Homework #4

Instructions:

- Total of 6 questions:
- HW4 will count for 5% of the overall marks.
- Grading here will be out of 10+5+5+5+5+10 = 40 marks
- The HW should be submitted on Moodle.
- TA help session can be arranged based on your requests.

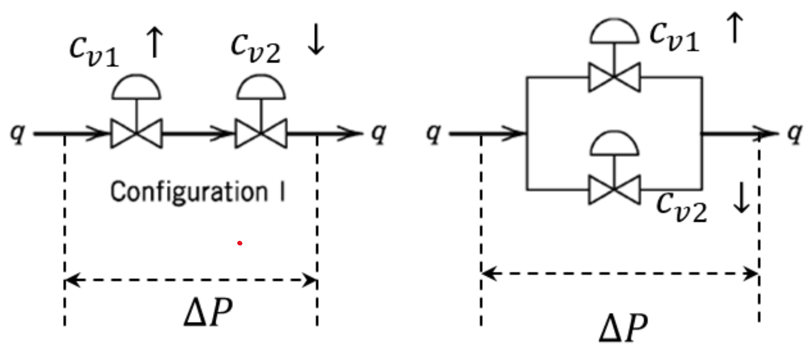
1: Instrumentation:

Consider the two valves having following specifications for water flow ($g_s = 1$):

V1: Linear valve with C_{v1}=100,

V2: Linear valve with C_{v2}=10.

Using V1 and V2 in the following two configurations, where the overall pressure drop is constant and set to $\Delta P = 20$ psi across the system (not across each valves). For the three lift values of the larger valve $l_1 = 0.05$, 0.1, 0.5 and 0.9, calculate the value of total flow rate (q) when the lift of smaller valve goes from 0-1.



a. Make 1 plot for each configuration consisting of 4 cuves. Plot q as a function of l_2 where l_1 =0.05, 0.1 0.5 and 0.9.
b. Compare and comment on the response.

9.4 Chilled ethylene glycol (sp gr = 1.11) is pumped through the shell side of a condenser and a control valve at a nominal flow rate of 200 gal/min. The total pressure drop over the entire system is constant. The pressure drop over the condenser is proportional to the square of the flow rate and is 30 psi at the nominal flow rate. Make plots of flow rate versus vs. stem position ℓ for linear and equal percentage control valves, assuming that the valves are set so that $f(\ell) = 0.5$ at the nominal flow rate. Prepare these plots for the situations where the pressure drop over the control valve at the design flow is

(a) 5 psi

(b) 30 psi

(c) 90 psi

What can you conclude concerning the results from these three sets of design conditions? In particular, for each case, comment on linearity of the installed valve, ability to handle flow rates greater than nominal, and pumping costs.

9.9 A temperature transmitter is used to measure the liquid temperature in a bioreactor. A steady-state calibration of this instrument yields the following data:

Temperature, °C	Measurement, mA
0	4.0
100	8.1
200	11.9
300	16.1
400	20.0

A process engineer runs a test on the reactor under controlled conditions in which its temperature is changed by +3 °C/min. The transmitter output was recorded during this test, converted to °C, and compared with a standard thermometer which is known to be accurate and to have a time constant of 20 s. The test data are

Time from	Temperature (°C)	
Start of Test, min	Std. Thermometer	T/C Transmitter
2.0	111.8	107.8
3.0	115.1	111.0
4.0	117.9	114.1
5.0	121.1	117.0

For steady-state conditions, the standard thermometer and thermocouple-transmitter outputs are identical. Assuming that the transmitter/thermocouple can be modeled by a first-order transfer function, find K and τ.

11.9 The block diagram of a special feedback control system is shown in Fig. E11.9. Derive an expression for the closed-loop transfer function, $Y(s)/D(s)$.

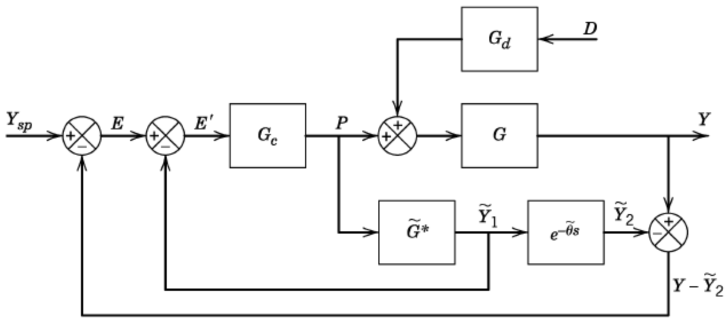


Figure E11.9

11.10 A block diagram of a closed-loop system is shown in Fig. E11.10.

(a) Derive a closed-loop transfer function for disturbance changes, $Y(s)/D(s)$.

(b) For the following transfer functions, what values of K_c will result in a stable closed-loop system?

$$G_1(s) = 5 \qquad G_2(s) = \frac{4}{2s+1}$$

$$K_m = 1 \qquad G_3(s) = \frac{1}{s-1}$$

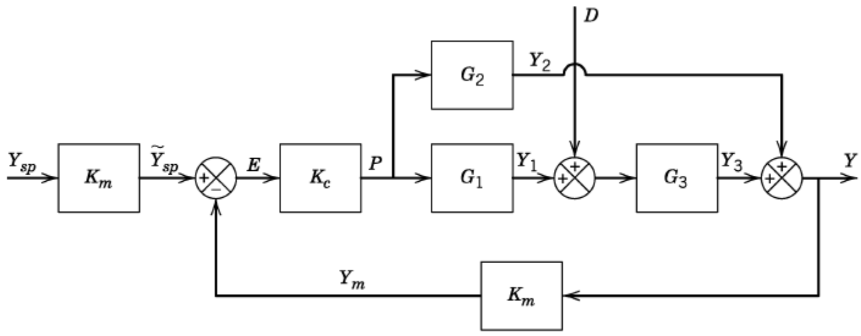


Figure E11.10

11.20 A feedback control system has the open-loop transfer function, $G_{OL}(s) = 0.5K_c e^{-3s}/(10s + 1)$. Determine the values of K_c for which the closed-loop system is stable using two approaches:

(a) An approximate analysis using the Routh stability criterion and a 1/1 Padé approximation for e^{-3s}.

(b) An exact analysis based on substitution of $s = j\omega$. (*Hint:* Recall Euler's identity.)

(c) An approximate analysis using the Routh stability criterion and a Taylor approximation $e^{-3s} = 1 - 3s$.

(d) An approximate analysis using the Routh stability criterion and a Taylor approximation $e^{-3s} = 1/(1+3s)$.

(e) An approximate analysis using the Routh stability criterion and a Pade 2/2 approximation $e^{-3s} \approx \frac{1-\frac{3}{2}s+\frac{3}{4}(s^2)}{1+\frac{3}{2}s+\frac{3}{4}(s^2)}$. Is using 2/2 Pade approximation leads to better bounds than Pade 1/1 approximation compared to true bounds as derived in part b?

Which one of the taylor series approximation *a*, *c* and *d* is the closest to the true answer as derived in part *b*.