National Exams December 2018

16-Chem-A6, Process Dynamics and 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%)

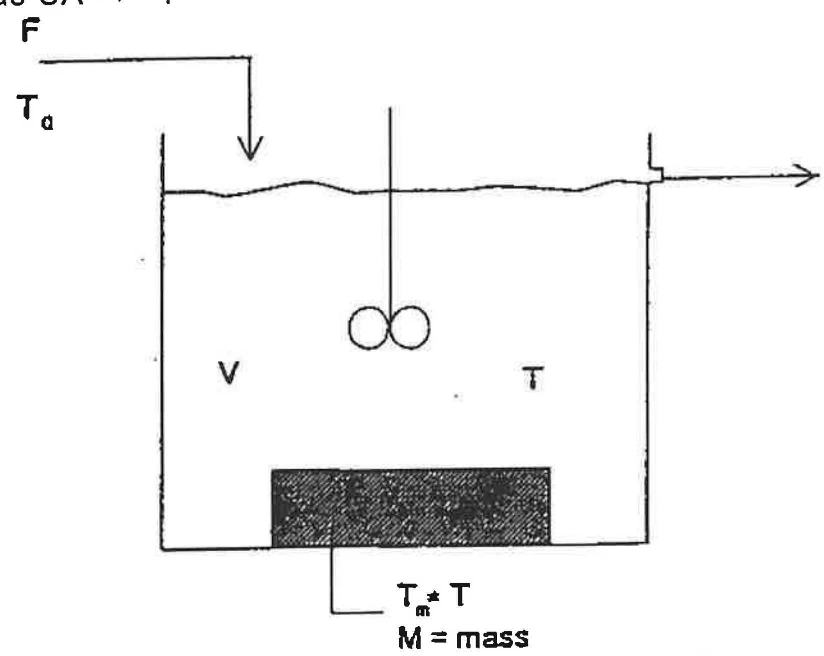
The process in the figure involves a continuous flow stirred tank with a mass of solid material. The assumptions for the system are:

1) well mixed tank
2) physical properties constant $C_v \approx C_p$,
3) V = constant , F = constant [volume/time],
4) the solid material contributes a significant portion of the energy storage, and the temperature is uniform throughout the solid.
5) the heat transfer from the liquid to the metal, is UA $(T-T_m)$, T_m is not equal to T.
6) heat losses are negligible, and
7) all variables are initially at steady state

10% a- Determine the fundamental model equations that relate the behavior of T(t) as inlet temperature $T_0(t)$ changes.

5% b- Derive the transfer function $\delta T(s)/\delta T_0(s)$ where δ indicates deviation variables.

5% c- Describe briefly how the results in steps a) and b) would change as UA $\rightarrow \infty$.



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PROBLEM # 2 (20%)

Consider the following system of equations:

$$\frac{dx_1}{dt} = -2.4048x_1 + 7u$$

$$\frac{dx_2}{dt} = 0.8333x_1 - 2.2381x_2 - 1.117u$$

$$y = x_2$$

10% a-Find the transfer function Y/U (Y and U are Laplace transforms of *y* and *u* respectively.

10% b-Solve for *y(t)* in response to a unit step change in *u*. Assume all initial condition to be equal to zero.

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PROBLEM #3 (20% total)

A process described by the following transfer function:

$$G(s) = \frac{5e^{-2s}}{10s + 1}$$

Is to be controlled by an IMC (Internal Model Controller) controller. Time is in seconds.

(10%) 1- Show the block diagram of the closed loop. Calculate the IMC controller Gc^* and the classical feedback controller equivalent Gc (**without assuming Pade approximation**). Assume that the IMC filter parameter is τ_C=20 sec. Is the resulting Gc of PID form?

(10%) 2- Calculate the closed loop response for the controlled variable δC(t) for a unit step change in set point for the case in item 1 above **where Pade was not assumed and the model is assumed to be perfect**.

PROBLEM # 4 (20% total)

A process given by:

$$G_p = \frac{20}{s - 3}$$

Is to be controlled by a proportional controller with gain.

(10%) (a) show a qualitative Nyquist plot (show only 2-3 key points along the plot and the general shape of the plot and the general shape of the plot for this problem) K_c = 1. Is the system stable for this gain?

(10%) (b) Based on the Nyquist criterion, compute a range of k_c values to obtain closed loop stability.

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Problem #5 (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.

PROBLEM #6 (20% total)

For the equation

$$\frac{d^2y}{dt^2} + k\frac{dy}{dt} + 10y = 2x$$

(10%) (a) Find the transfer function between the input x to the output y and put it in the standard gain-time constant form.

(5%) (b) Discuss for which values of k is the open loop response for a unit step in x (i) stable, (ii) underdamped, and (iii) overdamped.

(5%) (c) If the response is underdamped, compute expressions as a function of k for the time constant and the damping coefficient according to the standard form definitions.

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PROBLEM #7 (20% total)

A process given by

$$G_p = \frac{e^{-0.1s}}{0.5s+1}$$

is controlled by a proportional controller with gain K_c. Do not approximate the time delay.

(10%) (a) Plot qualitatively the Bode Plot for this system (show slope values, corner frequencies and extreme amplitude and phase values).

(10%) (b) Compute k_c to obtain a gain margin of 1.7.

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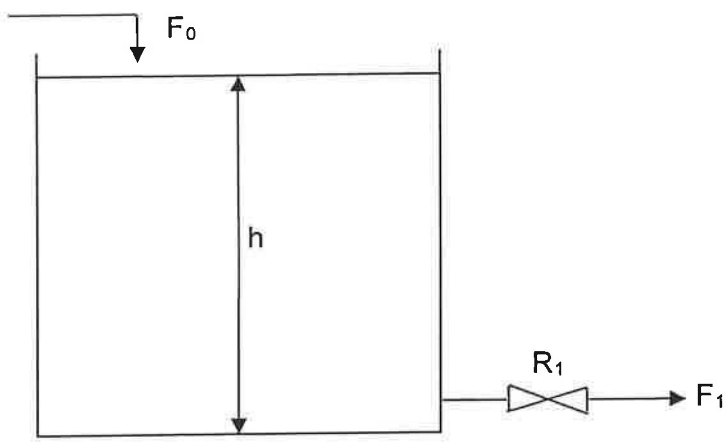
PROBLEM 8

For the draining tank shown in the figure



Compute the change in level $\delta h(t)$ with respect to an initial steady state for the following two cases:

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

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

The cross section area is $1m^2$. The initial level is 7m.

The flow out is given by $F_1 = R_1 \bullet h$, where the coefficient $R_1 = 4\frac{m^2}{min}$.