

A very small shear stress, but it has a profound effect on the flow pattern.

(b) The variation of shear stress across the boundary layer is a cosine wave,  $\tau = \mu (du/dy)$ :

$$\tau(y) = \frac{\pi \mu U}{2\delta} \cos\left(\frac{\pi y}{2\delta}\right) = \tau_w \cos\left(\frac{\pi y}{2\delta}\right) = \frac{\tau_w}{2} \quad \text{when} \quad \frac{\pi y}{2\delta} = \frac{\pi}{3}, \quad \text{or:} \quad y = \frac{2\delta}{3} \quad \text{Ans. (b)}$$

**1.57** The belt in Fig. P1.57 moves at steady velocity  $V$  and skims the top of a tank of oil of viscosity  $\mu$ . Assuming a linear velocity profile, develop a simple formula for the belt-drive power  $P$  required as a function of  $(h, L, V, B, \mu)$ . Neglect air drag. What power  $P$  in watts is required if the belt moves at 2.5 m/s over SAE 30W oil at 20°C, with  $L = 2$  m,  $b = 60$  cm, and  $h = 3$  cm?



Fig. P1.57

**Solution:** The power is the viscous resisting force times the belt velocity:

$$P = \tau_{oil} A_{belt} V_{belt} = \left( \mu \frac{V}{h} \right) (bL)V = \mu V^2 b \frac{L}{h} \quad \text{Ans.}$$

(b) For SAE 30W oil,  $\mu = 0.29 \text{ kg/m} \cdot \text{s}$ . Then, for the given belt parameters,

$$P = \mu V^2 bL/h = \left( 0.29 \frac{\text{kg}}{\text{m} \cdot \text{s}} \right) \left( 2.5 \frac{\text{m}}{\text{s}} \right)^2 (0.6 \text{ m}) \frac{2.0 \text{ m}}{0.03 \text{ m}} = 73 \frac{\text{kg} \cdot \text{m}^2}{\text{s}^3} = 73 \text{ W} \quad \text{Ans. (b)}$$

**1.58\*** A solid cone of base  $r_0$  and initial angular velocity  $\omega_0$  is rotating inside a conical seat. Neglect air drag and derive a formula for the cone's angular velocity  $\omega(t)$  if there is no applied torque.

**Solution:** At any radial position  $r < r_0$  on the cone surface and instantaneous rate  $\omega$ ,

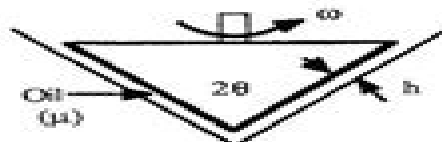


Fig. P1.58

$$d(\text{Torque}) = r \tau dA_w = r \left( \mu \frac{r\omega}{h} \right) \left( 2\pi r \frac{dr}{\sin\theta} \right),$$

$$\text{or: Torque } M = \int_0^{r_0} \frac{\mu \omega}{h \sin\theta} 2\pi r^3 dr = \frac{\pi \mu \omega r_0^4}{2h \sin\theta}$$

# Fluid Mechanics 7th Edition Ch 1 Solutions

**Wenbin Ji**



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