

Problem 2.46

[Difficulty: 2]

2.46 A block of mass 10 kg and measuring 250 mm on each edge is pulled up an inclined surface on which there is a film of SAE 10W-30 oil at 30°F (the oil film is 0.025 mm thick). Find the steady speed of the block if it is released. If a force of 75 N is applied to pull the block up the incline, find the steady speed of the block. If the force is now applied to push the block down the incline, find the steady speed of the block. Assume the velocity distribution in the oil film is linear. The surface is inclined at an angle of 30° from the horizontal.

Given: Block moving on incline on oil layer

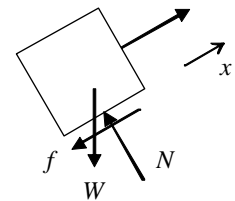
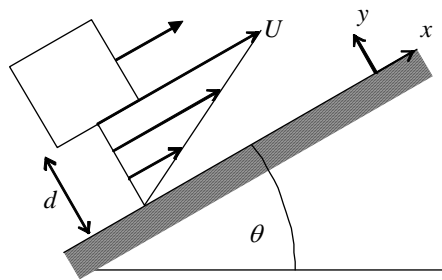
Find: Speed of block when free, pulled, and pushed

Solution:

Governing equations:

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

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



Assumptions: Laminar flow

The given data is $M = 10\text{-kg}$ $W = M \cdot g$ $W = 98.066\text{ N}$ $w = 250\text{-mm}$

$d = 0.025\text{-mm}$ $\theta = 30\text{-deg}$ $F = 75\text{-N}$

$\mu = 10^{-1} \cdot \frac{\text{N}\cdot\text{s}}{\text{m}^2}$ Fig. A.2 SAE 10-39 @ 30°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 for uphill motion $F = f + W \cdot \sin(\theta) = \mu \cdot \frac{U}{d} \cdot w^2 + W \cdot \sin(\theta)$ $U = \frac{d \cdot (F - W \cdot \sin(\theta))}{\mu \cdot w^2}$ (For downpush change sign of W)

For no force: $U = \frac{d \cdot W \cdot \sin(\theta)}{\mu \cdot w^2}$ $U = 0.196 \frac{\text{m}}{\text{s}}$

Pushing up: $U = \frac{d \cdot (F - W \cdot \sin(\theta))}{\mu \cdot w^2}$ $U = 0.104 \frac{\text{m}}{\text{s}}$ Pushing down: $U = \frac{d \cdot (F + W \cdot \sin(\theta))}{\mu \cdot w^2}$ $U = 0.496 \frac{\text{m}}{\text{s}}$