PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Midterm Examination: Semester I Academic year: 2009
Date: July 27, 2009 Time: 9.00-12.00
Subject: 230 – 425 Process Dynamics and Control Room: หัวหุ่นยนต์

ทุจริตในการสอบ โทษขั้นต่ำ คือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

- **Only hand written note on a sheet of A4, calculator and a dictionary are allowed.**
- There are 9 pages of the exam.
- Write your name or your code on each page.
- If need to write the answers on the back of each page, please identify the problem number.

Problem Number	Score	
1	20	
2	20	
3	40	
4	50	
5	50	
Total	180	

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Table 1 Laplace Transform

F(s)	f(t), t > 0
$Y(s) = \int_0^{\infty} \exp(-st) y(t) dt$	y(t)
Y(s)	$y(t) = \frac{1}{j2\pi} \int_{c-j\infty}^{c+j\infty} \exp(st) Y(s) ds$
$s^n Y(s) - s^{n-1}[y(0)] - s^{n-2}[y'(0)] - \cdots - s[y^{(n-2)}(0)] - [y^{(n-1)}(0)]$	nth derivative $y^{(n)}(t)$
$\frac{1}{s} F(s)$	$\int_0^t Y(\tau) d\tau$
F(s)G(s)	$\int_0^t f(t-\tau) g(\tau) d\tau$
$\frac{1}{\alpha} F\left(\frac{s}{\alpha}\right)$	$f(\alpha t)$
$F(s-\alpha)$	$\exp(\alpha t) f(t)$
$\frac{1}{s^2 - \alpha^2}$	$\frac{1}{\alpha} \sinh(\alpha t)$
$\frac{s}{s^2 - \alpha^2}$	$\cosh(\alpha t)$
$\arctan\left(\frac{\alpha}{s}\right)$	$\frac{1}{t} \sin(\alpha t)$
1	$\delta(t)$,
$\exp(-\alpha s), \quad \alpha \geq 0$	$\delta(t-\alpha)$
$\frac{1}{s}$	u(t)
$\frac{1}{s} \exp(-\alpha s)$	$u(t-\alpha)$
$\frac{1}{s^n}, \quad n = 1, 2, 3, \ldots$	$\frac{t^{n-1}}{(n-1)!}$
$\frac{1}{s+\alpha}$	$\exp(-\alpha t)$
$\frac{1}{(s+\alpha)^n}$, n=1, 2, 3,…	$\left[\frac{t^{n-1}}{(n-1)!}\right] \exp(-\alpha t)$
$\frac{\alpha}{s^2 + \alpha^2}$	$\sin(\alpha t)$
$\frac{s}{s^2 + \alpha^2}$	$\cos(\alpha t)$
$\exp(-\alpha s) F(s)$	$F(t-\alpha)$

1. (20 points) Write "**T**" for correct statement and "**F**" for false statement (2 points for the correct answers and **-1** point for incorrect answers)

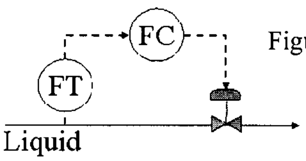


Figure ***a***

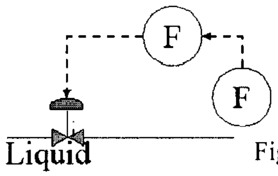


Figure ***b***

a) ____ Figure ***a*** is feed back control.

b) ____ Figure ***b*** is feed back control.

c) ____ Both feed back control and feed forward control require a measured variables.

d) ____The process variable to be controlled is measured in feedback control.

e) ____Feed forward controls definitely provide perfect control for all cases.

f) ____ Feedback control will always take action regardless of the accuracy of any process model that was used to design it and the source of a disturbance.

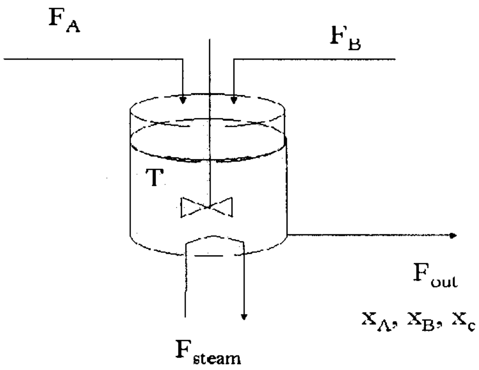
g) ____A transfer function can be used to provide information about how a process will respond to an input. For a particular input change, it provides only steady-state information about the resulting output change.

h) _____ A model equation developed using first principles contain the term $C_v h^{1.5}$ where C_v is a constant and h is a variable. The linearized form expressed in term of deviation variable h' is: $\frac{3}{2} C_v \bar{h}^{1/2} h'$

i) _____Laplace transform methods that form the basis for the development of transfer functions are only applicable, strictly speaking, when the process model is linear. If a process model is nonlinear, a transfer function that describes the process operation exactly can be obtained.

j) _____The following transfer function: $G(s) = \frac{5}{10s+1}$ has the steady-state gain of 5 and time constant of 0.1

2. (20 points) Fresh feed A and fresh feed B are fed to CSTR with the flow rate of F_A and F_B, respectively. The elementary reaction is assumed to use for A+B ⇔ C with reaction rate constant *k*(T). For safety reason, the level of the tank should not less than 1/3 and higher than 2/3 of the tank height. And for economic reason, the concentration of x_C must be higher than 95%. If the operator accidentally, opened valve for stream F_A greater than its steady-state opening" and F_B comes from the upstream.

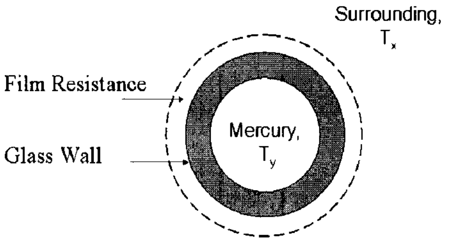


2.1 [10] In this case classify all variables in the table below (2 sets).

Controlled variables	**Disturbance**	**Manipulated variables**

2.2 [10] To eliminate the effect of changing in $F_{A,}$ Show feed forward control structure for the process.

3. (40 points) The temperature of the mercury in mercury thermometer can be described in the following equation:



$$mC\frac{dT_y}{dt} = hA(T_x - T_y) \qquad \text{eq. 3.1}$$

m = mass of mercury in bulb =1g

C = heat capacity of mercury = 0.25 cal/g °C

h = film heat transfer coefficient =20 cal/cm^2 hour °C

A= surface area of thermocouple = 3 cm^2

3.1 [5] Determine the assumptions for getting eq. 3.1

3.2 [15] From the differential equation, use Laplace transform and deviation variable to find transfer function of $T'_y(s) / T'_x(s)$

3.3 [20] If the thermocouple is initially at the room temperature of 23 °C and suddenly plunged into the 80 °C bath and held there for 20 seconds, (after that stays at the same room temperature)

a) Show the equation for T_y (t). (not in ODE form).

b) Find the maximum temperature of T_y.

c) Does the system have the steady state temperature? If it does find the final temperature of T_y.

4. (50 points) Liquid flow out of a spherical tank (diameter of D) discharging through a valve can be describe approximately by the following nonlinear differential equation:

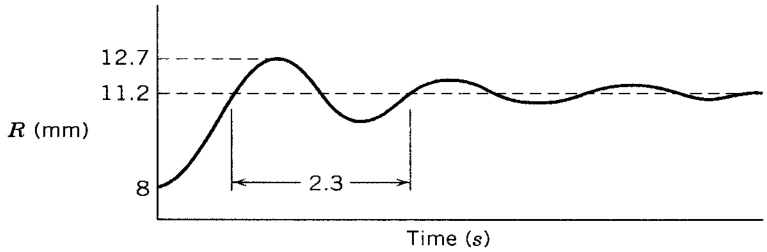
$$\frac{dh}{dt} = \frac{1}{\pi(D-h)h}(q_i - C_v\sqrt{h}),$$

4.1 [20] Derive a linearized model (in perturbation variables) of the form: $\frac{dh'}{dt} = ah' + bq_i'$

4.2 [15] Develop a transfer function related to the liquid level h' and volumetric input flowrate q'_i and provide the final steady gain and process time constant.

4.3 [15] From equation in 4.1, if a = -4 and b =1 for $q_i'(t) = \begin{cases} 0 & t < 0 \\ m & 0 \le t < 1/m \\ 0 & t \ge 1/m \end{cases}$, find the response of h'(t).

5. (50 points) A step change from 15 to 31 psi in actual pressure (P (psi)) results in the measured response (R (mm)) from a pressure indicating element shown in Figure 5



5.1 [5] Find % overshoot and period of oscillation

% overshoot =__________________________

Period of oscillation = ___________________

5.2 [35] Assuming second order system, determine process gain, process time constant and damping and write an approximate transfer function in form

$$\frac{R'(s)}{P'(s)} = \frac{K}{\tau^{s}s^{2} + 2\zeta\tau s + 1}$$

5.3 [10] Write an equivalent differential equation model in tem of actual (not deviation) variable