Friction Losses in Pipe Flow

(Relationship to Fluid and Pipe Properties)

The magnitude of the **friction loss** in a pipeline is:

- Proportional to
- Inversely Proportional to
- Proportional to some Power of
- Related to (Turbulent Flow)
- Independent of

Description of Pipe Friction

Definitions and Visualization

Question: What forces cause and resist the flow of water in the figure below (cylindrical pipe section of radius "r").

Cause Motion:

Resist Motion:

In laminar flow: $-2\pi rL[\mu(dv/dr)] = (P_1 - P_2)\pi r^2$ **Questions?**

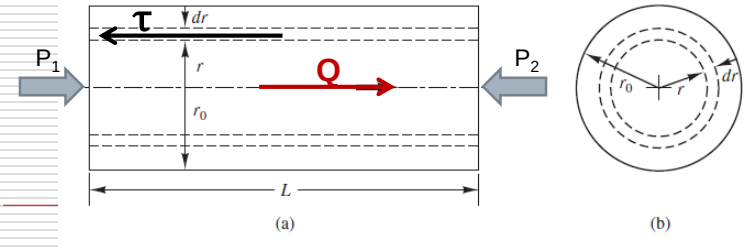


Figure 3.7 Geometry of a circular pipe

Friction Factor for Laminar Flow

(Visualization and Derivation – cont.)

Integrating the force balance results in:

$v = [(P_1 - P_2)/4\mu L](r_o^2 - r^2)]$; Solving for Q yields:

$Q = \int dQ = \int vdA = \int [(P_1 - P_2)/4\mu L](r_o^2 - r^2)]2\pi r dr$

$Q = [\pi r_o^4(P_1 - P_2)]/8\mu L = [\pi D^4(P_1 - P_2)]/128\mu L$

This is known as the Hagen-Poiseuille Law of laminar flow.

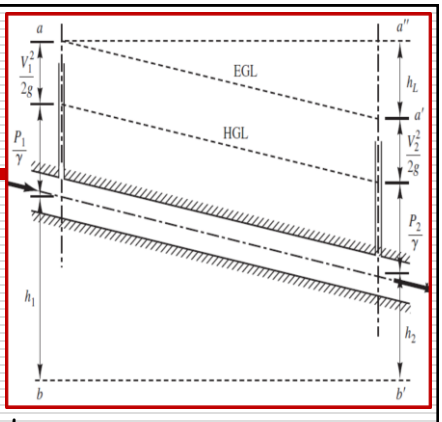
In small groups, formulate two questions about the development (derivation) of the Hagen-Poiseuille Law.

Now, solving for the mean velocity of flow:

$V = Q/A = [\pi D^4(P_1 - P_2)]/[128\mu L(\pi D^2/4)] = [D^2(P_1 - P_2)]/32\mu L$

Friction Factor for Laminar Flow – cont.

Solve the energy equation for a horizontal pipe (constant area):



But the Darcy- Weisbach eq'n. is:
$h_f = f\,(L/D)(V^2/2g)$

Equating the two values of h_f yields:

$f(L/D)(V^2/2g) = (P_1 - P_2)/\gamma$; and combining this equation with:

$V = [D^2(P_1 - P_2)]/32\mu L$ ➔ from the previous slide yields:

$f = 64\,\mu g/\gamma VD = 64\mu/\rho VD = 64\nu/VD = 64/N_R$ ➔ **Laminar Flow**

Note: For laminar flow, the friction factor only depends on the Reynolds number (independent of surface roughness).

Friction Factors for Various Types of Flows

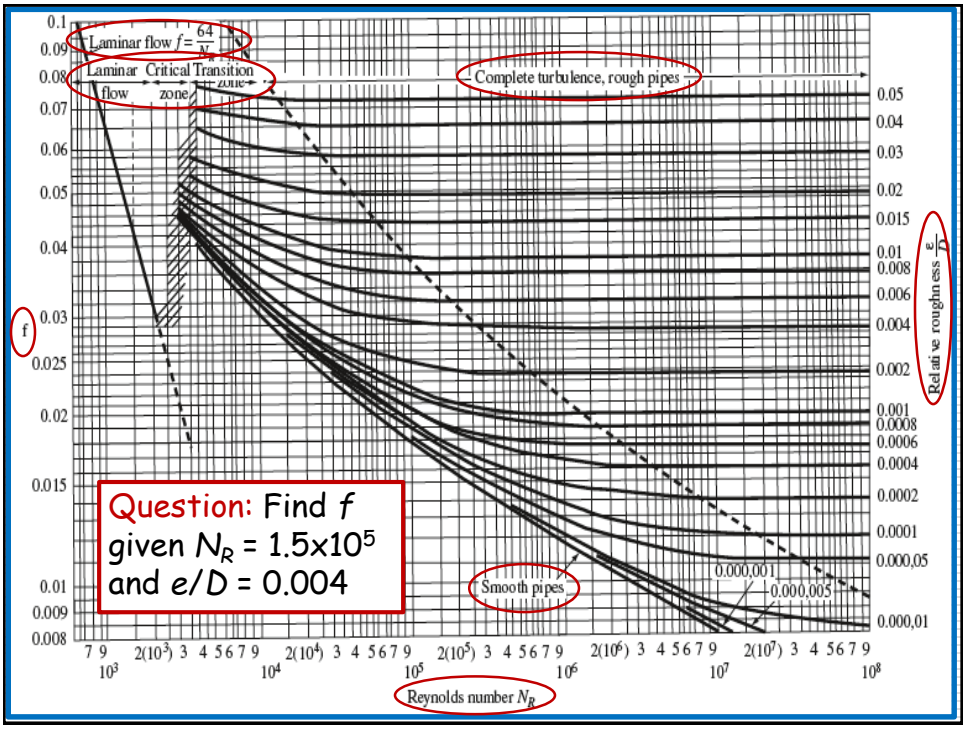
The Darcy-Weisbach Equation

$$h_f = f(L/D)(V^2/2g)$$

Determination of the Friction Factor

- Laminar Flow:
- Turbulent Flow:
- Complete Turbulence:
- Turb. (smooth pipe):

e = roughness height for pipe material (**Table 3.1**)



Friction Losses and the Energy Eq'n

(Example Problems – Solve on White Board)

Water at 20°C flows (3,500 L/sec) through a 1.5-m-diameter, commercial steel pipe. Find the flow regime and the friction factor.

Solution:

Friction Losses and the Energy Eq'n

(Example Problems – Solve on White Board)

Find Q (in L/sec) in a horizontal, 6-km long, cast iron pipeline if h = 408 m and D = 30 cm. (Assume complete turbulence.)

Solution:

Homework Problems: