Montogue

Quiz SM106
Friction

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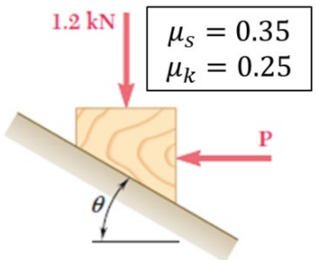
Problems

PROBLEM 1 A

Determine the magnitude of the friction force and whether the block is in equilibrium when $\theta = 25°$ and $P = 750$ N.



A) F = 172.6 N and the block is in equilibrium.

B) F = 172.6 N and the block is moving.

C) F = 351.1 N and the block is in equilibrium.

D) F = 351.1 N and the block is moving.

PROBLEM 1 B

Repeat the previous problem if θ = 30° and P = 150 N.

A) F = 278.6 N and the block is in equilibrium.

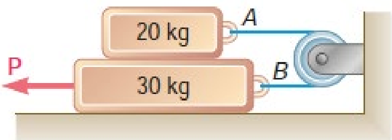
B) F = 278.6 N and the block is moving.

C) F = 390.0 N and the block is in equilibrium.

D) F = 390.0 N and the block is moving.

PROBLEM 2 (Beer et al., 2013, w/ permission)

The coefficients of friction are μ_s = 0.40 and μ_k = 0.30 between all surfaces of contact. Determine the smallest force P required to start the 30-kg block moving if cable AB is attached as shown.



A) P = 165.6 N

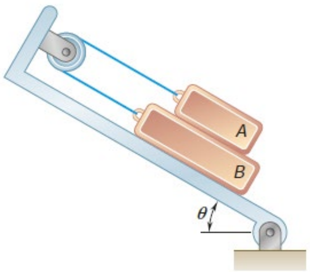
B) P = 276.5 N

C) P = 353.2 N

D) P = 449.8 N

PROBLEM 3 (Beer et al., 2013, w/ permission)

The 20-lb block A and the 30-lb block B are supported by an incline that is held that 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.



A) θ = 21°
B) θ = 26°
C) θ = 31°
D) θ = 36°

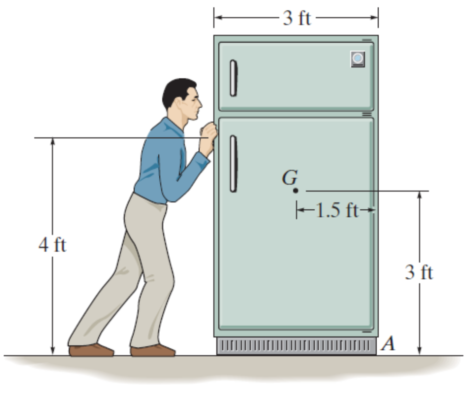
PROBLEM 4 (Bedford & Fowler, 2008, w/ permission)

The ladder and the person weigh 30 lb and 180 lb, respectively. The center of mass of the 12-ft ladder is at its midpoint. The angle α between the ladder and the vertical is 30°. Assume that the wall exerts a negligible friction force on the ladder. What minimum coefficient of static friction between the ladder and the floor is necessary for the person to be able to climb to the top of the ladder without slipping?

A) μ_s = 0.536
B) μ_s = 0.612
C) μ_s = 0.747
D) μ_s = 0.808

PROBLEM 5 (Hibbeler, 2010, w/ permission)

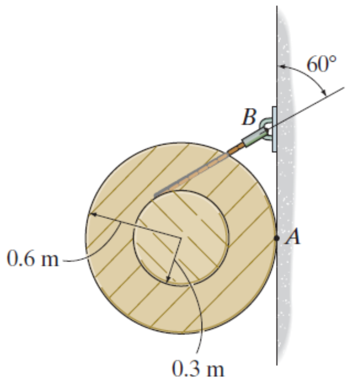
The refrigerator has a weight of 180 lb and rests on a tile floor for which μ_s = 0.25. If the man pushes horizontally on the refrigerator in the direction shown, determine the smallest magnitude of horizontal force needed to move it. Also, if the man has a weight of 150 lb, determine the smallest coefficient of friction between his shoes and the floor so that he does not slip.



A) P = 45 lb and μ_s = 0.20
B) P = 45 lb and μ_s = 0.30
C) P = 70 lb and μ_s = 0.20
D) P = 70 lb and μ_s = 0.30

PROBLEM 6 (Hibbeler, 2010, w/ permission)

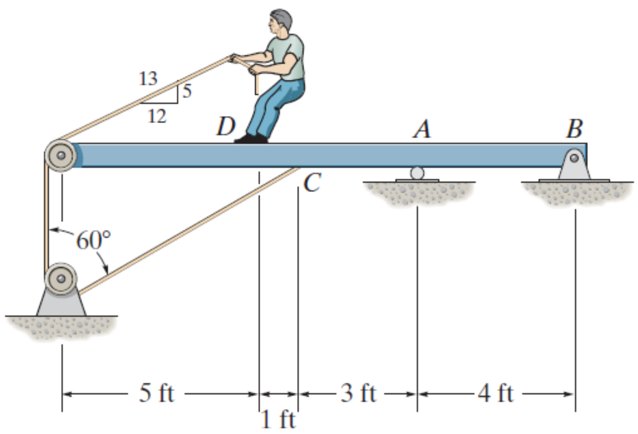
Determine the minimum coefficient of static friction between the uniform 50-kg spool and the wall so that the spool does not slip.



A) μ_s = 0.469
B) μ_s = 0.577
C) μ_s = 0.685
D) μ_s = 0.791

PROBLEM 7 (Hibbeler, 2010, w/ permission)

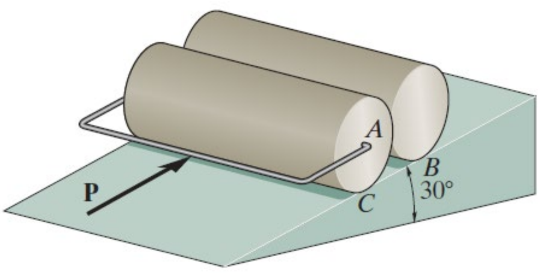
The 80-lb boy stands on the beam and pulls on the cord with a force enough to just cause him to slip. If the coefficient of static friction between his shoes and the beam is $(\mu_s)_D$ = 0.4, determine the reactions at A and B (resultant). The beam is uniform and has a weight of 100 lb. Neglect the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



A) A_y = 395.0 lb and B = 206.4 lb
B) A_y = 395.0 lb and B = 234.5 lb
C) A_y = 474.1 lb and B = 206.4 lb
D) A_y = 474.1 lb and B = 234.5 lb

PROBLEM 8 (Hibbeler, 2010, w/ permission)

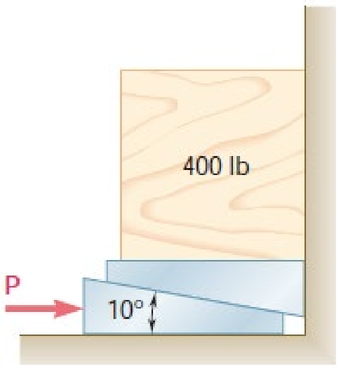
Determine the minimum force needed to push the two 75-kg cylinders up the incline. The force acts parallel to the plane and the coefficients of static friction are μ_A = 0.3, μ_B = 0.25, and μ_C = 0.4. Each cylinder has a radius of 150 mm.



A) P = 0.87 kN
B) P = 1.05 kN
C) P = 1.21 kN
D) P = 1.46 kN

PROBLEM 9 (Beer et al., 2008, w/ permission)

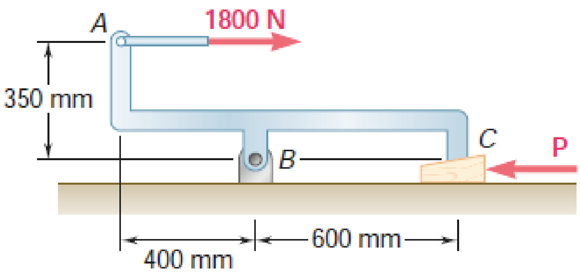
Two 10° wedges of negligible weight are used to move and position the 400-lb block. Knowing that the coefficient of static friction is 0.25 at all surfaces of contact, determine the smallest force P that should be applied as shown to one of the wedges.



A) P = 313.4 lb
B) P = 344.5 lb
C) P = 376.6 lb
D) P = 405.7 lb

PROBLEM 10 (Beer et al., 2008, w/ permission)

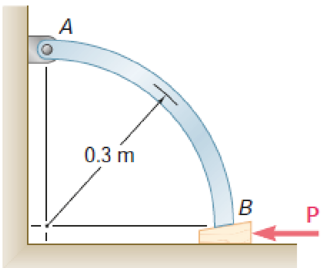
The machine part ABC is supported by a frictionless hinge at B and a 10° wedge at C. Knowing that the coefficient of static friction at both surfaces of the wedge is 0.20, determine the force P required to move the wedge.



A) P = 619.2 N
B) P = 667.1 N
C) P = 717.5 N
D) P = 768.4 N

PROBLEM 11 (Beer et al., 2008, w/ permission)

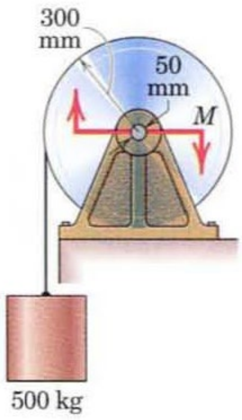
A 10° wedge is to be forced under end B of the 5-kg rod AB. Knowing that the coefficient of static friction is 0.40 between the wedge and the rod and 0.20 between the wedge and the floor, determine the smallest force P required to raise end B of the rod.



A) P = 45.8 N
B) P = 58.1 N
C) P = 67.4 N
D) P = 76.5 N

PROBLEM 12 (Merriam & Kraige, 2002, w/ permission)

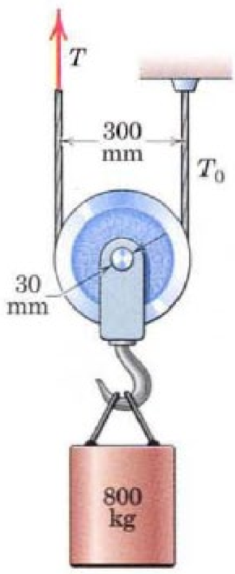
A torque *M* of 1510 Nm must be applied to the 50-mm diameter shaft of the hoisting drum to raise the 500-kg load at constant speed. Calculate the coefficient of friction for the bearing.



A) μ = 0.162
B) μ = 0.213
C) μ = 0.271
D) μ = 0.323

PROBLEM 13 (Merriam & Kraige, 2002, w/ permission)

Determine the tension *T* in the cable to raise the 800-kg load if the coefficient of friction for the 30-mm bearing is 0.25. Also find the tension T_0 in the stationary section of the cable. The mass of the cable and pulley is small and may be neglected.

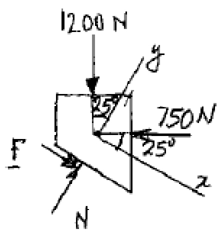


A) T = 3280 N and T_o = 4570 N
B) T = 3620 N and T_o = 4230 N
C) T = 4020 N and T_o = 3830 N
D) T = 4400 N and T_o = 3450 N

Solutions

P.1 ■ Solution

Part A: Assume that the block is in equilibrium. Consider the following free body diagram.



Summing forces in the direction parallel to the slope, we have

$$\Sigma F_{\backslash\backslash} = 0 \rightarrow F + 1200 \times \sin 25^{\circ} - 750 \times \cos 25^{\circ} = 0$$

$$\therefore F = 750 \times \cos 25^{\circ} - 1200 \times \sin 25^{\circ} = 172.6 \text{ N}$$

Then, considering forces in the direction perpendicular to the slope, we can compute the normal force *N*,

$$\Sigma F_{\perp} = 0 \rightarrow N - 1200 \times \cos 25^{\circ} - 750 \times \sin 25^{\circ} = 0$$

$$\therefore N = 1200 \times \cos 25^{\circ} + 750 \times \sin 25^{\circ} = 1404.5 \text{ N}$$

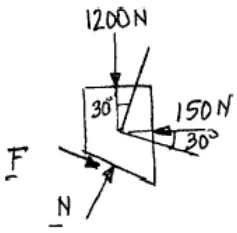
Thereafter, the maximum friction force when the block is standing still is

$$F_{\max} = \mu_s N = 0.35 \times 1404.5 = 491.6 \text{ N}$$

which is such that $F_{max} > F$, and hence implies that the block is in equilibrium. The magnitude of the friction force is equal to *F*, or 172.6 N, and points downhill.

■ The correct answer is **A**.

Part B: Consider the following free body diagram.



Suppose that the block is in equilibrium. In this case, summing forces in the direction parallel to the slope gives

$$\Sigma F_{\backslash\backslash} = 0 \rightarrow F + 1200 \times \sin 30^{\circ} - 150 \times \cos 30^{\circ} = 0$$

$$\therefore F = -470.1 \text{ N}$$

The negative sign implies that force *F* points to a direction opposite to the one initially supposed, i.e., the force points uphill. To determine the normal force, we examine the equilibrium of forces perpendicularly to the slope,

$$\Sigma F_{\perp} = 0 \rightarrow N - 1200 \times \cos 30^{\circ} - 150 \times \sin 30^{\circ}$$

$$\therefore N = 1200 \times \cos 30^{\circ} + 150 \times \sin 30^{\circ} = 1114.2 \text{ N}$$

Knowing the value of *N*, we are able to determine the maximum friction force,

$$F_{\max} = \mu_s N = 0.35 \times 1114.2 = 390.0 \text{ N}$$

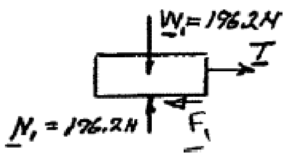
Because $F_{max} < F$, we conclude that the block is not in equilibrium; rather, it is moving down. The actual friction force is

$$F = \mu_k N = 0.25 \times 1114.2 = 278.6 \text{ N}$$

■ The correct answer is **B**.

P.2 ■ Solution

Consider the free body diagram for the 20 kg block.



The weight and friction force for this block are, respectively,

$$W_1 = 20 \times 9.81 = 196.2 \text{ N}$$

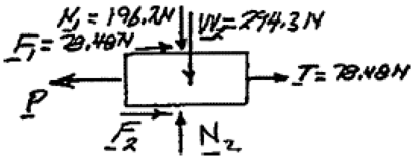
$$F_1 = \mu_s N_1 = 0.4 \times 196.2 = 78.5 \text{ N}$$

Equilibrium of forces in the *x*-direction enables us to write

$$\Sigma F_x = 0 \to T - F_1 = 0$$

$$\therefore T = F_1 = 78.5\,\text{N}$$

Next, consider the free body diagram for the lower block.



Computing the usual forces, we have

$$W_2 = 30 \times 9.81 = 294.3\,\text{N}$$

$$N_2 = 196.2 + 294.3 = 490.5\,\text{N}$$

$$F_2 = \mu_s N_2 = 0.4 \times 490.5 = 196.2\,\text{N}$$

Considering equilibrium in the *x*-direction, we find the lowest force *P* desired,

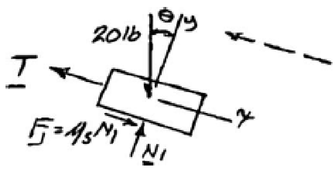
$$\Sigma F_x = 0 \to P - F_1 - F_2 - T = 0$$

$$\therefore P = F_1 + F_2 + T = 78.5 + 196.2 + 78.5 = \boxed{353.2\,\text{N}}$$

■ The correct answer is **C**.

P.3 ■ Solution

Consider the free body diagram for block A.



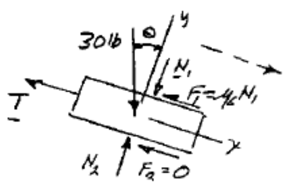
When the block is impending motion, the following expressions hold for force equilibrium perpendicular ($\Sigma F_\perp = 0$) and parallel ($\Sigma F_\parallel = 0$) to the incline,

$$\Sigma F_\perp = 0 \to N_1 = 20\cos\theta$$

$$\Sigma F_\parallel = 0 \to T - 20\sin\theta - \mu_s N_1 = 0$$

$$\therefore T = 20\sin\theta + 0.15(20\cos\theta) = 20\sin\theta + 3\cos\theta \text{ (I)}$$

Now, consider the free body diagram for block B.



Summing forces in the direction parallel to the slope gives

$$\Sigma F_\parallel = 0 \to T - 30\sin\theta + \mu_s N_1 = 0$$

$$\therefore T = 30\sin\theta - \mu_s N_1$$

$$\therefore T = 30\sin\theta - 0.15(20\cos\theta) = 30\sin\theta - 3\cos\theta \text{ (II)}$$

Subtracting equation (II) from equation (I), we obtain

$$20\sin\theta + 3\cos\theta - 30\sin\theta + 3\cos\theta = 0$$

$$\therefore -10\sin\theta + 6\cos\theta = 0$$

$$\therefore 10\sin\theta = 6\cos\theta$$

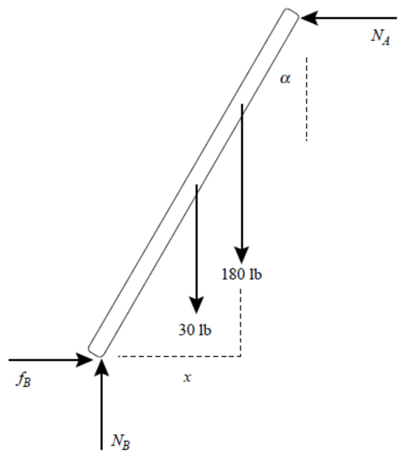
$$\therefore \tan\theta = 0.6$$

$$\therefore \theta = \arctan 0.6 = \boxed{31^\circ}$$

■ The correct answer is **C**.

P.4 ■ Solution

Since α = 30°, at the top of the ladder we have x = 6 ft. Consider the following free body diagram.



The equations for equilibrium are the sum of forces in the x-direction (ΣF_x = 0), the sum of forces in the y-direction (ΣF_y = 0), and the sum of moments relative to point B (ΣM_B = 0), namely,

$$\Sigma F_x = 0 \rightarrow f_B - N_A = 0$$
$$\Sigma F_y = 0 \rightarrow N_B - 210 = 0$$
$$\Sigma M_B = 0 \rightarrow N_A \times 12\cos\alpha - 30 \times 6\sin\alpha - 180x = 0$$

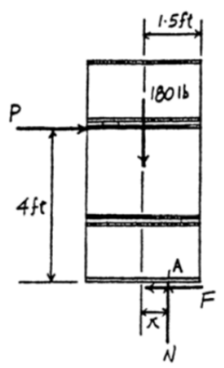
The second equation can be easily solved for the reaction N_B = 210 lb, while the third equation can be solved for the reaction N_A = 112.6 lb. Recalling that $f_B = \mu_s N_B$, we can substitute the available data in the first equation and solve for the coefficient of static friction,

$$f_B - N_A = 0 \rightarrow \mu_s N_B = N_A$$
$$\therefore \mu_s = \frac{N_A}{N_B} = \frac{112.6}{210} = \boxed{0.536}$$

■ The correct answer is **A**.

P.5 ■ Solution

The free body diagram for the refrigerator is shown below.



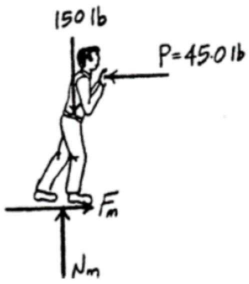
Consider equations of equilibrium in the x- and y-direction, along with a sum of moments about point A.

$$\Sigma F_y = 0 \rightarrow N - 180 = 0$$
$$\Sigma F_x = 0 \rightarrow P - F = 0$$
$$\Sigma M_A = 0 \rightarrow 180x - P \times 4 = 0$$

From the first equation, N = 180 lb. Assuming the refrigerator is on the verge of slipping, then $F = \mu N$ = 0.25 × 180 = 45 lb. Substituting this value into the second and third equations gives P = 45 lb and x = 1 ft. Since x < 1.5 ft, the refrigerator does not tip and the preceding assumption is correct. Hence,

$$\boxed{P = 45\text{ lb}}$$

Now, consider the free body diagram for the man pushing the refrigerator.



Equilibria of forces in the *x*- and *y*-directions enable us to write

$$\Sigma F_x = 0 \to F_m - 45 = 0$$
$$\therefore F_m = 45\,\text{lb}$$
$$\Sigma F_y = 0 \to N_m - 150 = 0$$
$$\therefore N_m = 150\,\text{lb}$$

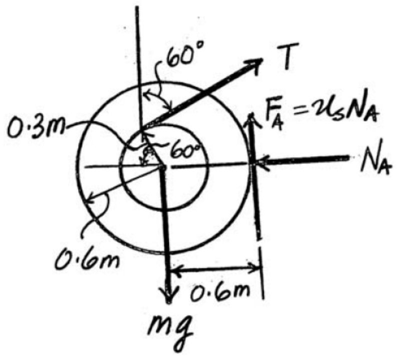
When the man is on the verge of slipping, the following equality applies,

$$F_m = \mu_s N_m \to \mu_s = \frac{F_m}{N_m}$$
$$\therefore \mu_s = \frac{45}{150} = \boxed{0.3}$$

■ The correct answer is **B**.

P.6 ■ Solution

The frictional force F_A must act upwards to produce the counterclockwise moment about the center of mass of the spool, opposing the impending clockwise rotational motion caused by force T as indicated on the free body diagram of the spool below. Since the spool is required to be on the verge of slipping, $F_A = \mu_A N_A$. Refer to the following figure.



Summing moments about point A, we obtain

$$\Sigma M_A = 0 \to mg \times 0.6 - T\cos 60^\circ \times \left(0.3\cos 60^\circ + 0.6\right) - T\sin 60^\circ \times 0.3\sin 60^\circ = 0$$
$$\therefore T = mg$$

Next, summing forces in the *x*-direction gives

$$\Sigma F_x = 0 \to T\sin 60^\circ - N_A = 0$$
$$\therefore N_A = 0.866mg$$

Finally, summing forces in the *y*-direction yields

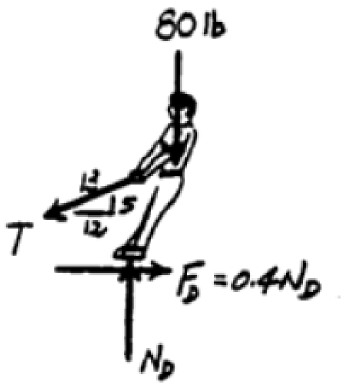
$$\Sigma F_y = 0 \to \mu_s \times N_A + mg\cos 60^\circ - mg = 0$$
$$\therefore \mu_s \times 0.866mg + 0.5mg - mg = 0$$
$$\therefore \mu_s = \frac{0.5mg}{0.866mg} = \boxed{0.577}$$

Note that μ_s is independent of the mass of the spool. The spool will not slip regardless of its mass provided $\mu_s > 0.577$.

■ The correct answer is **B**.

P.7 ■ Solution

Consider the free body diagram for the boy.

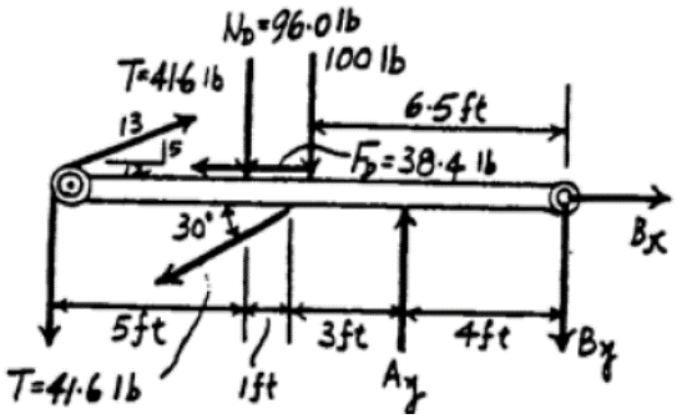


Applying the first condition of equilibrium in the *x*- and *y*-directions, we obtain

$$\Sigma F_x = 0 \rightarrow 0.4N_D - T\times\frac{12}{13} = 0$$

$$\Sigma F_y = 0 \rightarrow N_D - T\times\frac{5}{13} - 80 = 0$$

Solving the two equations simultaneously, we obtain T = 41.6 lb and N_D = 96.0 lb. Next, consider the free body diagram for the beam.



The reaction at A can be obtained by applying the second condition of equilibrium to point B,

$$\Sigma M_B = 0$$

$$\therefore 100\times 6.5 + 96.0\times 8 - 41.6\times\frac{5}{13}\times 13 + 41.6\times 13 + 41.6\times\sin 30^\circ\times 7 - 4\times A_y = 0$$

$$\therefore \boxed{A_y = 474.1\,\text{lb}}$$

The horizontal component of the reaction at B can be obtained by applying the first condition of equilibrium in the horizontal direction,

$$\Sigma F_x = 0 \rightarrow B_x + 41.6\times\frac{12}{13} - 38.4 - 41.6\times\cos 30^\circ = 0$$

$$\therefore B_x = 36.0\,\text{lb}$$

Applying the first condition of equilibrium in the vertical direction, in turn, we obtain

$$\Sigma F_y = 0 \rightarrow 474.1 + 41.6\times\frac{5}{13} - 41.6 - 41.6\times\sin 30^\circ - 96.0 - 100 - B_y = 0$$

$$\therefore B_y = 231.7\,\text{lb}$$

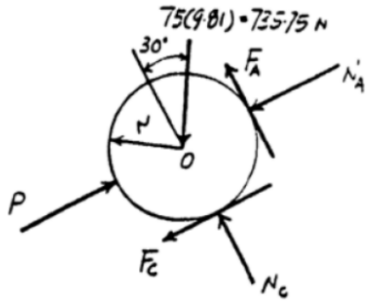
Finally, the resultant force at point B is

$$B = \sqrt{B_x^2 + B_y^2} = \sqrt{36.0^2 + 231.7^2} = \boxed{234.5\,\text{lb}}$$

■ The correct answer is **D**.

P.8 ■ Solution

Consider the free body diagram for the lower cylinder.



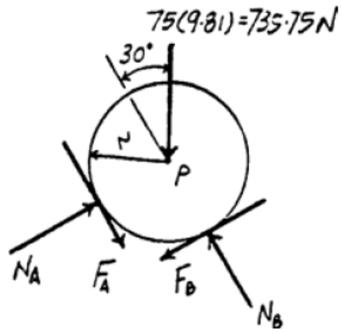
Three equilibrium equations are proposed: one for force equilibrium in the direction parallel to the incline, a force equilibrium perpendicular to the incline, and a sum of moments about the center O of the cylinder. Mathematically,

$$\Sigma F_{\backslash\backslash} = 0 \rightarrow P - N_A - F_C - (75 \times 9.81)\sin 30^\circ = 0$$

$$\Sigma F_{\perp} = 0 \rightarrow N_c + F_A - (735.8)\cos 30^\circ = 0$$

$$\Sigma M_O = 0 \rightarrow F_A \times r - F_C \times r = 0$$

Next, consider a free body diagram for the upper cylinder.



In this case, the equations of equilibrium are

$$\Sigma F_{\backslash\backslash} = 0 \rightarrow N_A - F_B - (75 \times 9.81)\sin 30^\circ = 0$$

$$\Sigma F_{\perp} = 0 \rightarrow N_B - F_A - (75 \times 9.81)\cos 30^\circ = 0$$

$$\Sigma M_O = 0 \rightarrow F_A \times r - F_B \times r = 0$$

Assuming that slipping occurs at point A, then $F_A = \mu_A N_A = 0.3 N_A$. Substituting this value into the six previous equations yields

$$N_A = 525.5 \text{ N} \; ; \; N_B = 794.8 \text{ N}$$

$$N_C = 479.5 \text{ N} \; ; \; F_C = F_B = 157.7 \text{ N}$$

and

$$P = 1051.1\text{N} = \boxed{1.05 \text{ kN}}$$

Since $(F_C)_{\max} = \mu_C N_C = 0.4 \times 479.5 = 191.8 \text{ N} > F_C$ and $(F_B)_{\max} = \mu_B N_B = 0.25 \times 794.8 = 198.7 \text{ N} > F_B$, slipping does not occur neither at point C nor at B, and our initial assumption is correct.

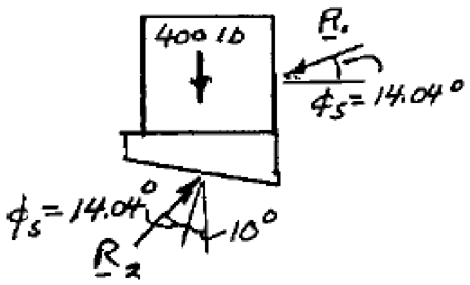
■ The correct answer is **B**.

P.9 ■ Solution

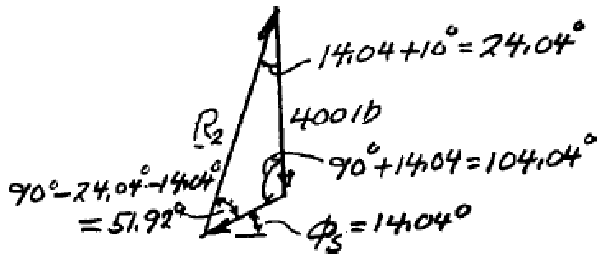
The friction angle is such that

$$\phi_s = \tan^{-1} 0.25 = 14.04^\circ$$

Consider the free body diagram for the ensemble of the upper wedge and the block.



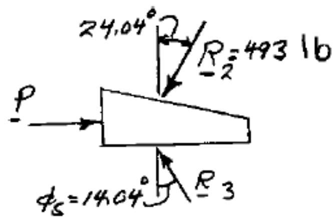
The force triangle is drawn below.



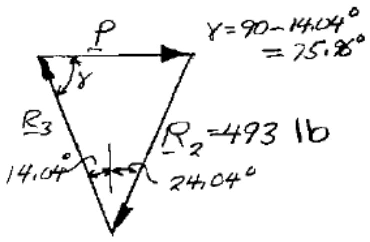
The force R_2 applied by one wedge to the other can be obtained from the law of sines,

$$\frac{R_2}{\sin 104.04^\circ} = \frac{400}{\sin 51.92^\circ} \rightarrow R_2 = \frac{\sin 104.04^\circ}{\sin 51.92^\circ} \times 400 = 493\,\text{lb}$$

Next, consider the free body diagram for the lower wedge.



The force triangle is shown below.



Applying the law of sines again, we have

$$\frac{P}{\sin\left(\underbrace{14.04^\circ + 24.04^\circ}_{=38.08^\circ}\right)} = \frac{493}{\sin\left(\underbrace{90^\circ - 14.04^\circ}_{=75.96^\circ}\right)} \rightarrow P = \frac{\sin 38.08^\circ}{\sin 75.96^\circ} \times 493 = \boxed{313.4\,\text{lb}}$$

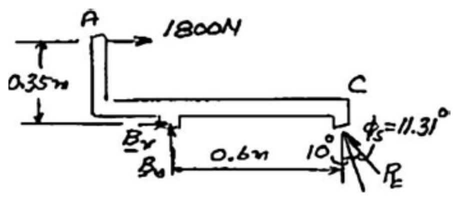
■ The correct answer is **A**.

P.10 ■ Solution

The friction angle ϕ_s is such that

$$\phi_s = \tan^{-1} 0.20 = 11.3^\circ$$

The free body diagram for the machine part is provided below.

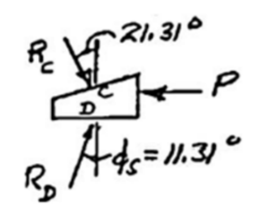


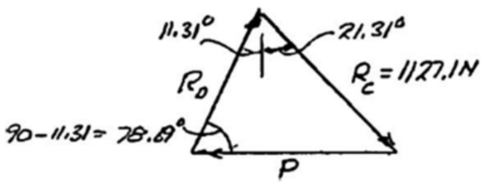
Force R_C imparted by the wedge onto the part can be obtained by taking moments about point B,

$$\Sigma M_B = 0 \rightarrow 1800\times 0.35 - R_C \cos 21.3^{\circ}\times 0.6 = 0$$

$$R_C = 1127.0\,\text{N}$$

Next, consider the free body diagram for the wedge and the corresponding force triangle.





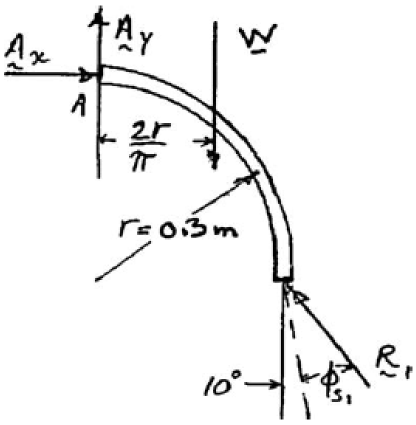
Applying the law of sines, we obtain

$$\frac{P}{\sin\left(\underbrace{11.31^{\circ}+21.31^{\circ}}_{=32.6^{\circ}}\right)} = \frac{1127.0}{\sin\left(\underbrace{90^{\circ}-11.31^{\circ}}_{=78.7^{\circ}}\right)} \rightarrow P = \frac{\sin 32.6^{\circ}}{\sin 78.7^{\circ}}\times 1127.0 = \boxed{619.2\,\text{N}}$$

■ The correct answer is **A**.

P.11 ■ Solution

The free body diagram for the rod is shown below.

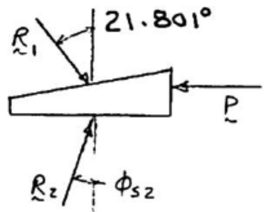


The weight W of the rod is $W = mg = 5\times 9.81 = 49.1$ N. Angle $\phi_{s,1}$ is such that $\phi_{s,1} = \tan^{-1}(\mu_s)_1 = \tan^{-1} 0.40 = 21.8°$. Applying the second condition of equilibrium to point A gives

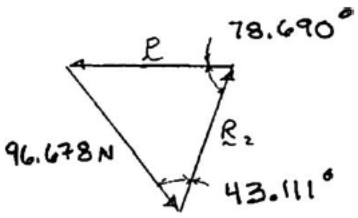
$$\Sigma M_A = 0 \rightarrow R_1 \times r\cos\left(10^{\circ}+21.8^{\circ}\right) - R_1\times r\sin\left(10^{\circ}+21.8^{\circ}\right) - \frac{2r}{\pi}\times 49.05 = 0$$

$$\therefore R_1 = 96.7\,\text{N}$$

Now, consider the free body diagram for the wedge.



Angle $\phi_{s,2}$ is such that $\phi_{s,2} = \tan^{-1}(\mu_s)_2 = \tan^{-1} 0.20 = 11.3°$. The force triangle that includes force P is shown below.



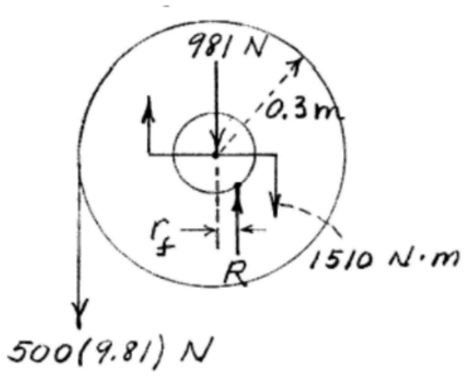
Applying the law of sines, the value of *P* follows as

$$\frac{P}{\sin 43.1^{\circ}}=\frac{96.7}{\sin 78.7^{\circ}} \rightarrow P=\frac{\sin 43.1^{\circ}}{\sin 78.7^{\circ}}\times 96.7=\boxed{67.4\,\mathrm{N}}$$

■ The correct answer is **C**.

P.12 ■ Solution

The free body diagram for the system is shown below.



The radius of the friction circle is

$$r_f=r\sin\phi=0.025\sin\phi$$

Summing moments about point A, we obtain

$$\Sigma M_A=0 \therefore 1510-981\times 0.025\sin\phi-500\times 9.81\times(0.3+0.025\sin\phi)=0$$

$$\therefore 38.5-147.15\sin\phi=0$$

$$\therefore \sin\phi=\frac{38.5}{147.15}=0.2616$$

$$\therefore \phi=15.17^{\circ}$$

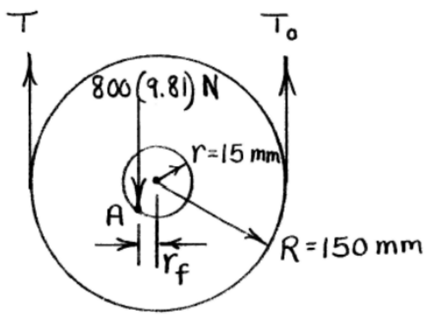
The coefficient of friction is then

$$\mu=\tan 15.17^{\circ}=\boxed{0.271}$$

■ The correct answer is **C**.

P.13 ■ Solution

The free body diagram for the system is shown below.



The value of ϕ and the radius of the friction circle follow as

$$\phi=\tan^{-1}0.25=14.04^{\circ}$$

$$r_f=r\sin\phi=15\times\sin 14.04^{\circ}=3.64\,\mathrm{mm}$$

Summing forces in the vertical direction and moments about point A, we obtain

$$\Sigma F_y=0\rightarrow T+T_o-800\times 9.81=0$$

$$\Sigma M_A=0\rightarrow T(150-3.64)-T_o(150+3.64)=0$$

The two previous equations can be solved simultaneously to yield T = 4020 N and T_o = 3830 N.

■ The correct answer is **C**.

Answer Summary

Problem 1	**1A**	A
	1B	B
Problem 2		C
Problem 3		C
Problem 4		A
Problem 5		B
Problem 6		B
Problem 7		D
Problem 8		B
Problem 9		A
Problem 10		A
Problem 11		C
Problem 12		C
Problem 13		C

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- BEER, F., JOHNSTON, E., MAZUREK, D., and CORNWELL, P. (2013). *Vector Mechanics for Engineers: Statics.* 10th edition. New York: McGraw-Hill.
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- MERIAM, J. and KRAIGE, L. (2002). *Engineering Mechanics*: *Statics*. 5th edition. Hoboken: John Wiley and Sons.

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