

# CHAPTER (10)

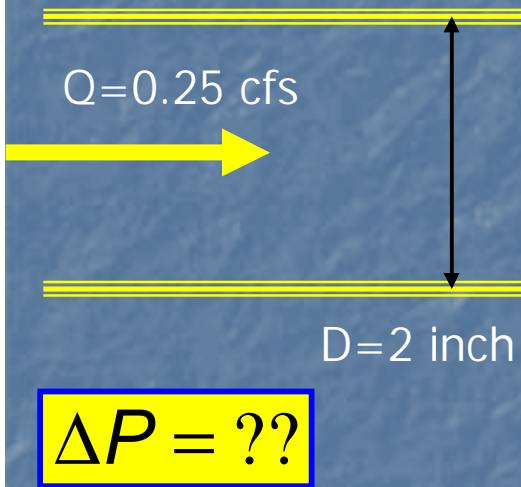
## FLOW IN CONDUITS

### HOMEWORK (2)

10.4, 10.34, 10.48, 10.86

Date: WINTER, 2012

## Problem (10.4)



### PROBLEM 10.4

Situation: Oil is pumped through a 2 in. pipe.  $Q = 0.25 \text{ cfs}$ .

Find: Pressure drop per 100 feet of level pipe.

Properties: Oil Properties:  $S = 0.97$ ,  $\mu = 10^{-2} \text{ lbf} \cdot \text{s}/\text{ft}^2$

### ANALYSIS

Flow rate equation

$$\begin{aligned} V &= Q/A \\ &= 0.05 / ((\pi/4) \times (1/12)^2) \\ &= 9.17 \text{ ft/sec} \end{aligned}$$

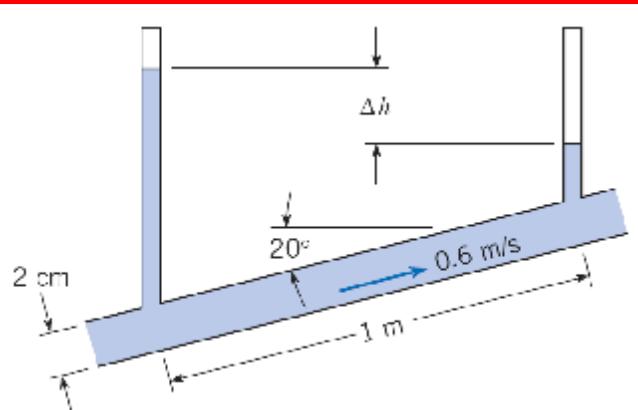
Reynolds number

$$\begin{aligned} \text{Re} &= VD\rho/\mu \\ &= 9.17 \times (1/12) \times 0.97 \times 1.94 / 10^{-2} \\ &= 144 \text{ (thus, flow is laminar)} \end{aligned}$$

Pressure Drop

$$\begin{aligned} \Delta p &= \frac{32\mu LV}{D^2} \\ &= \frac{32 \times 10^{-2} \times 100 \times 9.17}{(1/12)^2} \\ &= 42,255 \frac{\text{psf}}{100 \text{ ft}} \\ &= 293 \text{ psi/100 ft} \end{aligned}$$

## Problem (10.34)



### PROBLEM 10.34

Situation: Glycerin flows through a commercial steel pipe—other details are provided in the problem statement.

Find: Height differential between the two standpipes.

Properties: Glycerin at 20 °C from Table A.4:  $\rho = 1260 \text{ kg/m}^3$ ,  $S = 1.26$ ,  $\gamma = 12,300 \text{ N/m}^3$ ,  $\mu = 1.41 \text{ N}\cdot\text{s}/\text{m}^2$ ,  $\nu = 1.12 \times 10^{-3} \text{ m}^2/\text{s}$ .

### ANALYSIS

Energy equation (apply from one standpipe to the other)

$$\begin{aligned} p_1/\gamma + \alpha_1 V_1^2/2g + z_1 &= p_2/\gamma + \alpha_2 V_2^2/2g + z_2 + h_L \\ p_1/\gamma + z_1 &= p_2/\gamma + z_2 + h_L \\ ((p_1/\gamma) + z_1) - ((p_2/\gamma) + z_2) &= h_L \\ \Delta h &= h_L \end{aligned}$$

Reynolds number

$$\begin{aligned} \text{Re} &= \frac{VD}{\nu} \\ &= \frac{(0.6)(0.02)}{1.12 \times 10^{-3}} \\ &= 10.71 \end{aligned}$$

Since  $\text{Re} < 2000$ , the flow is laminar. The head loss for laminar flow is

$$\begin{aligned} h_L &= \frac{32\mu LV}{\gamma D^2} \\ &= \frac{(32)(1.41)(1)(0.6)}{12300 \times 0.02^2} \\ &= 5.502 \text{ m} \end{aligned}$$

Energy equation

$$\begin{aligned} \Delta h &= h_L \\ &= 5.50 \text{ m} \end{aligned}$$

## Problem (10.48)

Situation: Water ( $20^{\circ}\text{C}$ ) flows in cast iron pipe.  $D = 15\text{ cm}$   $Q = 0.05\text{ m}^3/\text{s}$   $k_s = 0.26\text{ mm}$

from Table A.5  $\nu(20^{\circ}\text{C}) = 10^{-6}\text{ m}^2/\text{s}$

- Find:
- (a) Shear stress at the wall.
  - (b) Shear stress 1 cm from wall.
  - (c) Velocity 1 cm from wall.

Properties: Table A.5 (water at  $20^{\circ}\text{C}$ ):  $\rho = 998\text{ kg/m}^3$ ,  $\nu = 1.00 \times 10^{-6}\text{ m}^2/\text{s}$ .

### ANALYSIS

#### Flow rate equation

$$\begin{aligned}V &= \frac{Q}{A} = \frac{0.05}{(\pi/4) \times 0.15^2} \\&= 2.83\text{ m/s}\end{aligned}$$

#### Reynolds number

$$\begin{aligned}\text{Re} &= \frac{VD}{\nu} = \frac{2.83 \times 0.15}{10^{-6}} \\&= 4.2 \times 10^5\end{aligned}$$

**CONT.**

Relative roughness

$$\begin{aligned}\frac{k_s}{D} &= \frac{0.26 \text{ mm}}{150 \text{ mm}} \\ &= 1.733 \times 10^{-3}\end{aligned}$$

Resistance coefficient (Swamee Jain correlation)

$$\begin{aligned}f &= \frac{0.25}{\left[\log_{10} \left( \frac{k_s}{3.7D} + \frac{5.74}{Re^{0.9}} \right) \right]^2} \\ &= \frac{0.25}{\left[ \log_{10} \left( \frac{1.733 \times 10^{-3}}{3.7} + \frac{5.74}{(4.2 \times 10^5)^{0.9}} \right) \right]^2} \\ &= 0.0232\end{aligned}$$

Eq. (10-21)

$$\begin{aligned}\tau_0 &= f \rho V^2 / 8 \\ \tau_0 &= 0.0232 \times 998 \times 2.83^2 / 8 \\ &= \boxed{23.2 \text{ N/m}^2}\end{aligned}$$

**CONT.**

In a pipe flow, the shear stress variation is linear; thus,

$$\begin{aligned}\tau_1 &= (6.5/7.5) \times \tau_0 \\ &= \boxed{20.0 \text{ N/m}^2}\end{aligned}$$

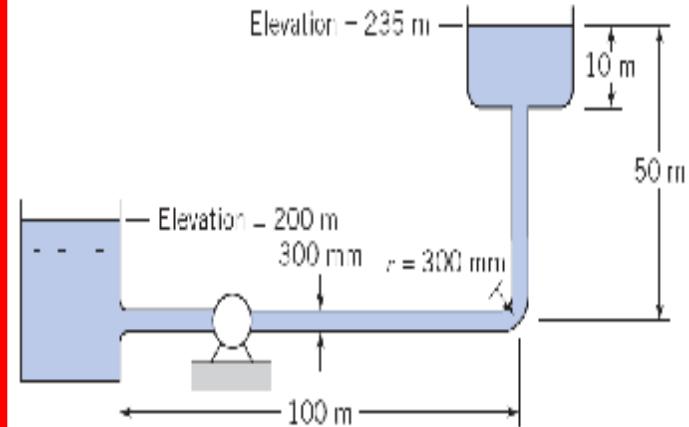
Velocity distribution (turbulent flow)

$$\begin{aligned}u_* &= \sqrt{\frac{\tau_0}{\rho}} = \sqrt{\frac{23.2}{998}} \\ &= 0.1524 \text{ m/s}\end{aligned}$$

$$\begin{aligned}\frac{u}{u_*} &= 5.75 \log \left( \frac{y}{k_s} \right) + 8.5 \\ u &= u_* \left( 5.75 \log \left( \frac{y}{k_s} \right) + 8.5 \right) \\ &= 0.1524 \left( 5.75 \log \left( \frac{0.01}{0.00026} \right) + 8.5 \right) \\ &= 2.684 \text{ m/s}\end{aligned}$$

$$\boxed{u = 2.68 \text{ m/s}}$$

## Problem (10.86)



Situation: A system with two tanks is described in the problem statement.

Find: The pump power.

Properties: From Table 10.3  $K_e = 0.03$ ;  $K_b = 0.35$ ;  $K_E = 1.0$ .

From Table A.5  $\nu = 10^{-6} \text{ m}^2/\text{s}$ .

From Table 10.2  $k_s = 0.046 \text{ mm}$ .

### APPROACH

Apply the energy equation from the water surface in the lower reservoir to the water surface in the upper reservoir.

**CONT.**

**ANALYSIS**

Energy equation

$$\begin{aligned} p_1/\gamma + V_1^2/2g + z_1 + h_p &= p_2/\gamma + V_2^2/2g + z_2 + \sum h_L \\ 0 + 0 + 200 \text{ m} + h_p &= 0 + 0 + 235 \text{ m} + (V^2/2g)(K_e + K_b + K_E + fL) \end{aligned}$$

Flow rate equation

$$\begin{aligned} V &= Q/A \\ &= 0.314/((\pi/4) \times 0.3^2) \\ &= 4.44 \text{ m/s} \\ V^2/2g &= 1.01 \text{ m} \end{aligned}$$

Reynolds number

$$\begin{aligned} \text{Re} &= VD/\nu \\ &= 4.44 \times 0.3/10^{-6} \\ &= 1.33 \times 10^6 \\ k_s/D &\approx 0.00015 \end{aligned}$$

Resistance coefficient (from the Moody diagram, Fig. 10.8)

$$f = 0.00014$$

So

$$\begin{aligned} fL/D &= 0.014 \times 140/0.3 = 6.53 \\ h_p &= 235 - 200 + 1.01(0.03 + 0.35 + 1 + 6.53) \\ &= 43.0 \text{ m} \end{aligned}$$

Power equation

$$\begin{aligned} P &= Q\gamma h_p \\ &= 0.314 \times 9,790 \times 43.0 \\ &= \boxed{132 \text{ kW}} \end{aligned}$$

# THE END