CE 3305 – Fluid Mechanics Exam 3

Purpose

Demonstrate ability to apply fluid mechanics and problem solving principles covering topics such as: Dimensional analysis and similitude; turbulent flow in closed conduits; pump system performance.

Instructions

1. Choose any **four (4)** of the six (6) problems. You do **not** need to complete all six problems.
2. Put your name on each sheet you submit.
3. Use additional sheets as needed.
4. Begin each problem on a separate page. Ok to disassemble the exam to keep pages in order.
5. Do not write on the back of sheets (I don't even look)
6. Use the **problem solving protocol** in the class notes. The discussion section can simply be the word "discussion"
7. Label and/or underline answers, be sure to include units.

Allowed Resources

1. Your notes
2. Your textbook
3. The mighty Internet with following proviso:

   You may not communicate with other people during the exam

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1. A smooth pipe designed to carry crude oil is to be modeled with a smooth pipe 0.75 inches in diameter carrying water (T =60^{o}F). The protoype properties are:

   - $D = 47$ inches
   - $\rho = 1.75$ slugs/ft^3
   - $\mu = 4 \times 10^{-4}\ \frac{lbf\ s}{ft^2}$

   Determine:

   (a) The mean velocity of the water in the model to ensure dynamically similar conditions, if the mean velocity in the prototype is to be 2 ft/s,?

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2. Flow around a bridge pier is studied using a $\frac{1}{12}$ scale model. The approach velocity in the model is 0.9 $\frac{m}{s}$ and at this speed the standing wave at the bridge pier nose is measured to be 2.5 cm in height (above the undisturbed water surface).

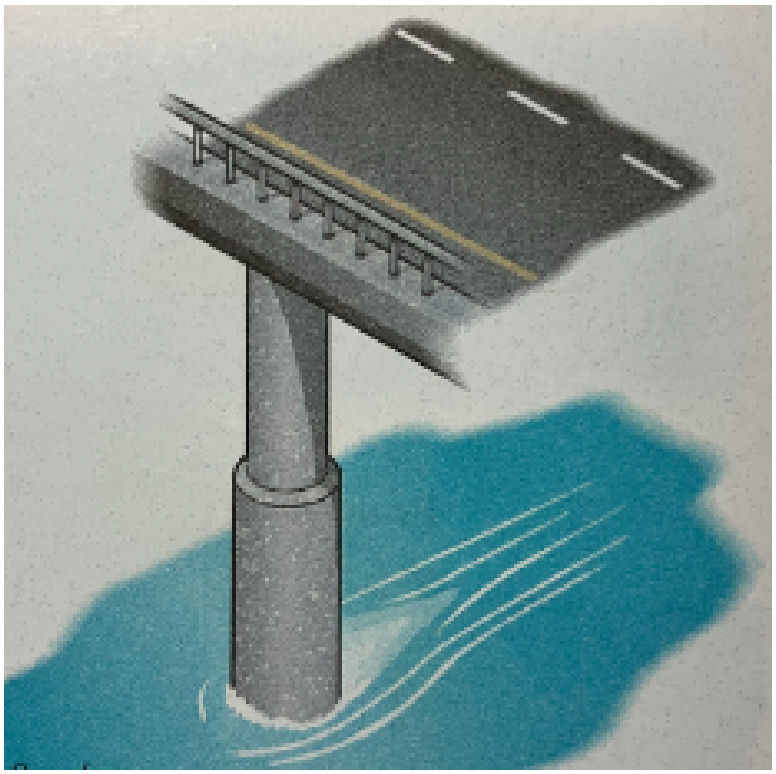

Figure 1:

Determine:

(a) The approach velocity in the prototype using Froude number matching ($Fr = \frac{V}{\sqrt{gL}}$).

(b) The wave height in the prototype.

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3. A prototype littoral frigate-class vessel has a length of 421 ft and is designed to travel on water at 75 ft/s[1]. A 4.21-ft-long model is tested in oil to maintain the same Froude number ($Fr = \frac{V}{\sqrt{gL}}$) and Reynolds number ($Re = \frac{\rho V D}{\mu}$) as the prototype. Determine:

   (a) The geometric scaling factor

   (b) The speed of model (V_m)

   (c) The required kinematic viscosity of oil (μ_m).

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[1]Roughly the specifications of the USS Independence (LCS-2) Littoral Combat Ship

4. In the design of a lift station, a bypass line is often installed parallel to the pump so some liquid recirculates as shown on Figure 2. The bypass valve then controls the flow rate in the system.

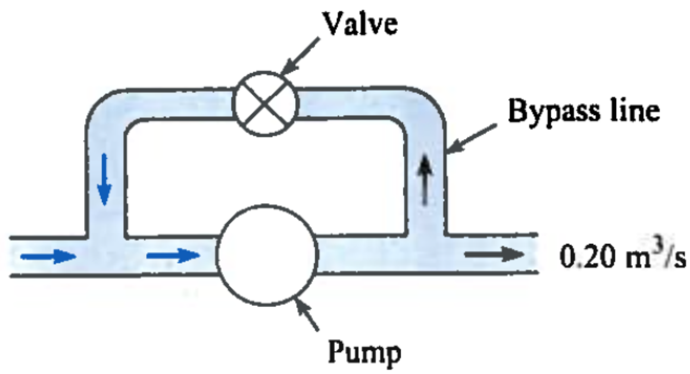

Figure 2:

The pump performance function is

$$h_p = 100 - 100Q$$

where h_p is in meters, and Q is in $\frac{m^3}{sec}$. The bypass line is 10 cm in diameter. The valve setting produces a fitting loss coefficient of $K = 0.2$ and this valve loss is the only meaningful head loss at the lift station. For a discharge leaving the lift station of $0.2\ \frac{m^3}{sec}$

Determine:

(a) The discharge through the pump

(b) The discharge through the bypass line

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5. The figure below is a schematic of a pumped-storage system. Water is pumped from the lower reservoir in a pipeline with the following characteristics: D = 300 mm, L = 150 m, f = 0.029, ΣK = 5.0. The radial-flow pump characteristic curve for a single-stage pump is $H_p = 22.9 + 10.7Q - 109Q^2$ where H_p is in meters and Q is in $\frac{m^3}{sec}$.

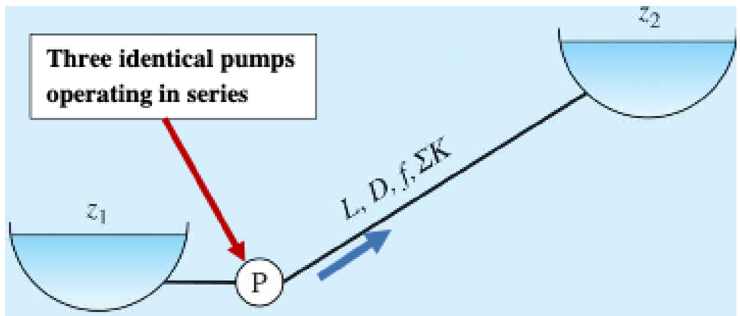

Figure 3:

Determine:

(a) Plot the lift station composite pump curve, and the system curve on the same graph.

(b) The discharge Q_D and pump added head H_D if the lift $(z_2 - z_1)$ is 40 m using a three-stage pump (treat as three identical pumps operating in series).

6. The figure below is a schematic of a parallel pipe system. Flow occurs from A to B as shown. To augment the flow a pump is located between C and C'. The network is on a plane (flat) surface; all the junction elevations are the same. The pipes are commercial steel.

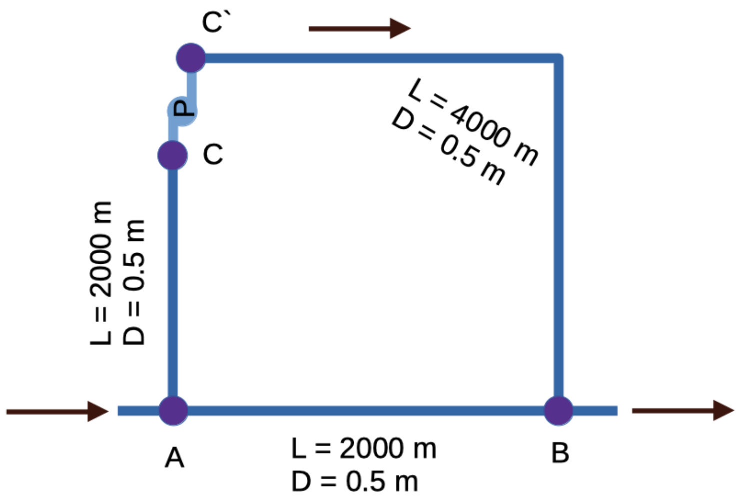

Figure 4:

The pump characteristic curve is shown below:

Total discharge is 0.60 $\frac{m^3}{sec}$

Determine:

(a) The division of flow between pipes A-B and A-C-B

(b) The head loss in pipe A-B

(c) The head loss in pipe A-C

(d) The head loss in pipe C'-B

(e) The pump operating conditions.

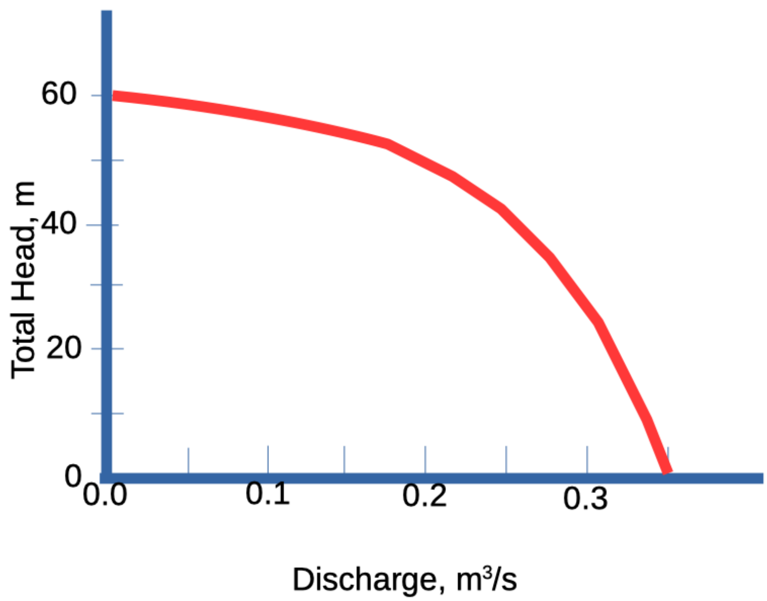

Figure 5: