BITS-Pilani Dubai, International Academic City, Dubai

Second Semester, Academic Year 2009-2010

Evaluation Component : **Comprehensive Examination (Closed Book)**

CHE C441 PROCESS CONTROL

Date : 25th May 2010
Duration: 3 hrs mts

Max. Marks: 75
Weightage: 25%

Note:- 1. ANSWER ALL QUESTIONS.
2. Make assumptions, if any, but explicitly indicate the assumptions made
3. Students will be provided Graph sheets, if required.

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1)

a) With the help of the schematic of a typical blending process as an illustrative example deduce its

i) design equation [1 M]

ii) Control question [2 M]

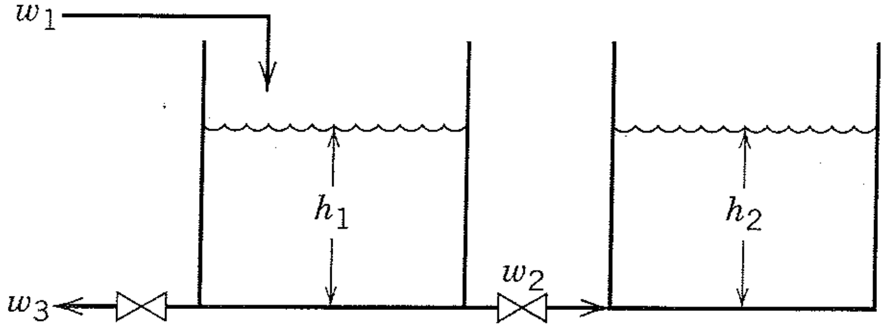
iii) Describe briefly each of the four most significant but varied control strategies for reducing the effect of disturbance variable on the control variable. [4 M]

b) By drawing a flow chart, organize typical process control activities in the form of a hierarchy with required functions at the lower levels and desirable, but optional functions at higher levels making the typical time-scale for each activity. [3+1=4 M]

2)

a) In the form of NINE self-explanatory steps, summarize the systematic steps for developing dynamic models from first principles for any typical process. [4.5 M]

b) Two tanks are connected together in the following unusal way



i) Develop a model for this system that can be used to find h_1, h_2, w_2 and w_3 as functions of time for any given variations in inputs. [4 M]

ii) Identify all input & output variables and perform degrees of freedom analysis. [1+1.5=2.5 M]

3)

a) Consider the transfer function: $G(s) = \frac{Y(s)}{U(s)} = \frac{5}{10s+1}$

i) What is the steady state gain and time constant? [1 M]

ii) If U(s) = 2/s, what is the value of the output y(t) when t tends to infinity? [2 M]

b) An electrically heated process is known to exhibit second-order dynamics with the following parameter values: K=3°C/kW, τ = 3 min, ξ=0.7. If the process initially is at steady state at 70 °C with heater input of 20 kW and the heater input is suddenly changed to 26 kW and held there:

(Please Turn Over)

i) What will be the expression for the process temperature as a function of time? [2]

ii) What will be the maximum temperature that one observers and when will it occur? [2+1=3M]

4)

a) List any four specific features, out of which, if a typical process is characterized by any one or more of those features, the process need to be considered as a "more complicated" process. [2 M]

b) A heat exchanger used to heat a glycol solution with a hot oil is known to exhibit first-order-plus-time-delay (FOPTD) behavior, $G_1(s)=T'(s)/Q'(s)$, where T' is the outlet temperature deviation and Q' is the hot oil flow rate deviation. A thermocouple is placed 3 m downstream from the outlet of the heat exchanger. The average velocity of the glycol in the outlet pipe is 0.5 m/s. The thermocouple also is known to exhibit first-order behavior; however, its time constant is expected to be considerably smaller than the heat exchanger time constant. Data from the unit step test in Q' on the complete system are shown in Figure.Q4b(i)a below.

i) Calculate the time constants of this process from the step response data employing Smith method (of fitting second- order models using unit steps) and the Smith method's relationships shown in Figure Q4b(i)b below. [3 M]

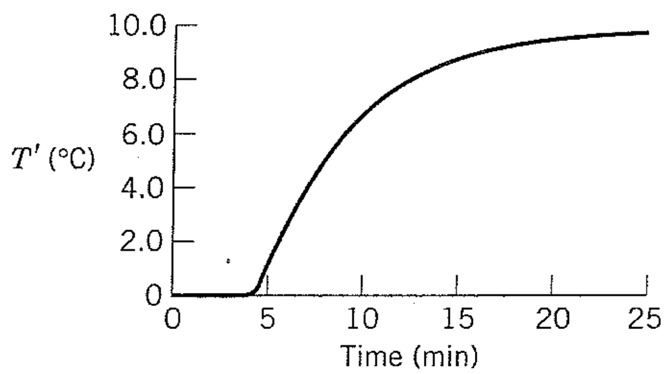


Figure.Q4b(i)a

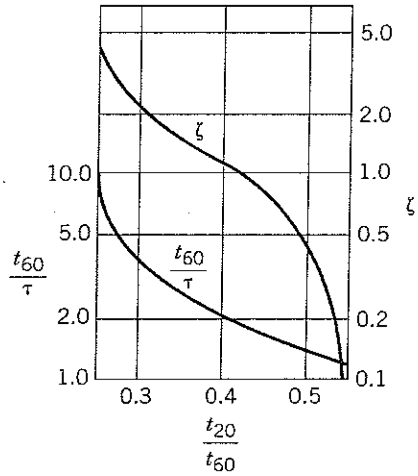


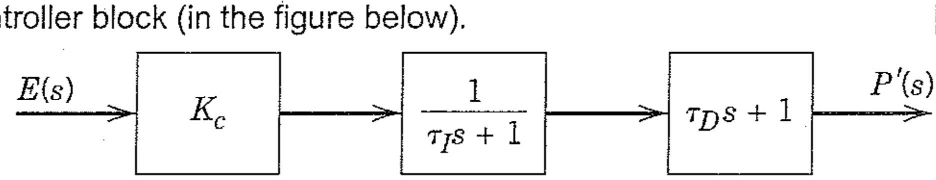
Figure.Q4b(i)b

ii) Indicating the process overall transfer function of the empirical model, find transfer functions for the heat exchanger, for the pipe and for the thermocouple. Think of the model as the product of three transfer functions: process, pipe flow, and sensor. [3 M]

iii) What assumptions do you have to make to obtain these individual transfer functions as in (ii) above from the overall transfer function? [2 M]

5)

a) What is the differential equation model of the series PID controller, shown below? Qualitatively describe its response to a step change in error signal, e(t), the input to the controller block (in the figure below). [2+2=4 M]



(continued in next page)

b) List all the five general requirements that need to be satisfied during an overview of a process control system design and discuss very briefly (in one or two sentences each) each one of them. [5 M]

6)

a) List & write a brief (in a couple of sentences) on each of the most important eight factors to be considered while selecting a measuring device [8 M]

b) A process temperature sensor/transmitter in a fermentation reactor exhibits second-order dynamics with time constants of 1 s and 0.1 s. If the quantity being measured changes at a constant rate of 0.1 °C /s,

i) What is the maximum error that this instrument combination will exhibit? [2 M]

ii) What is the effect of neglecting the smaller time constant? Show your result on a response plot. [2+2=4 M]

7) Write short notes on any FOUR of all the following four topics [4x3=12]

a) Linearization of non-linear models

b) Standard process inputs

c) Development of neural network models

d) Feedforward controller design based on dynamic models

e) An overview of Model Predictive control using its block diagram

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ALL THE BEST

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BITS-Pilani Dubai, International Academic City, Dubai

Second Semester, Academic Year 2009-2010

Evaluation Component : **TEST-II (Open Book)**

CHE C441 PROCESS CONTROL

Date : 9th May 2010 | **Max. Marks: 20**

Duration: 50 mts | **Weightage: 20%**

Note:- 1. ANSWER ALL QUESTIONS and ANSWER only to specific point being questioned.
2. Make assumptions, if any, but explicitly indicate the assumptions made
3. Students will be provided Graph sheets, if required.
4. Only the prescribed text book: Dale E Seborg et. al, Process Dynamics and Control, is allowed

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1) A process transfer has the function G(s)= K / {(10s+1)(5s+1)} where K has a nominal value of K = 1. PID controller settings are to be calculated using the Direct Synthesis approach with τ_c=5min. Suppose that these controller constants are employed and that K changes unexpectedly from 1 to 1+α,

   a) For what values of a will the closed-loop system be stable? (2.0 M)

   b) Suppose that the PID controller constants are calculated using the nominal value of K=1 but it is desired that the resulting closed-loop system be stable for $|\alpha| \le 0.2$. What is the smallest value of τ_c that can be used? (2.0 M)

   c) What conclusions can be made concerning the effect that the choice of τ_c has on the robustness of the closed-loop system to changes in steady-state gain K? (1.0 M)

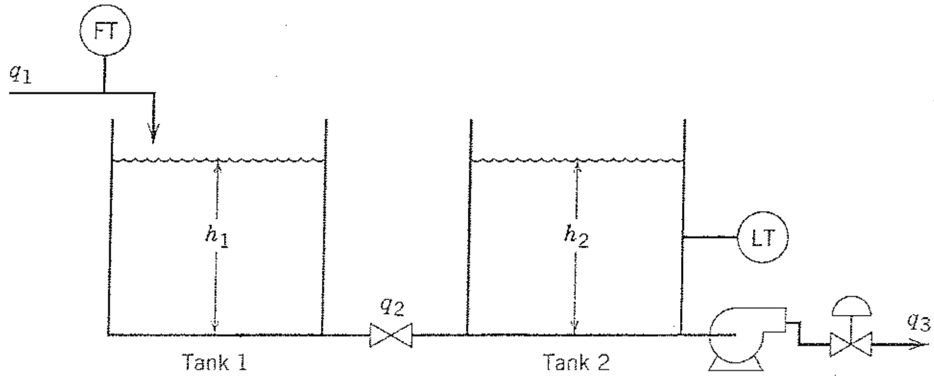
2) A data acquisition system for environmental monitoring is used to record the temperature of an airstream as measured by a thermocouple. It shows an essentially sinusoidal variation after about 15 s. The maximum recorded temperature is 127°F, and the minimum is 119°F at 1.8 cycles per min. It is estimated that the thermocouple has a time constant of 4.5 s. Estimate the actual maximum and minimum air temperatures. (2.0M)

3) A process that can be modeled as a time delay is controlled using a proportional feedback controller. The control valve and measurement device have negligible dynamics and steady-state gains of Kv = 0.5 and Km = 1, respectively. After a small set-point change is made, a sustained oscillation occurs, which has period of 10min.

   a) What controller gain is used? (2.0 M)

   b) How large is time delay? (2.0 M)

4) It is desired to control liquid level h_2 in the storage tank system shown in Fig. below by



manipulating flow rate q_3. Disturbance variable q_1 can be measured. Use the information available to do the following:

[Please Turn Over]

a) Draw a block diagram for a feedforward-feedback control system. (2.0 M)

b) Derive an ideal feedforward controller based on a steady-state analysis. (1.5 M)

c) Suppose that the flow-head relation for the hand valve is $q_2=C(h_1-h_2)^{1/2}$. Does the ideal feedforward controller of part (b) change? (1.5 M)

Available information

i) The two tanks have uniform cross-sectional areas, A_1 and A_2, respectively.

ii) The valve on the exit line of Tank1 acts as a linear resistance with a flow-head relation $q_2=(h_1-h_2)/R$.

iii) The transmitters and control valve are pneumatic instruments that have negligible dynamics.

iv) The pump operates so that flow rate q_3 is independent of h_2 when the control valve stem position is maintained constant.

5) A process control researcher has proposed a delay-time compensator of the form: $G_c = K_c\left(\dfrac{1+\tau_I s}{1+\tau_I s - e^{-\theta s}}\right)$ for a First-Order-Plus-Time-Delay (FOPTD) process with $K_c = 1/K_p$ and $\tau_I = \tau$.

a) Derive the closed-loop transfer function and show that the time delay is eliminated frm the characteristic equation. (3.0 M)

b) Will the closed-loop response exhibit overshoot? (1.0 M)

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ALL THE BEST

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BITS-Pilani Dubai,
Dubai International Academic City, Dubai
III Year, II Semester, Academic Year 2009-10

Evaluation Component : **TEST-I (Closed Book)**

CHE C441 PROCESS CONTROL

Date : 28th March 2010 **Max. Marks: 25**
Duration: 50 mts **Weightage: 20%**

Note:- 1. ANSWER ALL QUESTIONS
2. Make assumptions, if any, but explicitly indicate the assumptions made

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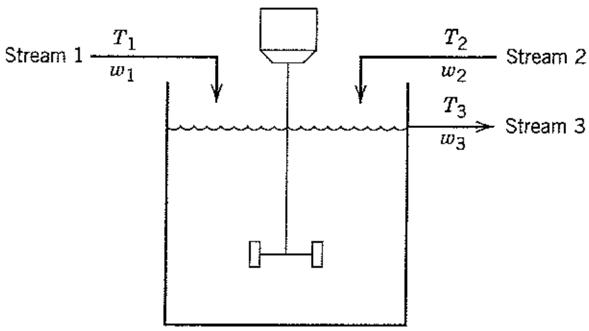
1)

a) Sketch a flow chart depicting the major steps in the development of process Control System, Indicating distinctly the engineering and the activities involved and the information base, if any, to be used for each activities. (2.0 M)

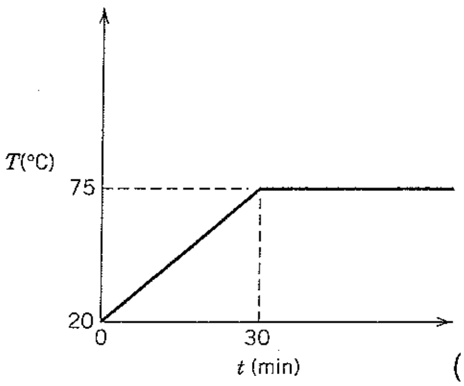
b) A perfectly stirred, constant – volume tank has two input streams, both consisting of the same liquid. The temperature and the flow rate of each of the streams can vary with time.



Derive a dynamic model that will describe transient operation. Make a degree of freedom analysis assuming that both stream1 and 2 come from upstream units (i.e their flow rates and temperature are known function of time) (2+1=3.0 M)

2)

a) The start–up procedure for batch reactor includes a heating step where the reactor temperature is gradually heated to the nominal operating temperature of 75°C.The desired temperature profile T(t) is shown in the figure . What is *T(s)*.. (2.0 M)



(Please Turn Over to Page 2)

b) For the process modeled by

$$2\frac{dy_1}{dt} = -2y_1 - 3y_2 + 2u_1$$

$$\frac{dy_2}{dt} = 4y_1 - 6y_2 + 2u_1 + 4u_2$$

Find the four transfer functions relating the outputs (y_1,y_2) to the inputs (u_1,u_2). Note that u and y are deviation variables. (3.0 M)

3)

a) A tank used to dampen liquid flow rate surges is known to exhibit second order dynamics. The input flow rate changes suddenly from 120 to 140 gal/min. An operator notes that the tank level changes as follows:

Before input change: Level = 6 ft and steady
Four minutes later: Level = 11 ft
Forty minutes later: Level = 10 ft and steady

i) Find a transfer function model that describes this process, at least approximately. Evaluate all parameters in your model, including units. (2.0 M)

ii) Is your model unique? Why or why not? (1.0 M)

b) State Skogestad's Half Rule. Using this rule, for the process described by the exact transfer function G(s) indicated below, find the approximate transfer function in the SOPTD form. (1+2=3.0M)

$$G(s) = \frac{5e^{-s}}{(10s+1)(4s+1)(s+1)(0.2s+1)}$$

4)

a) An operator introduces a step change in the flow rate q_i to a particular process at 3:05 A.M., changing the flow from 500 to 540 gal / min. The first change in the process temperature T (initially at 120°F) comes at 3:09 A.M. After that, the response in T is quite rapid, showing down gradually until it appears to reach a steady-state value of 124.7 °F. The operator notes in the logbook that there is no change after 3:34 A.M. What approximate transfer function might be used to relate temperature to flow rate for this process in the absence of more accurate information? What should the operator do next time to obtain a better estimate? (1+1=2.0M)

b) Briefly explain about Control Valve Positioners and Control Valve sizing (1.5+1.5 = 3.0M)

5) Explain about any two out of three common enhancements of the basic PID Controllers that greatly improve their performance. (4.0 M)

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WISH YOU ALL THE BEST

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NAME: ______________________; **ID NO:**______________________; Prog.:B.E. (Hons.) Chemical Engg.

Version B

BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

Course Code: **CHE C441** **THIRD YEAR** Date: 12.**04.10**

Course Title: **Process Control** **QUIZ - 2** Max Marks: **14**

Duration : 15 **minutes** Weightage: 7**%**

Instructions: 1.ANSWER All the questions **with most appropriate answer(s)**, at the space provided.
2. Make assumptions, if any, but explicitly indicate the assumptions made

1. The driving element in a measurement transducer used in Process control is termed as "______________________".

[1 M]

2. Fill-in the blanks of table below appropriately with variables the sensors indicated measures. [1.5 M]

Q. No.	Sensors	Variable
A	Magnetic Resonance Analysis (MRA) sensor	
B	Turbine	
C	Bubble Tube	
D	Bourdon Tube	
E	Pyrometer	
F	Tunable Diode laser absorption sensor	

3. The valve characteristic described by flow (f) Vs lift(l) for an equal percentile valve is given by ____________ [1M]

4. The design equation used for sizing control valve relates lift (l) to the actual flow rate (q) by the expression:

____ [1 M]

5. An measurement transducer has been installed to measure level. As per its calibration it is supposed to indicate: 20 m as 5 V DC and 0.5 m as 1V DC. Develop an expression for the output of this measurement transducer as a function of its input.

____ [1 M]

6. Indicate, in the brackets provided, whether the general guidelines provided for selection of controlled variables from the available output variables are True (T) or False (F) [1.5 M]

A. All variables that are not self-regulating may (or) may not be controlled variables. [ ]

B. Choose output variables (as controlled variables) that must be kept within equipment and operating constraints. [ ]

C. Select output variables (as controlled variables) that represent a direct measure of product quality. [ ]

NAME: ____________________; **ID NO:**____________________; Prog.:B.E. (Hons.) Chemical Engg.

Version B

7. List the most important five general requirements that any process control plant need to comply with while reviewing the entire control system design. [2.5 M]

   (i) ____

   (ii) ____

   (iii) ____

   (iv) ____

   (v) ____

8. Typical layers of protection in a modern chemical plant has the following three layers as its inner most layers: [1.5 M]

   (i) ____

   (ii) ____

   (iii) ____

   (iv) ____

9. Draw the "standard" block diagram of a feedback control system that can be used to arrive at closed loop transfer function, indicating inputs, outputs and the transfer functions of each block, employing symbols used in the **standard notation**, [3 M]

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NAME: ______________________; **ID NO:**______________________; Prog.:B.E. (Hons.) Chemical Engg.

Version A

BITS, PILANI – DUBAI

SECOND SEMESTER 2009 – 2010

Course Code: **CHE C441** | **THIRD YEAR** | Date: 22.**02.10**

Course Title: **Process Control** | **QUIZ-1** | Max Marks: **16**

Duration : 15 **minutes** | Weightage: **8%**

Instructions: 1.ANSWER All the questions **with most appropriate answer(s)**, at the space provided.
2. Make assumptions, if any, but explicitly indicate the assumptions made

1. Empirical models are obtained by ____ [1 M]

2. Indicate, in the brackets provided, whether the following statements are True (T) or False (F) [2.5 M]

A. Both Feedback and Feedforward control require a measured variable. [ ]

B. The process variable to be controlled is measured in feedback control. [ ]

C. Feedforward control can be perfect in the theoretical sense that the controller can take action via the manipulated variable even while the controlled variable remains equal to its desired value. [ ]

D. Feedforward control can provide perfect control; that is, the output can be kept at its desired value, even with an imperfect process model. [ ]

E. 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. [ ]

3. Match the following terms (a, b, c, d, e) with their corresponding description (1, 2, 3, 4, 5), by indicating the appropriate alphabets in the braces given against the later. [2.5 M]

(i)	Controlled Variable (CV)	1. Conversion of "feed" to products using certain operations	[ ]
(ii)	Disturbance Variable	2. Process variable that can be adjusted to keep CV near set point	[ ]
(iii)	Manipulated Variable	3. Process variable that is controlled	[ ]
(iv)	Process	4. Unsteady-state (or transient) process behavior	[ ]
(v)	Process dynamics	5. Process variable that affect CV but cannot be manipulated	[ ]

4. Depict pictorially hierarchy of process control activities along with time scale for each activity, in the space provided below: [2.5 M]

NAME: ______________________; **ID NO:**______________________; Prog.:B.E. (Hons.) Chemical Engg.

Version A

5. In a blending process use of a larger tank to ensure that the outlet composition remains at or near its desired value is a strategy that can be labeled as "________________________________". [1 M]

6. List the Six major steps in the development of Process Control System employing model based approach. [1.5 M]

(i) ______________________________________

(ii) ______________________________________

(iii) ______________________________________

(iv) ______________________________________

(v) ______________________________________

(vi) ______________________________________

7. Fill-in the blanks of table below appropriately with corresponding f(t) or its Laplace Transform F(s). [3 M]

Q. No.	f(t)	F(s)
A		1
B		$1/s^2$
C	$\cos \omega t$	
D	$\sin (\omega t + \phi)$	
E		$1/(s+b)$
F	df/dt	

8. The Model for the process involved in Double-pipe Heat Exchanger is called ____________________ parameter type model, since the process inherently employs parameter of that nature. [1M]

9. Transfer function is an ____ for the dynamic relation between a selected input and output of the process model. [0.5M]

10. Many important bioreactors are operated in a semi-continuous manner that is referred to as ________

________________________________ operation. [0.5M]

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