

## Problem 2.44

[Difficulty: 2]

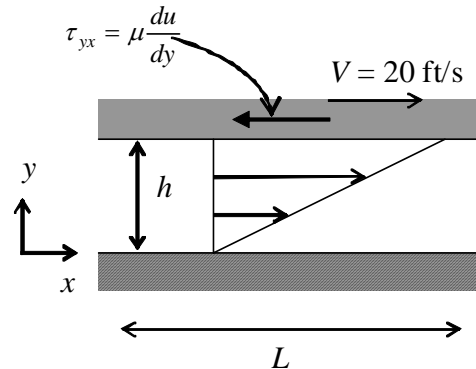
**2.44** A female freestyle ice skater, weighing 100 lbf, glides on one skate at speed  $V = 20$  ft/s. Her weight is supported by a thin film of liquid water melted from the ice by the pressure of the skate blade. Assume the blade is  $L = 11.5$  in. long and  $w = 0.125$  in. wide, and that the water film is  $h = 0.0000575$  in. thick. Estimate the deceleration of the skater that results from viscous shear in the water film, if end effects are neglected.

**Given:** Ice skater and skate geometry

**Find:** Deceleration of skater

**Solution:**

**Governing equation:**  $\tau_{yx} = \mu \frac{du}{dy}$   $\Sigma F_x = M \cdot a_x$



**Assumptions:** Laminar flow

The given data is  $W = 100 \cdot \text{lbf}$   $V = 20 \cdot \frac{\text{ft}}{\text{s}}$   $L = 11.5 \cdot \text{in}$   $w = 0.125 \cdot \text{in}$   $h = 0.0000575 \cdot \text{in}$

$$\mu = 3.68 \times 10^{-5} \cdot \frac{\text{lbf} \cdot \text{s}}{\text{ft}^2} \quad \text{Table A.7 @ } 32^\circ\text{F}$$

Then 
$$\tau_{yx} = \mu \frac{du}{dy} = \mu \cdot \frac{V}{h} = 3.68 \times 10^{-5} \cdot \frac{\text{lbf} \cdot \text{s}}{\text{ft}^2} \times 20 \cdot \frac{\text{ft}}{\text{s}} \times \frac{1}{0.0000575 \cdot \text{in}} \times \frac{12 \cdot \text{in}}{\text{ft}}$$

$$\tau_{yx} = 154 \cdot \frac{\text{lbf}}{\text{ft}^2}$$

Equation of motion  $\Sigma F_x = M \cdot a_x$  or  $\tau_{yx} \cdot A = \frac{-W}{g} \cdot a_x$

$$a_x = -\frac{\tau_{yx} \cdot A \cdot g}{W} = -\frac{\tau_{yx} \cdot L \cdot w \cdot g}{W}$$

$$a_x = -154 \cdot \frac{\text{lbf}}{\text{ft}^2} \times 11.5 \cdot \text{in} \times 0.125 \cdot \text{in} \times 32.2 \cdot \frac{\text{ft}}{\text{s}^2} \times \frac{1}{100 \cdot \text{lbf}} \times \frac{\text{ft}^2}{(12 \cdot \text{in})^2}$$

$$a_x = -0.495 \cdot \frac{\text{ft}}{\text{s}^2}$$