{-1}(0.35) = 19.2900^\circ$$

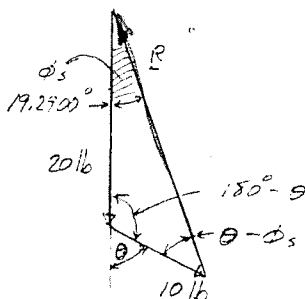
*Good*

From force triangle,

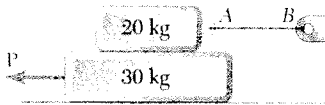
$$\frac{20 \text{ lb}}{\sin(\theta - \phi_s)} = \frac{10 \text{ lb}}{\sin \phi_s}, \quad 2 \sin \phi_s = \sin(\theta - \phi_s)$$

$$\theta = \sin^{-1}(2 \sin 19.2900^\circ) + 19.2900^\circ = 60.64^\circ$$

$$\theta_{\max} = 60.6^\circ \blacktriangleleft$$



**PROBLEM 8.11**



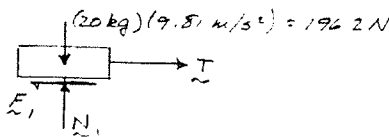
The coefficients of friction are  $\mu_s = 0.40$  and  $\mu_k = 0.30$  between all surfaces of contact. Determine the force  $\mathbf{P}$  for which motion of the 30-kg block is impending if cable  $AB$  (a) is attached as shown, (b) is removed.

**SOLUTION**

**FBD top block:**

$$\uparrow \Sigma F_y = 0: \quad N_1 - 196.2 \text{ N} = 0$$

$$N_1 = 196.2 \text{ N} \uparrow$$



(a) With cable in place, impending motion of bottom block requires impending slip between blocks, so  $F_1 = \mu_s N_1 = 0.4(196.2 \text{ N})$

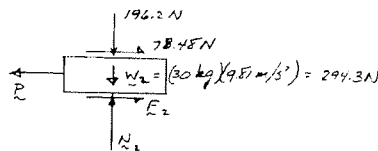
$$F_1 = 78.48 \text{ N} \leftarrow$$

$$\uparrow \Sigma F_y = 0: \quad N_2 - 196.2 \text{ N} - 294.3 \text{ N} = 0$$

$$N_2 = 490.5 \text{ N} \uparrow$$

**FBD bottom block:**

$$F_2 = \mu_s N_2 = 0.4(490.5 \text{ N}) = 196.2 \text{ N}$$



$$\rightarrow \Sigma F_x = 0: \quad -P + 78.48 \text{ N} + 196.2 \text{ N} = 0$$

$$\mathbf{P} = 275 \text{ N} \leftarrow$$

**FBD block:**

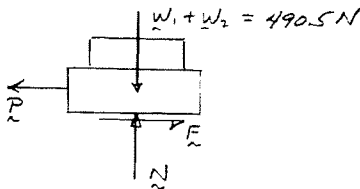
(b) Without cable  $AB$ , top and bottom blocks will move together

$$\uparrow \Sigma F_y = 0: \quad N - 490.5 \text{ N} = 0, \quad N = 490.5 \text{ N}$$

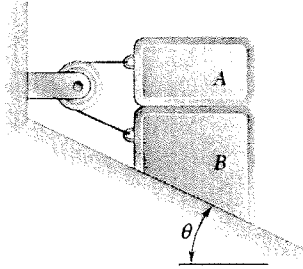
Impending slip:  $F = \mu_s N = 0.40(490.5 \text{ N}) = 196.2 \text{ N}$

$$\rightarrow \Sigma F_x = 0: \quad -P + 196.2 \text{ N} = 0$$

$$\mathbf{P} = 196.2 \text{ N} \leftarrow$$



### PROBLEM 8.14



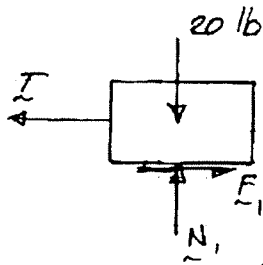
The 20-lb block  $A$  and the 40-lb block  $B$  are at rest on an incline as shown. Knowing that the coefficient of static friction is 0.25 between all surfaces of contact, determine the value of  $\theta$  for which motion is impending.

### SOLUTION

Note: Slip must impend at both surfaces simultaneously.

FBD's:

A:



$$\uparrow \Sigma F_y = 0: \quad N_1 - 20 \text{ lb} = 0, \quad N_1 = 20 \text{ lb}$$

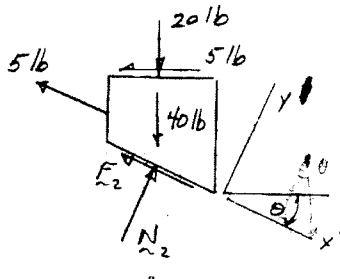
Impending slip:  $F_1 = \mu_s N_1 = (0.25)(20 \text{ lb}) = 5 \text{ lb}$

$$\rightarrow \Sigma F_x = 0: \quad -T + 5 \text{ lb} = 0, \quad T = 5 \text{ lb}$$

$$\nearrow \Sigma F_{y'} = 0: \quad N_2 - (20 \text{ lb} + 40 \text{ lb}) \cos \theta - (5 \text{ lb}) \sin \theta = 0$$

$$N_2 = (60 \text{ lb}) \cos \theta - (5 \text{ lb}) \sin \theta$$

B:



Impending slip:  $F_2 = \mu_s N_2 = (0.25)(60 \cos \theta - 5 \sin \theta) \text{ lb}$

$$\searrow \Sigma F_{x'} = 0: \quad -F_2 - 5 \text{ lb} - (5 \text{ lb}) \cos \theta + (20 \text{ lb} + 40 \text{ lb}) \sin \theta = 0$$

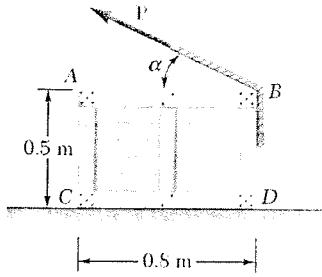
$$-20 \cos \theta + 58.75 \sin \theta - 5 = 0$$

Solving numerically,

$$\theta = 23.4^\circ \blacktriangleleft$$

Good ☺

Final Exam Review



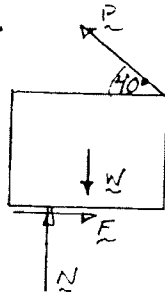
**PROBLEM 8.16**

A packing crate of mass 40 kg is pulled by a rope as shown. The coefficient of static friction between the crate and the floor is 0.35. If  $\alpha = 40^\circ$ , determine (a) the magnitude of the force **P** required for impending motion of the crate, (b) whether sliding or tipping is impending.

**SOLUTION**

First assume slip impends without tipping, so  $F = \mu_s N$

**FBD**



$$\uparrow \Sigma F_y = 0: \quad N + P \sin 40^\circ - W = 0, \quad N = W - P \sin 40^\circ$$

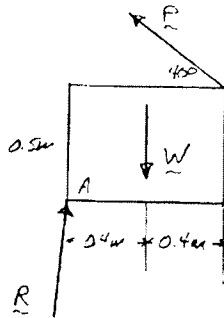
$$F = \mu_s N = 0.35(W - P \sin 40^\circ)$$

$$\rightarrow \Sigma F_x = 0: \quad F - P \cos 40^\circ = 0$$

$$0.35W = P(\cos 40^\circ + 0.35 \sin 40^\circ)$$

$$P_s = 0.35317W \tag{1}$$

Next assume tip impends without slipping, **R** acts at C.



$$\curvearrowleft \Sigma M_A = 0: \quad (0.8 \text{ m})P \sin 40^\circ + (0.5 \text{ m})P \cos 40^\circ - (0.4 \text{ m})W = 0$$

$$P_t = 0.4458W > P_s \text{ from (1)}$$

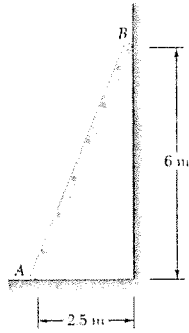
$$\therefore P_{\max} = P_s = 0.35317(40 \text{ kg})(9.81 \text{ m/s}^2)$$

$$= 138.584 \text{ N}$$

(a)  $P_{\max} = 138.6 \text{ N} \blacktriangleleft$

(b) Slip is impending  $\blacktriangleleft$

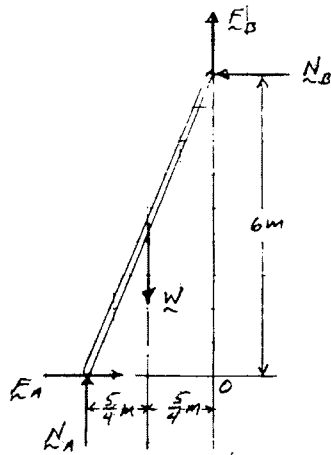
### PROBLEM 8.22



A 6.5-m ladder  $AB$  of mass 10 kg leans against a wall as shown. Assuming that the coefficient of static friction  $\mu_s$  is the same at both surfaces of contact, determine the smallest value of  $\mu_s$  for which equilibrium can be maintained.

### SOLUTION

FBD ladder:



Slip impends at both  $A$  and  $B$ ,  $F_A = \mu_s N_A$ ,  $F_B = \mu_s N_B$

$$\Sigma F_x = 0: \quad F_A - N_B = 0, \quad N_B = F_A = \mu_s N_A$$

$$\uparrow \Sigma F_y = 0: \quad N_A - W + F_B = 0, \quad N_A + F_B = W$$

$$N_A + \mu_s N_B = W$$

$$N_A(1 + \mu_s^2) = W$$

$$\Sigma M_O = 0: \quad (6 \text{ m})N_B + \left(\frac{5}{4} \text{ m}\right)W - \left(\frac{5}{2} \text{ m}\right)N_A = 0$$

$$6\mu_s N_A + \frac{5}{4}N_A(1 + \mu_s^2) - \frac{5}{2}N_A = 0$$

$$\mu_s^2 + \frac{24}{5}\mu_s - 1 = 0$$

$$\mu_s = -2.4 \pm 2.6$$

$$\mu_{s \text{ min}} = 0.200 \quad \blacktriangleleft$$

Very Good

**PROBLEM 8.102**

Blocks *A* and *B* are connected by a cable that passes over support *C*. Friction between the blocks and the inclined surfaces may be neglected. Knowing that motion of block *B* (up) the incline is impending when  $m_B = 8 \text{ kg}$ , determine (a) the coefficient of static friction between the rope and the support, (b) the largest value of  $m_B$  for which equilibrium is maintained. (Hint: See Prob. 8.128.)

**SOLUTION**

**FBD A:**

$$W_A = (10 \text{ kg})(9.81 \text{ m/s}^2) = 98.1 \text{ N}$$

$$\sum F_x = 0: \quad T_A - W_A \sin 30^\circ = 0, \quad T_A = \frac{W_A}{2}$$

**FBD B:**

$$\sum F_{x'} = 0: \quad W_B \sin 30^\circ - T_B = 0, \quad T_B = \frac{W_B}{2}$$

(a) Motion of *B* impends up incline and  $m_B = 8 \text{ kg}$

$$\frac{T_A}{T_B} = e^{\mu_s \beta}, \quad \mu_s = \frac{1}{\beta} \ln \frac{T_A}{T_B} = \frac{1}{\beta} \ln \frac{W_A}{W_B}$$

$$= \frac{1}{\beta} \ln \frac{m_A}{m_B} = \frac{3}{\pi} \ln \left( \frac{10 \text{ kg}}{8 \text{ kg}} \right)$$

$$\mu_s = 0.21309$$

$\mu_s = 0.213 \blacktriangleleft$

(b) For maximum  $m_B$ , motion of *B* impend down incline

$$\frac{T_B}{T_A} = e^{\mu_s \beta}, \quad T_B = T_A e^{0.21309 \frac{\pi}{3}} = 1.250 T_A$$

$$\therefore W_B = 1.25 W_A \text{ and } m_B = 1.25 m_A = 1.25(10 \text{ kg})$$

$m_{B \text{ max}} = 12.50 \text{ kg} \blacktriangleleft$

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