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Chapter 10, Problem 20P

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Problem

A 50-cm × 30-cm × 20-cm block weighing 150 N is to be moved at a constant velocity of 0.8 m/s on an inclined surface with a friction coefficient of 0.27. (a) Determine the force F that needs to be applied in the horizontal direction. (b) If a 0.4-mm-thick oil film with a dynamic viscosity of 0.012 Pa·s is applied between the block and inclined surface, determine the percent reduction in the required force.

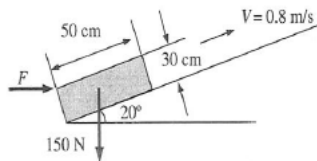


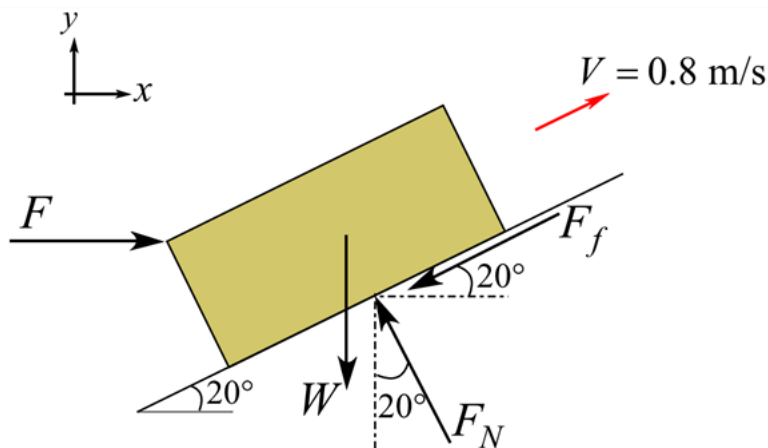
FIGURE P10-20

Step-by-step solution

Step 1 of 8

(a)

Draw the free body diagram of the block.



Comment

Step 2 of 8

Consider the equilibrium of forces in y direction.

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$$F_N \cos 20^\circ - W - (\mu_s F_N) \sin 20^\circ = 0$$

Here, the frictional force acting on the surface is F_f , coefficient of static friction is μ_s , the normal force acting on the block is F_N , the weight of the block is W , and applied horizontal force is F .

Substitute 150 N for W and 0.27 for μ_s .

$$F_N \cos 20^\circ - 150 - (0.27 F_N) \sin 20^\circ = 0$$

$$F_N (0.9397) - (0.27 F_N)(0.342) = 150$$

$$0.84736 F_N = 150$$

$$F_N = 177.02 \text{ N}$$

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Step 3 of 8

Calculate the applied horizontal force.

Consider the equilibrium of forces in x direction.

$$\sum F_x = 0$$

$$F - F_N \sin 20^\circ - F_f \cos 20^\circ = 0$$

$$F - F_N \sin 20^\circ - \mu_s F_N \cos 20^\circ = 0$$

Substitute 177.02 N for F_N and 0.27 for F_f .

$$F - (177.02) \sin 20^\circ - (0.27 \times 177.02) \cos 20^\circ = 0$$

$$F = 105.45 \text{ N}$$

Hence, the required horizontal force to be applied is 105.45 N.

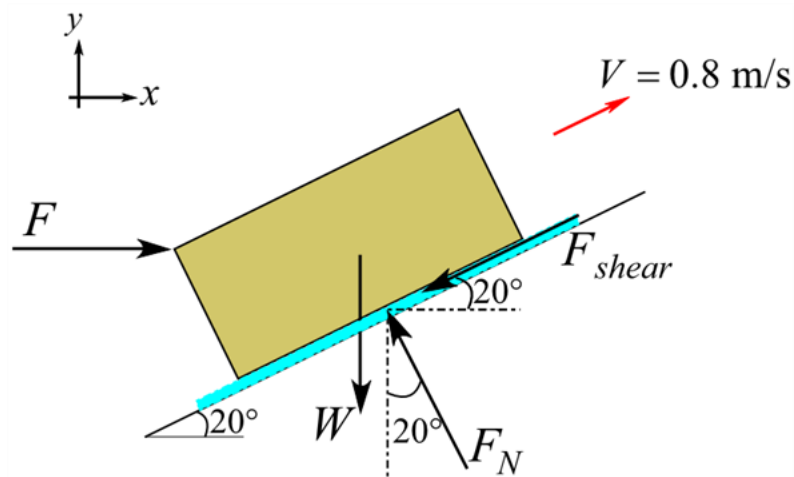
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Step 4 of 8

(b)

An oil film of thickness 4 mm and dynamic viscosity of 0.012 Pa · s is introduced between the block and surface.

Draw the free body diagram of the block showing the oil film.



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Calculate the area of contact (shear area) between the oil film and block

$$A_s = L \times B$$

Here, the length of the block is L and breadth of the block into the paper is B .

Substitute 50 cm for L and 20 cm for B ,

$$\begin{aligned} A_s &= 50 \times 20 \\ &= 1000 \text{ cm}^2 \\ &= 0.1 \text{ m}^2 \end{aligned}$$

Calculate the shear force acting on the block.

$$F_{shear} = \mu A_s \frac{V}{l}$$

Here, dynamic viscosity is μ , area of shear is A_s , velocity of the block is V , and thickness of the oil film is l .

Substitute $0.012 \text{ Pa}\cdot\text{s}$ for μ , 0.1 m^2 for A_s , 0.8 m/s for V , and $0.4 \times 10^{-3} \text{ m}$ (0.4 mm) for l .

$$\begin{aligned} F_{shear} &= (0.012)(0.1) \frac{0.8}{(0.4 \times 10^{-3})} \\ &= 2.4 \text{ N} \end{aligned}$$

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Step 6 of 8

Consider the equilibrium of forces in y direction.

$$\begin{aligned} \sum F_y &= 0 \\ F_N \cos 20^\circ - W - F_{shear} \sin 20^\circ &= 0 \end{aligned}$$

Substitute 150 N for W and 2.4 N for F_{shear} .

$$\begin{aligned} F_N \cos 20^\circ - 150 - (2.4) \sin 20^\circ &= 0 \\ F_N &= 160.5 \text{ N} \end{aligned}$$

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Step 7 of 8

Consider the equilibrium of forces in x direction.

$$\begin{aligned} \sum F_x &= 0 \\ F - F_N \sin 20^\circ - F_{shear} \cos 20^\circ &= 0 \end{aligned}$$

Substitute 160.5 N for F_N and 2.4 N for F_{shear} .

$$\begin{aligned} F - (160.5) \sin 20^\circ - (2.4) \cos 20^\circ \\ F &= 160.5 \sin 20^\circ + 2.4 \cos 20^\circ \\ &= 57.15 \text{ N} \end{aligned}$$

Thus, required force with oil film, $F_{withoil}$ is 57.15 N.

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Step 8 of 8

Calculate the percentage reduction in applied force.



$$= \left(\frac{105.45 \text{ N} - 57.15 \text{ N}}{105.45 \text{ N}} \right) \times 100$$

$$= 45.80$$

Hence, the percentage reduction in the applied force when the oil film is used is **45.80%**.

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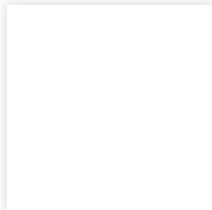
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