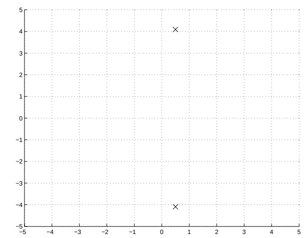
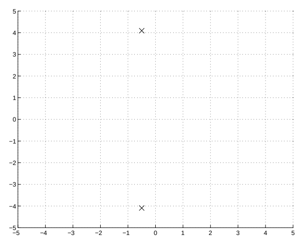
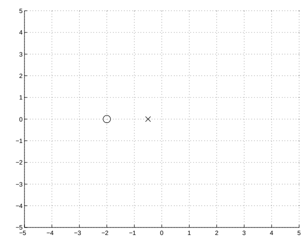
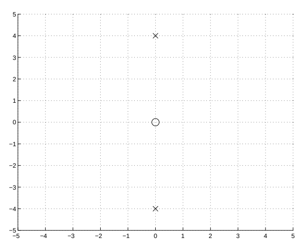
Problem 1

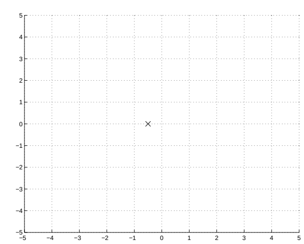
Match each of the following pole-zero diagrams to the corresponding Bode plot and step response from the following two pages. For example is you think that pole-zero diagram (1) corresponds to step response (q) and Bode plot (r), write "1,q,r" on your exam paper.

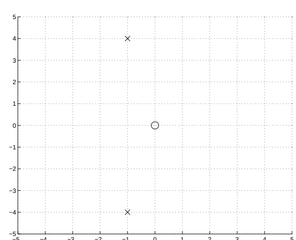


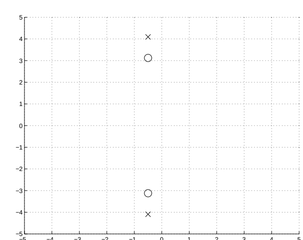


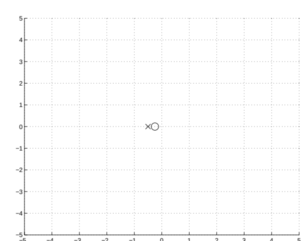


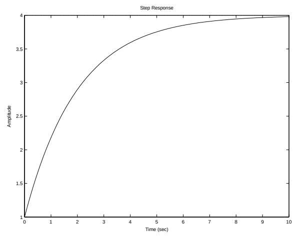


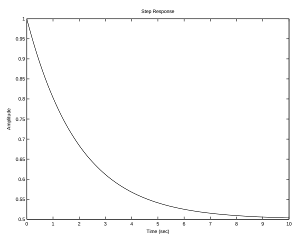


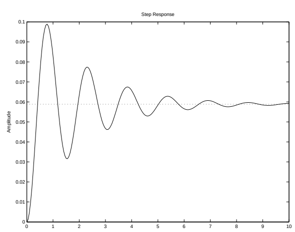


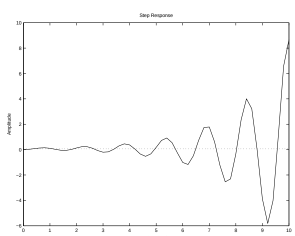


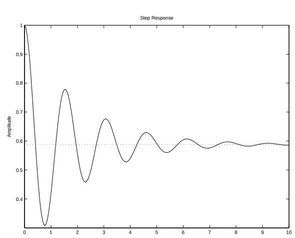


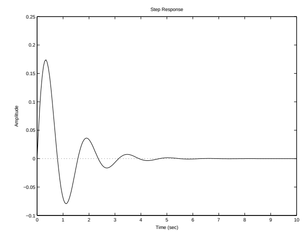

Step Response
Amplitude
Time (sec)

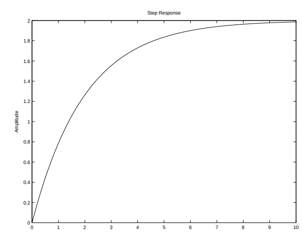

Step Response
Amplitude
Time (sec)

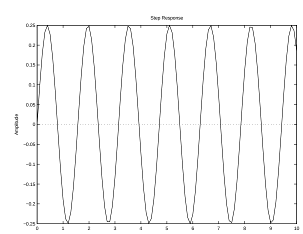

Step Response
Amplitude
Time (sec)

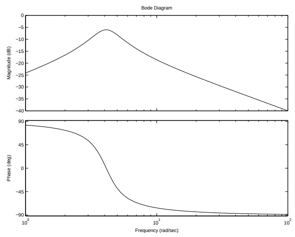

Step Response
Amplitude
Time (sec)

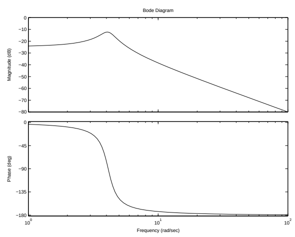

Step Response
Amplitude
Time (sec)

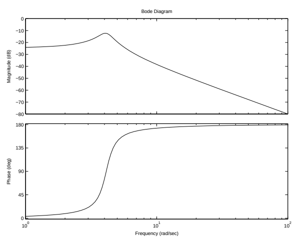

Step Response
Amplitude
Time (sec)

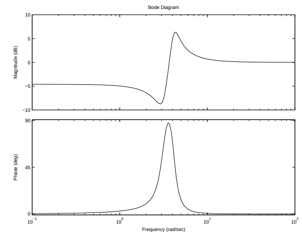

Step Response
Amplitude
Time (sec)

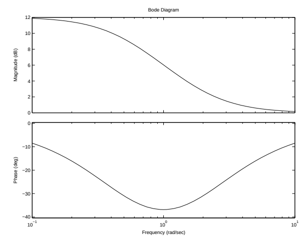

Step Response
Amplitude
Time (sec)

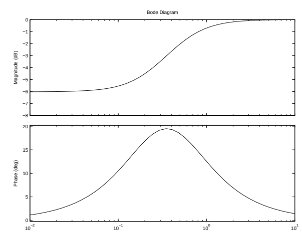

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)

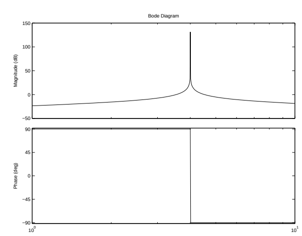

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)

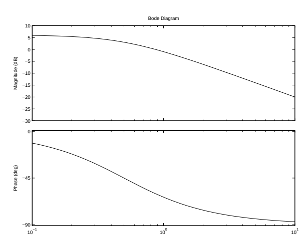

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)

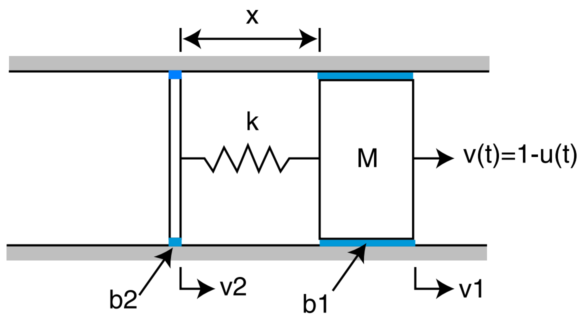

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)

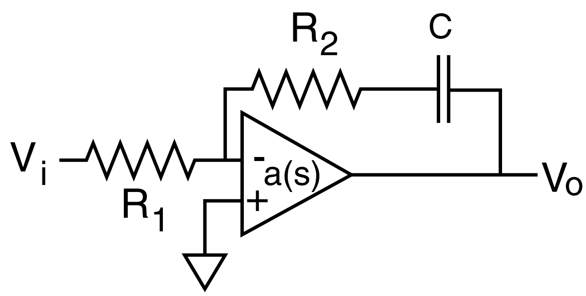
Problem 2



The figure above shows a system which consist of a mass (M), spring (k), and two dampers (b1, b2). The spring is attached at one end to the mass and to the damper (b2), which is massless at the other. The mass is pulled by a velocity source (v(t)). x denotes the extension of the spring. v_1 is the velocity of the mass and v_2 is the velocity of the second damper. $M = 1$ kg, $b_1 = 1$ Ns/m, $b_2 = 9$ Ns/m, $k = 9$ N/m.

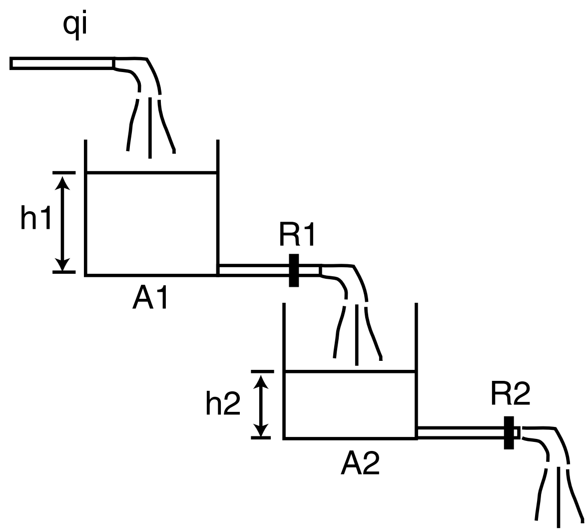
a) find $v_1(0^-)$, $v_2(0^-)$, and $x(0^-)$
b) find $x(0^+)$ and $\dot{x}(0^+)$
c) write the differential equation for the system in terms of x.
d) find $x(t)$ given the initial conditions in c.

Problem 3



a) If $a(s) = 10^6$, find the transfer function of Op-Amp circuit above.
b) If this circuit were used as a controller, what type of controller would it be?
c) If $a(s) = \frac{10^6}{s}$ what is the transfer function of the circuit?
d) $C = 1\,\mu F$, $R_1 = 1e4\,\Omega$, $R_2 = 5e4\,\Omega$. Plot $M(\omega)$ and $\phi(\omega)$

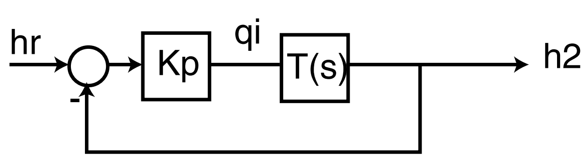
Problem 4



You are asked to control the level of the 2nd tank in the 2 tank system shown above. There is an fluid flow in q_i. The first tank has an area A_1 with an outlet resistance of R_1. The 2nd tank has an area A_2 with an outlet resistance of R_2. $A_1 = 2\,m^2$, $A_2 = 1\,m^2$, $g = 9.8\,m/s^2$, $R_1 = 1000\,1/(m\,s)$, $R_2 = 10000\,1/(m\,s)$, $\rho_{water} = 1000\,kg/m^3$

a) Find the transfer function $\frac{h_2}{q_i}(s)$

b) Determine the value of K_p which results in a steady state error of 5%



c) How long does is take this system to reach the steady state value.