BITS-Pilani Dubai,
Dubai International Academic City, Dubai
IV Year, I Semester, Academic Year 2008-09

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

INSTR U451 PROCESS CONTROL (Elective)

Date : 9th Oct. 2008
Duration: 50 mts

Max. Marks: 20
Weightage: 20%

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

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1) Define the following terms with reference to Process Control Systems, in general:

a) Process

b) A controlled variable

c) A manipulated variable

d) A disturbance variable

e) Degrees of freedom

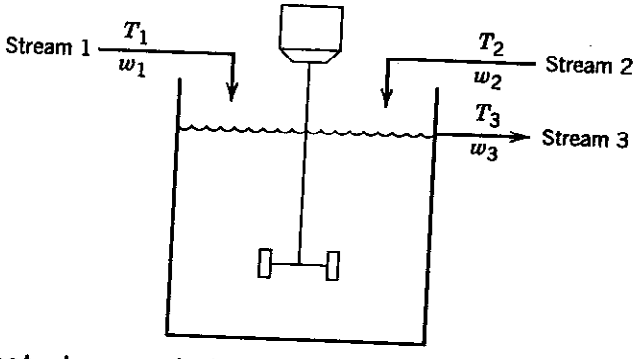
f) A dynamic model

g) A standard process input

(4.0 M)

2) a) Depict using a sketch the hierarchy of process control activities indicating the time scale for each activity. Briefly describe each activity. (1.5+3.0 M)

b) A stirred-tank blending process with a constant liquid hold up of 2 m^3 is used to blend two streams whose densities are both approximately 800 kg/m^3.



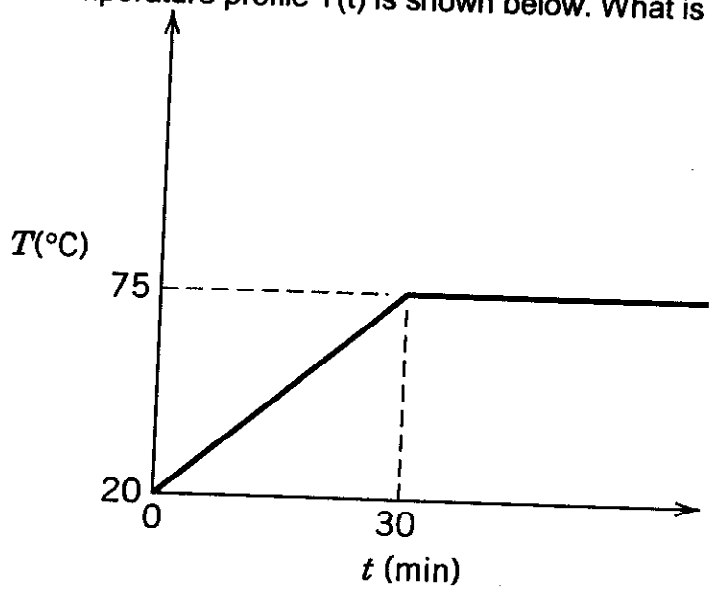
The density does not change during mixing. Assume that the process has been operating for a long period of time with flow rates of w_1=400 kg/min and w_2=250 kg/min, and feed compositions (mass fractions of x_1 = 0.4 and x_2 = 0.75.

i) What is the steady state value of x? (1.0 M)

ii) Suppose that w_1 changes suddenly from 400 kg/min to 300 kg/min and remains at new value, determine an expression for x(t). (1.5 M)

(Please Turn Over to Page 2)

3) The start-up procedure for a 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 below. What is T(s)? (2.0 M)



4)

a) For the following transfer function:

$$G(s)=\frac{Y(s)}{U(s)}=\frac{5}{10s+1}$$

What is

i) the steady-state gain? (4.0 M)
ii) time constant?
iii) the value of the output y(t)? when t tends to infinity assuming U(s) = 2/s
iv) the output when t=10 units? assuming the same U(s) as in iii.
v) the output when t tends to infinity if U(s) is a unit rectangular pulse:U(s) = $(1-e^{-s})/s$
vi) the output when t tends to infinity if u(t) is a unit impulse, $\delta(t)$

b) A heated process is used to heat a semiconductor wafer operates with first order dynamics, that is, the transfer function relating changes in temperature T to changes in the heater input power level P is:

$$\frac{T'(s)}{P'(s)}=\frac{K}{\tau s+1}$$

where K has units [°C/Kw] and t has units [minutes]. The process is at steady-state when an engineer changes the power input stepwise from 1 to 1.5 Kw. The engineer notes the following:

i) The process temperature initially is 80 °C.
ii) Four minutes after changing the power input, the temperature is 230°C.
iii) Thirty minutes later the temperature is 280°C.

Answer the following:

(1) What are K and τ in the process transfer function [1.0 M]
(2) If at another time the engineer changes the power input linearly at a rate of 0.5 kW/min, comment on the maximum rate of change of the process temperature: i.e., when will it occur? and How large will it be? [2.0 M]

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WISH YOU ALL THE BEST

BITS-Pilani Dubai,
Dubai International Academic City, Dubai
IV Year, I Semester, Academic Year 2008-09

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

INSTR U451 PROCESS CONTROL (Elective)

Date : 9th Nov. 2008
Duration: 50 mts

Max. Marks: 20
Weightage: 20%

Note:- 1. ANSWER ALL QUESTIONS – Use ordinary graph sheets, wherever necessary.
2. Make assumptions, if necessary, but explicitly indicate the assumptions made.
3. ONLY the PRESCRIBED TEXT titled: "Process Dynamics and Control" authored by: Dale E. Seborg, Thomas F.Edgar and Duncan A. Millichamp is allowed

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1) 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:

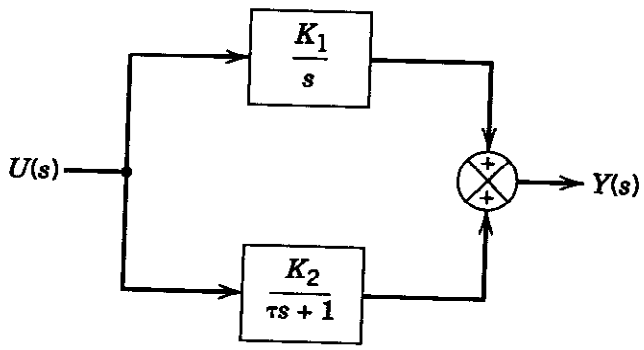
- before input change = 6 ft. and steady
- four minutes later =11 ft.
- forty minutes later = 10 ft. and steady

a) Find a transfer function model that describes this process, at least approximately. Evaluate all parameters in your model, including units. (1.5 M)

b) Is your model unique? Why or why not? – Justify. (0.5+1M)

2)

a) A process consists of an integrating element operating in parallel with a first-order element as indicated below:



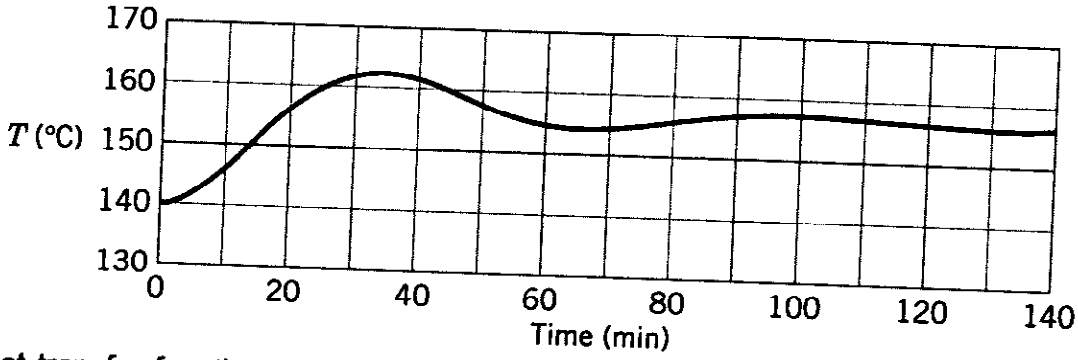
i) What is the order of the overall transfer function G(s)=[Y(s)] / [U(s)]? (0.5 M)

ii) What is the gain of G(s)? Under what condition(s) is the process gain negative? (1.5 M)

iii) What are the poles of G(s)? Where are they located in the complex s-plane? (1.0 M)

b) When an experimental data has been plotted a process is found to exhibit its response, as shown in next page,:

(Please Turn Over to Page No. 2)



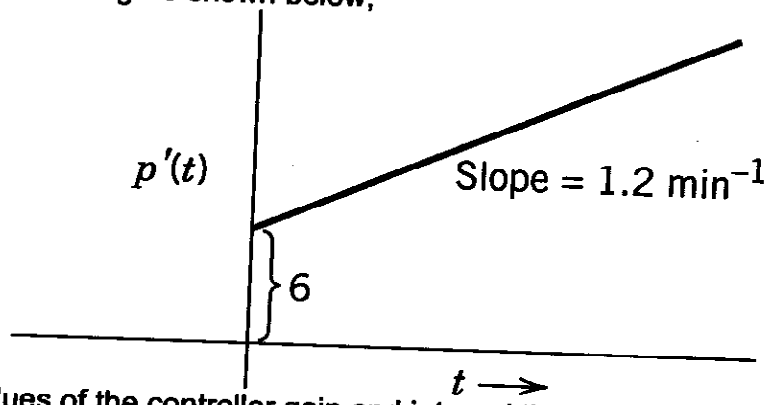
i) What transfer function approximately describes the operation of this process? Provide units for all parameters (1.5 M)

ii) If a ramp input was used instead, Q'=Bt with B>0, what would be the form of temperature response? – sketch the response without finding the analytical solution and state a few supporting arguments. (2.5 M)

3) Your boss has discussed implementing a level controller on a troublesome process tank that contains a boiling liquid. Someone told him that a level transmitter used with such a system has a very noisy output and that a P or PI controller will require a noise filter on the measurement.

a) Show how a measurement noise filter can be implemented with a PI controller by drawing a block diagram of the controller, modified with a first order transfer function (time constant=τ_f where $\tau_f << \tau_I$) in the appropriate location.? (1.0 M)

b) If the input Y_m to a PI controller changes stepwise: $Y_m(s) = 2/s$, and the controller output changes initially as in the figure shown below,



i) What are the values of the controller gain and integral time? (2.0 M)

ii) How would the above figure modified to illustrate the response of PI controller to a step change say in the filtered measurement, as in 3(a). If necessary, calculate (and also plot) the time response. (3.0 M)

iii) The company owning trouble some level process plant purchased, several years ago, a digital control system (with the controller's sampling interval = 1s) that provides a first-order digital filter as one of its many features. Indicate why this required noise filter ought to be implemented using an analog instrument, instead of using the available digital control system, during implementation? (2.0 M)

(Please Turn Over to Page No. 3)

4) A couple of linear transmitters have been installed and calibrated as follows:

T1	Flow rate	400 gal/min -> 15 psig 0 gal / min -> 3 psig	Pneumatic transmitter
T2	Pressure	30 in Hg -> 20 mA 10 in Hg -> 4 mA	Current transmitter

a) Develop an expression for the output of each transmitter as a function of its input. Be sure to include appropriate units. (1.0 M)

b) What is the gain of each transmitter? (1.0M

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WISH YOU ALL THE BEST

BITS ID No.:_____ Student Name:

BITS, Pilani-Dubai, International Academic City, Dubai

Surprize Quiz No.1

FIRST SEMESTER, ACADEMIC YEAR: 2008-2009.

INSTR C 451 PROCESS CONTROL

Date : 14th Sept. 2008

Duration:15 mts
Max.Marks:20

Note:- 1. Respond ALL questions with **"most appropriate"** answers.

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

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

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

   iii. 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. [ ]

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

   v. 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. [ ]

2. 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]

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: [5 M]

5. List the Six major steps in the development of Process Control System employing model based approach. [3 M]

i. _____

ii. _____

iii. _____

iv. _____

v. _____

vi. _____

6. Theoretical models are developed using the principles of _____ [1M]

7. Empirical models are obtained by _____ [1 M]

8. What should be the value of N_F, the degrees of freedom, if [1.5 M]

i. a process model is said to be exactly specified: _____

ii. a process model is said to be underspecified: _____

iii. a process model is said to be over-specified: _____

9. List the five steps involved in the Degrees of Freedom Analysis: [2.5 M]

i. _____

ii. _____

iii. _____

iv. _____

v. _____

* * * ALL THE BEST * * *

BITS ID No.:_____ Student Name: _____

BITS, Pilani-Dubai, International Academic City, Dubai

Surprize Quiz No.2

I Semester Academic Year: 2008-09

INSTR UC 451 PROCESS CONTROL

Date : 30th October 2008

Duration:15 mts
Marks :15

Note:- 1. Respond ALL questions with **"most appropriate"** answers.
2. Unless otherwise stated, all questions carry 1 mark each.

- - -

1. List the three most common forms of PID Controllers: [1.5 Marks]
   A. _____
   B. _____
   C. _____
2. Indicate typical range of following parameters in commercial PID controllers: [1.5 Marks]
   A. The Controller gain, K_c during Proportional mode: _____
   B. Integral time, τ_I during Integral Mode: _____
   C. Derivative time, τ_D during Derivative mode: _____
3. On-Off control is also referred as _____ or _____ control.
4. Express the controller output p(t) in terms of its input signal $y_m(t)$ and the desired set-point input $y_{sp}(t)$ in the space provided below and indicate when it can be called a reverse acting control or direct acting control.

   [2 Marks]

5. The response of a first order system subjected to a step input reaches 95% of its maximum at a time which equals _____.
6. Whenever two first order processes are connected in series the response of the overall system can be that of _____ order.
7. The response of a first order system can be characterized by the following two parameters: [2 Marks]
   A. _____
   B. _____
8. The dimensions of damping coefficient, ξ (zeta) in a typical second order system is:_____.
9. The degree of oscillation in the response after perturbation applied to a second order system is characterized by the parameter_____.
10. The system response will have larger oscillations when _____ (parameter) has smaller value.

11. In order to design a typical feedback controller, what are the three main aspects that one needs to answer / address?

    A. _____

    B. _____

    C. _____

12. The principal steady-state performance criterion usually employed while designing a Feedback control system is "_____".

13. The most often quoted simple performance criteria, while designing the feedback controllers are based on certain "characteristic features" of the closed loop response system. List any five of those characteristic features:

    A. _____

    B. _____

    C. _____

    D. _____

    E. _____

* * * ALL THE BEST * * *

BITS ID No.:_____ Student Name: _____

BITS, Pilani-Dubai, International Academic City, Dubai

Surprize Quiz No.4

I Semester Academic Year: 2008-09

INSTR UC 451 PROCESS CONTROL

Date : 18th December 2008

Duration:15 mts
Marks : 30

Note:- 1. Respond ALL questions with **"most appropriate"** answers.
2. Unless otherwise stated, all questions carry 1 mark each.

- - -

1. Feedback control has four inherent disadvantages as below which are addressed using Feedforward / Ratio control strategies: [4.0 Marks]
   A. _____
   B. _____
   C. _____
   D. _____
2. In a Ratio control, conceptually, the following ratio is controlled: The ratio of _____variable to _____ variable [2.0 Marks]
3. Indicate any two "specific" applications of Ratio Control: [2.0 Marks]
   A. _____
   B. _____
4. List the three steps using which feed forward controllers can be tuned: [3.0 Marks]
   A. _____
   B. _____
   C. _____
5. List any six different Enhanced Single-loop control strategies [6.0 Marks]
   A. _____
   B. _____
   C. _____
   D. _____
   E. _____
   F. _____
6. In _____ control, where process measurements that can be obtained more rapidly are used with a mathematical model sometimes called _____, to infer the value of the controlled variable. [2.0 Marks]
7. When the control problems have fewer manipulated variables than controlled variables, _____ are employed for sharing the manipulated variables among the controlled variables in a typical enhanced single-loop control strategy. [1.0 Mark]

8. If a typical process plant scenario is characterized with i) changes in equipment characteristics, ii)unusual operational status, iii) changes in product specifications or iv)inherent non-liner behavior _____ control can be employed as a enhanced single-loop strategy. [1.0 Mark]

9. List the three typical questions that the specifications of a typical computer-based system to perform data acquisition and control must address : [3 Marks]

   A. _____

   B. _____

   C. _____

10. In Digital sampling, filtering and control, Aliasing is a phenomenon described in terms of sampling of a sinusoidal signal as :_____

_____. [1 Mark]

11. The range of sampling period used for controller output changes in a typical control algorithm (say Astrom and Wittern mark) can be expressed as : _____. [1 Mark]

12. While tuning of digital controllers if sampling period is not small, use of zero-order-hold (ZOH) requires a modification in the controller design procedure because: the smapler plus ZOH introduces _____

_____. [2Marks]

13. In multi-loop control, draw, in the space provided below, the typical set-point response expected of while employing (i) manual or (ii)automatic control in a typical two loop control system, overlapping on plot on the other. [2 marks]

BITS-Pilani Dubai,
Dubai International Academic City, Dubai
IV Year, I Semester, Academic Year 2008-09

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

INSTR U451 PROCESS CONTROL (Elective)

Date : 24th Dec. 2008
Duration: 3 hours

Max. Marks: 100
Weightage: 35%

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

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1) Define the following terms with reference to Process Control Systems, in general:

a) Define the following terms with reference to Process Control Systems, in general:

i) Process

ii) A disturbance variable

iii) Degrees of freedom

iv) A dynamic model

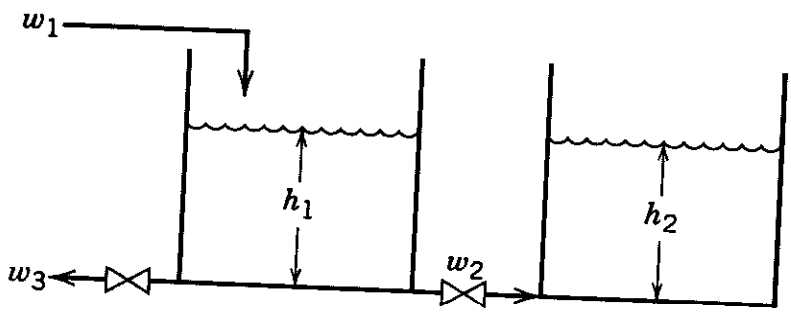
v) A standard process input

(5.0 M)

b) Draw a flow chart and explain all the major steps in designing and installing of a process control system, employing model based approach. (5.0 M)

2) a) Summarize the systematic step-by-step procedure for developing process dynamic models from first principles (5.0 M)

b) Two tanks are connected together in the following unusual way as in figure below. The density of the incoming liquid, ρ, is constant. The cross sectional areas of the two tanks are A_1 and A_2. W_2 is positive for flow from Tank 1 to Tank 2. The two valves are linear with resistances R_2 and R_3.



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 input. (3.0 M)

ii) Perform a degrees of freedom analysis. Identify all input and output variables. (2.0 M)

(Please Turn Over to Page 2)

3)

a) Depict (in the form of a flow chart) and summarize the general procedure to develop a transfer function of a nonlinear model. (5.0 M)

b) A stirred tank blending system initially is full of water and is being fed pure water at a constant flow rate, q. At a particular time, an operator adds caustic solution at the same volumetric flow rate q but concentration c_i. If the liquid volume V is constant, the dynamic model for this process is $V\frac{dc}{dt} + qc = qc_i$ with C(0)=0. Assume: V = 2 m^3; q = 0.4 m3/min; c_i = 50 kg/m^3.

i) What is the concentration response of the reactor effluent stream, c(t)? (3.0 M)

ii) Sketch it as a function of time. (2.0 M)

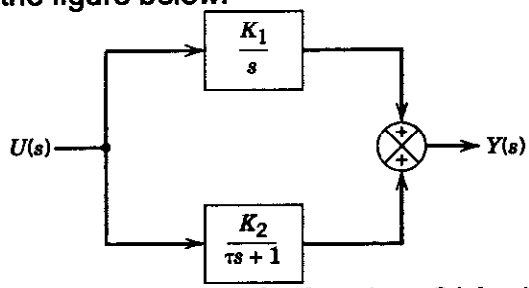
4) The dynamic model of a process is found to follow the following equation:

$$\frac{d^2y}{dt^2} + K\frac{dy}{dt} + 4y = u$$

a) Find the transfer function and put it in standard gain/time constant form. (5.0 M)

b) Discuss the qualitative form of the response of this system (independent of input forcing) over the range, -10 < K < 10. Specify the values of K where the response will converge and where it will not. Write the form of the response without evaluating any coefficients (5.0 M)

5) A process consists of an integrating element operating in parallel with a first order element as shown in the figure below:



a) What is the order of the overall transfer function, G(s) = Y(s) / U(s)? (1.0 M)

b) What is the gain of G(s)? (1.0 M)

c) Under what condition(s) is the gain negative? (1.0 M)

d) What are the poles of G(s)? and where are they located in complex-s plane? (1.0 M)

e) What are the zeros of G(s)? and where are they located? (1.0 M)

f) Under what condition(s) will one or more of the zeros be located in the right-half s-plane? (1.0 M)

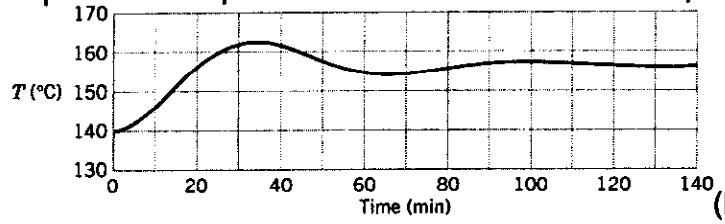
g) Under what condition(s), if any, can this process exhibit both a negative gain and a right-half plane zero? (1.0 M)

h) For any input change, what functions of time (response modes) will be included in the response, y(t)? (1.0 M)

i) Is the output bounded for any bounded input change, for example, u(t) = M? (2.0 M)

6)

a) A plot of the experimental data obtained about a process is found as shown below:

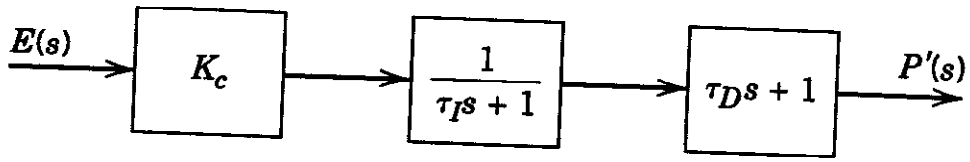


(Please Turn Over to Page 3)

i) What transfer function approximately describes the operation of the process? Provide units for all parameters. (3.0 M)

ii) If a ramp input was used instead, Q' = Bt with B>0, what would be the form of the temperature response? Sketch the response without finding the analytical solution and state a few supporting arguments justifying the same. (2.0 M)

b) Obtain the differential equation model of the series PID controller shown in figure below. Qualitatively describe its response to a step change in e(t). (5.0 M)



7) A thermocouple located in a thermowell and connected to a temperature transmitter is used to measure the liquid temperature in a bioreactor. A stead-state calibration of this instrument (transducer) yields the following data:

Temperature, °C	0	100	200	300	400
Measurement, mA	4.0	8.1	11.9	16.1	20.0

A process engineer runs a test on the reactor under controlled conditions in which its temperature is changed by +3°C/min. The transmitter output was recorded during this test, converted to oC, and compared with a standard thermometer which is known to be accurate and to have a time constant of 20s. The test data are:

Time from start of Test (min)		2.0	3.0	4.0	5.0
Temperature (°C)	**Std. Thermometer**	111.8	115.1	117.9	121.1
	T/C Transmitter	107.8	111.0	114.1	117.0

For steady state conditions, the standard thermometer and thermocouple-transmitter outputs are identical. If the transmitter / thermocouple can be modeled by a first-order transfer function, find K and τ. (10.0 M)

8)

a) List and briefly explain the five general requirements that every process control system designer need to address. (5.0 M)

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

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

ii) Suppose that PID controller constants are calculated using the nominal value of K = 1, but is desired that the resulting closed-loop system be stable for $|\alpha| \leq 0.2$, what is the smallest value of τ_c that can be used? (3.0 M)

9) Write a short notes on <u>any four</u> of the following the following

a) Guidelines for the Selection of controlled, manipulated and measured variables while designing process control system (5.0 M)

b) Feed forward controller design based on steady-state models (5.0 M)

c) Direct Synthesis for design of digital controllers (5.0 M)

d) Tuning of Multi-loop PID Controller Systems (5.0 M)

e) Stability of closed loop control systems (5.0 M)

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WISH YOU ALL THE BEST