An-Najah National University
Faculty of Engineering and IT

جامعة النجاح الوطنية
كلية الهندسة وتكنولوجيا المعلومات

Chemical Engineering Department
Fluid Mechanics (10626231)
Second Exam

Instructor Name: Amjad El-Qanni
Academic Year: 2022/2023
Semester: Spring
Credit Hours: 3
Date: April 17th, 2023
Exam Duration: 60 minutes

Student Name: ………………………
Registration Number: ……………....

Total Exam Mark: 20
Exam Weight: 20

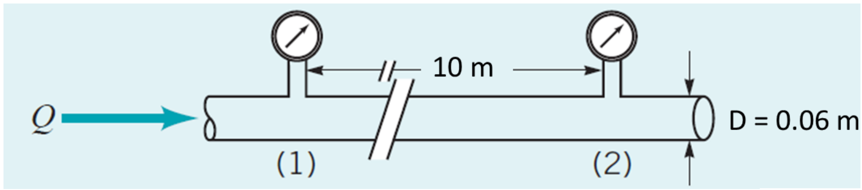
Question	Marks	Question Grade
Q1	7	
Q2	6	
Q3	7	
Total grade		

Exam Notes:

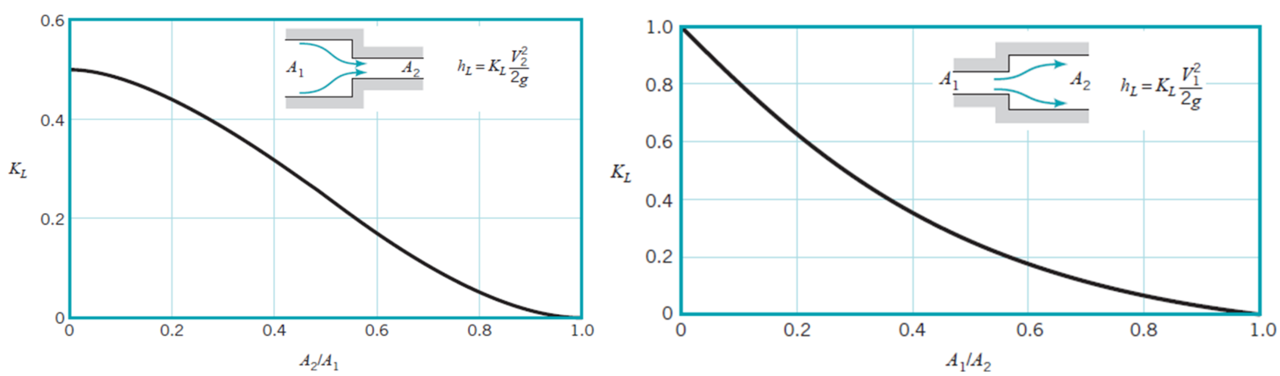
1- Closed Books & Notes.
2- Read each problem carefully before attempting to solve it.
3- Write all work on this exam paper.
4- Show **complete solutions** to get full marks.

Good Luck

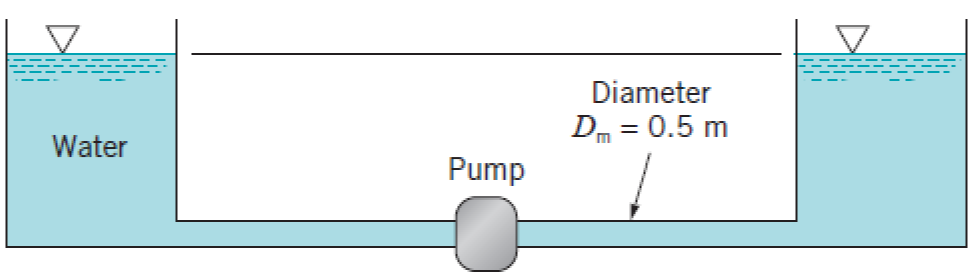
Q1 (7 Marks): Water flows through a horizontal 60-mm-diameter galvanized iron pipe, its roughness equal to 0.15 mm, at a rate of 0.02 m^3/s. If the pressure drop ($P_1 - P_2$) is 135 kPa per 10 m of pipe, do you think this pipe is **(a)** a new pipe, **(b)** an old pipe with a somewhat increased roughness due to aging, or **(c)** a very old pipe that is partially clogged by deposits? Justify your answer. The water's kinematic viscosity is 1.12×10^{-6} m^2/s.



Q2 (6 Marks): Water flows at a rate of 0.04 m^3/s in a 0.12-m-diameter pipe that contains a sudden contraction to a 0.06-m-diameter pipe. Determine the pressure drop across the contraction section. The manufacturer gave you the below plots for your information.



Q3 (7 Marks): Water is pumped between two large open tanks as shown in the Figure below. If the pump adds 50 kW of power to the fluid, what is the flow rate passing between the tanks? Assume the friction factor to be equal to 0.02 and minor losses to be negligible.



Pipe length = 600 m

Answers/Solutions Key

Q1:

For the horizontal pipe ($z_1 = z_2$) with $V_1 = V_2$ the energy equation

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + f\frac{\ell}{D}\frac{V^2}{2g} \text{ reduces to } p_1 - p_2 = f\frac{\ell}{D}\frac{1}{2}\rho V^2$$

or $135 \times 10^3 \frac{N}{m^2} = f\frac{10m}{0.06m}\,\frac{1}{2}(999\frac{kg}{m^3})(7.07\frac{m}{s})^2$, or $f = 0.0324$

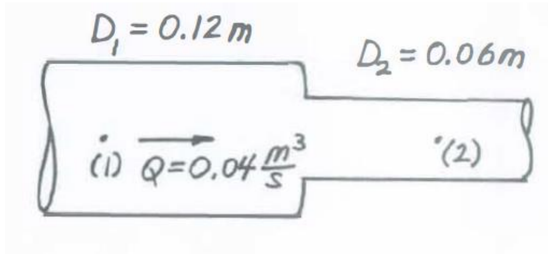
where we have used $V = \frac{Q}{A} = \frac{0.02\frac{m^3}{s}}{\frac{\pi}{4}(0.06m)^2} = 7.07\frac{m}{s}$

With $Re = \frac{VD}{\nu} = \frac{(7.07\frac{m}{s})(0.06m)}{1.12 \times 10^{-6}\frac{m^2}{s}} = 3.79 \times 10^5$ and $\frac{\varepsilon}{D} = \frac{0.15\ mm}{60\ mm} = 2.5 \times 10^{-3}$

for a new galvanized iron pipe (see Table 8.1), the friction factor should be (see Fig. 8.20) $f = 0.0255$. Since this is less than the actual value $f = 0.0324$, the pipe is not a new pipe.

With $Re = 3.79 \times 10^5$ and $f = 0.0324$ we obtain from Fig. 8.20 a relative roughness of $\frac{\varepsilon}{D} = 0.006$. This is approximately twice the roughness of a new pipe — certainly quite possible. A very old partially clogged pipe would have considerably greater head loss. Thus, the pipe is an old pipe with somewhat increased roughness.

Q2:



$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + K_L \frac{V_2^2}{2g}, \quad \text{where } z_1 = z_2 \qquad (1)$$

and

$$V_1 = \frac{Q}{A_1} = \frac{0.04 \frac{m^3}{s}}{\frac{\pi}{4}(0.12m)^2} = 3.54 \frac{m}{s}, \quad V_2 = \frac{Q}{A_2} = \frac{0.04 \frac{m^3}{s}}{\frac{\pi}{4}(0.06m)^2} = 14.1 \frac{m}{s}$$

Thus, with $\frac{A_2}{A_1} = \left(\frac{D_2}{D_1}\right)^2 = \left(\frac{0.06m}{0.12m}\right)^2 = 0.25$ we obtain from Fig. 8.30

$K_L = 0.40$

Hence, from Eq. (1)

$$p_1 - p_2 = \frac{1}{2}\rho\left[K_L V_2^2 + V_2^2 - V_1^2\right] = \frac{1}{2}\left(999 \frac{kg}{m^3}\right)\left[0.40\left(14.1 \frac{m}{s}\right)^2 + \left(14.1 \frac{m}{s}\right)^2 - \left(3.54 \frac{m}{s}\right)^2\right]$$

or

$$p_1 - p_2 = 39.7 \times 10^3 \frac{N}{m^2} + 93.0 \times 10^3 \frac{N}{m^2} = \underline{\underline{133\ kPa}}$$

This represents a <u>39.7 kPa</u> drop from losses and a <u>93.0 kPa</u> drop due to an increase in kinetic energy.

Q3:

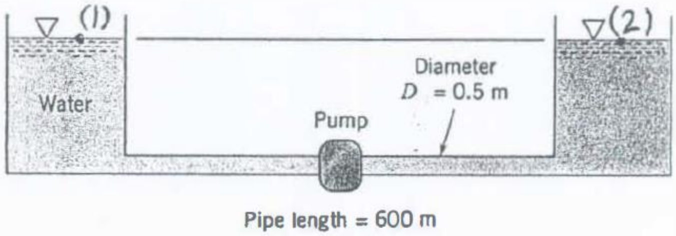


FIGURE P8.95

With $p_1 = p_2 = 0$, $V_1 = V_2 = 0$, and $z_1 = z_2$

$$h_p = h_L = f \frac{\ell}{D} \frac{V^2}{2g} \qquad (1)$$

With the pump adding 50 kW of power

$$\dot{W} = 50 \times 10^3 \, W = h_p Q \gamma$$

$$h_p = \frac{50 \times 10^3}{Q (9.8 \times 10^3)} = \frac{5.10}{Q}$$

Sub into (1)

$$\frac{5.10}{Q} = f \frac{\ell}{D} \frac{V^2}{2g} = f \frac{\ell}{D} \frac{Q^2}{2gA^2}$$

$$Q^3 = \frac{5.10(2)(D)gA^2)}{f\ell} \quad \text{where } A = \frac{\pi}{4}(0.5)^2 = 0.196 \, m^2$$

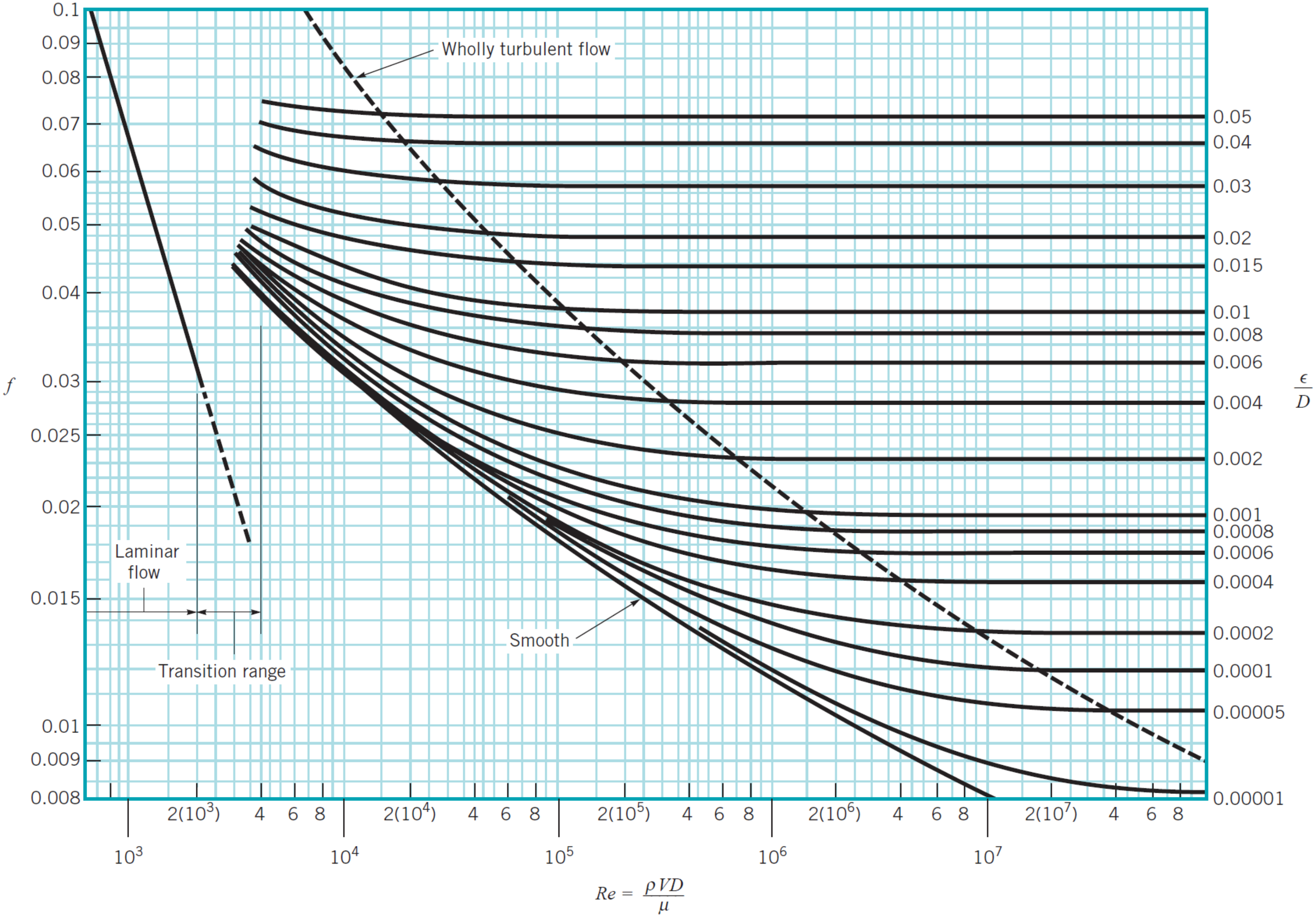
Thus,

$$Q^3 = \frac{5.10(2)(0.5)(9.81)(0.196)^2}{(0.02)(600)}$$

$$= 0.1602$$

or

$$\underline{\underline{Q = 0.543 \, m^3/s}}$$



Wholly turbulent flow
Laminar flow
Transition range
Smooth
f
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
ε/D
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.00001
10^3
2(10^3)
4
6
8
10^4
2(10^4)
10^5
2(10^5)
10^6
2(10^6)
10^7
2(10^7)
Re = ρVD/μ