EE105 Lab 6 Fluids

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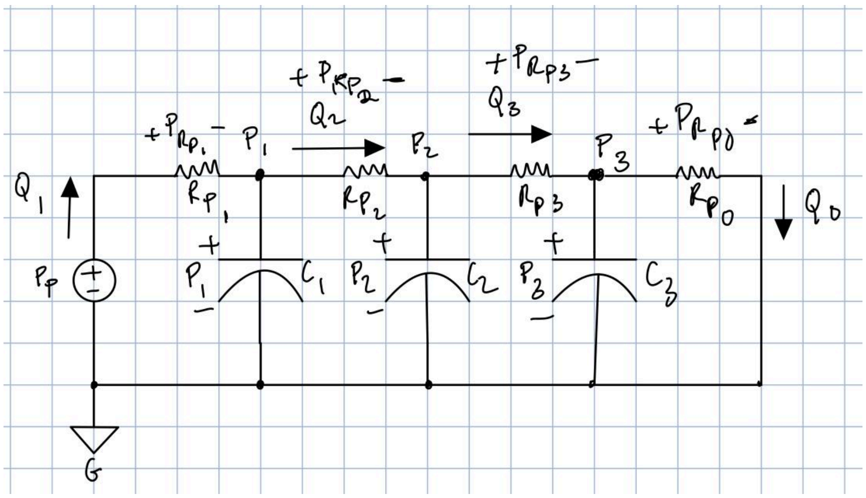
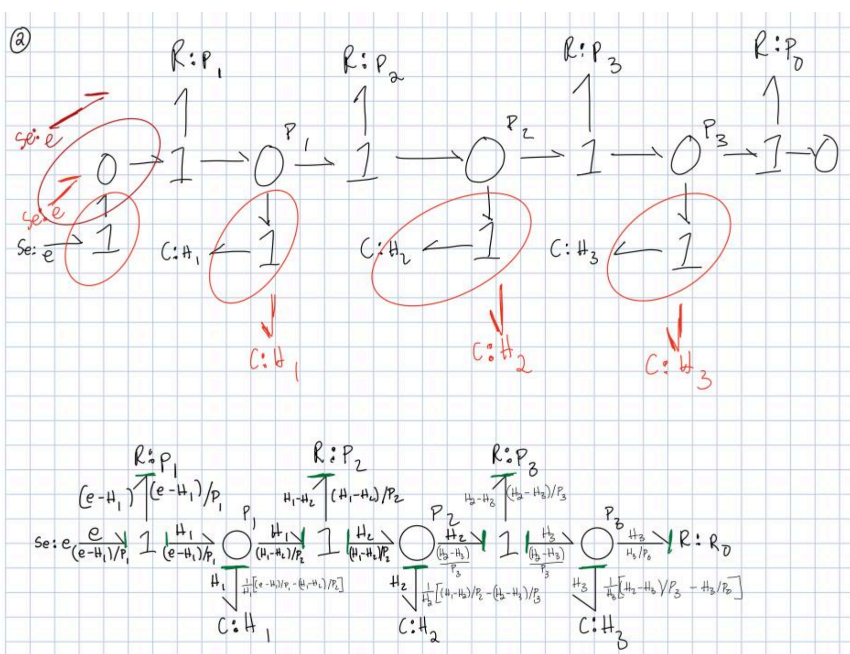
1. Draw and label the equivalent circuit. Ignore inertia of the fluid flowing within the pipes. **(5'')**



2. Construct and simplify a bond graph model. **(5'')**



3. **(10'')**

Find the state space model in matrix form. **(Be careful, if your state space model is wrong, then the entire simulation below will be incorrect)**

Define the A, B, C, and D matrices:

(3)

$$x(t) = \begin{bmatrix} V_{H_1} \\ V_{H_2} \\ V_{H_3} \end{bmatrix} \in R^{3\times 1}$$

$$x_1(t) = V_{H_1}$$
$$\dot{x}_1(t) = \dot{V}_{H_1}$$
$$= -\frac{1}{H_1 P_1} x_1(t) - \frac{1}{H_1 P_2} x_1(t) + \frac{1}{H_1 P_2} x_2(t) + \frac{1}{H_1} \frac{e}{P_1}$$
$$= \left(-\frac{1}{H_1 P_1} - \frac{1}{H_1 P_2}\right) x_1(t) + \frac{1}{H_1 P_2} x_2(t) + \frac{1}{H_1} e$$

$$x_2(t) = V_{H_2}$$
$$\dot{x}_2(t) = \dot{V}_{H_2}$$
$$= \frac{1}{H_2 P_2} x_1(t) - \frac{1}{H_2 P_2} x_2(t) - \frac{1}{H_2 P_3} x_2(t) + \frac{1}{H_2 P_3} x_3(t)$$
$$= \frac{1}{H_2 P_2} x_1(t) - \left(\frac{1}{H_2 P_2} + \frac{1}{H_2 P_3}\right) x_2(t) + \frac{1}{H_2 P_3} x_3(t)$$

$$x_3(t) = V_{H_3}$$
$$\dot{x}_3(t) = \dot{V}_{H_3}$$
$$= \frac{1}{H_3}\left[(H_2 - H_3)/P_3 - H_3/P_0\right]$$
$$= \frac{1}{H_3 P_3} x_2(t) - \frac{1}{H_3 P_3} x_3(t) - \frac{1}{H_3 P_0} x_3(t)$$
$$= \frac{1}{H_3 P_3} x_2(t) - \left(\frac{1}{H_3 P_3} + \frac{1}{H_3 P_0}\right) x_3(t)$$

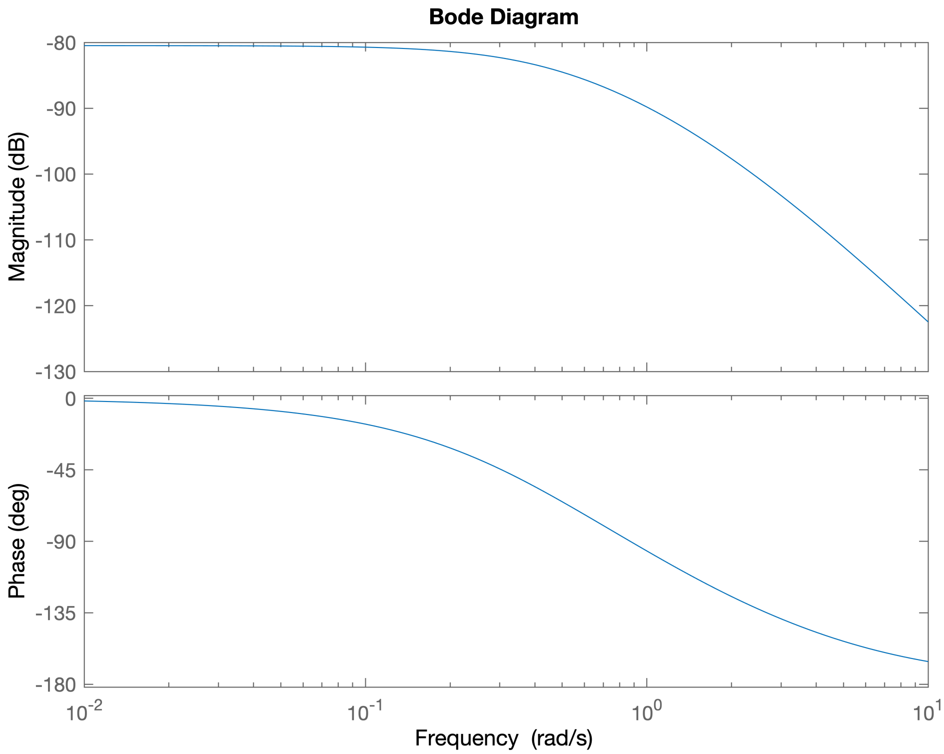
$$\begin{bmatrix} \left(-1/H_1P_1 - 1/H_1P_2\right) & 1/H_1P_2 & 0 \\ 1/H_2P_2 & -\left(\frac{1}{H_2P_2} + \frac{1}{H_2P_3}\right) & 1/H_2P_3 \\ 0 & 1/H_3P_3 & -\left(1/H_3P_3 + 1/H_3P_0\right) \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1/H_1P_1 \\ 0 \\ 0 \end{bmatrix} u$$

4. Correct the A, B, C, and D matrices in 'fluid_animation_init.m'

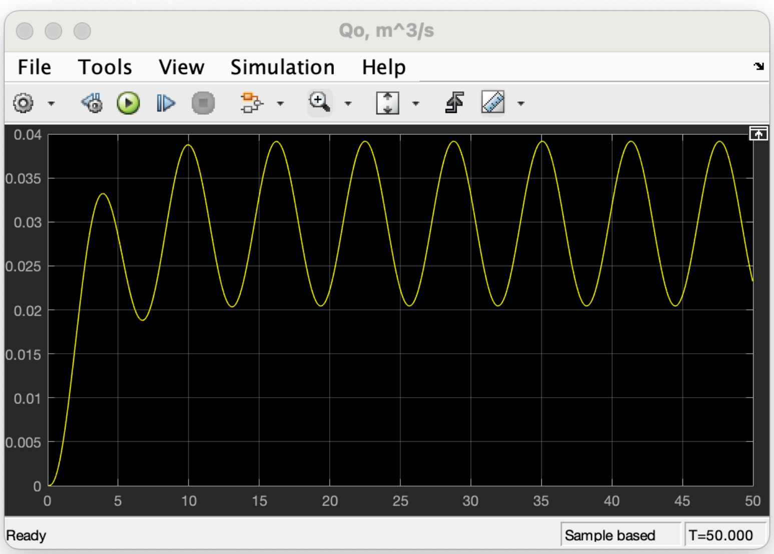
Then, run the file above. (Simulink file will be opened automatically)

```
run fluid_animation_init.mlx;
```

```
R1 = 7.9577e+03
R2 = 1.5915e+04
R3 = 5.0301e+04
R0 = 2.5465e+05
C1 = 2.0408e-04
C2 = 5.1020e-05
C3 = 1.0204e-05
```



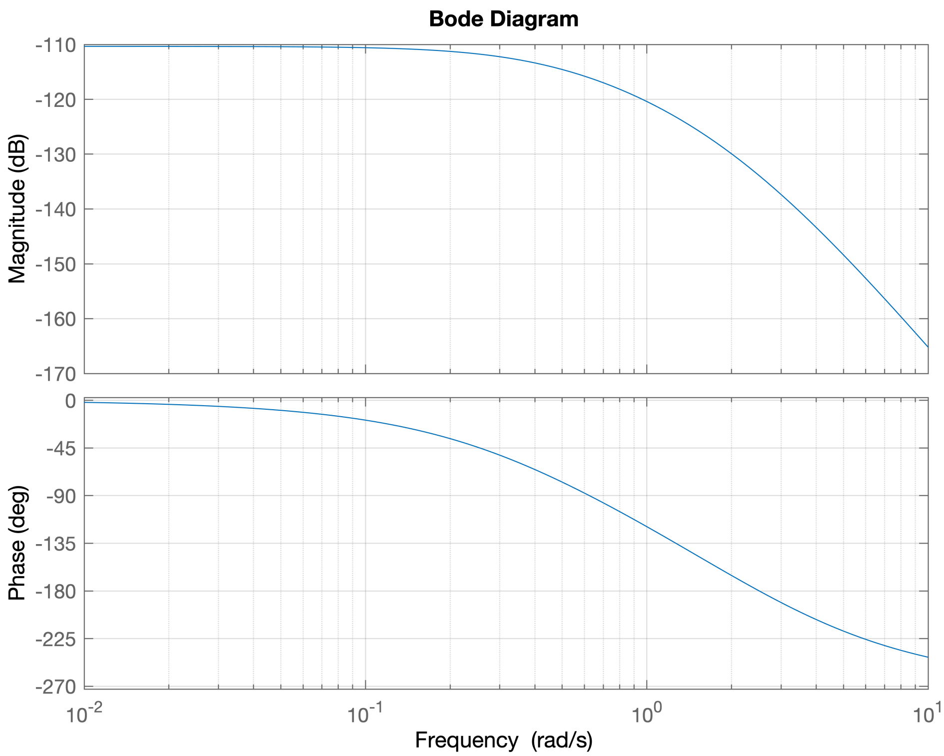
(10'') Display the output graph Qo. (No graph will be given for checking this time. Notice that no tank should overflow otherwise your simulation will show errors if the matrices not be set correctly.)



5. Bode graph **(10'')**

```
w=logspace(-2,1,100);
% Please re-define the matrices C_Qo and D_Qo
```

```
C_Qo = [0 0 1/R0];
D_Qo = zeros(1,1);
% Because in this problem, it's to plot the magnitude of the transfer function from Pp
% to Qo. So, the output y = Qo.
sys = ss(A,B,C_Qo,D_Qo);
[mag, phase, omega] = bode(sys,w); % Get the data
figure
bode(sys,w); % Plot the gragh
grid on;
```



Using 'find' function.

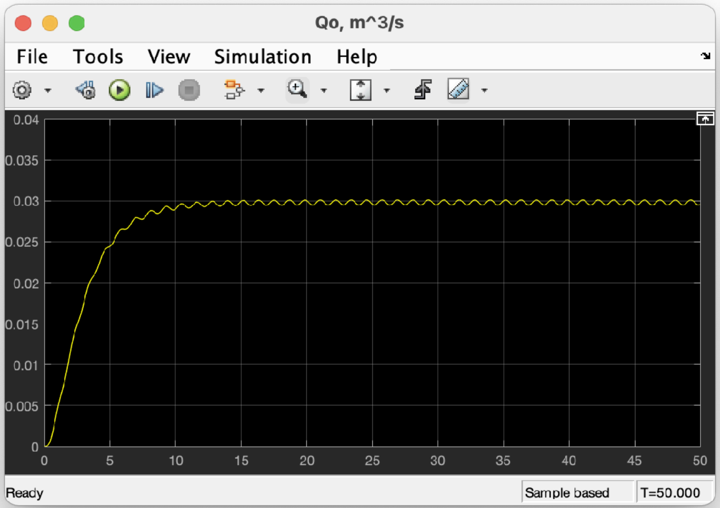
Find the minimum frequency where its magnitude <= mag(1)*1%. **(5'')**

```
indx = find(abs(mag-mag(1)*0.01)<=(min(abs(mag-mag(1)*0.01))))
```

```
indx = 91
```

6. Go to 'fluid_animation_init.m', set the value of ωo to the value that you compute from last step.

(10'') Display the output graph Qo. (No graph will be given for checking)



Using cursor measurement measure the max and min at the steady state flow.

Compute $\frac{\max - \min}{(\max + \min)/2}$. **(5'')**

max = 3.010e-02

min = 2.948e-02

Does this value approximately achieve 1%? **(5'')**

No, this value does not approximately achieve 1%. It is over by 1%.

7.

For example, to compute the minimum height of H1 **(10'')**

```
% Get the magnitude information
sys = ss(A,B,C(1,:),D(1,:));
[magh1, phaseh1, omegah1] = bode(sys,w);
% the steady state amplitude at DC is magh1(1)
% and at ωo is magh1(ωo-1) where wo is the idex you get from step 5.
H1= (magh1(1) + magh1(indx(1)-1))*9800
```

```
H1 = 1.0957
```

Then compute H2 **(10'')**

```
sys = ss(A,B,C(2,:),D(2,:));
[magh2, phaseh2, omegah2] = bode(sys,w);
H2= (magh2(1) + magh2(indx(1)-1))*9800
```

```
H2 = 0.9549
```

and H3 **(10'')**.

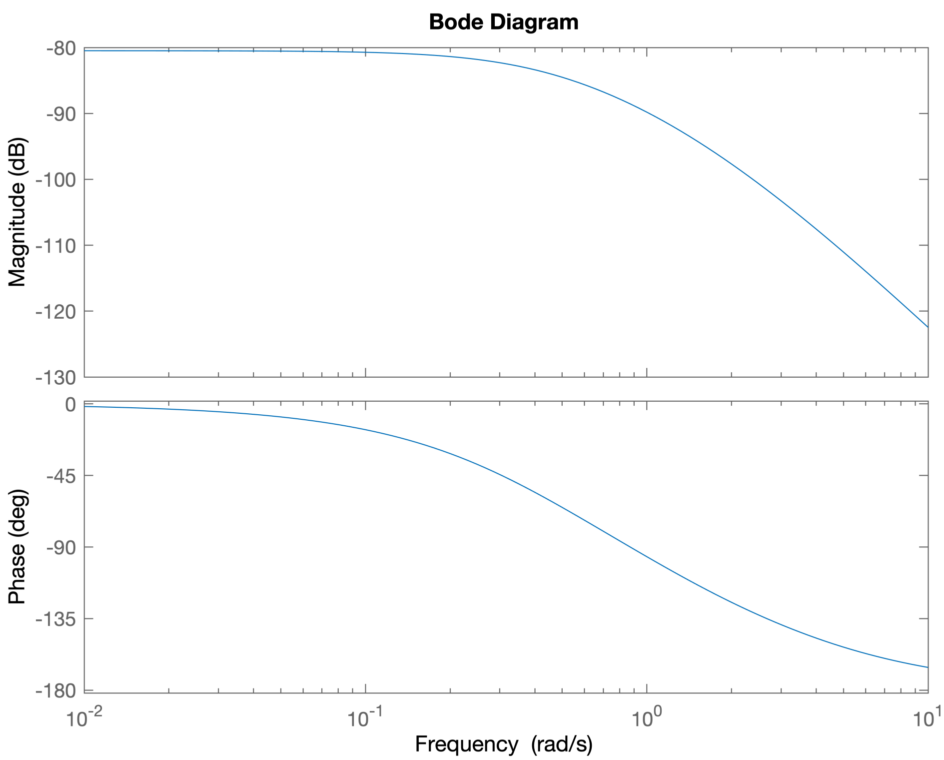
```
sys = ss(A,B,C(3,:),D(3,:));
[magh3, phaseh3, omegah3] = bode(sys,w);
H3= (magh3(1) + magh3(indx(1)-1))*9800
```

```
H3 = 0.7840
```

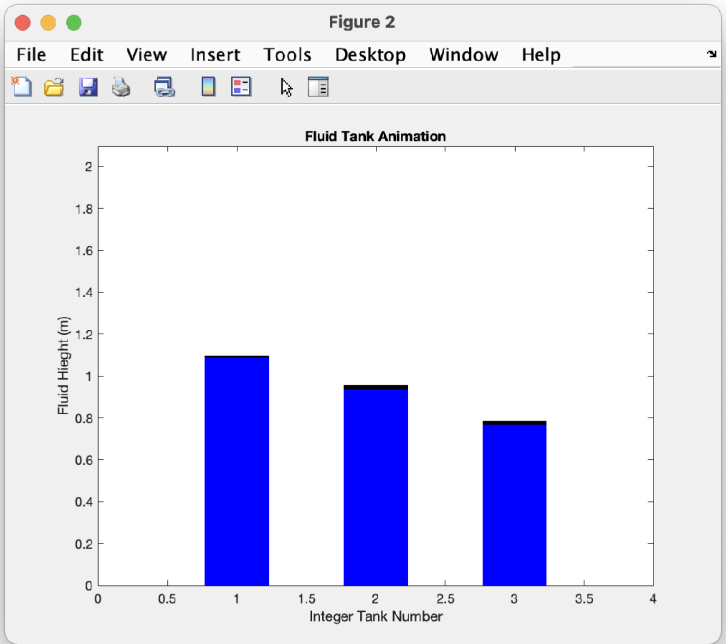
Change the 'Height' in 'fluid_animation_init.m' using the value of H1, H2 and H3.

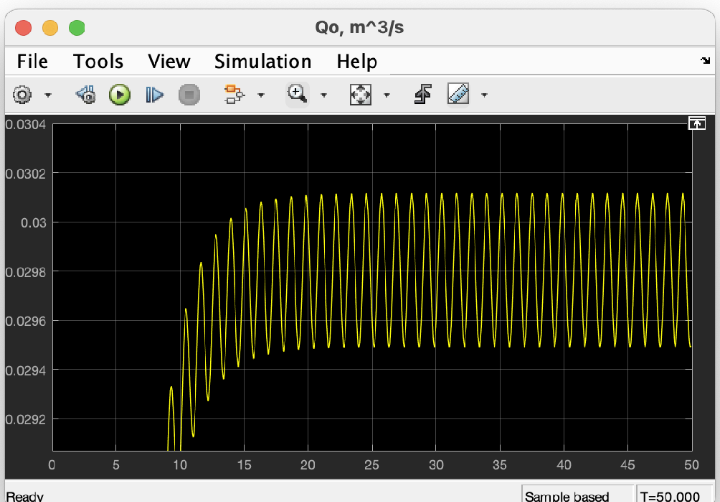
```
run fluid_animation_init.mlx;
```

```
R1 = 7.9577e+03
R2 = 1.5915e+04
R3 = 5.0301e+04
R0 = 2.5465e+05
C1 = 2.0408e-04
C2 = 5.1020e-05
C3 = 1.0204e-05
```



Re-simulate. Do any tanks overflow? **(5'')**





None of the tanks were overflown.