EE 105: Fluids

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Figure 1 depicts a fluid system. In the figure, h_i and H_i indicate the height of the fluid and height of the tank i-th tank, respectively. Perform the following steps relative to this fluid simulation.

1. Draw and label the equivalent circuit. Ignore inertia within the pipes.
2. Construct and simplify a bond graph model.
3. Use the bond graph model to find the state space model in matrix form. The output vector should be $y = [h_1, h_2, h_3, Q_0]^\top$. Define the A, B, C, and D matrices symbolically in terms of the resistances and capacitances.
4. ILearn contains a zip file related to this lab. The zip file includes a Simulink block diagram, an init file, an animation file, and files that compute resistance and capacitance. The init file computes the resistances and capacitances, defines the matrices for the state space model, and opens the Simulink fluid simulation. The fluid simulation will work correctly if the state space matrices are defined correctly. Currently the state space models in the simulation are arbitrary. Correct the state space matrices using your answer from above. Until you are told to do so, do not change the frequency of the input signal and do not change the tank heights. Run the simulation. If you have the state space model correct, then the following should be true:
   (a) No tank should overflow. If $h_i(t) > H_i$ at any time, the simulation should give an error message and stop.
   (b) No tank should ever have a negative height or pressure. If $h_i(t) < 0$ or $P_i(t) < 0$ at any time, the simulation should give an error message and stop.
   (c) The output flow in steady state should oscillate between 0.020 and 0.039 $\frac{m^3}{s}$. This you need to check visually.

   Use these conditions as checks to make sure your model is accurate. Note that each time you change the init file, you must save and rerun it (F5) to affect the parameters in the simulation model.
5. Use the Bode function to plot the magnitude of the transfer function from P_p to Q_o. Note that the input signal $P_p(t)$ contains two frequency components $\omega = 0$ and ω_o. The DC component is the rated pressure of the pump. The sinusoidal oscillation at frequency ω_o represents the oscillation in the pressure caused by the rotating blades inside the pump. Use the Bode plot to determine the minimum value of the pump rotation rate ω_o that is required if the amplitude of the oscillation at frequency ω_o must be less than 1% of the DC flow rate.
6. In the init file, set the value of ω_o to the value that you compute. Run the simulation until the system reaches its steady state oscillation. Does the steady state flow achieve the 1% oscillation specification?
7. With the pump rotation rate set as in the previous step, use Bode analysis to compute the minimum height of each tank (accurate the nearest cm) such that none of the tanks overflow. To do this, use the Bode plot to compute the steady state amplitude at DC and at ω_o. Then use superposition. Remember that the input magnitude is 9800 N/m^2. In the init file, set the tank heights to the values that you compute. Do any tanks overflow?

Your lab report should include your state space model derivation and the analysis and plots required to answer the various questions in the lab. Each figure that you include in your report should have a label, a caption, and be discussed by name in the lab report.

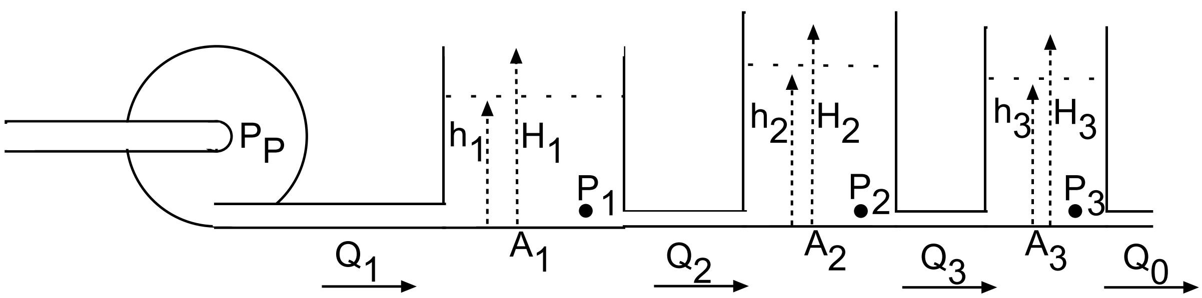

Figure 1: Fluid system diagram.