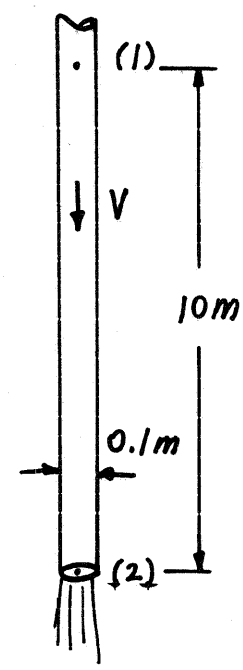
8.15

8.15 A fluid of density $\rho = 1000\ \text{kg/m}^3$ and viscosity $\mu = 0.30\ \text{N}\cdot\text{s/m}^2$ flows steadily down a vertical 0.10-m-diameter pipe and exits as a free jet from the lower end. Determine the maximum pressure allowed in the pipe at a location 10 m above the pipe exit if the flow is to be laminar.



Re = 2100 for maximum pressure.

Thus,

$$2100 = \frac{\rho V D}{\mu} = \frac{1000\,\frac{kg}{m^3}\,V\,(0.1m)}{0.30\,\frac{N\cdot s}{m^2}}$$

or

$$V = 6.30\,\frac{m}{s}$$

But for laminar flow,

$$V = \frac{(\Delta p - \gamma \ell \sin\theta)\,D^2}{32\mu\ell}$$ where $D = 0.1m$, $\ell = 10m$, and $\theta = -90°$

$\gamma = \rho g = 9{,}810\,\frac{N}{m^3}$

Thus,

$$6.30\,\frac{m}{s} = \frac{(\Delta p - 9{,}810\,\frac{N}{m^3}\,(10m)\sin(-90°))(0.1m)^2}{32\,(0.30\,\frac{N\cdot s}{m^2})\,(10m)}$$

so that

$$\Delta p = -3.76\times10^4\,\frac{N}{m^2} = \underline{\underline{-37.6\ kPa}}$$