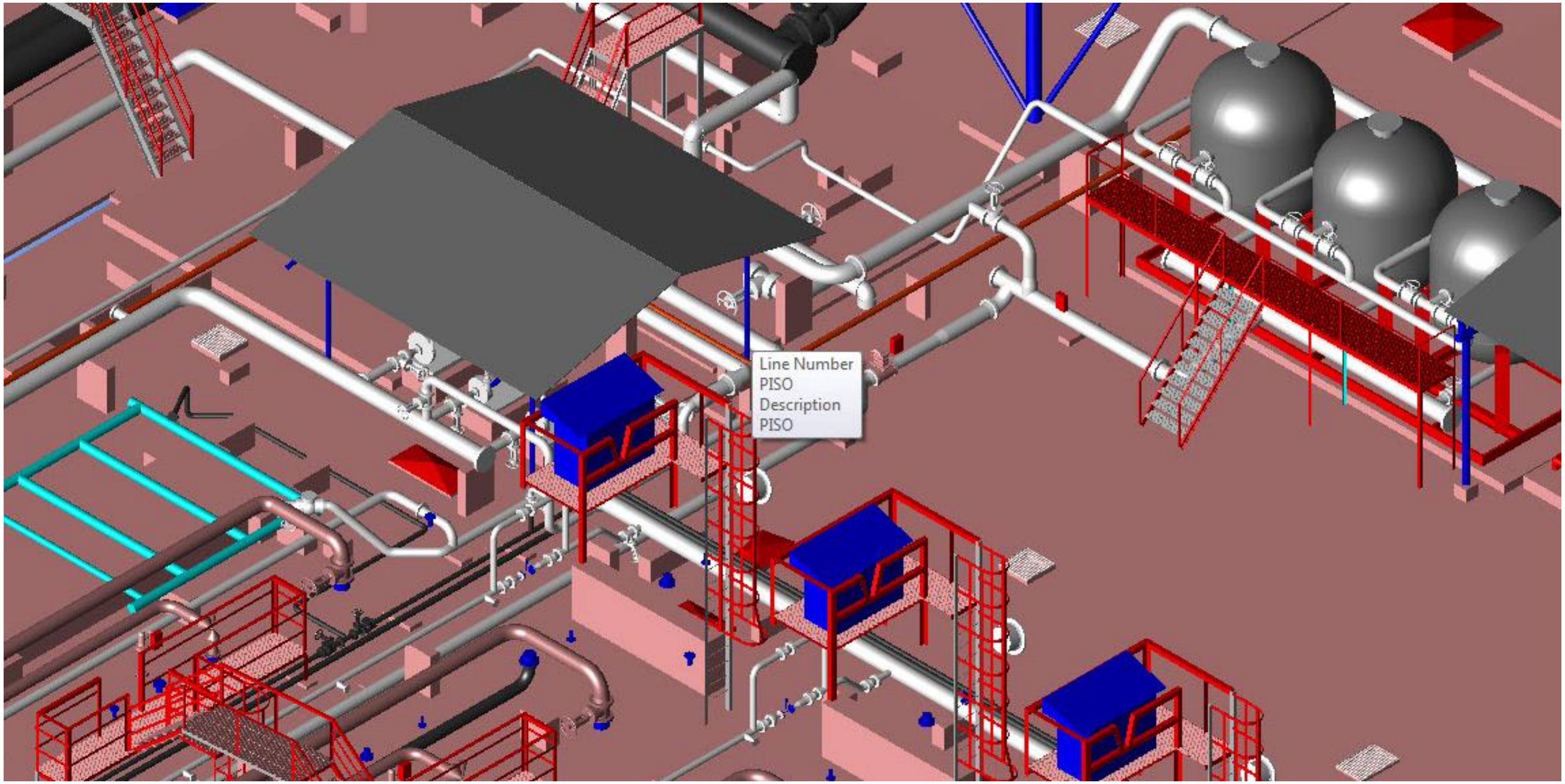
Florida International University
CWR 3201 - Fluid Mechanics, Fall 2018

Fluid Flow in Pipes (Single-pipe)



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Learning Objectives

(1) Identify and understand various characteristics of flows in pipes

(2) Discuss the main properties of laminar and turbulent flows

(3) Calculate losses, flow rates and pipe diameters in a single piping system

Video of pipe flows

3D Petrochemical Refinery

https://www.youtube.com/watch?v=tkmozP-97M4

Typical components of a pipe system

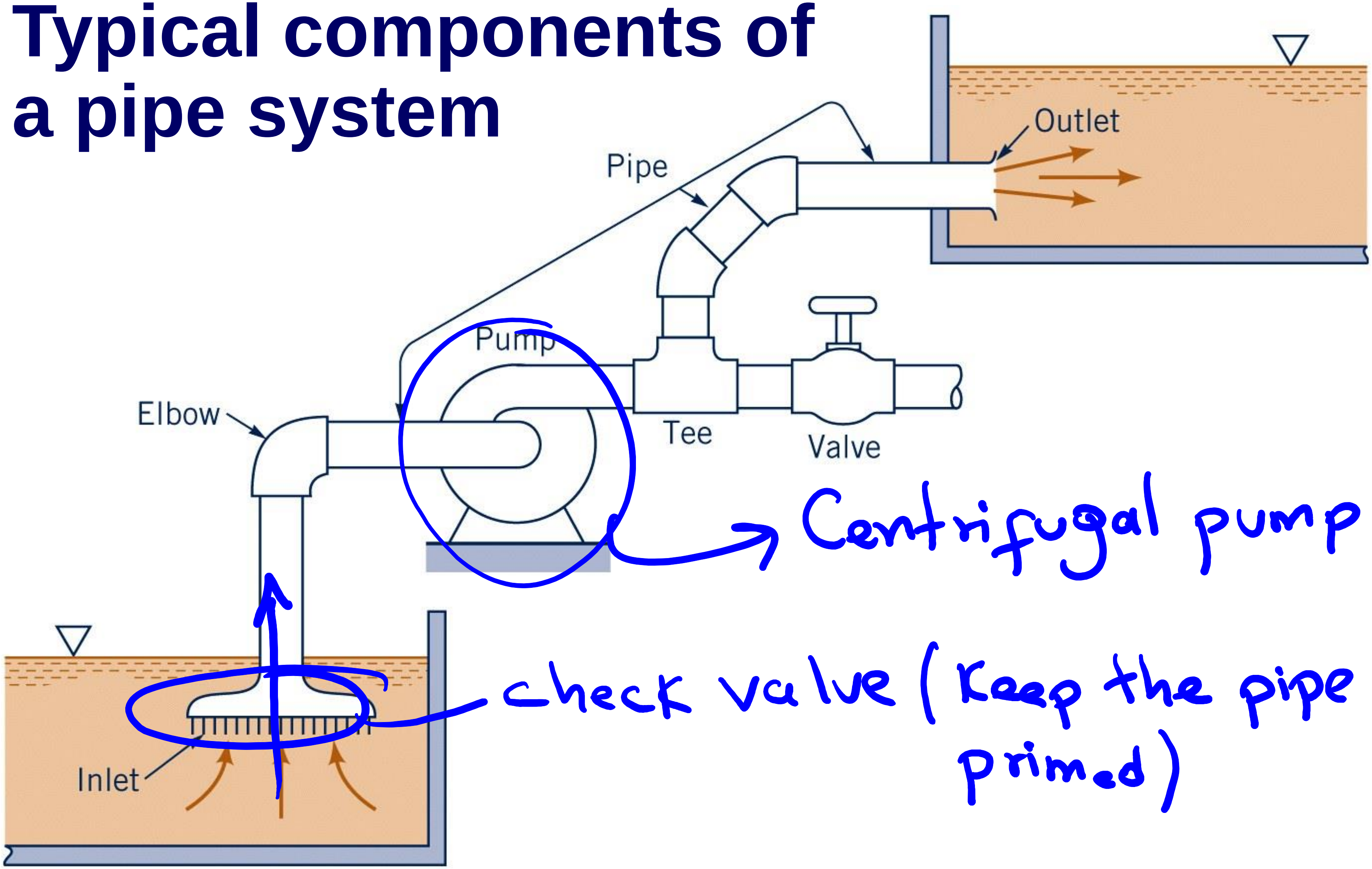

Figure 8.1
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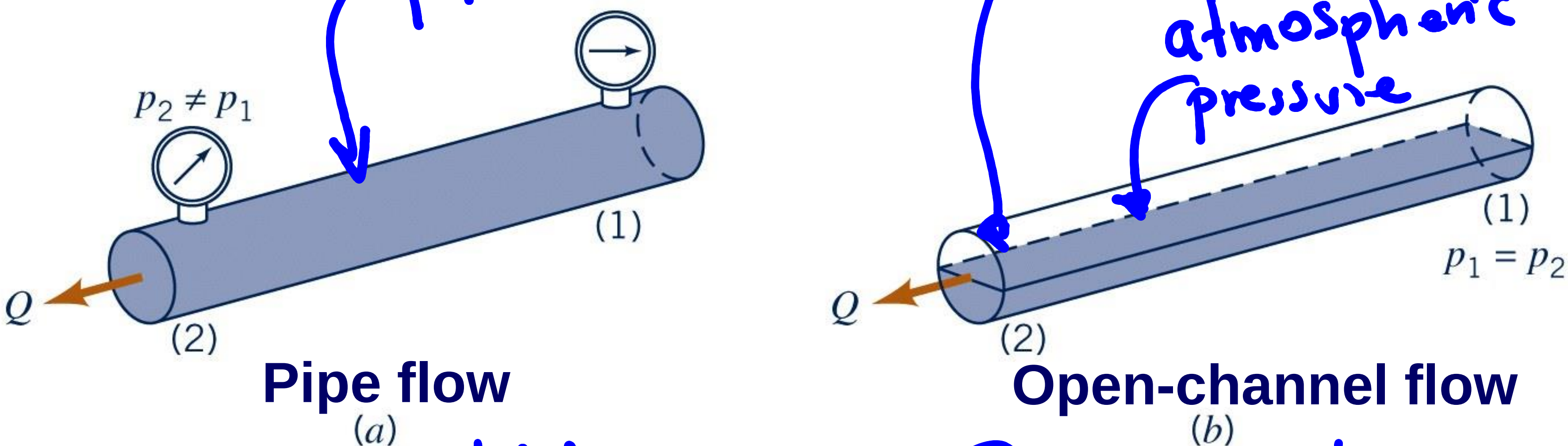
General Characteristics of pipe flow

fluid fills the pipe

pipe is not completely filled

atmospheric pressure



Pressure is driving force

Gravity is driving force

Figure 8.2
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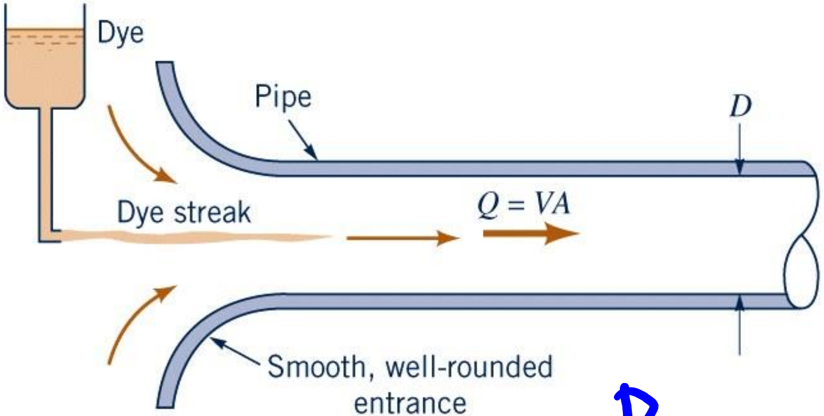
Laminar or Turbulent Flow?
(http://www.youtube.com/watch?v=WG-YCpAGgQQ)

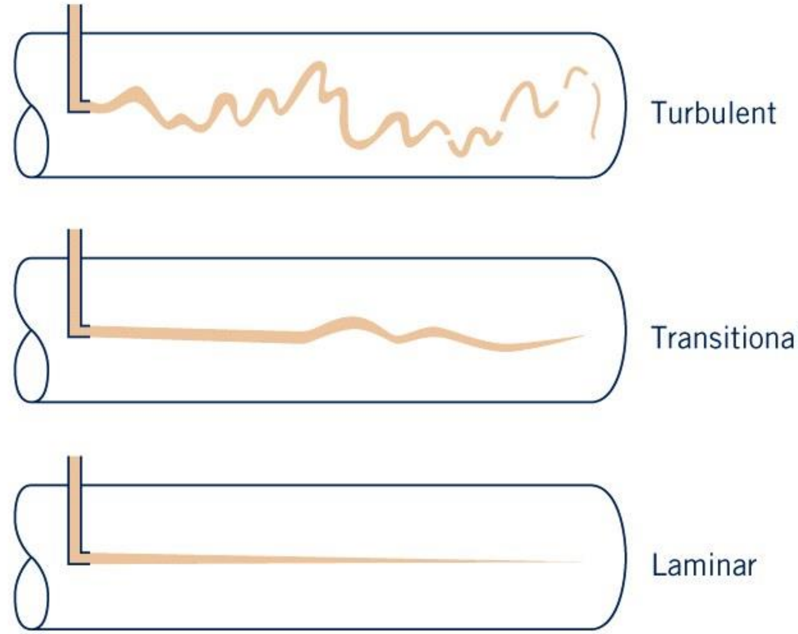
Laminar or Turbulent Flow?



(a)

$$\boxed{Re = \frac{V \cdot D}{\nu}}$$

Reynolds number



(b)

Typical dye streaks

V : velocity

D : Pipe diameter

ν : kinematic viscosity

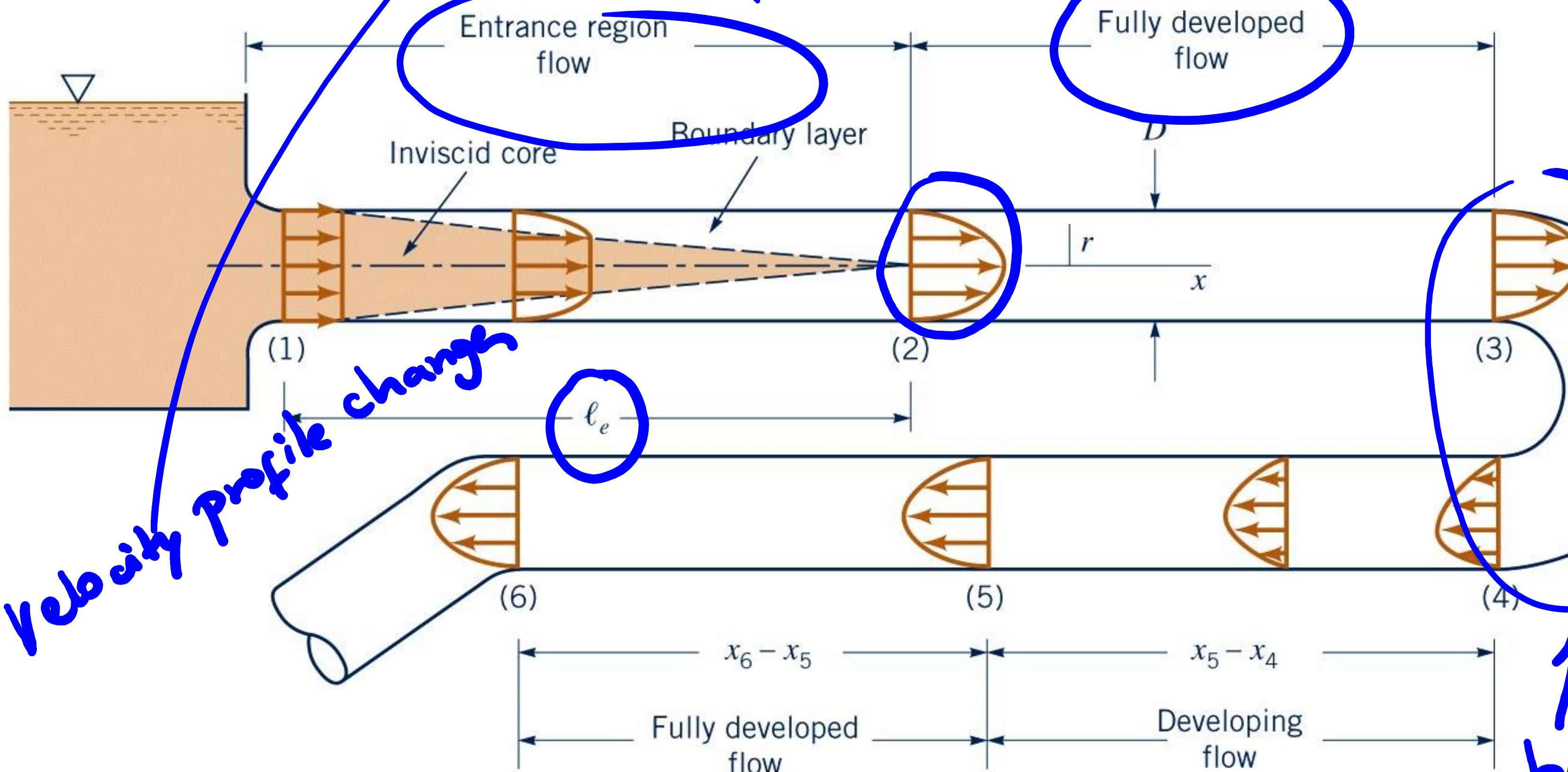
$Re \leq 2000$ (Laminar)

$2000 < Re \leq 4000$ (transitional)

$Re > 4000$ (turbulent)

Fully Developed Flow

velocity profile doesn't change



$$\frac{l_e}{D} = 0.065\,Re \quad [\text{for laminar flow}]$$

$$\frac{l_e}{D} = 4.4\,Re^{1/6} \quad [\text{for turbulent flows}]$$

Example: P7.21. A laboratory experiment is designed to create a laminar flow in a 2-mm diameter tube shown in Fig.P7.21. Water flows from a reservoir through the tube. If 18 liters is collected in 2 hours can the entrance length be neglected?

$$Q = 18\,\frac{lt}{2\,h} = 9\,\frac{lt}{h}$$

$$l_e = 0.065\,Re \cdot D \quad \cdots (1)$$

$$Re = \frac{V \cdot D}{\nu}$$

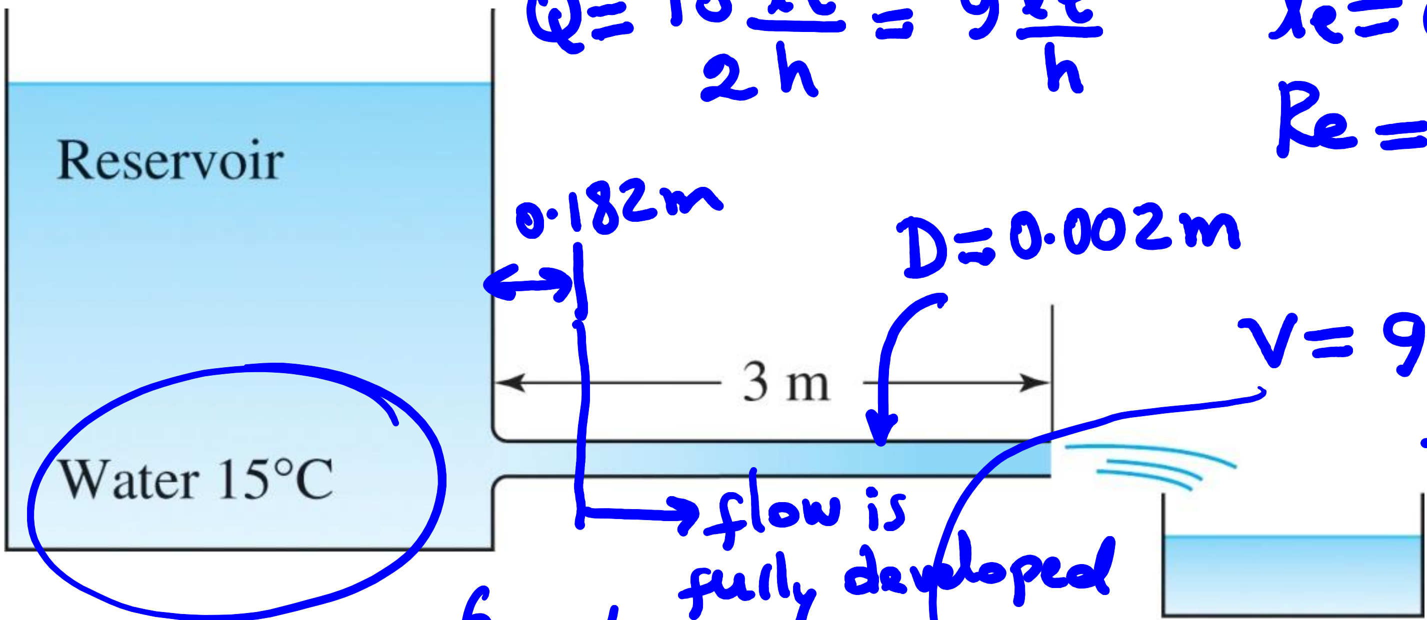


Fig. P7.21

$$V = 9\,\frac{\cancel{lt}}{\cancel{h}} \left(\frac{1\cancel{h}}{3600\,s}\right) \frac{1\,m^3}{1000\,\cancel{lt}} \Big/ A$$

$$\nu = 1.14 \times 10^{-6}\ m^2/s$$

$$V = \frac{9}{3600 \times 1000} \times \frac{4}{\pi \times 0.002^2}$$

$$V = 0.796\ m/s$$

* $Re = \dfrac{0.796 \times 0.002}{1.14 \times 10^{-6}} = 1396.5$ (Laminar flow)

In 1

$l_e = 0.065 \times 1396.5 \times 0.002$

$\boxed{l_e = 0.182 m}$

Because $0.18m \ll 3m$, we can neglect the entrance length
much smaller

Turbulent Flow in a Pipe

τ_0: wall shear stress
ν: kinematic visc.
ρ: density

7.6.2 Velocity Profile

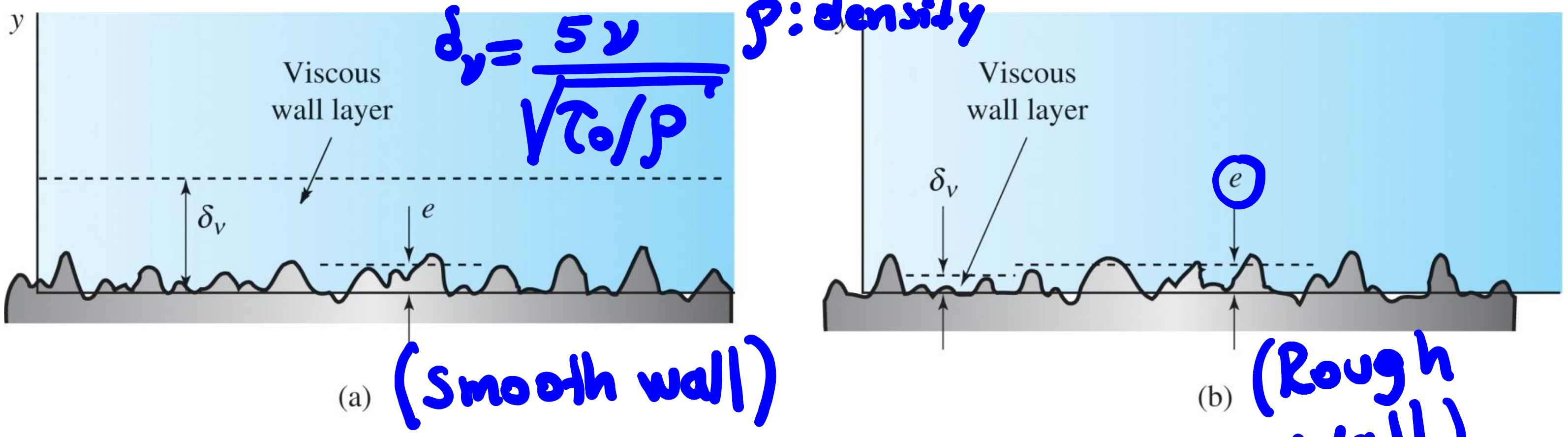


Fig. 7.10 (a) A smooth wall and (b) a rough wall.

e or ε = Average wall roughness height

δ_v = Viscous wall layer thickness

- ***Hydraulically smooth***: The viscous wall thickness (δ_v) is large enough that it submerges the wall roughness elements→ Negligible effect on the flow (almost as if the wall is smooth).
- If the viscous wall layer is very thin→ Roughness elements protrude off the layer→ ***The wall is rough***.
- The relative roughness *e*/*D* (or ε/*D*) and Reynolds number can be used to find if a pipe is smooth/rough.

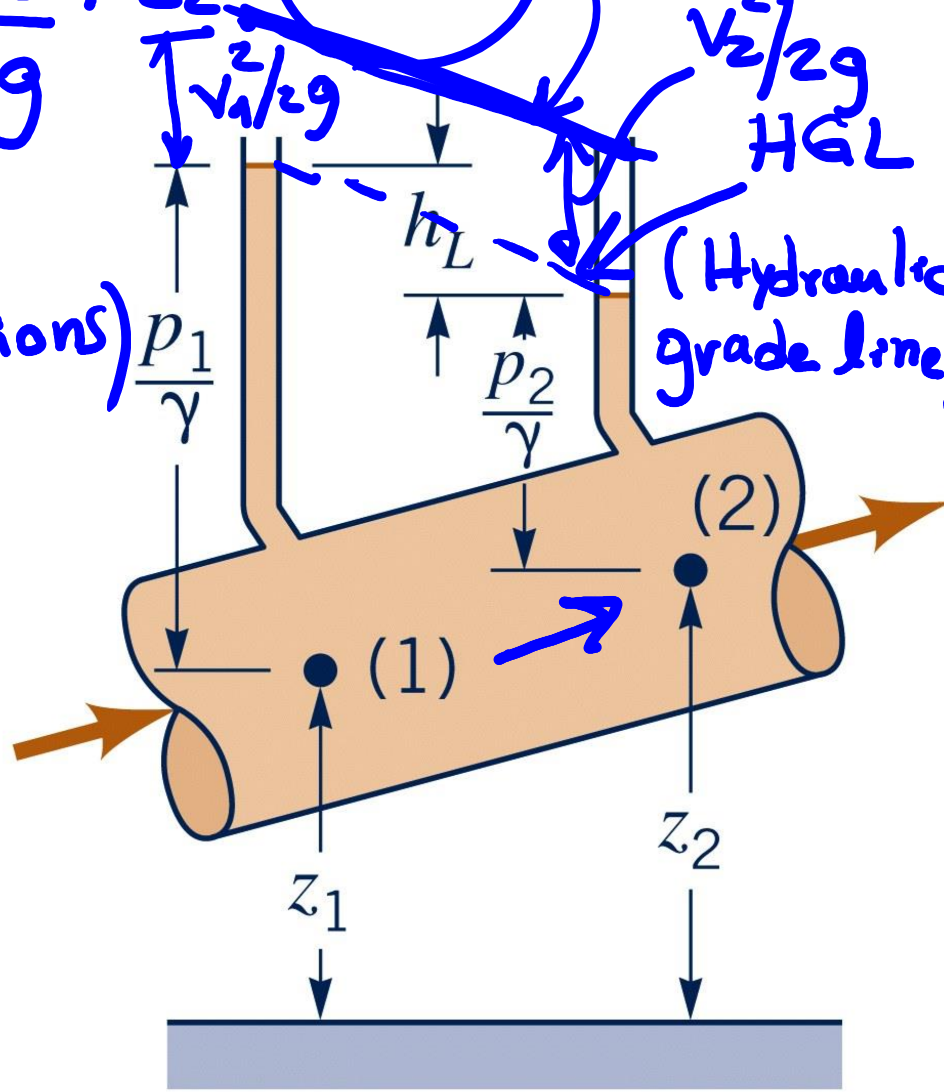
Energy considerations

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

Energy grade line

head losses

$\alpha_1, \alpha_2 \approx 1.0$ (for most applications)



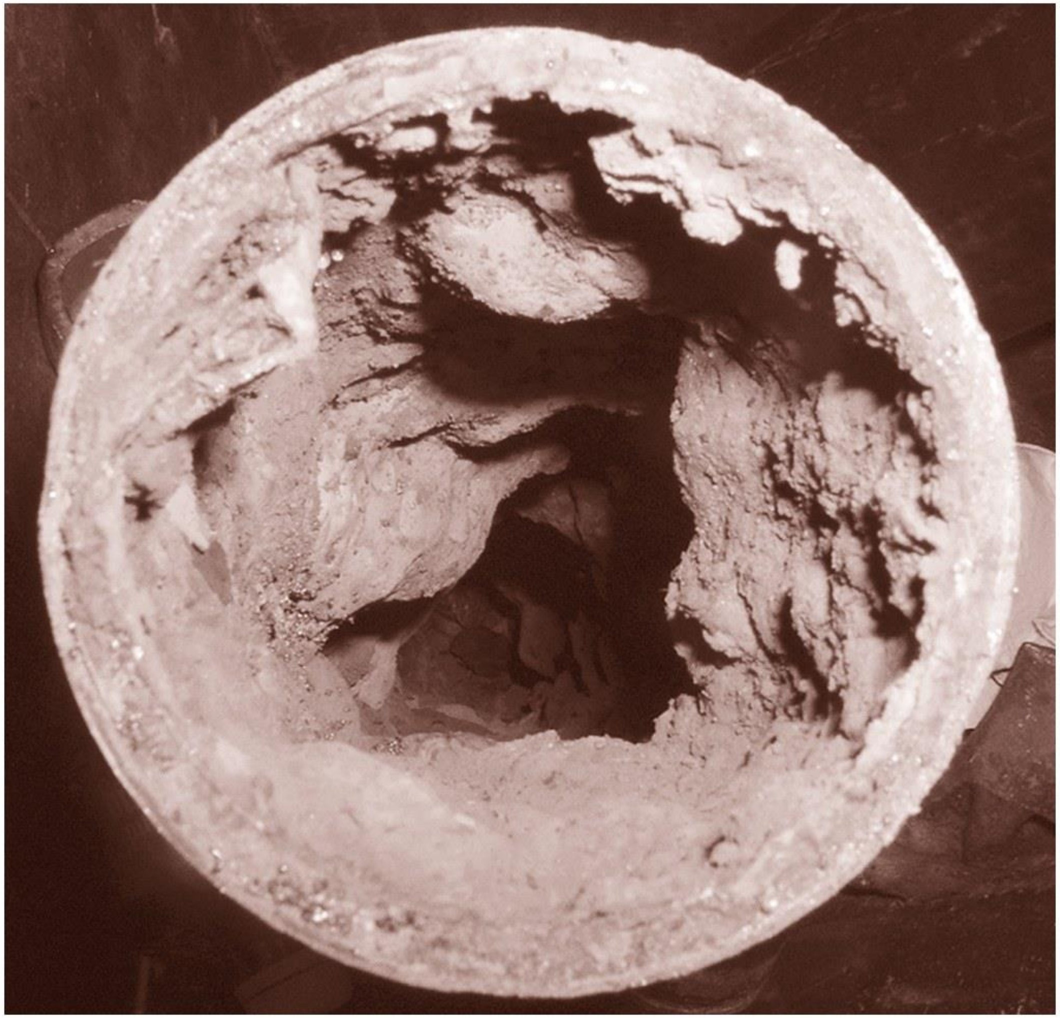
$\frac{p}{\gamma}$: Pressure head

$\frac{V^2}{2g}$: velocity head

z : elevation head

Major losses

$$\boxed{h_{L_{total}} = h_{L_{major}} + h_{L_{minor}}}$$



Unnumbered 8 p429a
Photograph courtesy of CorrView

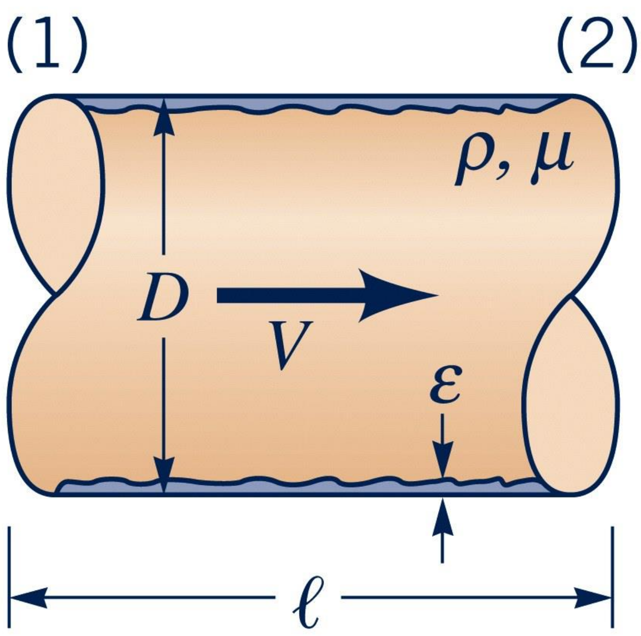
major: pipe friction

minor: fittings and accesories (gates, values, bends)

Major Losses in Developed Pipe Flow

- Most calculated quantity in pipe flow is the **head loss**.
  - Allows pressure change to be found→ pump selection.

$$\Delta p = p_1 - p_2$$



$$\boxed{\Delta p = f \frac{L}{D} \rho \frac{V^2}{2}}$$

from dimensional analysis

$$\frac{\Delta p}{\gamma} = f \frac{L}{D} \frac{V^2}{2g}$$

$$\boxed{h_{L\,major} = f \frac{L}{D} \frac{V^2}{2g}}$$

Head loss from wall shear in a developed flow is related to the friction factor(f).

- f = $f(\rho, \mu, V, D, \varepsilon)$
- **Darcy-Weisbach equation**

f: friction factor

ε: Equivalent roughness height

Table 8.1

Equivalent Roughness for New Pipes [Adapted from Moody (Ref. 7) and Colebrook (Ref. 8)]

	Equivalent Roughness, ε	
Pipe	**Feet**	**Millimeters**
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Wood stave	0.0006–0.003	0.18–0.9
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.045
Drawn tubing	0.000005	0.0015
Plastic, glass	0.0 (smooth)	0.0 (smooth)

Table 8.1
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low high } depends on finishing of surface

The Moody diagram

a) Re = 4x10^4
ε/D = 0.001
f =? 0.026

b) Re = 3x10^4
ε/D = 0.0001
f =? 0.024

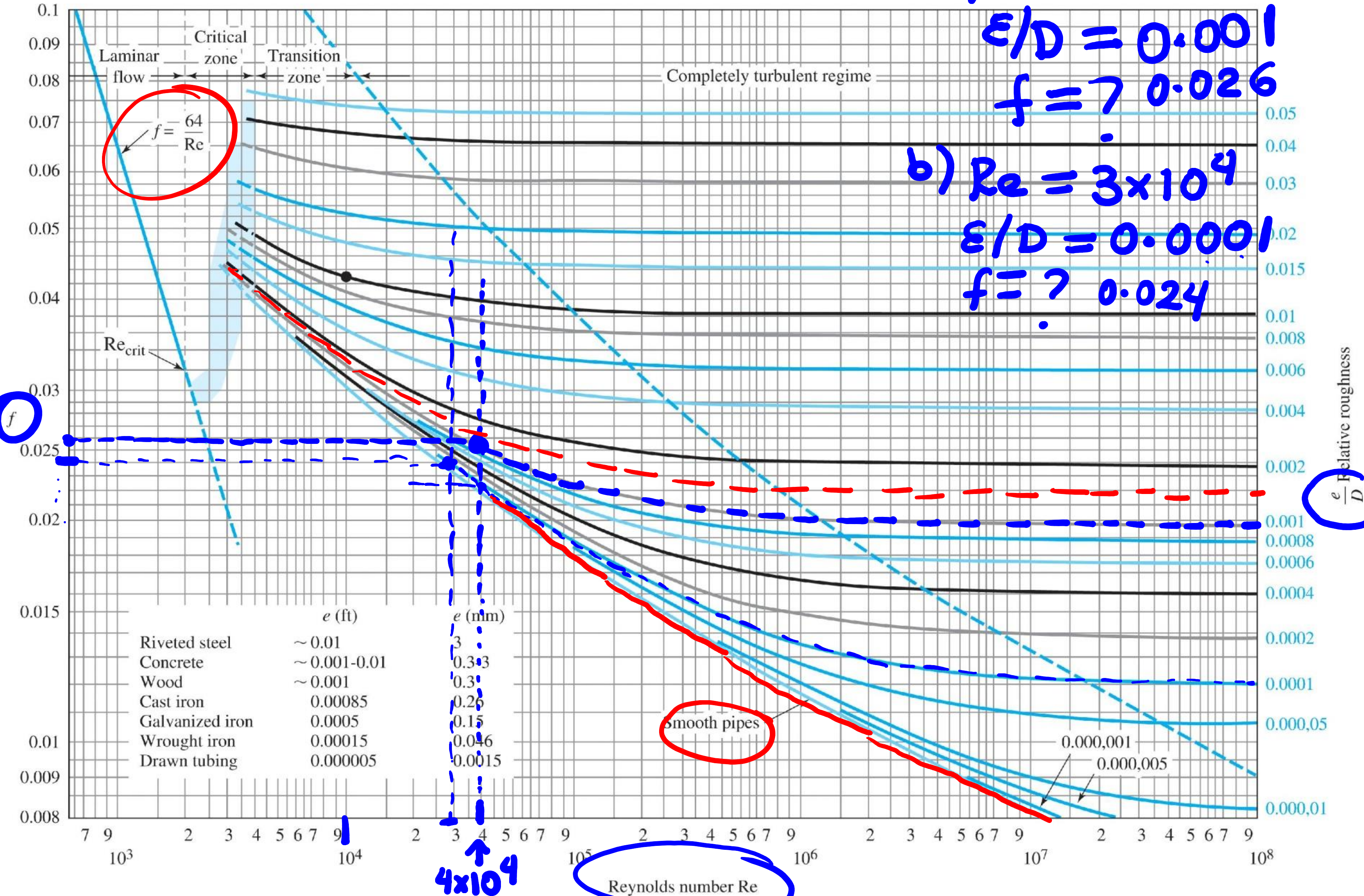


Fig. 7.13 Moody diagram. (From L. F. Moody, Trans. ASME, Vol. 66, 1944. Reproduced with permission of ASME.) (Note: If e/D = 0.01 and Re = 10^4, the dot locates f = 0.043.)

Major Losses in Developed Pipe Flow

- Moody diagram is a plot of experimental data relating friction factor to the Reynolds number.
- For a given wall roughness→ There is a large enough Re to get a constant friction factor→ **Completely turbulent regime.**
- For smaller relative roughness→ As Re decreases, friction factor increases→ **Transition zone**→ Friction factor becomes like that of a smooth pipe.
- For Re < 2000→ The **critical zone** couples the turbulent flow to the laminar flow and may represent an oscillatory flow that alternately exists between turbulent and laminar flow.
- Assume new pipes→ As a pipe gets older, corrosion occurs changing both the roughness and the pipe diameter.

Friction factor for the entire nonlaminar range (smooth + completely turbulent regime)

Empirical equations for Re > 4000

Colebrook formula (Implicit)

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

$$\frac{1}{\sqrt{f}} = -0.86 \ln\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$

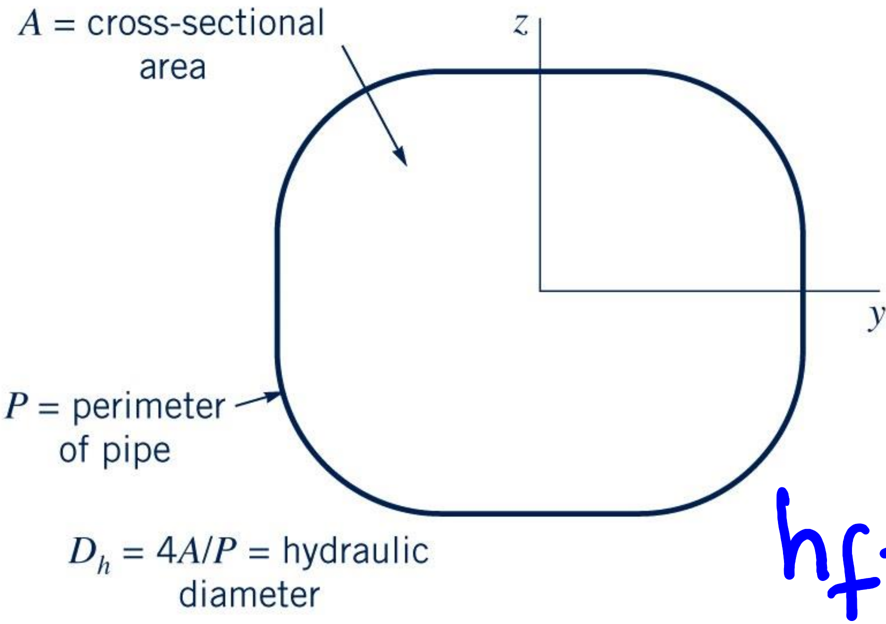
Haaland formula (To avoid trial-and-error [Explicit]

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

Major Losses in Noncircular Conduits

- Can approximate for conduits with noncircular cross sections:
  - Using hydraulic radius R

$$R = \frac{A}{P} = \frac{\cancel{\pi} D^2}{4(\cancel{\pi} D)} = \frac{D}{4}$$



A: Cross-sectional area
P: Wetted perimeter→ **Perimeter where the fluid is in contact with the solid boundary**

$$D_e = 4R$$

$$h_f = f\frac{L}{D_e}\frac{V^2}{2g} = f\frac{L}{4R}\frac{V^2}{2g}$$

- E.g., for a circular pipe:
  - Hydraulic radius *R* =

$$\frac{\varepsilon}{D_e} = \frac{\varepsilon}{4R}, \quad Re = \frac{V \cdot D_e}{\nu}$$

- The head-loss then becomes:

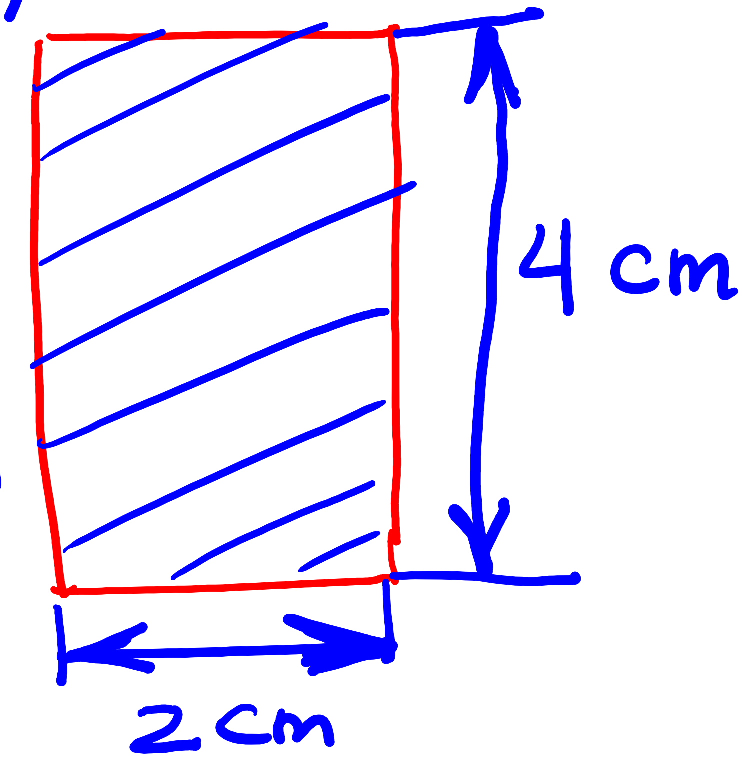
Example: P.7.112. Water at 20ºC is transported through a 2 cm x 4 cm smooth conduit and experiences a pressure drop of 80 Pa over a 2-m horizontal length. What is the flow rate?

$\Delta p = 80\ \text{Pa}$ $\qquad \nu = 10^{-6}\ \text{m}^2/\text{s}$

$L = 2\ \text{m}$

$Q = ??$ $\qquad \Delta p = f \dfrac{L}{D_e} \rho \dfrac{V^2}{2}$

$D_e \begin{cases} D \text{ (circular)} \\ 4R \text{ any cross section} \end{cases}$



$D_e = 4R = 2.6667\ \text{cm}$

$D_e = 0.02667\ \text{m}$ $\qquad R = \dfrac{A}{P} = \dfrac{2 \times 4}{12}$

$$\frac{80\ Pa}{9810} = f\frac{L}{De}\frac{V^2}{2g} \qquad \frac{80}{9810} = f\frac{(2)}{0.02667}\frac{V^2}{(2\times 9.81)} \quad \cdots (1)$$

$$f = f\left(Re, \frac{\varepsilon}{De}\right)$$

V (m/s) GUESS	Re	f	V (m/s) Calculated
0.5	13350	0.027	0.281
0.281	7476	0.032	0.26
0.26	6492	0.034	0.25
0.25	6675	0.034	0.25

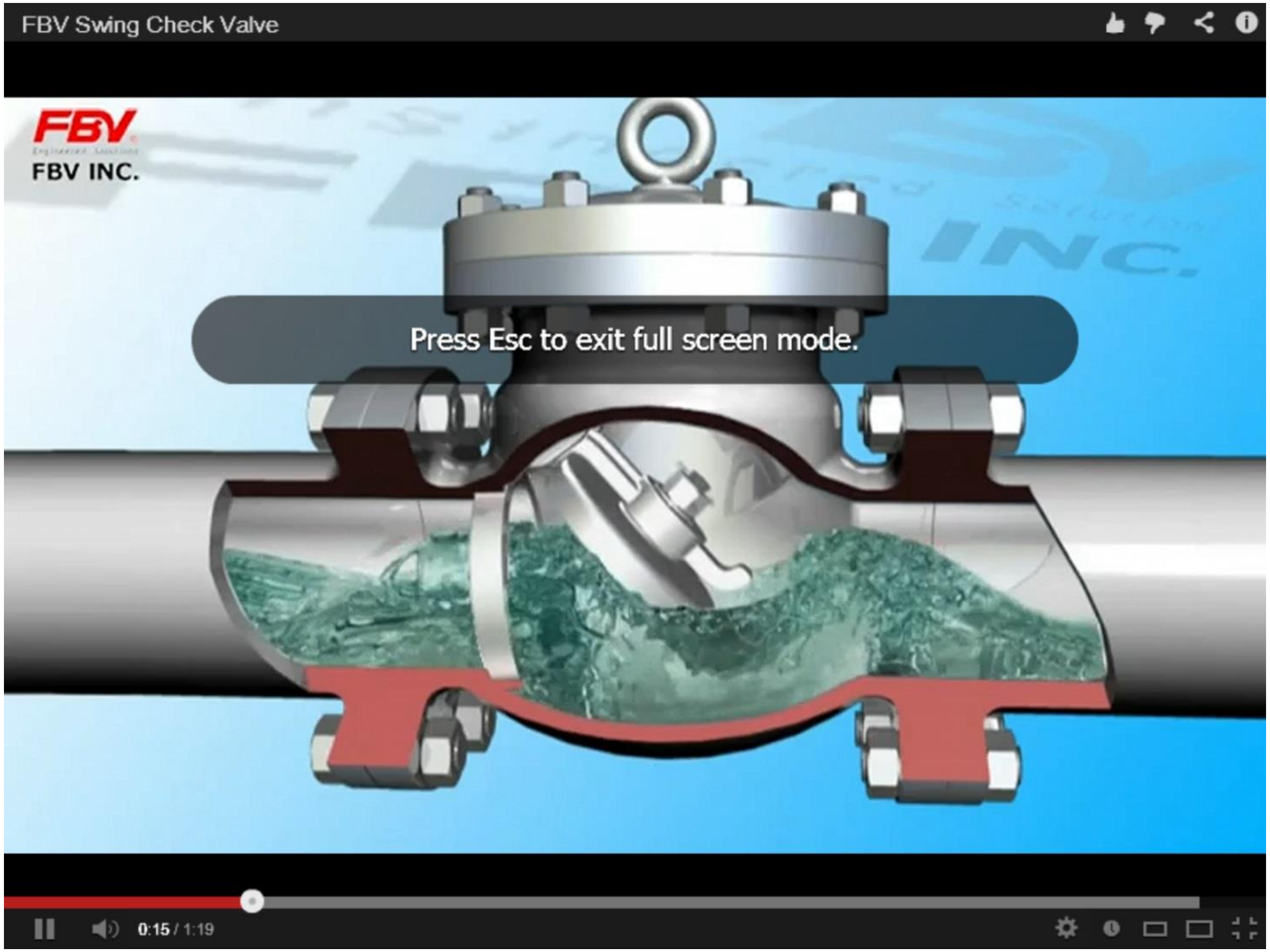
$$Q = V \cdot A = 0.25 \times \frac{2}{100} \times \frac{4}{100} = 0.0002\ m^3/s$$

$$= \underline{0.2\ L/s}$$

Minor losses

Swing check valve video

http://www.youtube.com/watch?v=Krp6pOnaNsk

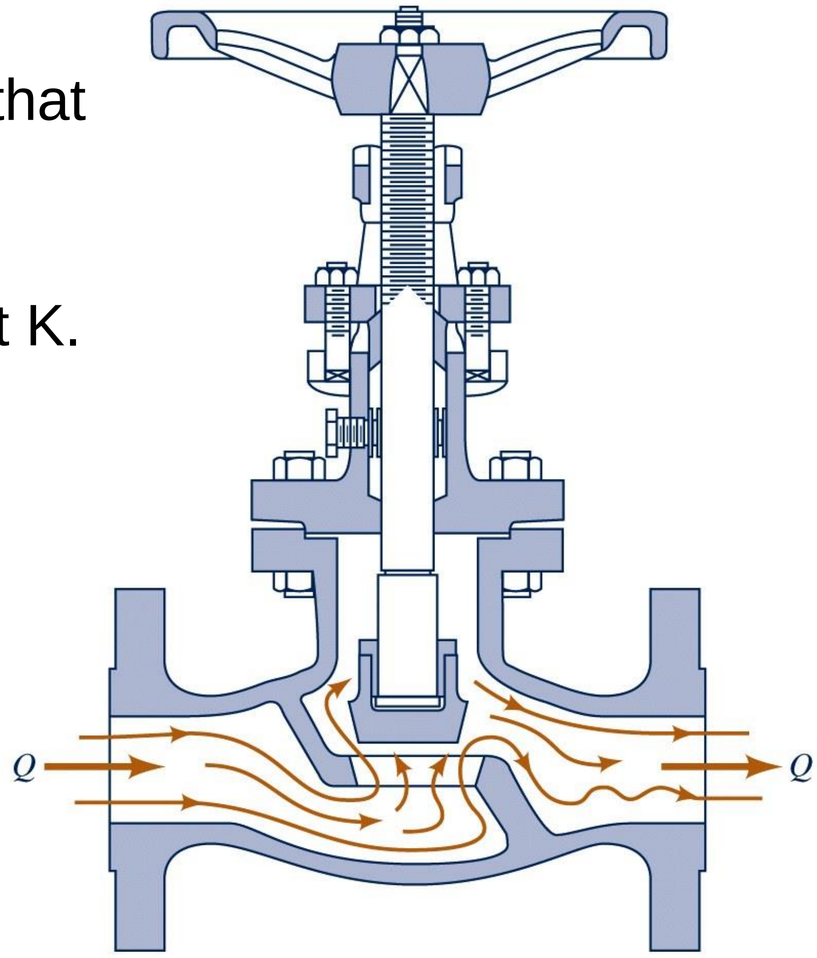


Minor losses (Cont.)

- Sometimes *minor losses* (from fittings that cause additional losses) can exceed frictional losses.
- Expressed in terms of a loss coefficient K.

$$h_L = K \frac{V^2}{2g}$$

- *K* can be determined experimentally.



(b)

Minor Losses in Pipe Flow

- A loss coefficient can be expressed as an ***equivalent length L_e*** of pipe:

$$h_{L\,minor} = K\frac{V^2}{2g}$$

$$h_{L\,major} = f\frac{L_e}{D}\frac{V^2}{2g}$$

$$K\cancel{\frac{V^2}{2g}} = f\frac{L}{D}\cancel{\frac{V^2}{2g}} \longrightarrow L_e = K\frac{D}{f}$$

$$\boxed{h_f = f\frac{(L+L_e)}{D}\frac{V^2}{2g}}$$

$$\boxed{L_e = \sum \frac{K_i D_i}{f_i}}$$

- For long segments of pipe, minor losses can usually be neglected.

Entrance flow conditions and loss coefficient

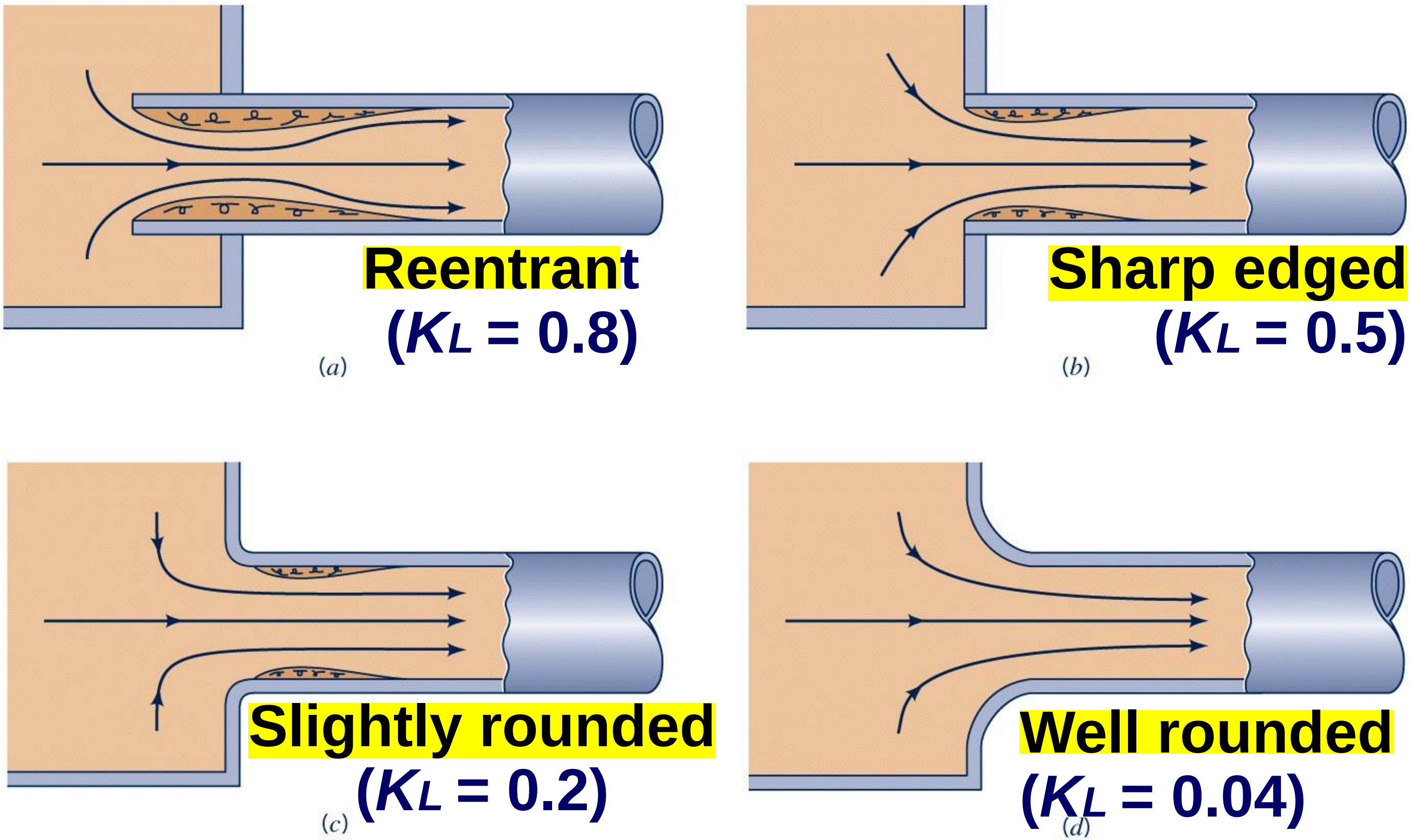


Figure 8.22
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Exit flow conditions and loss coefficient

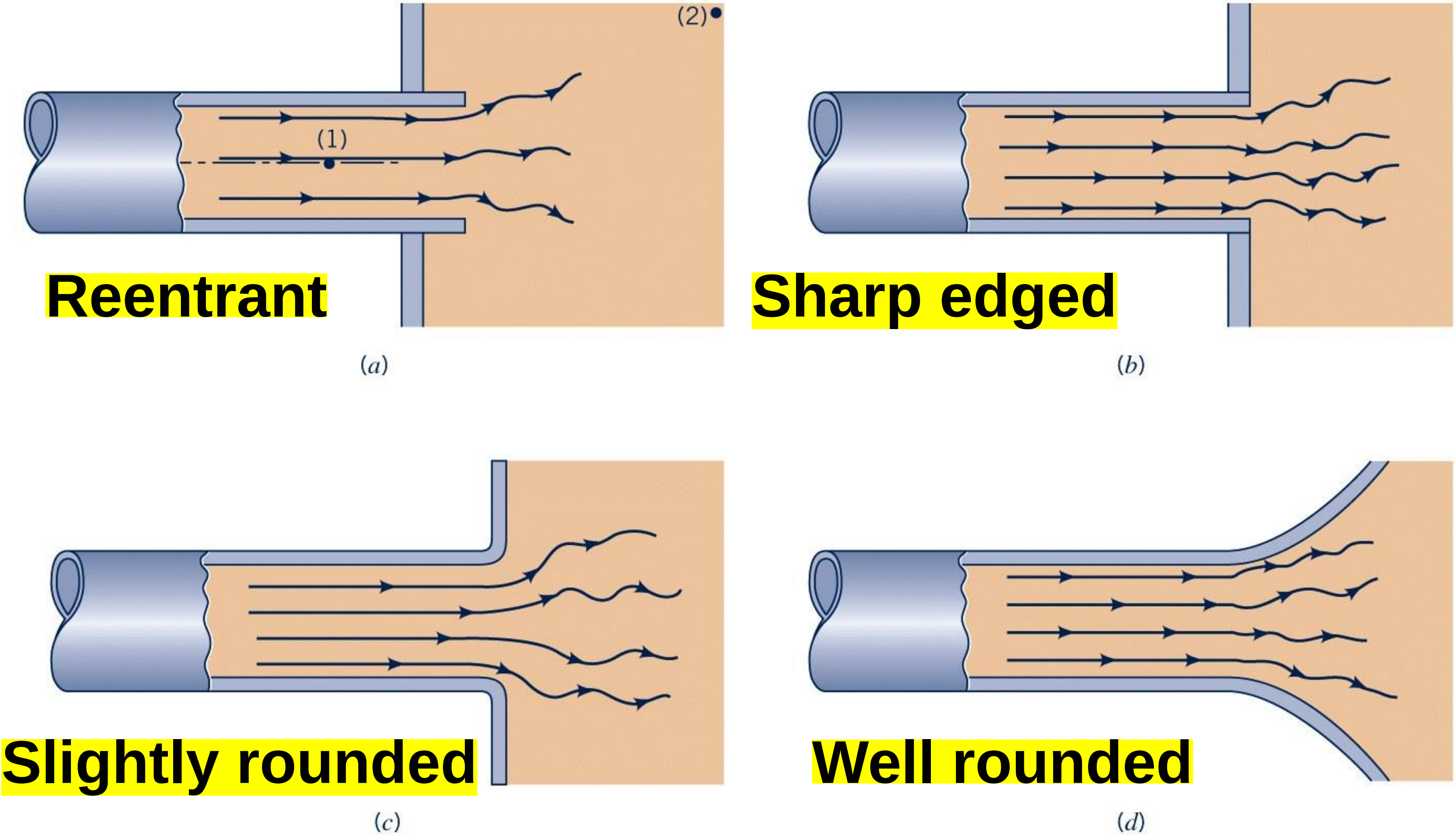

Figure 8.25

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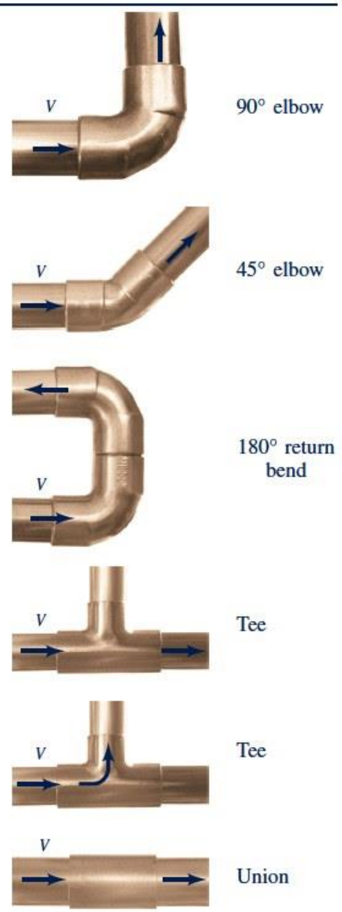
Loss coefficients for Pipe Components

Table 8.2

Loss Coefficients for Pipe Components $\left(h_L = K_L \frac{V^2}{2g}\right)$ (Data from Refs. 5, 10, 27)

Component	K_L
a. Elbows	
Regular 90°, flanged	0.3
Regular 90°, threaded	1.5
Long radius 90°, flanged	0.2
Long radius 90°, threaded	0.7
Long radius 45°, flanged	0.2
Regular 45°, threaded	0.4
b. 180° return bends	
180° return bend, flanged	0.2
180° return bend, threaded	1.5
c. Tees	
Line flow, flanged	0.2
Line flow, threaded	0.9
Branch flow, flanged	1.0
Branch flow, threaded	2.0
d. Union, threaded	0.08
***e. Valves**	
Globe, fully open	10
Angle, fully open	2
Gate, fully open	0.15
Gate, $\frac{1}{4}$ closed	0.26
Gate, $\frac{1}{2}$ closed	2.1
Gate, $\frac{3}{4}$ closed	17
Swing check, forward flow	2
Swing check, backward flow	∞
Ball valve, fully open	0.05
Ball valve, $\frac{1}{3}$ closed	5.5
Ball valve, $\frac{2}{3}$ closed	210



*See Fig. 8.32 for typical valve geometry.

Table 8.2

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Threaded elbow

Flanged elbow

Example:

Water flows from the container shown in Fig. 8.59. Determine the loss coefficient needed in the valve if the water is to "bubble up" 3 in above the outlet pipe. The entrance is slightly rounded.

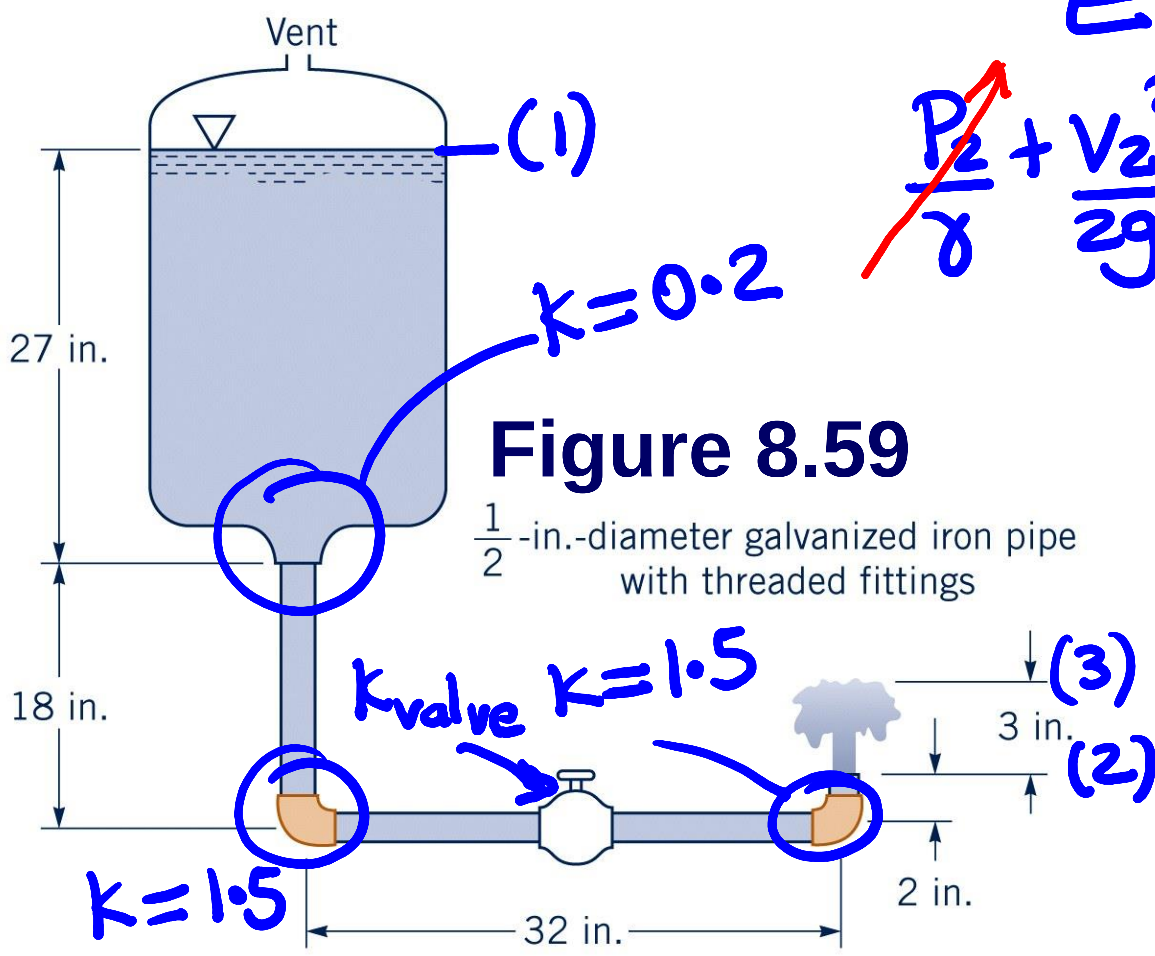

Figure 8.59

$\frac{1}{2}$-in.-diameter galvanized iron pipe with threaded fittings

$$E_2 = E_3$$

$$\cancel{\frac{p_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2 = \cancel{\frac{p_3}{\gamma}} + \cancel{\frac{V_3^2}{2g}}^{\,0} + z_3 + h_L \approx 0$$

$$\frac{V^2}{2g} = \frac{3}{12}\ (\text{feet})$$

$$\boxed{V = 4.01\ \text{ft/s}}$$

$$\Sigma K = 0.2 + 2 \times 1.5 + K_{valve}$$

$$* \quad E_1 = E_2$$

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + z_2 + h_{L_{1-2}}$$

$$\frac{18+27-2}{12} = \frac{V_2^2}{2g} + f\frac{L}{D}\frac{V_2^2}{2g} + (0.2+3+K_v)\frac{V_2^2}{2g}$$

$$3.58 = \frac{4.01^2}{2\times 32.2}\left[1 + f\times\frac{52\,\cancel{in}}{0.5\,\cancel{in}} + 3.2 + K_v\right]$$

$$Re = \frac{V_2 \cdot D}{\nu} = \frac{4.01 \times \frac{0.5}{12}}{1.21\times 10^{-5}\ ft^2/s} = 13808$$

$$\frac{\varepsilon}{D} = \frac{0.0005\ ft \times 12}{0.5}$$ Table 8.1

$$\frac{\varepsilon}{D} = 0.012$$

f(Moody Chart) $= 0.043$

f(Haaland's equation) $= 0.0439$

In Eq. (1), $\boxed{K_{valve} = 5.68}$

Example: P.7.129. What is the maximum flow rate through the pipe shown in Figure P.7.129 if the elevation difference of the reservoir surfaces is 80 m.

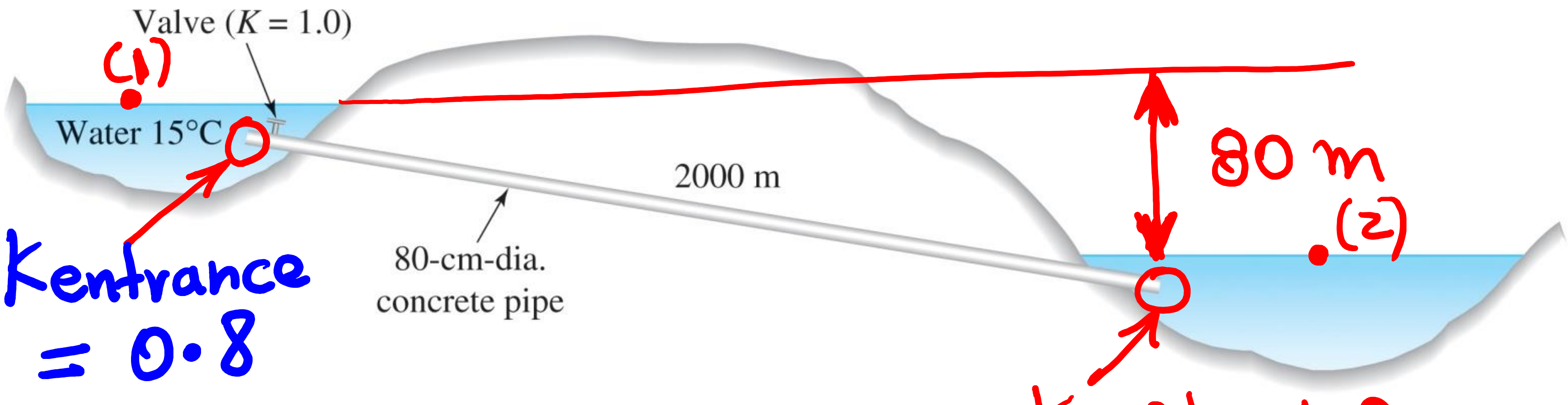

Fig. P7.129

$$\Sigma K = K_{entrance} + K_{valve} + K_{exit}$$

$$= 0.8 + 1.0 + 1.0 = 2.8$$

$$* \; E_1 = E_2$$

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2 + f\frac{L}{D}\frac{V^2}{2g} + \Sigma K \frac{V^2}{2g}$$

$$80 = \frac{V^2}{2g}\left(f \times \frac{2000}{0.8} + 2.8\right) \quad \ldots\ldots \ 1$$

$$\frac{\varepsilon}{D} = \frac{1.65\ mm}{800\ mm} = 0.00206$$

* maximum flow rate = minimum "f"

f minimum $= 0.024$
Moody chart

In 1

$$80 = (60 + 2.8)\frac{V^2}{19.62}$$

$$V = 5.0\ m/s$$

$$Q = 5 \times \pi \times \frac{0.8^2}{4}$$

$$Q = 2.51\ m^3/s$$

* check $Re = \frac{5.0 \times 0.8}{10^{-6}} = 4 \times 10^{6}$

From Moody Chart

$f = 0.024$ (Same as before)

$\therefore \boxed{Q = 2.51\ m^3/s}$

Example:

A 40-m long, 12-mm diameter pipe with a friction factor of 0.020 is used to siphon 30°C water from a tank as shown in Fig. 8.50. Determine the maximum value of *h* allowed if there is to be no cavitation within the hose. Neglect minor losses.

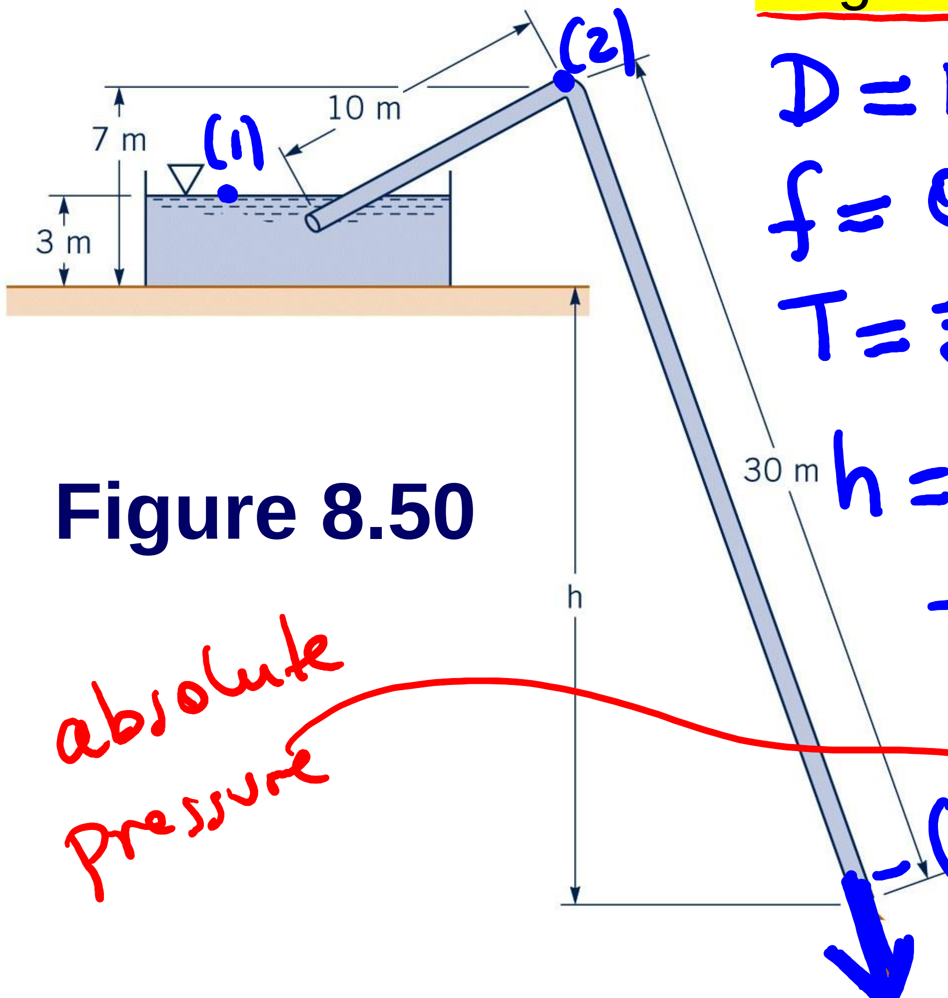

Figure 8.50

absolute pressure

$D = 12\,mm\ (0.012\,m)$

$f = 0.020$

$T = 30^\circ C$

$h = ??$

Cavitation at point (2)

$P_2 = P_v$

Table B-1

$P_{v\,(30^\circ c)} = 4.24 \times 10^3\ \dfrac{N}{m^2}$

$\rho_{30^\circ c} = 995.7\ kg/m^3$

$\gamma_{30^\circ c} = \rho g = 9.768 \ \frac{kN}{m^3}$

$* \ E_1 = E_2$

$$\frac{P_1}{\gamma} + \cancel{\frac{V_1^2}{2g}} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L_{1-2}}$$

$$\frac{101.3 \ \cancel{kN}/m^2}{9.768 \ \cancel{kN}/m^3} = \frac{4.24 \ \cancel{kN}/m^2}{9.768 \ \cancel{kN}/m^3} + \frac{V_2^2}{2g} + 4 + 0.020 \times \frac{10}{0.012}\left(\frac{V_2^2}{2g}\right)$$

$$\boxed{V_2 = 2.56 \ m/s}$$

$V_2 = V_3$ (same diameter)

$h_{L\,1-3}$

$P_1 = P_3$

$E_1 = E_3$

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}}^{\,0} + z_1 = \cancel{\frac{P_3}{\gamma}} + \frac{V_3^2}{2g} + z_3 + f\frac{L}{D}\frac{V_3^2}{2g}$$

$$h + 3 = \frac{2.56^2}{2 \times 9.81}\left[1 + 0.02 \times \frac{40}{0.012}\right]$$

$$\boxed{h = 19.6\ m}$$

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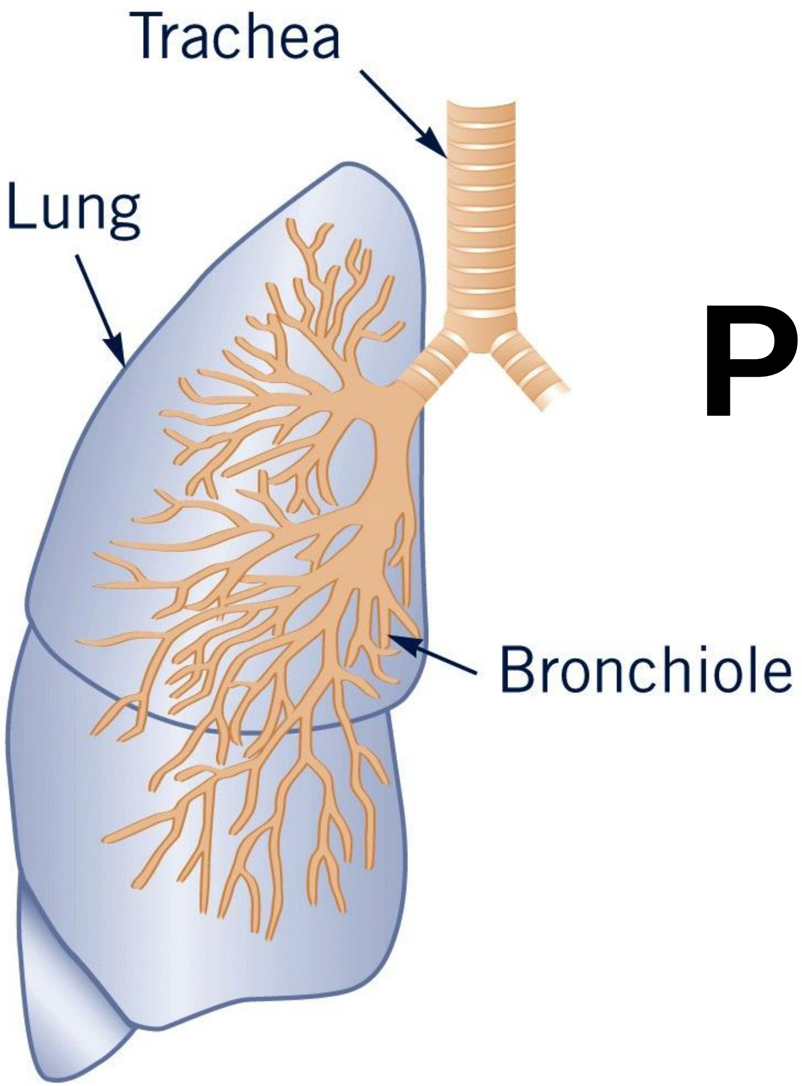

Pipe Networks

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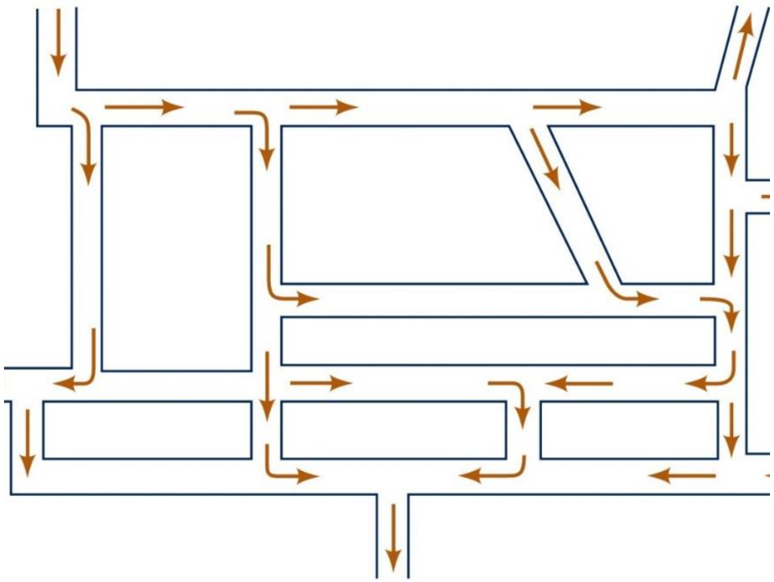
Pipe networks



(b)

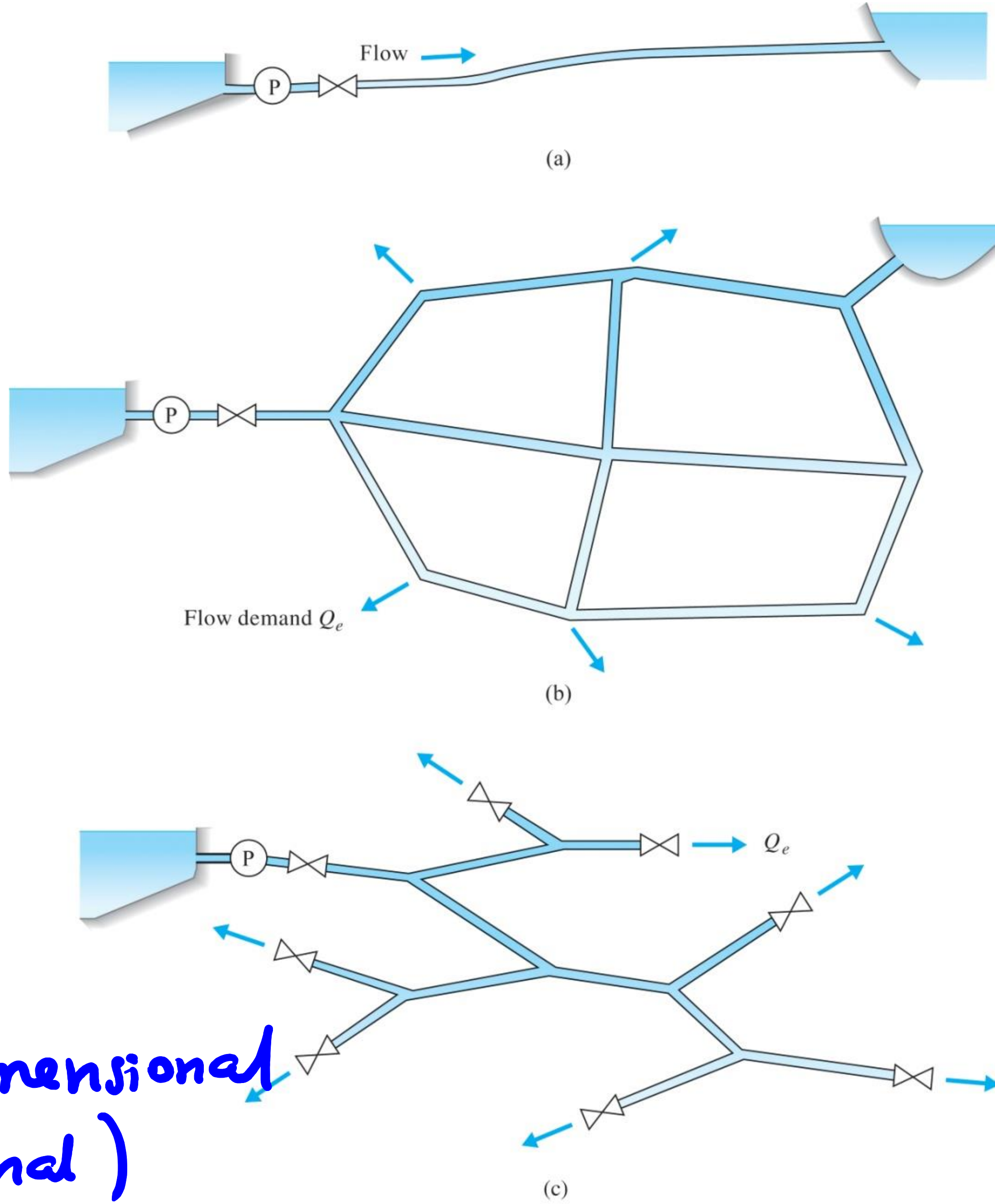


Fig. 11.1 Pipe systems: (a) single pipe; (b) distribution network; (c) tree network.

Assumptions :

* steady flow
* flow is one-dimensional (bi-directional)

Frictional Losses in Pipe Elements

Frictional losses in piping are commonly evaluated using the **Darcy–Weisbach** or **Hazen–Williams** equation. The Darcy–Weisbach formulation provides a more accurate estimation.

$$\boxed{h_L = RQ^{\beta}}$$

Where:

h_L = head loss over length L of pipe

***R* = Resistance coefficient** **(This is not hydraulic radius)**

Q = discharge in the pipe

β = exponent

$$R = \frac{fL}{2gDA^2} = \frac{8fL}{g\pi^2 D^5}$$

<u>Darcy-Weisbach relation</u> (β = 2)

Explicit formulas for f

$$f = 1.325\left\{\ln_e\left[0.27\left(\frac{\varepsilon}{D}\right) + 5.74\left(\frac{1}{Re}\right)^{0.9}\right]\right\}^{-2}$$

Swamee-Jain

$$f = \left\{-1.8\log_{10}\left[\left(\frac{\varepsilon}{3.7D}\right)^{1.11} + \frac{6.9}{Re}\right]\right\}^{-2}$$

Haaland

Table 8.1

Equivalent Roughness for New Pipes [Adapted from Moody (Ref. 7) and Colebrook (Ref. 8)]

	Equivalent Roughness, ε	
Pipe	**Feet**	**Millimeters**
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Wood stave	0.0006–0.003	0.18–0.9
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.045
Drawn tubing	0.000005	0.0015
Plastic, glass	0.0 (smooth)	0.0 (smooth)

Table 8.1

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Hazen–Williams equation (For Water)

$$R = \frac{k_1 L}{C^{\beta} D^{m}}$$

$$k_1 = \begin{cases} 10.59 & \text{SI units} \\ 4.72 & \text{English} \end{cases}$$

Empirical

Where:

C = Hazen–Williams roughness coefficient, m = 4.87, β = 1.85

Table 11.1 Nominal Values of the Hazen–Williams Coefficient C

Type of pipe	C
Extremely smooth; asbestos-cement	140
New or smooth cast iron; concrete	130
Wood stave; newly welded steel	120
Average cast iron; newly riveted steel; vitrified clay	110
Cast iron or riveted steel after some years of use	95–100
Deteriorated old pipes	60–80

11.2 Losses in Piping Systems

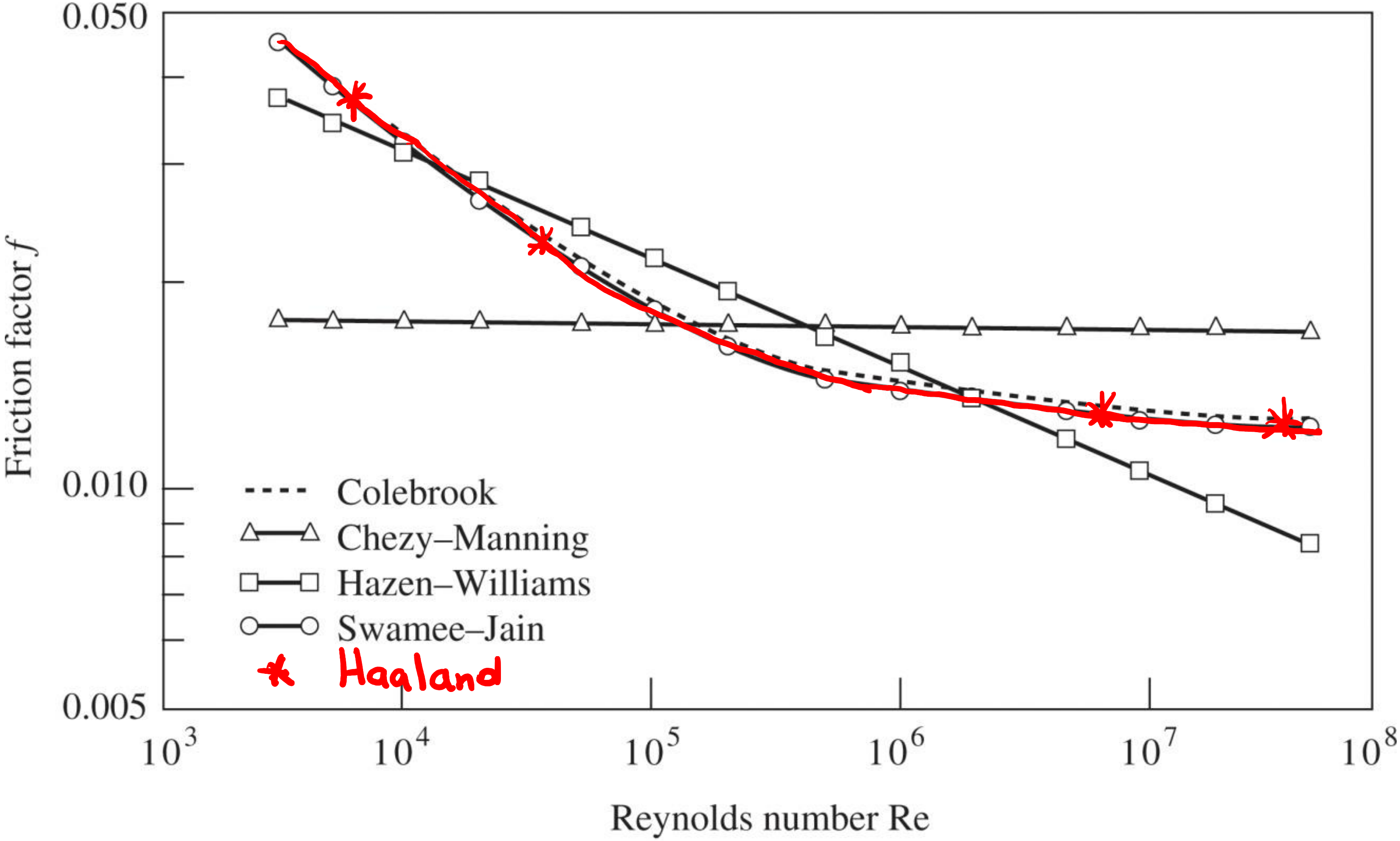
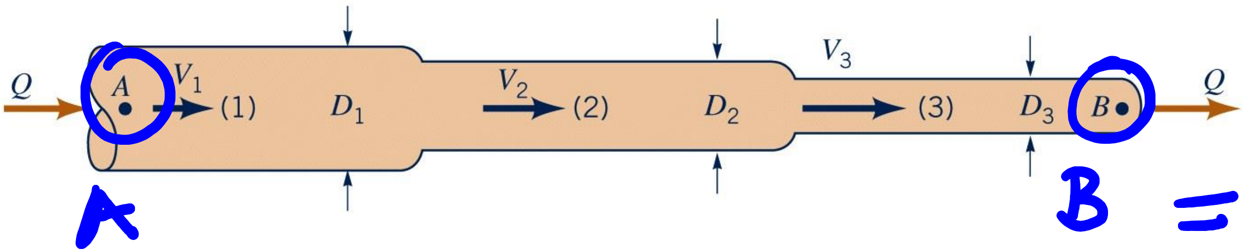


Fig. 11.2 Comparison of several approximate formulas with the original Colebrook formula.

Simple Pipe Systems

Series Piping System



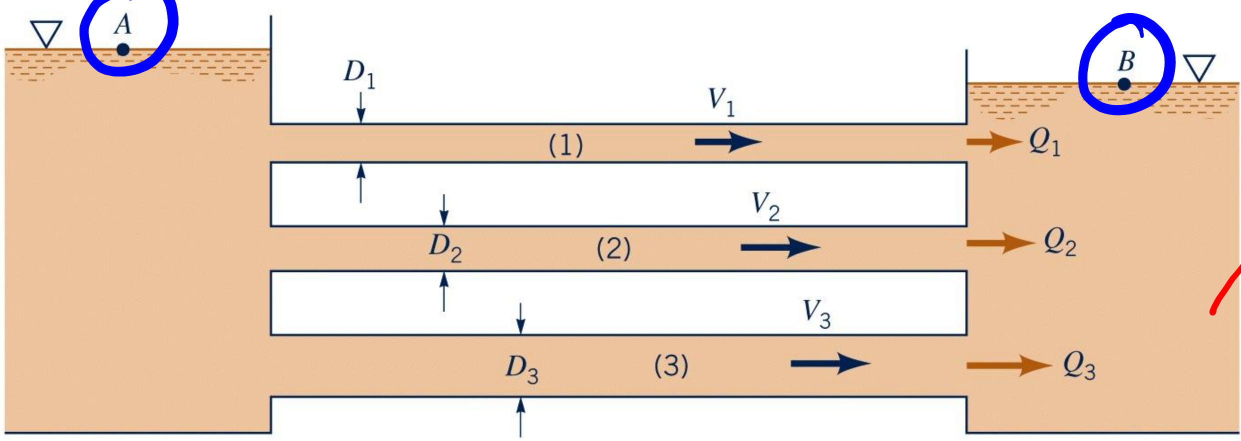
$$Q_1 = Q_2 = Q_3$$

$$h_{L_{A-B}} = h_{L_1} + h_{L_2} + h_{L_3}$$

$$Q_{AB} = Q_1 + Q_2 + Q_3$$

$$h_{L_{AB}} = h_{L_1} = h_{L_2} = h_{L_3}$$

Parallel Piping System



$$\cancel{\frac{p_A}{\gamma}} + \cancel{\frac{V_A^2}{2g}} + z_A = \cancel{\frac{p_B}{\gamma}} + \cancel{\frac{V_B^2}{2g}} + z_B + h_{L_{AB}}$$

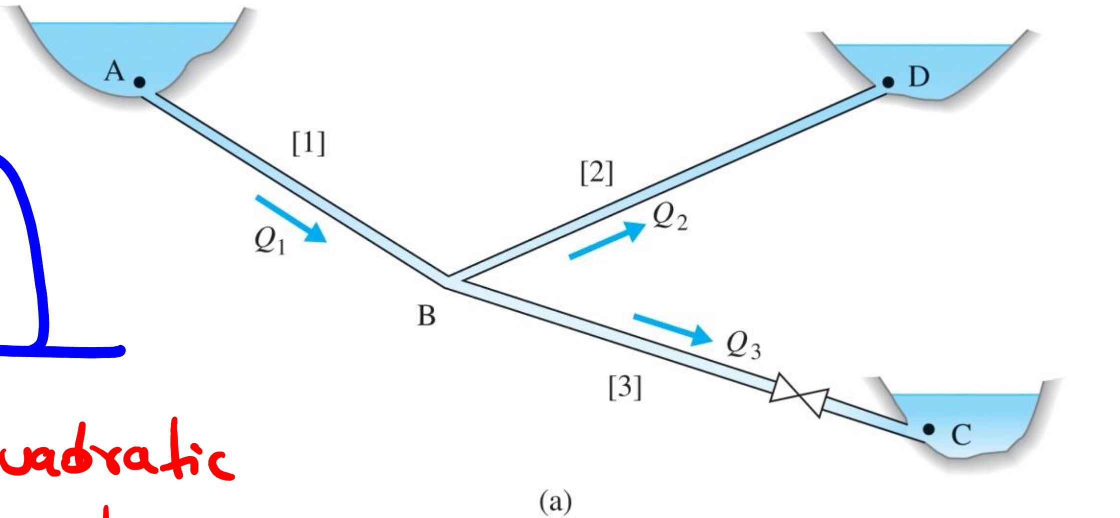
Same for pipe 1, pipe 2, pipe 3

Branch Piping

$\Sigma Q_{node} = 0$

$\Sigma Q_{in} = \Sigma Q_{out}$

$$\boxed{Q_1 = Q_2 + Q_3}$$

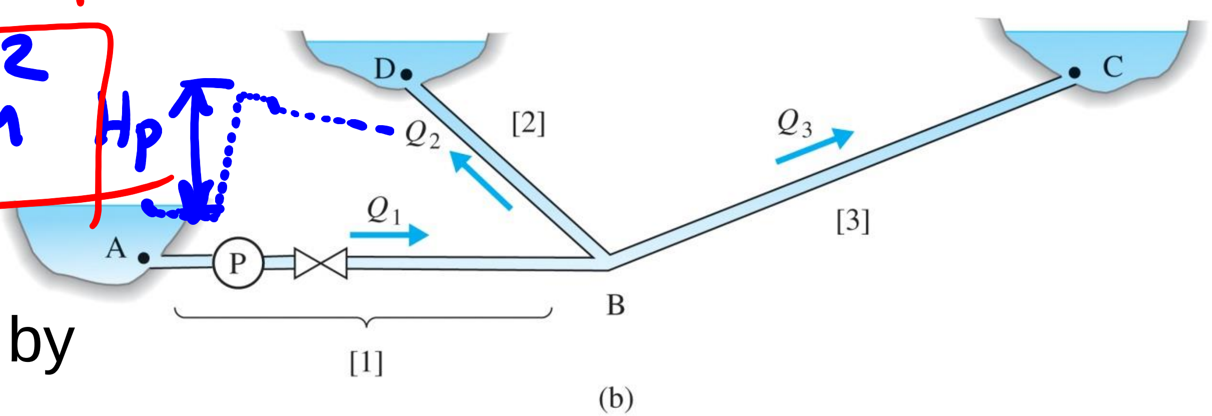


quadratic equation

Approximation of pump curves:

$$\boxed{H_p(Q_1) = a_0 + a_1 Q_1 + a_2 Q_1^2}$$

H_p



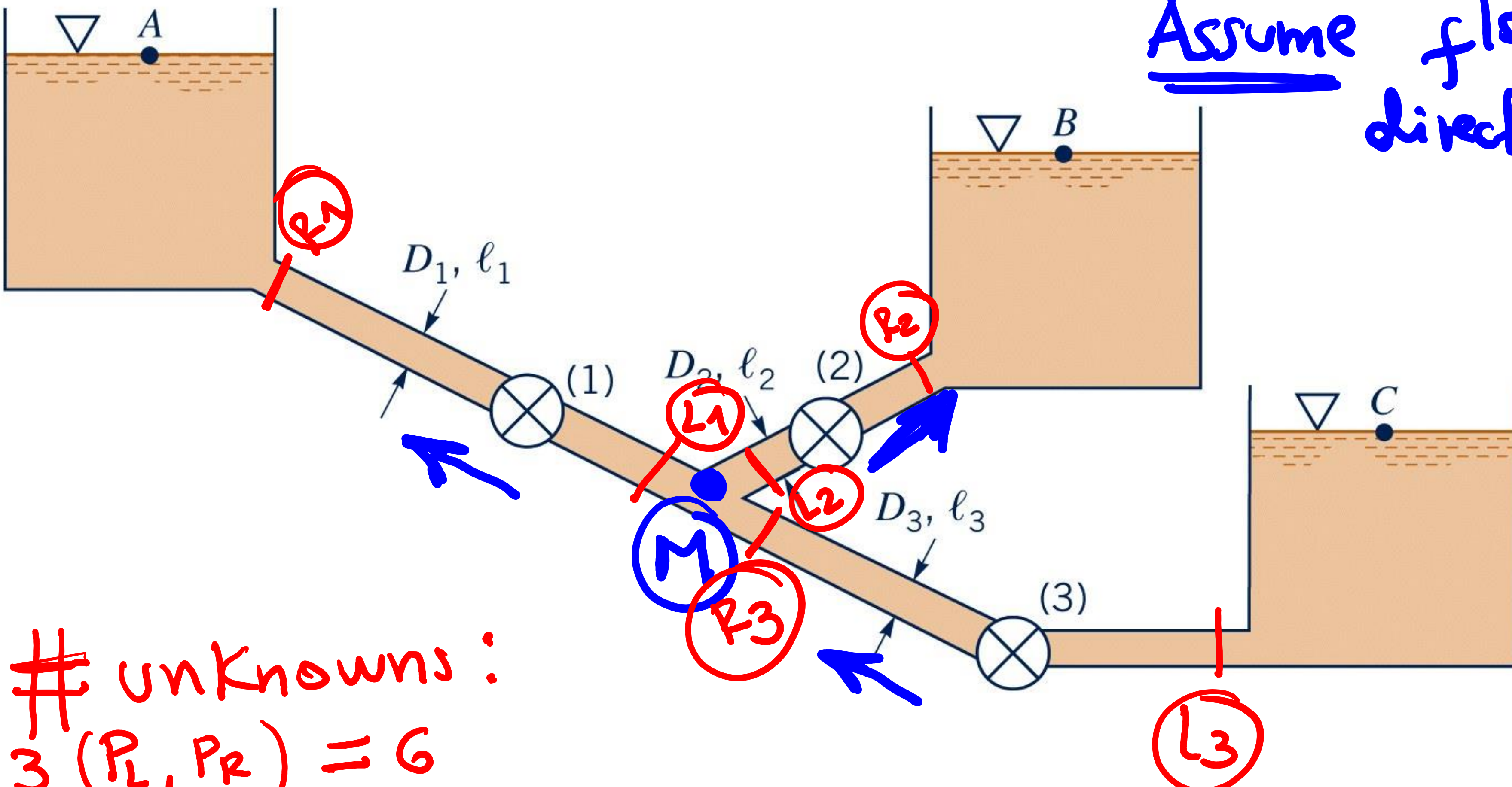
H_p = actual head gained by the fluid from the pump

Fig. 11.5 Branch piping systems: (a) gravity flow; (b) pump-driven flow.

Method for Analyzing pipe Networks

Method used in ***Flows in Pipe Networks***

Assume flow directions



unknowns:

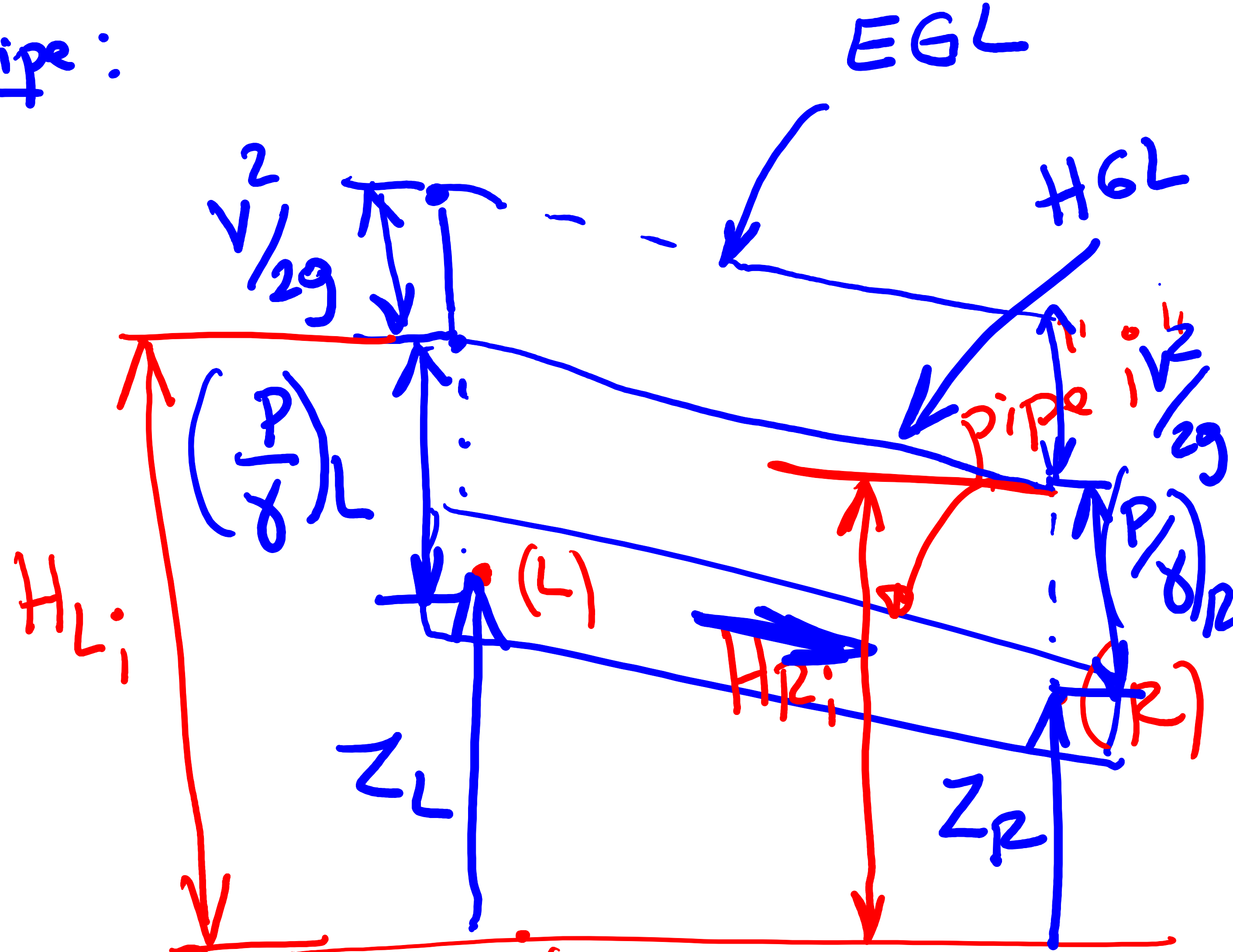
$3\,(P_L, P_R) = 6$

$3\,(V \text{ or } Q) = \underline{3}$

9

For each pipe:

$$H = z + \frac{p}{\gamma}$$



$$H_{L_i} + \cancel{\left(\frac{V^2}{2g}\right)_{L_i}} + H_{p_i} = H_{R_i} + \cancel{\left(\frac{V^2}{2g}\right)_{R_i}} + \sum h_{L_i}$$

pumps if available

$V_L = V_R$ (D is the same)

$$H_{L_i} + H_{P_i} - H_{R_i} - \Sigma h_{L_i} = 0$$

[3 equations]

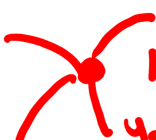
$$\boxed{H_{L_i} + f(Q_i) - H_{R_i} - \left(\frac{f_i L_i}{D_i} + \Sigma k\right)\frac{Q_i|Q_i|}{2gA_i^2} = 0}$$

* Continuity

$$Q_3 = Q_1 + Q_2$$

* Compatibility of Heads:

$$H_{L_1} + \frac{Q_1^2}{2gA_1^2} = H_{L_2} + \frac{Q_2^2}{2gA_2^2}$$

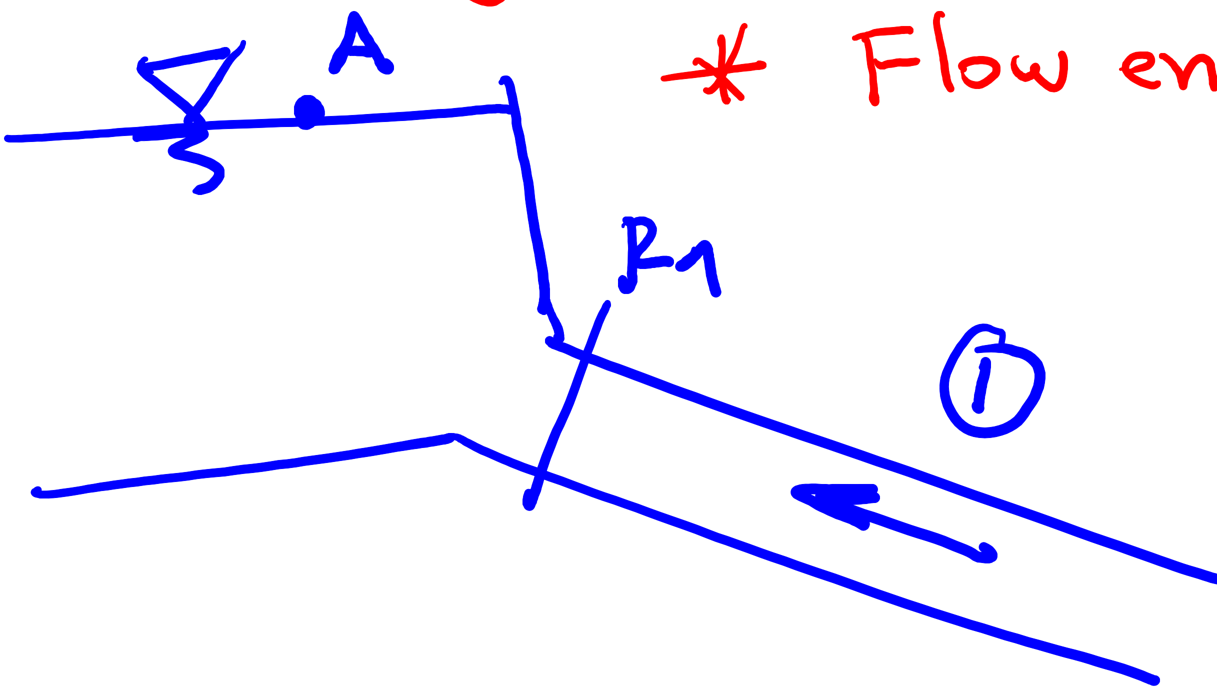


for N pipes, you have N-1 equations.

$$H_{L_1} + \frac{Q_1^2}{2gA_1^2} = H_{R_3} + \frac{Q_3^2}{2gA_3^2}$$

* Boundary conditions

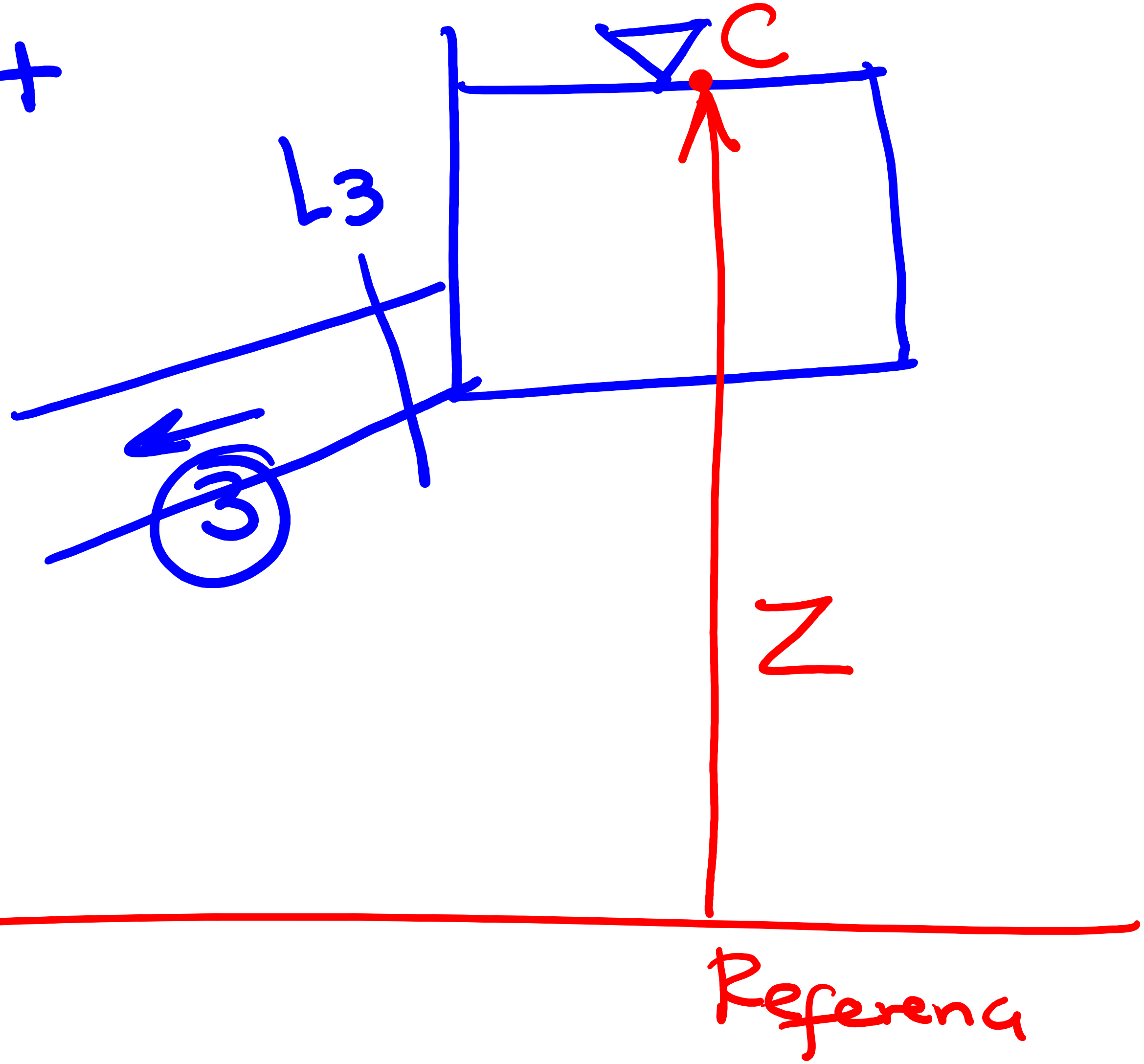
* Flow enters a reservoir



$$H_{R_1} + \frac{Q_1^2}{2gA_1^2} = Z_A + \frac{k\,Q_1|Q_1|}{2gA_1^2}$$

* Flow leaves a reservoir

$$Z_c = H_{L_3} + \frac{Q_3^2}{2gA_3^2} + \frac{k\,Q_3\,|Q_3|}{2gA_3^2}$$



9 unknowns

9 equations

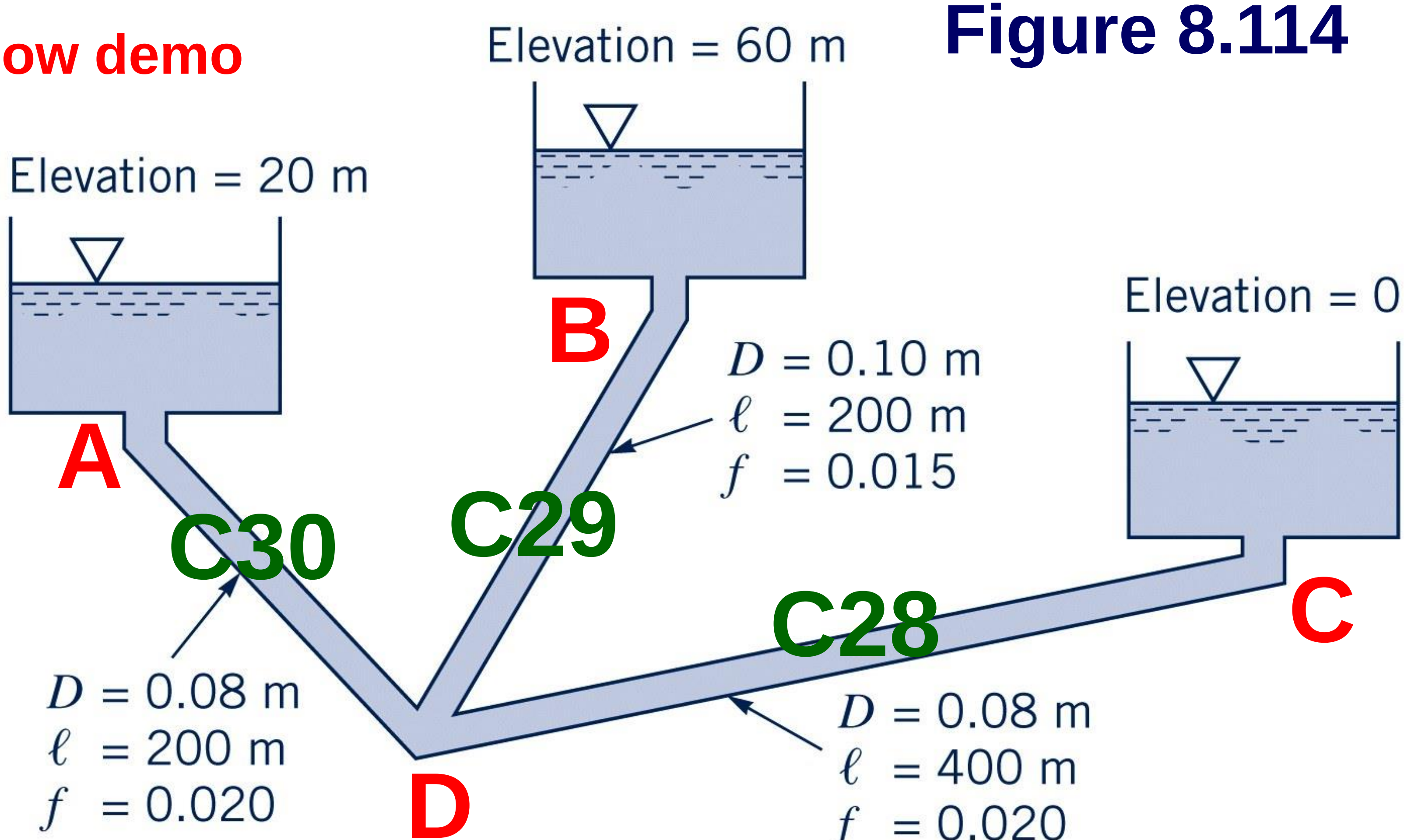
[Many methods to solve this]

Example (Proposed problems):

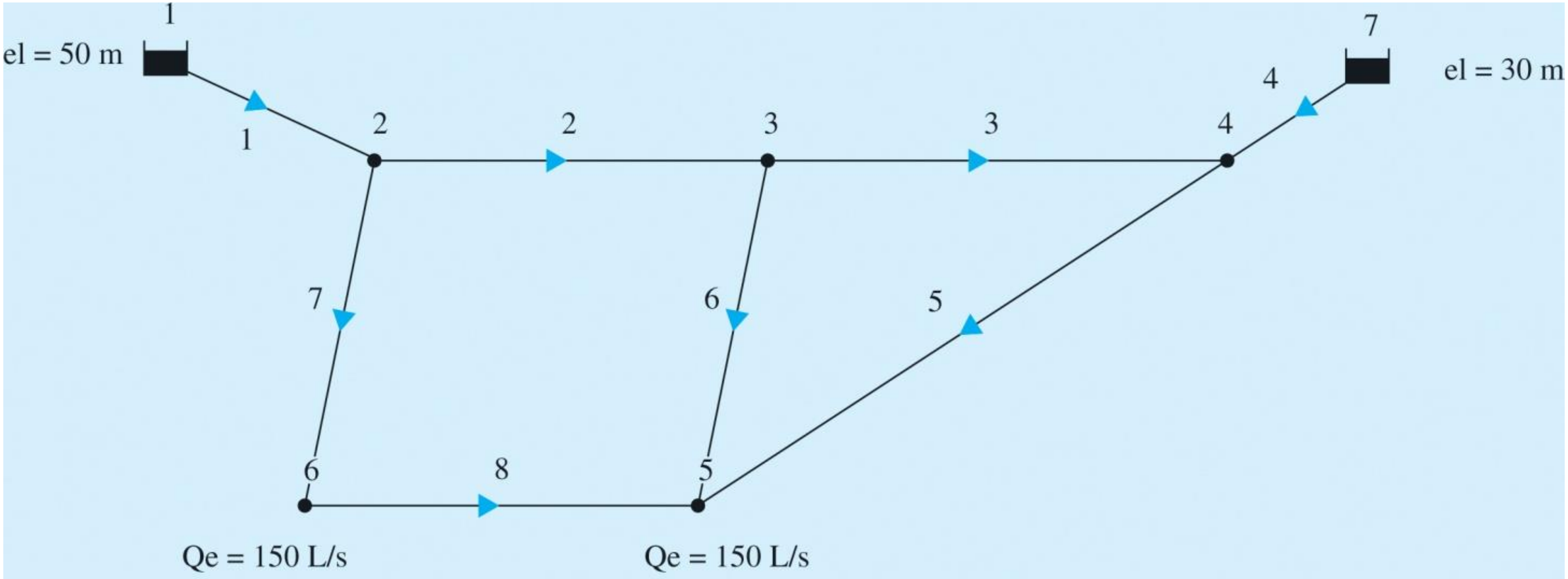
The three water filled-tanks shown in Fig P.8.114 are connected by pipes as indicated. If minor losses are neglected, determine the flow rate in each pipe. Use **Flows in Pipe Networks** (http://web.eng.fiu.edu/arleon/Pipe_Network.html) or **EPANET** (https://www.epa.gov/water-research/epanet)

Show demo

Figure 8.114



Example 11.7. For the piping system (**commercial steel**) shown below, determine the flow distribution and piezometric heads at the junctions. Use the **EPANET Model** (https://www.epa.gov/water-research/epanet).



Link – Node Table:

Link ID	Start Node	End Node	Length m	Diameter mm
1	1	2	66	250
2	2	3	330	250
3	3	4	130	250
4	4	7	66	250
5	4	5	260	250
6	3	5	200	250
7	2	6	200	250
8	6	5	260	250

Show demo on how to use the EPANET Model

Important Considerations in EPANET

EPANET defaults to gallons per minute and other Customary US units. To change to SI units do the following:
Project > Analysis Options... > Flow Units > LPS **(or LPM or other SI units for flow)** (This also changes units for pipe lengths and head to meters and pipe diameters to mm.)

- **Length:** The actual length of the pipe in feet (meters)
- **Diameter:** The pipe diameter in inches (mm)
- **Roughness:** The roughness coefficient of the pipe. It is unitless for Hazen-Williams or Chezy-Manning roughness and has units of millifeet (mm) for Darcy-Weisbach roughness.
- **Loss Coefficient:** Unitless minor loss coefficient associated with bends, fittings, etc. Assumed 0 if left blank.
- **Initial Status:** Determines whether the pipe is initially open, closed, or contains a check valve. **If a check valve is specified then the flow direction in the pipe will always be from the Start node to the End node**

Results:

Network Table - Links at 24:00 Hrs

Link ID	Length m	Diameter mm	Roughness mm	Flow LPS	Velocity m/s	Friction Factor	Status
Pipe C1	66	250	0.045	341.34	6.95	0.014	Open
Pipe C2	330	250	0.045	143.08	2.91	0.015	Open
Pipe C3	330	250	0.045	66.54	1.36	0.016	Open
Pipe C8	260	250	0.045	48.26	0.98	0.017	Open
Pipe C7	200	250	0.045	198.26	4.04	0.015	Open
Pipe C6	260	250	0.045	76.54	1.56	0.016	Open
Pipe C5	55	250	0.045	25.19	0.51	0.018	Open
Pipe C4	130	250	0.045	-41.34	0.84	0.017	Open

Network Table - Nodes at 0:00 Hrs

Node ID	Elevation m	Base Demand LPS	Demand LPS	Head m	Pressure m
Junc N2	0	0	0.00	40.79	40.79
Junc N3	0	0	0.00	32.29	32.29
Junc N4	0	0	0.00	30.32	30.32
Junc N6	0	150	150.00	31.11	31.11
Junc N5	0	150	150.00	30.26	30.26
Resvr N1	50	#N/A	-341.34	50.00	0.00
Resvr N7	30	#N/A	41.34	30.00	0.00

Results (Cont.):