CHEN.3030 Fluid Mechanics

VIII. Pipe Flow Applications

Prof. John R. White
Chemical and Nuclear Engineering
UMass-Lowell, Lowell MA

See Chapter 10 (all sections) + Chapter 14 (sections 14.6-14.8) in your text by Hibbeler

Major and Minor Losses

This lesson makes practical use of the relationships and concepts developed in the previous lesson on Viscous Internal Flows.

In particular, the head loss term is broken into two components:

Major Losses:

$$h_{L_{major}} = f \frac{L}{D_h} \frac{v^2}{2g}$$

Darcy Eqn. with f as the friction factor

h_{Lmajor} accounts for friction loss along a pipe of length L.

Minor Losses:

$$h_{L_{minor}} = \left(\sum_i K_i \right) \frac{v^2}{2g} = K \frac{v^2}{2g}$$

K is the resistance or loss coefficient

h_{Lminor} accounts for friction loss in pipe bends, fittings, valves, exits and entrances, etc. (anything that causes acceleration changes).

The Friction Factor -- f

$$h_L = f \frac{L}{D_h} \frac{v^2}{2g}$$

Darcy Eqn.

Laminar Flow: $f = 64/Re$ (discussed in previous lesson)

Turbulent Flow: $f = \phi(\varepsilon/D, Re)$ where ε/D is the **relative roughness**

For turbulent flow, the function dependence, $\phi(\varepsilon/D, Re)$, is given as:

Colebrook Eqn. (implicit eq.)

$$\frac{1}{\sqrt{f}} = -2.0\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$

This is used to create the Moody Chart

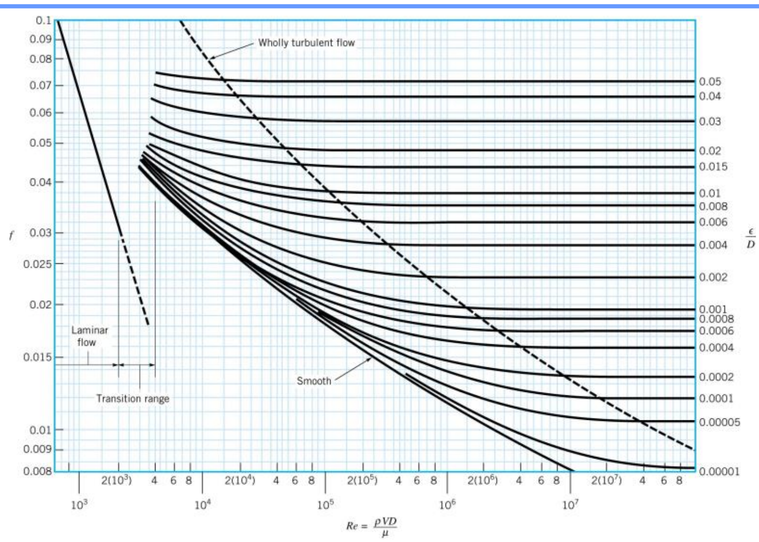
Swamee-Jain Eqn. (explicit eqn.)

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right]^2}$$

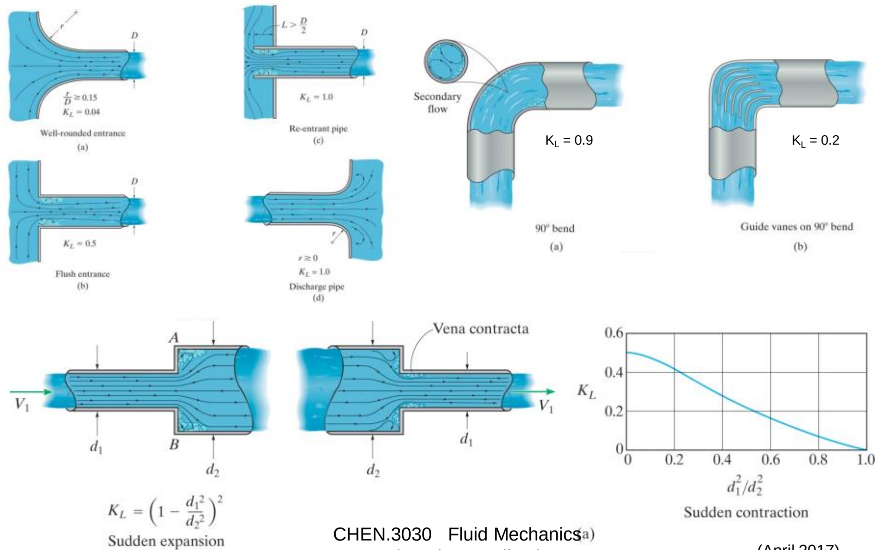
Haaland Eqn. (explicit eqn.)

$$\frac{1}{\sqrt{f}} = -1.8\log_{10}\left(\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right)$$

The Moody Chart



Minor Losses (due to acceleration changes)



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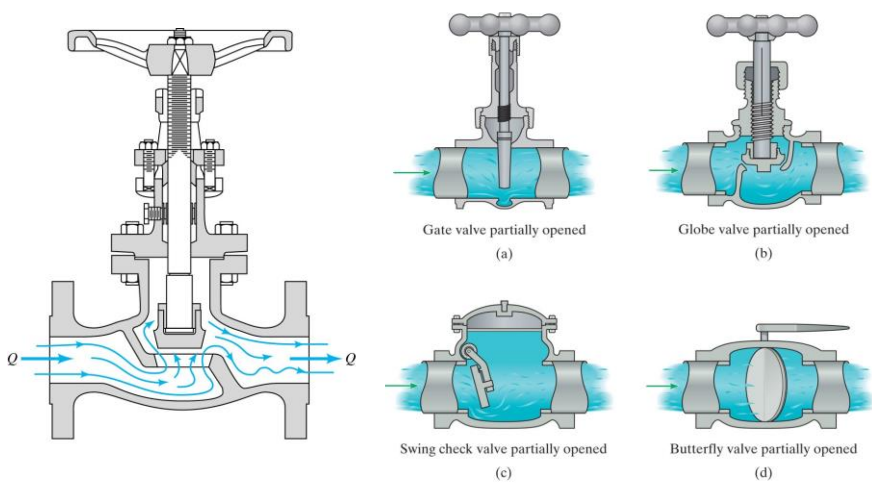
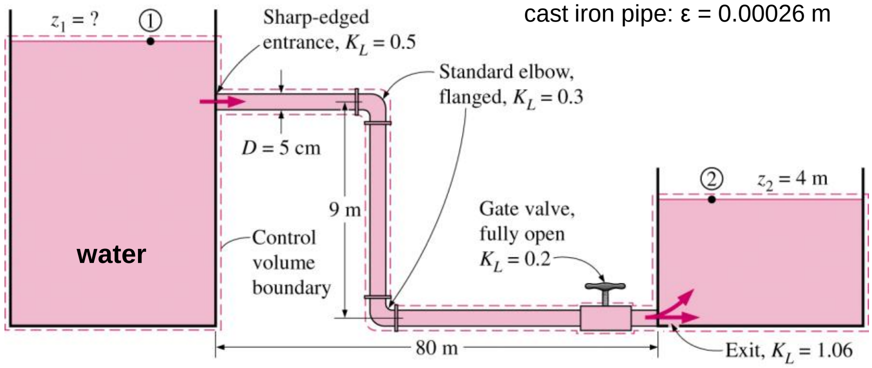
Minor Losses (due to acceleration changes)

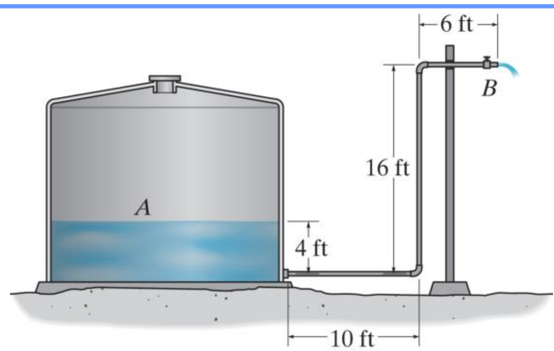


Ex. #1 -- Type I (Q and D given)



Find the elevation z_1 needed for a flow rate of $6{\times}10^{-3}$ m^3/s.

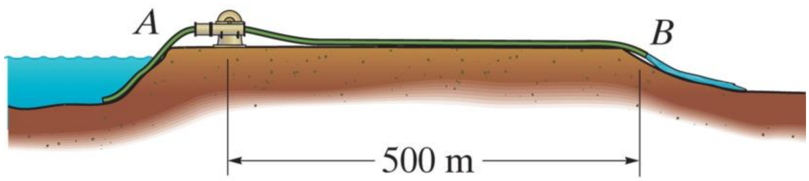
Ex. #2 -- Type II (D given, Q is unknown)



The pressure at A is 40 psi and the 2″ pipe is galvanized iron. The minor losses include the 2 elbows, a flush entrance, and an open gate valve.

Estimate the water flow rate (gpm) under these conditions.

Ex. #3 -- Type III (Q given, D is unknown)



Water is to be delivered at 0.04 m^3/s to point B along the ground.

The pump supplies 40 kW of power to the fluid.

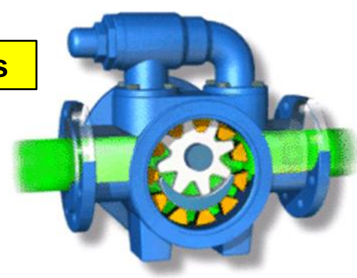
Assuming minimal elevation change, determine the smallest diameter flexible tubing that can be used for this application (use ε = 0.00002 m).

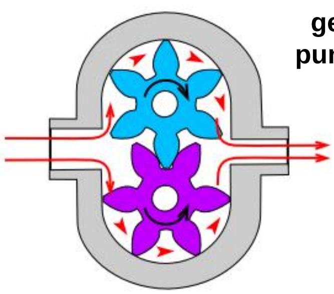
water properties:

ρ = 1000 kg/m^3 and $\mu = 1.15\times10^{-3}$ $N\text{-}s/m^2$

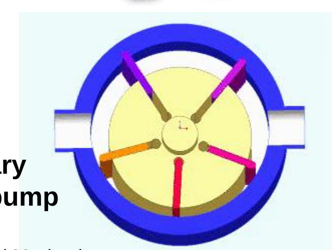
Two Main Types of Pumps

Positive Displacement Pumps



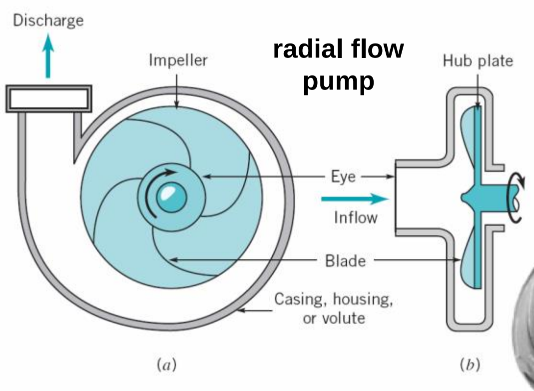


gear pumps



rotary vane pump

Two Main Types of Pumps



Centrifugal (kinetic) Pumps

open enclosed

impeller designs

PD vs Centrifugal Pumps

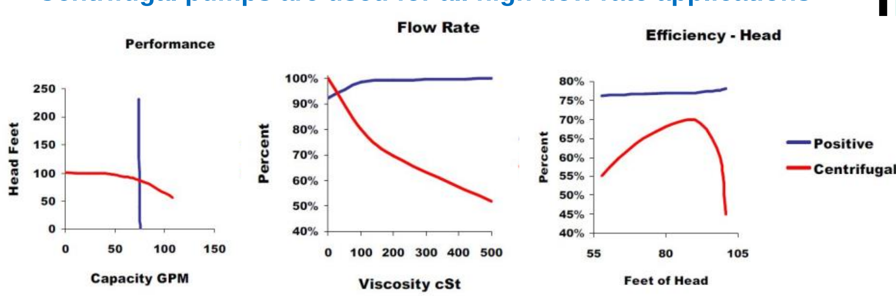
PD pumps have nearly constant capacity (flow rate) vs head

PD pumps work nicely with high viscosity fluids

The efficiency of PD pumps is nearly constant vs head, but

They only allow relatively low to moderate flow rates (< 100 gpm)

Centrifugal pumps are used for all high flow rate applications



Typical Centrifugal Pump Curves

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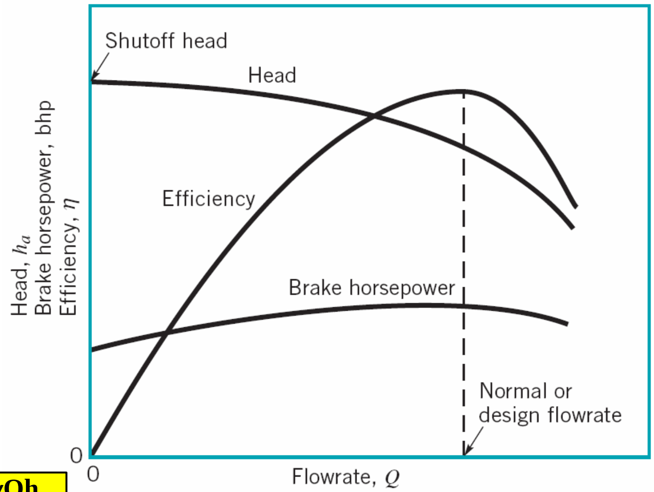

$$\eta = \frac{P_A}{P_I} = \frac{\gamma Q h_A}{P_I}$$

Actual Centrifugal Pump Curves

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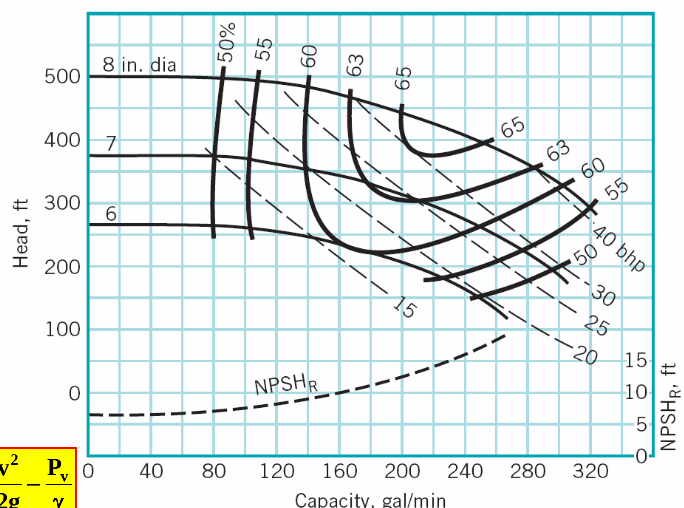

$$NPSH|_{avail} = \frac{P}{\gamma} + \frac{v^2}{2g} - \frac{P_v}{\gamma}$$

(at pump inlet)

Example #4 -- The Operating Point

Water is pumped from the lake to the tank through a 5 cm diameter galvanized iron pipe.

The pipe length is 50 m. Also include the minor loss associated with 5 90º elbows.

With the pump performance curve given, determine the flow rate that will develop in this system.

water properties:

ρ = 1000 kg/m^3 and μ = 1.0×10^{-3} N-s/m^2