Florida International University
CWR 3201 Fluid Mechanics, Fall 2022
Mid-term # 2

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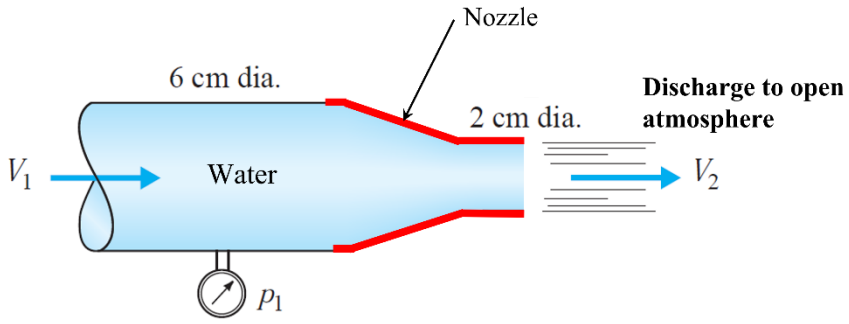
Student Name: _____ Panther ID: _____

- ✓ **You will have 1 h 15 minutes to complete the exam. The exam is closed book and closed notes.**

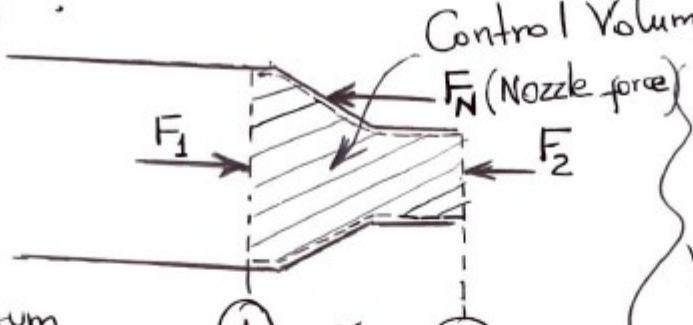
Only one page (front and back) with handwritten equations are allowed

1. **(35 points)** The water flow discharge in the system below is 0.1 m^3/s. Determine the force the water exerts on the nozzle. Neglect all head losses.



(1) $Q = 0.1\ m^3/s$

$F_N = ?$



$$V_1 = \frac{Q_1}{A_1} = \frac{0.1}{\pi \frac{(0.06)^2}{4}}$$

$$V_1 = 35.4\ m/s$$

$$V_2 = 318.3\ m/s$$

$$\dot{m} = \rho A V = \rho Q$$

* Momentum

$$\Sigma F_x = \dot{m}(V_{2x} - V_{1x})$$

$$F_1 - F_2 - F_N = 1000 \times 0.1 (318.3 - 35.4)$$

$$P_1 A_1 - \cancel{P_2}^{0} A_2 - F_N = 28{,}290 \quad \cdots (1)$$

* Bernoulli Equation

$$\frac{P_1}{\gamma_1} + \frac{V_1^2}{2g} + \cancel{Z_1} = \cancel{\frac{P_2}{\gamma_2}}^{0} + \frac{V_2^2}{2g} + \cancel{Z_2} \qquad Z_1 = Z_2$$

$$P_1 = \frac{(V_2^2 - V_1^2)}{2g}\gamma = \frac{(318.3^2 - 35.4^2) \times 1000 \times \cancel{9.8}}{2 \times \cancel{9.8}}$$

$$P_1 = 50{,}030{,}865\ Pa$$

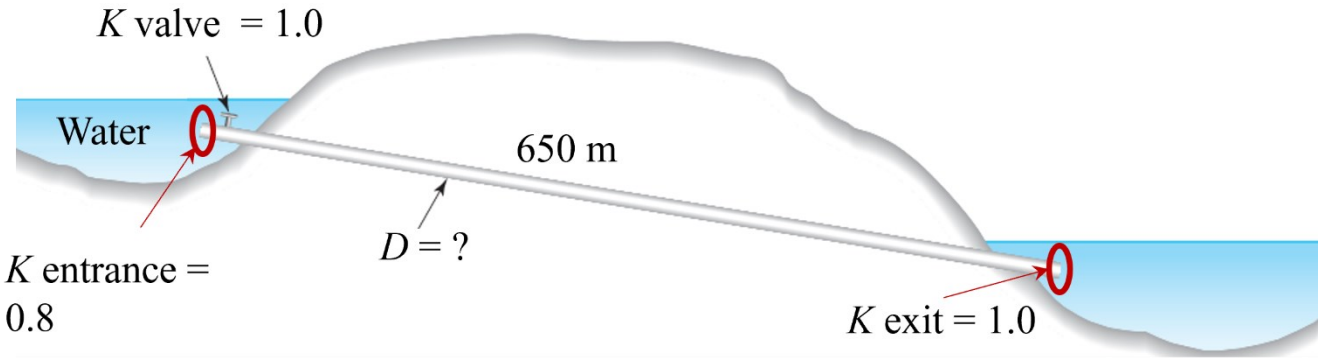
$$A_1 = \frac{\pi \times 0.06^2}{4}$$

In (1)

$$141{,}459 - F_N = 28{,}290$$

$$F_N = 113{,}169\ N = 113.2\ KN$$

2. **(30 points)** For the pipeline below, the friction factor f is 0.028, the reservoirs elevation difference is 200 m, and the flow rate through the pipe is 2 m^3/s. Determine the pipe diameter (D).



(2) $f = 0.028$

$\Delta z = 200\ m$

$Q = 2\ m^3/s$

$D = ?$

$\Delta z = z_1 - z_2 = 200\ m$

$V = \frac{Q}{A} = \frac{2}{\pi D^2/4} = \frac{2.55}{D^2}$

$\Sigma K = 2.8$

* Energy eq. between (1) and (2)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + \left(\frac{fL}{D} + \Sigma K\right)\frac{V^2}{2g}$$

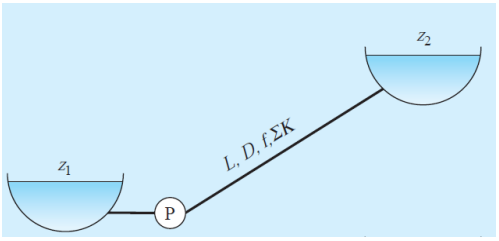
$$200 = \left[\frac{0.028 \times 650}{D} + 2.8\right]\frac{\left(\frac{2.55}{D^2}\right)^2}{19.6}$$

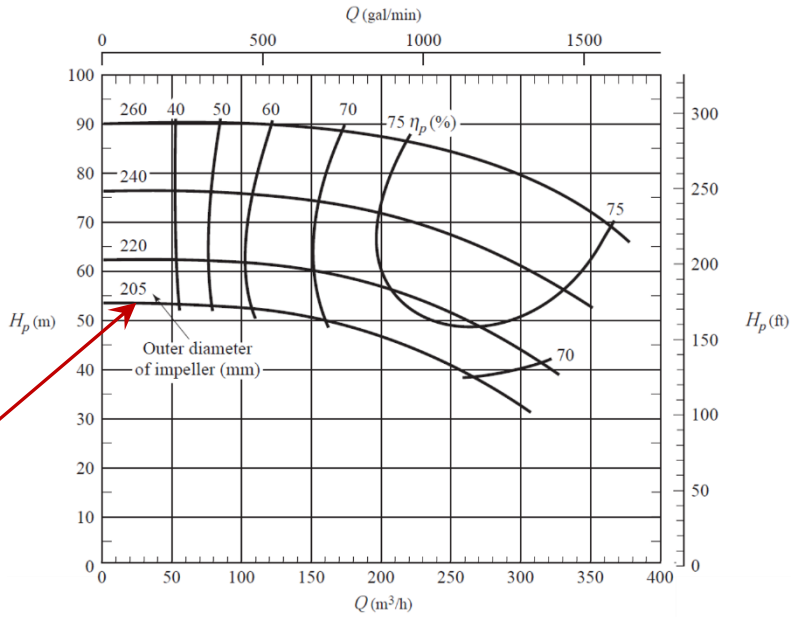
$$604.5 = \left(\frac{18.2}{D} + 2.8\right)\frac{1}{D^4}$$

Solving for "D"

$D = 0.5\ m$

3. **(35 points)** The **205-mm**-diameter pump represented in the figure below is used to move water between two reservoirs through a pipeline with the following characteristics: $D = 150$ mm, $L = 100$ m, $f = 0.024$, $\Sigma K = 2.0$. Find the actual discharge and pump head when a **single pump** (205-mm outer diameter of impeller) is used. The elevation difference between the reservoirs is 30 m ($z_2 - z_1 = 30$ m).





Use the 205-mm outer diameter of impeller

(3) Q = ? H = ?

System curve:

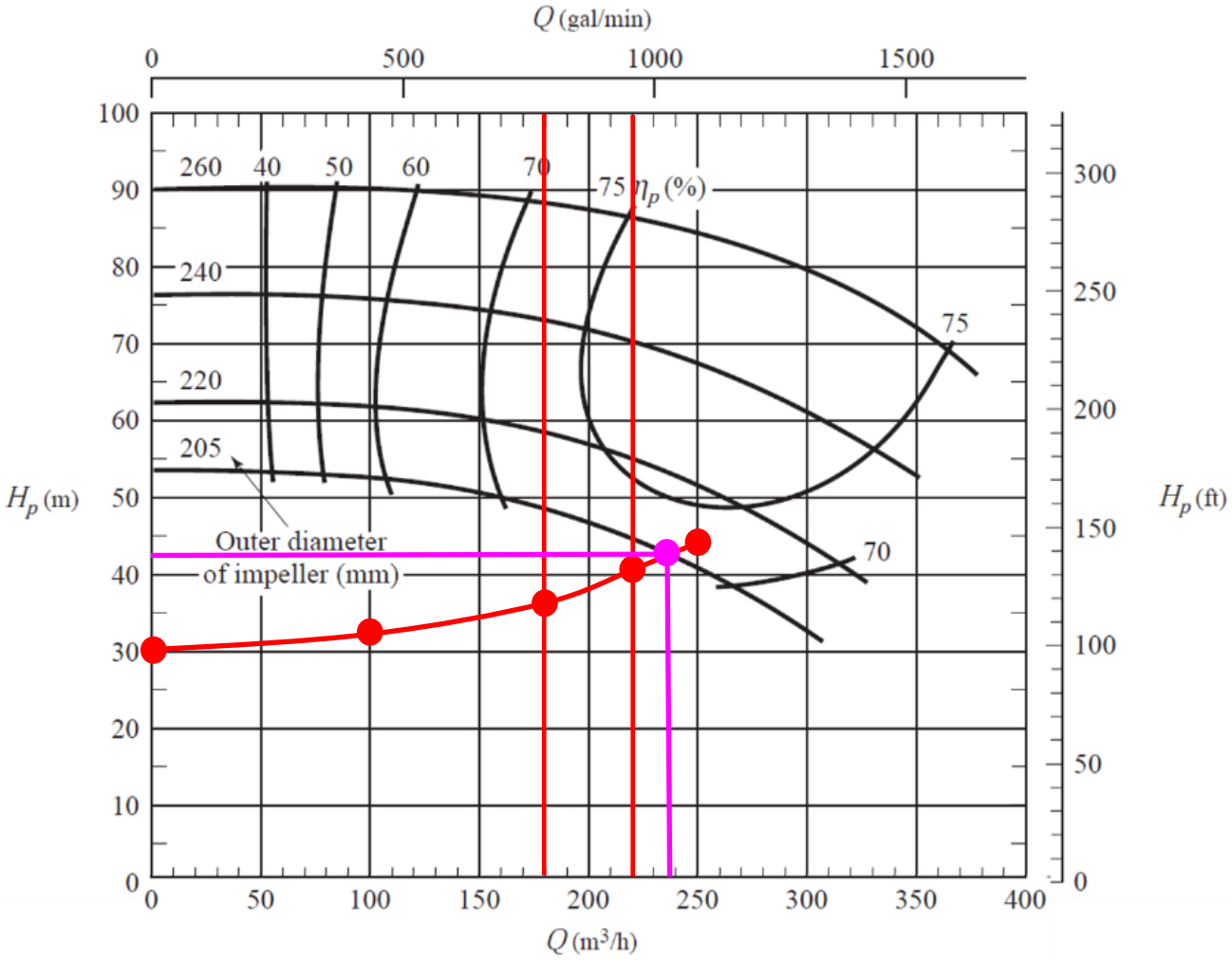
$$H_p = z_2 - z_1 + \left(\frac{fL}{D} + \Sigma K\right)\frac{Q^2}{2gA^2}$$

$$H_p = 30 + \left(\frac{0.024 \times 100}{0.15} + 2\right)\frac{Q^2}{19.6 \times \left[\frac{\pi \times 0.15^2}{4}\right]^2}$$

$$H_p = 30 + 2940.84\,Q^2$$ → Q is in m^3/s

Q (m^3/h)	Q (m^3/s)	H (m)
0	0	30
360	0.1	59.4
180	0.05	37.4
250	0.069	44.2
100	0.0278	32.3
220	0.0611	40.98

The above points (Q [m^3/h] and H [m]) are plotted in the pump curve. The intersection of the pump curve and system curve gives H = 42 m, Q = 240 m^3/h


Q (gal/min)
0
500
1000
1500
100
90
80
70
60
50
40
30
20
10
0
260
40
50
60
70
75
η_p (%)
240
220
205
75
70
Outer diameter
of impeller (mm)
H_p (m)
H_p (ft)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
350
400
Q (m³/h)