10.19

$\nu = 5.1 \times 10^{-4}$

$\gamma = 12{,}300$

$$Re = \frac{VD}{\nu} = \frac{.4 \times .04}{5.1 \times 10^{-4}} = 31.4$$

$$h_f = 32\mu L\bar{V}/\gamma D^2 = \frac{L}{\gamma}\left[-\frac{d}{ds}(p+\gamma z)\right]$$

$$\frac{d}{ds}(p+\gamma z) = -32\mu V/D^2$$

10.19 Glycerin (20°C) flows in a 4-cm steel tube with a mean velocity of 40 cm/s. Is the flow laminar or turbulent? What is the shear stress at the center of the tube and at the wall? If the tube is vertical and the flow is downward, will the pressure increase or decrease in the direction of flow? At what rate?

$$= -32 \times .62 \times .4 / .04^2$$

$$= -4960 \quad N/m^3$$

$$\tau = \frac{r}{2}\left[-\frac{d}{ds}(p+\gamma z)\right]$$

$$= \frac{r}{2}[4960]$$

$$\tau(0) = 0$$

$$\tau_w = \tau(r_0) = \frac{r_0}{2}[4960] = 49.6 \quad N/m^2$$

$$\frac{d}{ds}(p+\gamma z) = \frac{dp}{ds} + \gamma\frac{dz}{ds} = -4960$$

$\frac{dz}{ds} = -1$ flow downward

$$\frac{dp}{ds} = -4960 + \gamma$$

$$= 7340 \quad Pa$$

pressure increases downward

But piezometric pressure gradient < 0 so flow is in fact downward.