Series 9 (2 May 2025)

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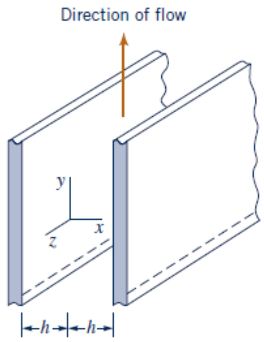
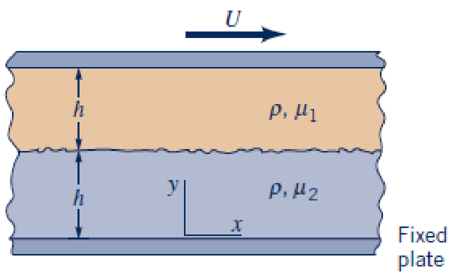
6.87. Oil (SAE 30) at 15.6 °C flows steadily between fixed, horizontal, parallel plates. The pressure drop per unit length along the channel is 30 kPa/m, and the distance between the plates is 4 mm. The flow is laminar. Determine: (**a**) the volume rate of flow (per meter of width), (**b**) the magnitude and direction of the shearing stress acting on the bottom plate, and (**c**) the velocity along the centerline of the channel.

6.89. A viscous, incompressible fluid flows between the two infinite, vertical, parallel plates of Fig. P6.89. Determine, by use of the Navier–Stokes equations, an expression for the pressure gradient in the direction of flow. Express your answer in terms of the mean velocity. Assume that the flow is laminar, steady, and uniform.



■ Figure P6.89

6.95. Two immiscible, incompressible, viscous fluids having the same densities but different viscosities are contained between two infinite, horizontal, parallel plates (Fig. P6.95). The bottom plate is fixed, and the upper plate moves with a constant velocity U. Determine the velocity at the interface. Express your answer in terms of U, m_1, and m_2. The motion of the fluid is caused entirely by the movement of the upper plate; that is, there is no pressure gradient in the x direction. The fluid velocity and shearing stress are continuous across the interface between the two fluids. Assume laminar flow.



■ Figure P6.95

6.99. A vertical shaft passes through a bearing and is lubricated with an oil having a viscosity of 0.2 $\mathrm{Ns/m^2}$ as shown in Fig. P6.99. Assume that the flow characteristics in the gap between the shaft and bearing are the same as those for laminar flow between infinite parallel plates with zero pressure gradient in the direction of flow. Estimate the torque required to overcome viscous resistance when the shaft is turning at 80 rev/min.

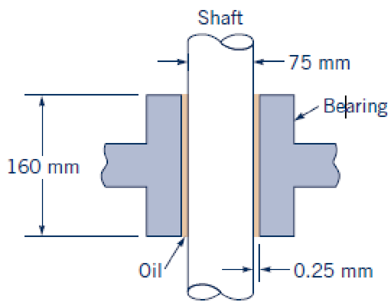


Figure P6.99

6.103. A simple flow system to be used for steady-flow tests consists of a constant head tank connected to a length of 4-mm diameter tubing as shown in Fig. P6.103. The liquid has a viscosity of 0.015 $\mathrm{Ns/m^2}$, a density of 1200 $\mathrm{kg/m^3}$, and discharges into the atmosphere with a mean velocity of 2 m/s. (**a**) Verify that the flow will be laminar. (**b**) The flow is fully developed in the last 3 m of the tube. What is the pressure at the pressure gage? (**c**) What is the magnitude of the wall shearing stress, τ_{rz}, in the fully developed region?

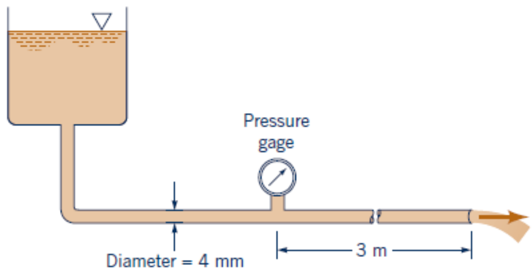


Figure P6.103

6.104. (**a**) Show that for Poiseuille flow in a tube of radius R the magnitude of the wall shearing stress, τ_{rz}, can be obtained from the relationship:

$$|(\tau_{rz})_{wall}| = \frac{4\mu Q}{\pi R^3}$$

for a Newtonian fluid of viscosity m. The volume rate of flow is Q. (**b**) Determine the magnitude of the wall shearing stress for a fluid having a viscosity of 0.004 $\mathrm{Ns/m^2}$ flowing with an average velocity of 130 mm/s in a 2-mm-diameter tube.