National Exams May 2016

04-Chem-A6, Process Dynamics & Control

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

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PROBLEM 1 (20%)

A thermometer with a time constant of 0.2 min is immersed in a temperature bath and after the thermometer comes to equilibrium with the bath, the bath temperature is increased linearly with time at the rate of 1 ^{0}C / min.

10% (a) what is the difference between the indicated temperature and bath temperature (i) 0.1 min (ii) 10 min after the change in temperature is applied?

5% (b) What is the maximum deviation between the indicated temperature and bath temperature and when does it occurs?

5% (c) Plot the forcing function and the response on the same graph. After a long enough time by how many minutes the response will lag after the input?

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PROBLEM 2 (20%)

The input (e) to a PI controller is as follows:

$$for\ 0 \le t < 1 \quad e = 0.5,$$

$$for\ 1 \le t < 2 \quad e = 0$$

$$for\ 2 \le t < 3 \quad e = -0.5$$

$$for\ t \ge 3 \quad e = 0$$

10% a) Find the Laplace transform E(s) (transform of e(t)).

10% b) Find and plot the output of the controller with proportional gain $K_C = 2$ and reset time (integration constant) $\tau_I = 0.5$ min.

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PROBLEM 3 (20%)

The characteristic equation of a closed loop system is given by:

$$C(s) = s^4 + 4s^3 + 6s^2 + 4s + (1 + K_c)$$

10% a) Find the range of values of the gain K_c for which the closed loop is stable.

10% b) Determine the values of K_c for which the closed loop is at the limit of stability.

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PROBLEM # 4 (20%)

A heat exchanger system consists of two tanks, one tank (tank 1) is placed concentrically inside the other tank (tank 2). Heat is transferred by convection through the wall of the inner tank.

1. Hold up volume of each tank is 1 ft^3
2. The cross sectional area for heat transfer is 1 ft^2
3. The overall heat transfer coefficient for the flow of heat between the tanks is 10 Btu/(hr)(ft^2)(^oF)
4. Heat capacity of fluid in each tank is 2 Btu/(lb)(^oF)
5. Density of each fluid is 50 lb/ft^3
6. Assume that the fluids in each tank are well mixed.

Fluid is entering and exiting the outer tank at a rate of 10 lb/hr. No fluid is fed to the inner tank. The temperature of the feed stream to the outer tank remains constant and equal to 100 ^oF and the initial temperature in the outer tank is also equal to 100 ^oF. The fluid in the inner tank is initially at 100 ^oF. A step change in heat flow is introduced to the inner tank (Q) from 0 to 500 Btu/hr through an electric heater immersed in the inner tank.

10% (a) Obtain an expression for the Laplace transform of the temperature of inner tank T(s).

10% (b) Invert T(s) and obtain T for t= 0 hr and t=5 hr.

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Problem #5 (20% total)

A process is described by the following transfer function:

$$G_p = \frac{10(0.5 - s)e^{-10s}}{100s + 1}$$

(10%) (a) Design an IMC (Internal Model Controller) for this process. Show your design with a block diagram.

(10%) (b) Assuming a perfect model of the process, compute the closed loop response for a unit step in set point if the desired closed loop time constant is equal to 5.

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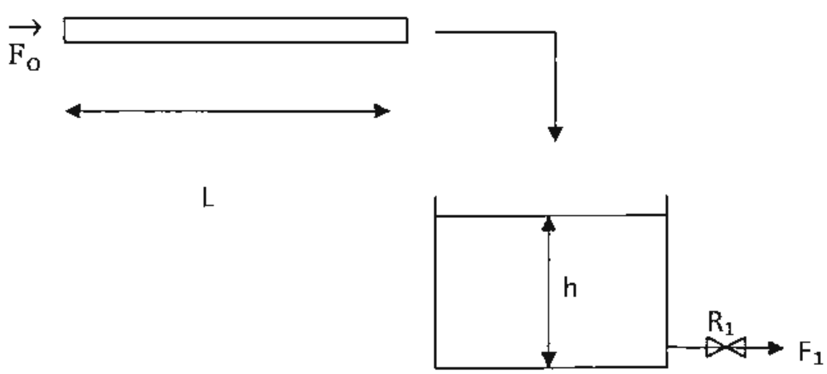
PROBLEM 6 (20%)

For the draining tank shown in the figure



Compute the change in level δh(t) as a function of time for the following two cases:

(10%) (a) a step of one unit in inlet flow F_0

(10%) (b) a unit impulse (Dirac function) in inlet flow F_0

The cross-section area of the tank is 1 m^2. The length of the inlet pipe is 1.0m and the cross sectional area of the pipe is 0.01m^2. Initial level = 1 m. The flow out is given by $F_1 = R_1 \bullet h$, where the hydraulic resistance $R_1 = \frac{1m^2}{min}$.

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PROBLEM 7 (20%)

A process given by:

$$G_p = \frac{100}{s - 10}$$

is controlled by a proportional controller with gain K_c.

(10%) (a) Using the Nyquist theorem test the closed loop stability for

$K_c = 1$ and $K_c = 0.01$.

(10%) (b) Using the Nyquist criterion, compute the limiting value of K_c for which the system is stable.

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Problem #8 (20% total)

A first order process is given by

$$Gp = \frac{1}{(s+5)}$$

This process is controlled by a PI controller given by:

$$Gp = K_c(1 + \frac{1}{s})$$

(10%) Compute ranges of K_c values for which the closed loop is stable.

(10%) For a controller with gain K_c=1 compute the closed loop time response for a unit step change in the set point.