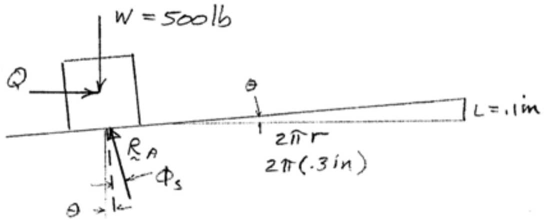
PROBLEM 8.71

Assuming that in Problem 8.70 a right-handed thread is used on *both* rods *A* and *B*, determine the magnitude of the couple that must be applied to the sleeve in order to rotate it.

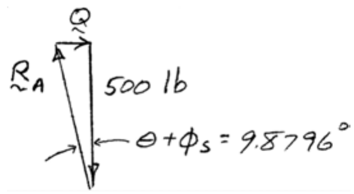
SOLUTION

Block on incline *A*:



$$\theta = \tan^{-1}\frac{0.1\text{ in.}}{2\pi(0.3\text{ in.})} = 3.0368°$$

$$\phi_s = \tan^{-1}\mu_s = \tan^{-1}0.12 = 6.8428°$$



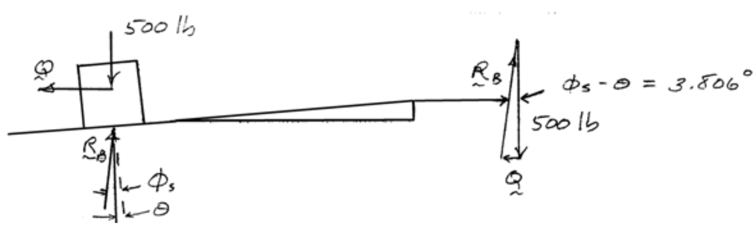
$$Q = (500\text{ lb})\tan 9.8796°$$

$$= 87.08\text{ lb}$$

$$\text{Couple at } A = (0.3\text{ in.})(87.08\text{ lb})$$

$$= 26.124\text{ lb}\cdot\text{in.}$$

Block on incline *B*:



$$Q = (500\text{ lb})\tan 3.806°$$

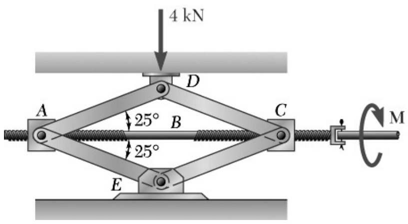
$$= 33.26\text{ lb}$$

$$\text{Couple at } B = (0.3\text{ in.})(33.26\text{ lb})$$

$$= 9.979\text{ lb}\cdot\text{in.}$$

$$\text{Total couple} = 26.124\text{ lb}\cdot\text{in.} + 9.979\text{ lb}\cdot\text{in.}$$

$$\text{Couple to turn} = 36.1\text{ lb}\cdot\text{in.} \blacktriangleleft$$

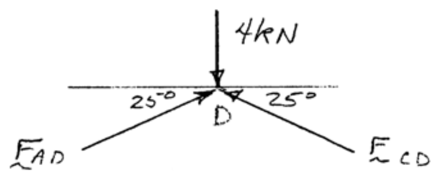


PROBLEM 8.72

The position of the automobile jack shown is controlled by a screw *ABC* that is single-threaded at each end (right-handed thread at *A*, left-handed thread at *C*). Each thread has a pitch of 2 mm and a mean diameter of 7.5 mm. If the coefficient of static friction is 0.15, determine the magnitude of the couple **M** that must be applied to raise the automobile.

SOLUTION

FBD joint *D*:



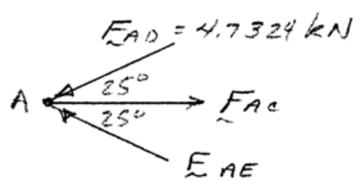
By symmetry:

$$F_{AD} = F_{CD}$$

$$\uparrow \Sigma F_y = 0: \quad 2F_{AD}\sin 25° - 4 \text{ kN} = 0$$

$$F_{AD} = F_{CD} = 4.7324 \text{ kN}$$

FBD joint *A*:



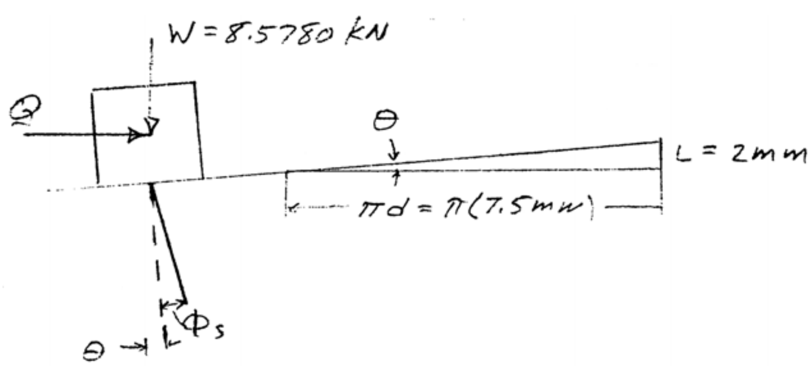
By symmetry:

$$F_{AE} = F_{AD}$$

$$\longrightarrow \Sigma F_x = 0: \quad F_{AC} - 2(4.7324 \text{ kN})\cos 25° = 0$$

$$F_{AC} = 8.5780 \text{ kN}$$

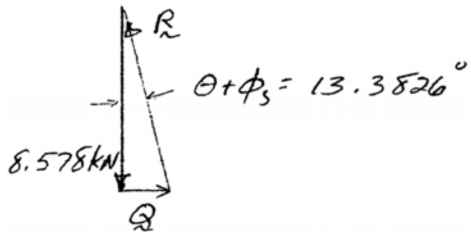
Block and incline *A*:



$$\theta = \tan^{-1}\frac{2 \text{ mm}}{\pi(7.5 \text{ mm})} = 4.8518°$$

$$\phi_s = \tan^{-1}\mu_s = \tan^{-1}0.15 = 8.5308°$$

PROBLEM 8.72 CONTINUED



$$Q = (8.578\ \text{kN})\tan(13.3826°)$$

$$= 2.0408\ \text{kN}$$

Couple at A: $$M_A = rQ$$

$$= \left(\frac{7.5}{2}\ \text{mm}\right)(2.0408\ \text{kN})$$

$$= 7.653\ \text{N}\cdot\text{m}$$

By symmetry: Couple at C: $$M_C = 7.653\ \text{N}\cdot\text{m}$$

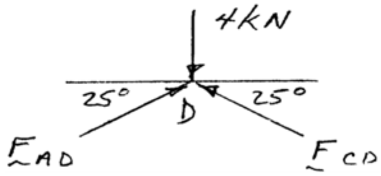
Total couple $M = 2(7.653\ \text{N}\cdot\text{m})$ $\quad M = 15.31\ \text{N}\cdot\text{m}$ ◀

PROBLEM 8.73

For the jack of Problem 8.72, determine the magnitude of the couple **M** that must be applied to lower the automobile.

SOLUTION

FBD joint *D*:

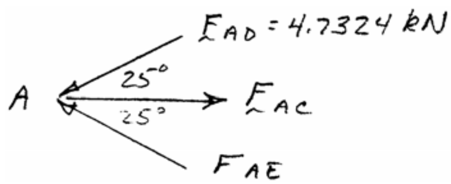


By symmetry: $F_{AD} = F_{CD}$

$$\uparrow \Sigma F_y = 0: \quad 2F_{AD} \sin 25° - 4 \text{ kN} = 0$$

$$F_{AD} = F_{CD} = 4.7324 \text{ kN}$$

FBD joint *A*:

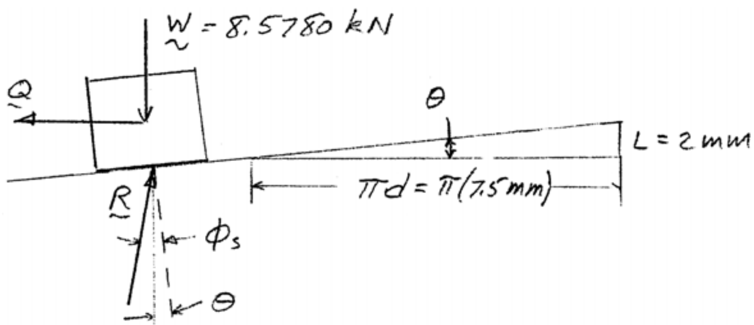


By symmetry: $F_{AE} = F_{AD}$

$$\longrightarrow \Sigma F_x = 0: \quad F_{AC} - 2(4.7324 \text{ kN})\cos 25° = 0$$

$$F_{AC} = 8.5780 \text{ kN}$$

Block and incline at *A*:

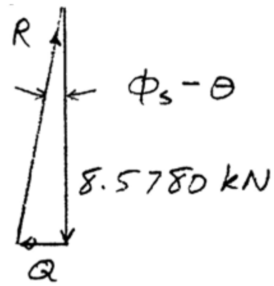


$$\theta = \tan^{-1} \frac{2 \text{ mm}}{\pi(7.5 \text{ mm})} = 4.8518°$$

$$\phi_s = \tan^{-1} \mu_s = \tan^{-1} 0.15$$

$$\phi_s = 8.5308°$$

PROBLEM 8.73 CONTINUED



$$\phi_s - \theta = 3.679°$$

$$Q = (8.5780 \text{ kN}) \tan 3.679°$$

$$Q = 0.55156 \text{ kN}$$

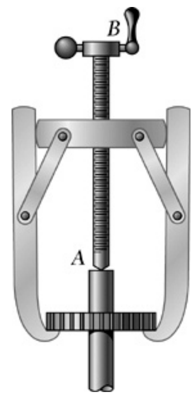
Couple at A: $M_A = Qr$

$$= (0.55156 \text{ kN})\left(\frac{7.5 \text{ mm}}{2}\right)$$

$$= 2.0683 \text{ N}\cdot\text{m}$$

By symmetry: Couple at C: $M_C = 2.0683 \text{ N}\cdot\text{m}$

Total couple $M = 2(2.0683 \text{ N}\cdot\text{m})$ $M = 4.14 \text{ N}\cdot\text{m}$ ◀

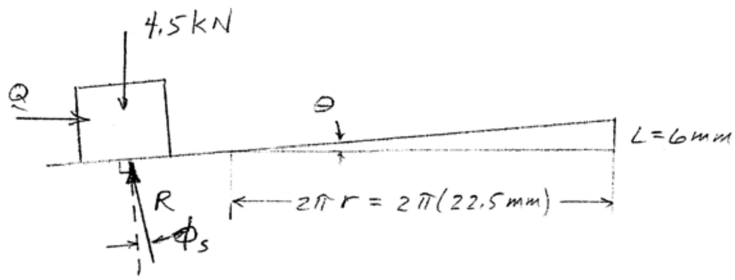


PROBLEM 8.74

In the gear-pulling assembly shown, the square-threaded screw *AB* has a mean radius of 22.5 mm and a lead of 6 mm. Knowing that the coefficient of static friction is 0.10, determine the couple which must be applied to the screw in order to produce a force of 4.5 kN on the gear. Neglect friction at end *A* of the screw.

SOLUTION

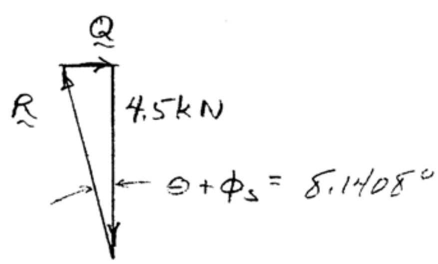
Block on incline:



$$\theta = \tan^{-1}\frac{6\text{ mm}}{2\pi(22.5\text{ mm})} = 2.4302°$$

$$\phi_s = \tan^{-1}\mu_s = \tan^{-1}0.1$$

$$\phi_s = 5.7106°$$



$$Q = (4.5\text{ kN})\tan 8.1408°$$

$$= 0.6437\text{ kN}$$

$$\text{Couple } M = rQ$$

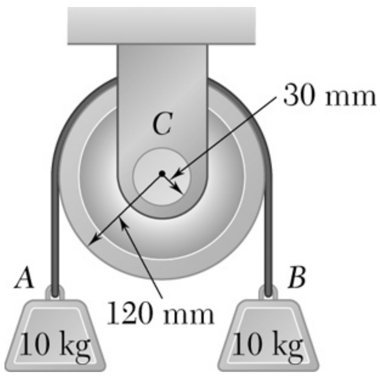
$$= (22.5\text{ mm})(0.6437\text{ kN})$$

$$= 14.483\text{ N}\cdot\text{m}$$

$$M = 14.48\text{ N}\cdot\text{m} ◀$$

NOTE FOR PROBLEMS 8.75–8.89

Note to instructors: In this manual, the singular $\sin(\tan^{-1}\mu) \approx \mu$ is NOT used in the solution of journal bearing and axle friction problems. While this approximation may be valid for very small values of μ, there is little if any reason to use it, and the error may be significant. For example, in Problems 8.76–8.79, $\mu_s = 0.40$, and the error made by using the approximation is about 7.7%.

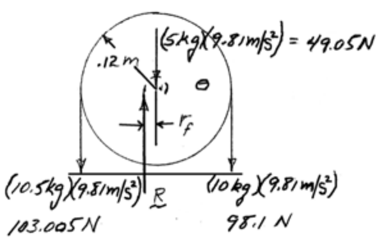


PROBLEM 8.75

A 120-mm-radius pulley of mass 5 kg is attached to a 30-mm-radius shaft which fits loosely in a fixed bearing. It is observed that the pulley will just start rotating if a 0.5-kg mass is added to block *A*. Determine the coefficient of static friction between the shaft and the bearing.

SOLUTION

FBD pulley:



$$+\uparrow \Sigma F_y = 0: \quad R - 103.005\text{ N} - 49.05\text{ N} - 98.1\text{ N} = 0$$

$$R = 250.155\text{ N}$$

$$\circlearrowleft \Sigma M_O = 0: \quad (0.12\text{ m})(103.005\text{ N} - 98.1\text{ N}) - r_f(250.155\text{ N}) = 0$$

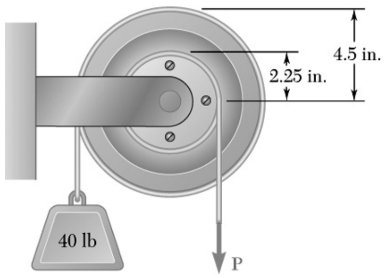
$$r_f = 0.0023529\text{ m} = 2.3529\text{ mm}$$

$$\phi_s = \sin^{-1}\frac{r_f}{r_s}$$

$$\mu_s = \tan\phi_s = \tan\left(\sin^{-1}\frac{r_f}{r_s}\right) = \tan\left(\sin^{-1}\frac{2.3529\text{ mm}}{30\text{ mm}}\right)$$

$$\mu_s = 0.0787 \blacktriangleleft$$

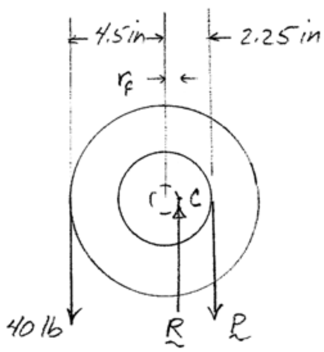
PROBLEM 8.76



The double pulley shown is attached to a 0.5-in.-radius shaft which fits loosely in a fixed bearing. Knowing that the coefficient of static friction between the shaft and the poorly lubricated bearing is 0.40, determine the magnitude of the force **P** required to start raising the load.

SOLUTION

FDB pulley:



$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)^*$$

$$r_f = (0.5 \text{ in.})\sin\left(\tan^{-1} 0.40\right) = 0.185695 \text{ in.}$$

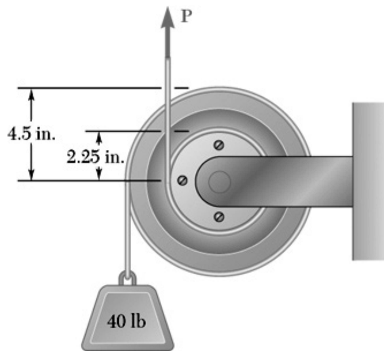
$$\circlearrowleft \Sigma M_C = 0: \quad (4.5 \text{ in.} + 0.185695 \text{ in.})(40 \text{ lb})$$

$$-(2.25 \text{ in.} - 0.185695 \text{ in.})P = 0$$

$$P = 90.8 \text{ lb} \blacktriangleleft$$

* See note before Problem 8.75.

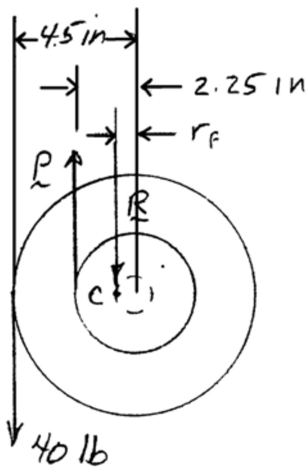
PROBLEM 8.77



The double pulley shown is attached to a 0.5-in.-radius shaft which fits loosely in a fixed bearing. Knowing that the coefficient of static friction between the shaft and the poorly lubricated bearing is 0.40, determine the magnitude of the force **P** required to start raising the load.

SOLUTION

FBD pulley:



$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right) = (0.5\text{ in.})\sin\left(\tan^{-1}0.4\right)^*$$

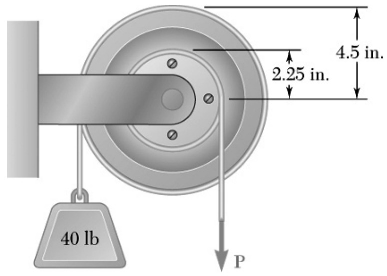
$$r_f = 0.185695\text{ in.}$$

$$\circlearrowleft \Sigma M_C = 0: \quad (4.5\text{ in.} - 0.185695\text{ in.})(40\text{ lb})$$

$$-(2.25\text{ in.} - 0.185695\text{ in.})P = 0$$

$$P = 83.6\text{ lb} \blacktriangleleft$$

* See note before Problem 8.75.

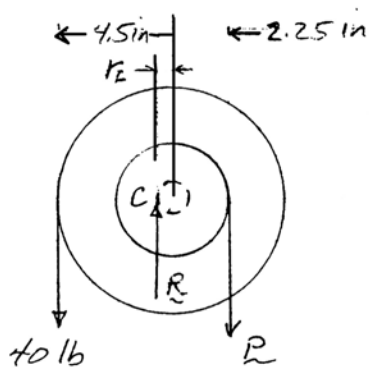


PROBLEM 8.78

The double pulley shown is attached to a 0.5-in.-radius shaft which fits loosely in a fixed bearing. Knowing that the coefficient of static friction between the shaft and the poorly lubricated bearing is 0.40, determine the magnitude of the force **P** required to maintain equilibrium.

SOLUTION

FBD pulley:



$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)^*$$

$$r_f = (0.5\text{ in.})\sin\left(\tan^{-1}0.40\right) = 0.185695\text{ in.}$$

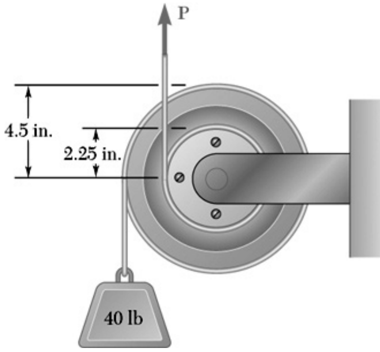
$$\circlearrowleft \Sigma M_C = 0: \quad (4.5\text{ in.} - 0.185695\text{ in.})(40\text{ lb})$$

$$-(2.25\text{ in.} + 0.185695\text{ in.})(P) = 0$$

$$P = 70.9\text{ lb} \blacktriangleleft$$

* See note before Problem 8.75.

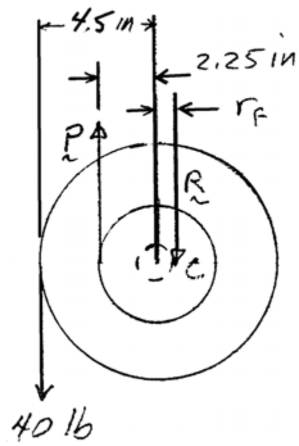
PROBLEM 8.79



The double pulley shown is attached to a 0.5-in.-radius shaft which fits loosely in a fixed bearing. Knowing that the coefficient of static friction between the shaft and the poorly lubricated bearing is 0.40, determine the magnitude of the force **P** required to maintain equilibrium.

SOLUTION

FBD pulley:



$$r_f = r_s \sin\phi_s = r_s \sin\left(\tan^{-1}\mu_s\right)^*$$

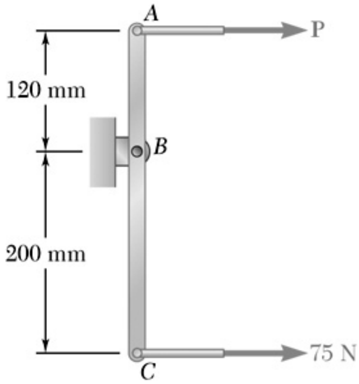
$$r_f = (0.5\text{ in.})\sin\left(\tan^{-1}0.4\right) = 0.185695\text{ in.}$$

$$\circlearrowleft \Sigma M_C = 0: \quad (4.5\text{ in.} + 0.185695\text{ in.})(40\text{ lb})$$

$$-(2.25\text{ in.} + 0.185695\text{ in.})P = 0$$

$$P = 77.0\text{ lb} \blacktriangleleft$$

* See note before Problem 8.75.

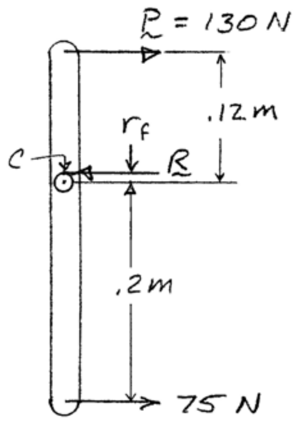


PROBLEM 8.80

Control lever *ABC* fits loosely on a 18-mm-diameter shaft at support *B*. Knowing that $P = 130\text{ N}$ for impending clockwise rotation of the lever, determine (*a*) the coefficient of static friction between the pin and the lever, (*b*) the magnitude of the force **P** for which counterclockwise rotation of the lever is impending.

SOLUTION

(*a*) **FBD lever** (Impending *CW* rotation):



$$\circlearrowleft \Sigma M_C = 0: \quad (0.2\text{ m} + r_f)(75\text{ N}) - (0.12\text{ m} - r_f)(130\text{ N}) = 0$$

$$r_f = 0.0029268\text{ m} = 2.9268\text{ mm}$$

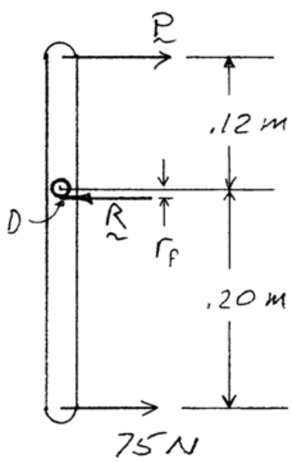
$$\sin\phi_s = \frac{r_f}{r_s}$$

$$\mu_s = \tan\phi_s = \tan\left(\sin^{-1}\frac{r_f}{r_s}\right) = \tan\left(\sin^{-1}\frac{2.9268\text{ mm}}{18\text{ mm}}\right)^*$$

$$= 0.34389$$

$$\mu_s = 0.344 \blacktriangleleft$$

(*b*) **FBD lever** (Impending *CCW* rotation):



$$\circlearrowleft \Sigma M_D = 0: \quad (0.20\text{ m} - 0.0029268\text{ m})(75\text{ N})$$

$$- (0.12\text{ m} + 0.0029268\text{ m})P = 0$$

$$P = 120.2\text{ N} \blacktriangleleft$$

* See note before Problem 8.75.