Mechanical and Aerospace System Analysis

Midterm #2

May. 14. 2009

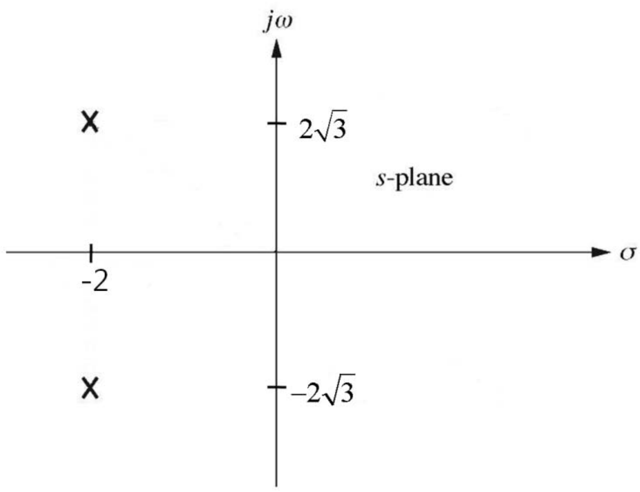
1. Briefly answer following questions.
   A. Explain the golden rules of OP-amp.

B. Plot a pole placement graph for an under damped second order system.
   i. On the graph, describe the values of the pole's real and imaginary value using the damping ratio and the natural frequency.
   ii. What is the relationship between the angle of the line that intersects the origin and the pole, with the damping ratio?

C. Derive the %OS of a 2nd order system with C(s)

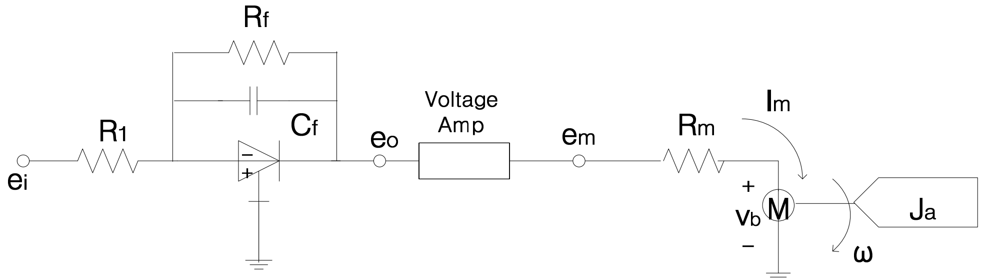
$$C(s) = \frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$$

D. Answer the following for a system with poles shown in the graph below.
   i. What is the settling time(2%) and the peak time of a system with the poles shown in the pole placement graph below?
   ii. Describe what is needed in order to reduce the settling time to 1/2 of the current value, without changing the % overshoot?



<Figure P1.D>

2. A small DC motor is used to spin a disk with an OP-amp as illustrated in the figure. In this application, we do not want the disk to spin up very fast, so a dynamic filter is added to the OP-amp. (the back emf: K_b, the motor torque constant: K_t, Voltage Amp Gain: G)



A. Derive the transfer function of the OP-amp, $E_o(s)/E_i(s)$

B. Derive the transfer function of the Motor system $\omega(s)/E_m(s)$

C. Write the transfer function of the whole system.

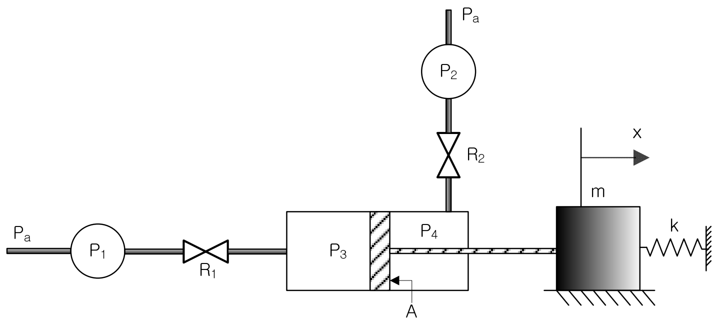
D. What is the settling time of the system?

E. What is the peak time of the system?

F. If you want to decrease the peak time, how would you change the components in the OP-amp?

G. If you want to reduce the overshoot, how would you change the components in the OP-amp?

3. The figure shows a double-acting piston and cylinder. The device moves the load mass m and spring with a spring constant k in response to the pressure sources p_1 and p_2. Assume the fluid is incompressible, the resistances are linear and the piston mass is included in m.



A. What is/are the input(s) to the system?

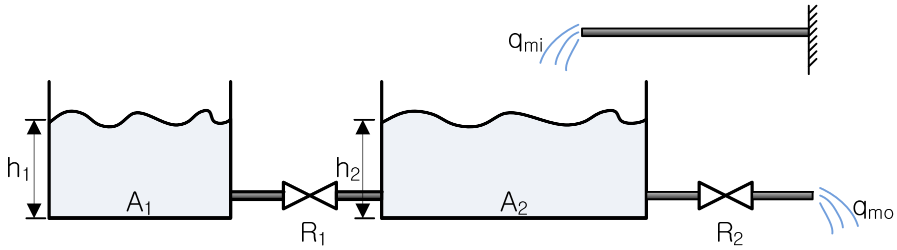
B. Derive the equation of motion for the mass m and write the transfer function(s) of the system.

C. What is the settling time (2%) of the system?

D. What is the peak time of the system?

E. In order to change the dynamics of the system, you can turn the knob of the valve R_1. How would you turn the knob in order to reduce the % overshoot?

4. The cylindrical tanks shown in the figure has circular bottom areas A_1 and A_2. The mass inflow rate $q_i(t)$ from the flow source is a function of time. The resistances are linear and the outlet discharges to atmospheric pressure p_a. (at initial time, h_1=0, h_2=0)



A. Derive a model of the liquid level height h_1 and h_2

B. $R_1 = R_2 = R$ and $A_1 = A$ and $A_2 = 3A$. obtain the transfer function $H_1(s)/Q_i(s)$

C. Solve for the steady state response h_1 for a unit step input of $q_{mi}(t)$. Hint: Use the transfer function.

D. What is the rise time of the system?

E. Can the system oscillate? Explain why or why not.

F. Obtain the transfer function of $Q_o(s)/Q_i(s)$.

G. Solve for the steady state response of $q_o(t)$ for a unit step input of $q_{mi}(t)$. Hint: Use the transfer function.