

Problem 2.45

[Difficulty: 2]

2.45 A block weighing 10 lbf and having dimensions 10 in. on each edge is pulled up an inclined surface on which there is a film of SAE 10W oil at 100°F. If the speed of the block is 2 ft/s and the oil film is 0.001 in. thick, find the force required to pull the block. Assume the velocity distribution in the oil film is linear. The surface is inclined at an angle of 25° from the horizontal.

Given: Block pulled up incline on oil layer

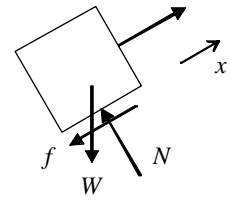
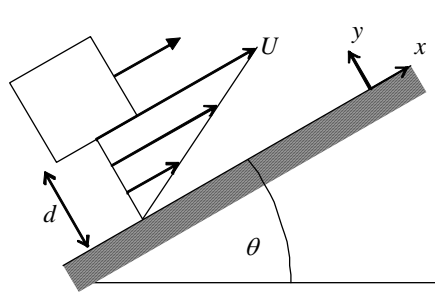
Find: Force required to pull the block

Solution:

Governing equations:

$$\tau_{yx} = \mu \cdot \frac{du}{dy}$$

$$\Sigma F_x = M \cdot a_x$$



Assumptions: Laminar flow

The given data is $W = 10 \cdot \text{lbf}$ $U = 2 \cdot \frac{\text{ft}}{\text{s}}$ $w = 10 \cdot \text{in}$ $d = 0.001 \cdot \text{in}$ $\theta = 25 \cdot \text{deg}$

$$\mu = 3.7 \times 10^{-2} \cdot \frac{\text{N} \cdot \text{s}}{\text{m}^2} \quad \text{Fig. A.2 @ } 100^\circ\text{F (38}^\circ\text{C)}$$

Equation of motion $\Sigma F_x = M \cdot a_x = 0$ so $F - f - W \cdot \sin(\theta) = 0$

The friction force is $f = \tau_{yx} \cdot A = \mu \cdot \frac{du}{dy} \cdot A = \mu \cdot \frac{U}{d} \cdot w^2$

Hence $F = f + W \cdot \sin(\theta) = \mu \cdot \frac{U}{d} \cdot w^2 + W \cdot \sin(\theta)$

$$F = 3.7 \times 10^{-2} \cdot \frac{\text{N} \cdot \text{s}}{\text{m}^2} \times 0.0209 \cdot \frac{\text{lbf} \cdot \text{s}}{\text{ft}^2} \cdot \frac{\text{m}^2}{\text{N} \cdot \text{s}} \times 2 \cdot \frac{\text{ft}}{\text{s}} \times \frac{1}{0.001 \cdot \text{in}} \times (10 \cdot \text{in})^2 \times \frac{\text{ft}}{12 \cdot \text{in}} + 10 \cdot \text{lbf} \cdot \sin(25 \cdot \text{deg})$$

$$F = 17.1 \cdot \text{lbf}$$