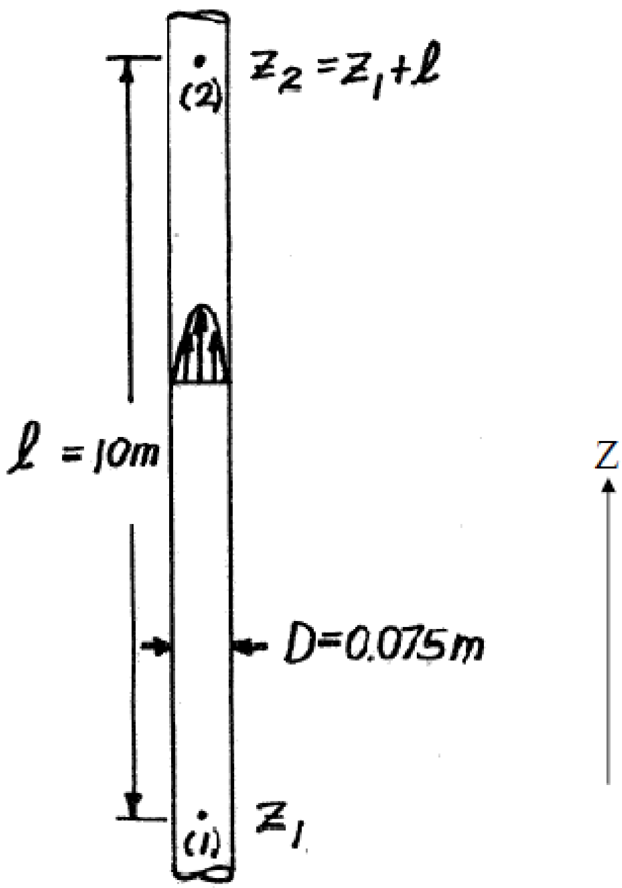
**8.17** Glycerin at 20 °C flows upward in a vertical 75-mm-diameter pipe with a centerline velocity of 1.0 m/s. Determine the head loss and pressure drop in a 10-m length of the pipe.

**Solutions**: (1) sketch the problem, establish coordinates and found flow properties ($\rho$=1260 kg/m$^3$; $\mu$=1.50 N.S/m$^2$)




(2) Is the flow laminar or turbulent?

Assume laminar flow, $V_C$=1.0 m/s, so average velocity $\bar{V} = 0.5V_c = 0.5\,m/s$

$$\mathrm{Re} = \frac{\rho V D}{\mu} = \frac{\left(1260\frac{kg}{m^3}\right)\left(0.5\frac{m}{s}\right)(0.075m)}{1.50\frac{N \bullet S}{m^2}} = 31.5 < 2100$$ assumption valid!

(3) Compute pressure drop:

$$\overline{V} = \frac{r_0^2}{8\mu}\left[-\frac{d}{ds}(p+\gamma z)\right] = \frac{D^2}{32\mu}\left[-\frac{dp}{dz}-\gamma\right] = \frac{D^2}{32\mu}\left[-\frac{p_2-p_1}{l}-\gamma\right]$$

$$= \frac{D^2}{32\mu}\left[\frac{p_1-p_2}{l}-\gamma\right]$$

So,

$$\Delta p = p_1 - p_2 = \frac{32\mu\overline{V}l}{D^2}+\gamma l = \frac{32\left(1.50\frac{N\bullet S}{m^2}\right)\left(0.5\frac{m}{s}\right)(10m)}{(0.075m)^2}+\left(9.81\frac{m}{s^2}\right)\left(1260\frac{kg}{m^3}\right)(10m)$$

$= 166 \quad KPa$

(4) compute head loss (energy equation):

$$\frac{p_1}{\gamma}+\alpha_1\frac{\overline{V_1}^2}{2g}+z_1 = \frac{p_2}{\gamma}+\alpha_2\frac{\overline{V_2}^2}{2g}+z_2+h_L$$

note: $\overline{V}_1 = \overline{V}_2$, $\Delta p = p_1 - p_2$ and $Z_2 - Z_1 = l$

$$h_L = \frac{\Delta p}{\gamma} - l = \frac{1.66\times10^5\,\frac{N}{m^2}}{\left(9.81\frac{m}{s^2}\right)\left(1260\frac{kg}{m^3}\right)} - 10m = 3.43m$$