National Exams May 2019

04-BIO-A2, 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 process is described by the following transfer function $G(s) = \frac{2(1+cs)}{(s+1)(s+2)}$

10% (a) Find the response to a unit step change as a function of c.

10% (b) Find the values of c for which there is an overshoot. Find the magnitude of the overshoot as a function of c.

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PROBLEM #2 (20% total)

A process given by:

$$G_p = \frac{20}{s-2}$$

Is to be controlled by a proportional controller with gain K_c.

(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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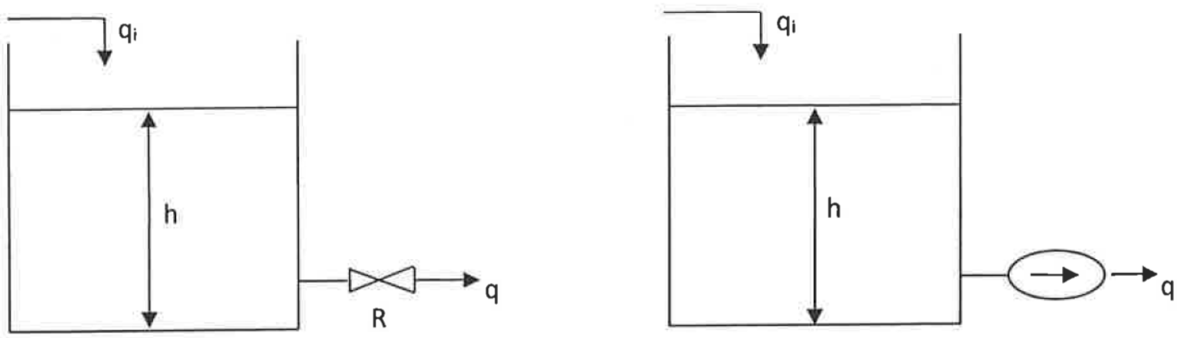
PROBLEM 3 (20% total)

Two liquid storage tanks are shown in the drawing:



Case I Case II

Each tank is $1 m^2$ in cross sectional area.

For case I, the valve acts as a resistance to flow and $q = R\sqrt{\frac{\Delta P}{\rho g}}$ where ΔP is the pressure difference across the valve (ρ is the density, g is gravity acceleration). For case II, the exit flow q is determined by the exit pump. Suppose that each system is initially at steady state with $h(t=0) = 1 m$ and $q = 1\frac{m^3}{s}$, $R = 1$. At t=0 the inlet flow is suddenly changed from its initial value to $2\frac{m^3}{s}$.

(10%) (a) Compute the transfer function $\delta h/\delta q_i$ (δ indicates deviation variable) for Case I and Case II around the initial steady state.

(10%) (b) Using the transfer functions, compute the transient response $\delta h(t)$ for each case.

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PROBLEM 4 (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(s)/U(s)

(10%) b) Solve for y in response to a unit step change in u.

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PROBLEM 5 (20% total)

A first order process is given by:

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

This process is controlled by a Proportional-Integral (PI) controller given by:

$$G_c(s) = k_c\left(1+\frac{1}{s}\right)$$

(10%) (a) Compute ranges of k_c values for which the closed loop is stable. Use the Routh Test.

(10%) (b) For $k_c = 1$, compute the closed loop time response for a unit step in the set point.

Note: 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.

PROBLEM 6 (20%)

Find the inverse transform for the following functions:

(10%) a) $Y(s) = \frac{s-3}{s(s^2-6s+18)}$, is the response stable?

(10%) b) $Y(s) = \frac{s-3}{s^2(s^2-6s+18)}$,is the response stable?

PROBLEM 7 (20% total)

A process is described by the following transfer function:

$$G_p = \frac{10e^{-5s}}{200s+1}$$

(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 10.

Note: 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.

PROBLEM 8 (20%)

A process given by

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

is controlled by a proportional controller with gain K_c.

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

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