

Pipes

Internal Flows (Pipes):

The boundary layers (vorticity) grows slowly to fill the entire domain.

Entrance length: $\frac{L_e}{D} = 0.06 \text{Re}_D$ for laminar flow ($\text{Re}_D < 2100$).

$$\frac{L_e}{D} = 4.4(\text{Re}_D)^{1/6} \quad \text{for turbulent flow } (\text{Re}_D > 4000).$$

We will ignore the start up (assume that the effect is negligible).

Almost always use the extended form of **Bernoulli's Equation**.

Always label the streamline and the two points A & B.

$$\underbrace{\left(\rho i + p + \frac{1}{2} \rho \vec{v} \cdot \vec{v} + \rho g z\right)}_{\text{Inflow}_A} = \underbrace{\left(\rho i + p + \frac{1}{2} \rho \vec{v} \cdot \vec{v} + \rho g z\right)}_{\text{Outflow}_B} + \rho g h_f$$

The head loss is given by

$$\rho g h_f = \left(\frac{L}{D}\right) \frac{1}{2} \rho V^2 f$$

where L is the length of the pipe and f is the non-dimensional friction factor.

The friction factor, $f(\text{Re}_D, \epsilon)$, is a function of the Reynolds number and pipe roughness.

A smooth pipe means the roughness ϵ , is zero (not $f = 0$). All laminar pipes are smooth.

The friction factor, f, is found from the Moody Chart (page 434).

The roughness, ϵ , is given in table 8.1 (page 433).

The Moody Chart is the same as these equations:

For laminar flow, $f = 64/\text{Re}_D$.

when $\text{Re}_D < 2100$

$$\text{For turbulent flow, } \frac{1}{f^{1/2}} = -2.0 \log_{10} \left[\frac{2.51}{\text{Re}_D f^{1/2}} + \left(\frac{\epsilon/D}{3.7} \right) \right] \quad \text{when } \text{Re}_D > 4000$$

For noncircular ducts, you can use the following engineering approximation:

Replace the diameter, D, by the 'hydraulic diameter', $D_h = 4 \cdot \text{Area} / \text{Perimeter}$.

For valves, diffusers, bends, inlets, etc ('minor losses'):

$$h_m = \frac{V_{\text{avg}}^2}{2g} K \quad \text{and look up K in the book.}$$

Add minor losses h_m to friction losses h_f , to obtain the total loss.