KATHMANDU UNIVERSITY
End Semester Examination
February/March, 2018

Marks scored:

Level : B. E.
Year : III

Course : CHEG 302
Semester: I

Exam Roll No.: Time: 30 mins F.M. : 10

Registration No.: Date MAR 05 2018

SECTION "A"
[20 Q.×0.5=10 marks]

1. Which of the following is an undesirable dynamic characteristic of an instrument?
   a. Reproducibility b. Time lag c. Dead zone d. Static error

2. Pick out the one which is a first order instrument.
   a. Mercury in glass thermometer (without any covering or air gap)
   b. Bare metallic thermometer
   c. Bare vapor pressure thermometer
   d. All (a), (b) & (c)

3. Typical specifications for design stipulates the gain margin and phase margin to be respectively
   a. >1.7 and >30° b. <1.7 and >30° c. <1.7 and <30° d. >1.7 and <30°

4. For an input forcing function, $X(t) = 2t^2$, the Laplace transform of this function is
   a. $2/s^2$ b. $4/s^2$ c. $2/s^3$ d. $4/s^3$

5. The second order system with the transfer function $\frac{4}{s^2 + 2s + 4}$ has a damping ratio of
   a. 2.0 b. 0.5 c. 1.0 d. 4.0

6. A negative gain margin expressed in decibels means a/an __________ system.
   a. Unstable b. Stable c. Critically damped d. None of these

7. Instrumentation in a plant offers the advantage of
   a. Greater safety of operation b. Better quality of product
   c. Greater operation economy d. All of the above

8. The roots locus plot of the roots of the characteristics equation of a closed loop system having the open loop transfer function given below will have a definite number of loci for variation of K from 0 to ∞. The number of loci is
   a. 3
   b. 2
   c. 1
   d. 4

$$\frac{K(s + 1)}{2(2s + 1)(3s + 1)}$$

9. What is the Laplace transform of sin t?
   a. $1/(s^2+1)$ b. $s/(s^2+1)$ c. $1/(s^2-1)$ d. $s/(s^2-1)$

10. Pick out the wrong statement.
   a. There is no transfer lag for a single first order system.
   b. Stirred tank with a water jacket exemplifies an interacting system.
   c. Transfer lag is a characteristics of all higher order systems (other than first order systems).
   d. Transfer lag decreases as the number of stages decreases.

11. The frequency at which maximum amplitude ratio is attained is called the __________ frequency.
   a. Resonant   b. Cross-over   c. Corner   d. Natural

12. In Bode plot, Φ *vs* ω is plotted on a/an __________ graph paper.
   a. Ordinary   b. Semi-log   c. Log-log   d. Triangular

13. Bode stability method uses __________ loop transfer function.
   a. Open   b. Closed   c. Either (a) or (b)   d. Neither (a) nor (b)

14. Phase lag of the frequency response of a second order system to a sinusoidal forcing function
   a. is 30°   b. is 90° at the most
   c. approaches 180° asymptotically   d. is 120°

15. Routh stability method uses __________ loop transfer function.
   a. Open   b. Closed   c. Either (a) or (b)   d. Neither (a) nor (b)

16. The offset introduced by proportional controller with gain K_c in response of first order system can be reduced by
   a. reducing value of K_c b. introducing integral control
   c. introducing derivative control   d. none of the above

17. Cascade system responds faster than conventional control with __________ frequency of oscillation.
   a. lower   b. higher
   c. equal   d. is specific to the control system

18. For two step unit decrease in the process input, the signal from the feedforward controller should be compensated by ____________ if there is to be no change in the process output.
   a. four step decrease   b. one step increase
   c. two step increase   d. four step increase

19. The maximum flow through valve for a pressure drop of 100 psi is 35.6 gal/min. Find the C_v rating for a valve used to throttle the flow of glycerine for which sg = 1.26.
   a. 2.0   b. 5.0   c. 10.0   d. 4.0

20. The unit impulse response of a second order system with a gain of 5 always returns a steady state value of
   a. 5   b. 1   c. 0   d. 10

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SECTION "B"

Attempt the following questions

1.

a. Draw input signals for [4]

I. f(t) = u(t) + (t - 1)u(t - 1) - (t - 2)u(t - 2) - u(t - 3)

II. f(t) = 2u(t - 2) - (t - 2)u(t - 2) + (t - 4)u(t - 4)

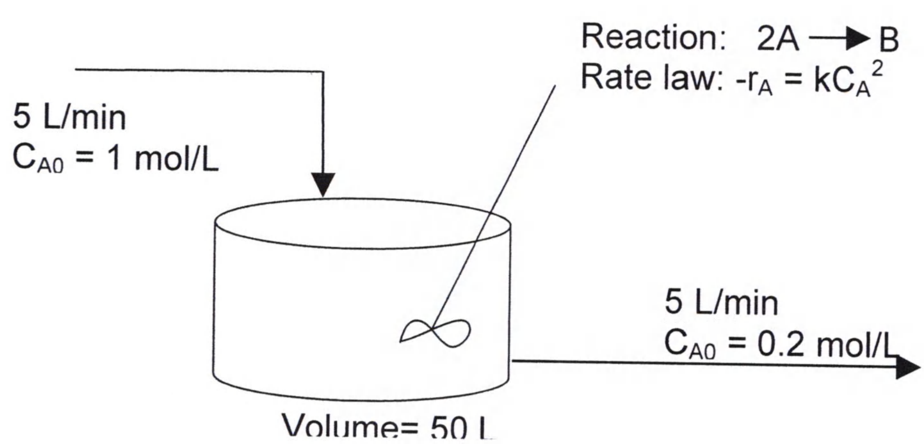
b. Solve the following using Laplace transforms. Do not invert the expression. [2]

$$\frac{d^2x}{dt^2}+3\frac{d\ x}{dt}+x=1 \qquad x(0) = x'(0) = 0$$

c. Invert the following transform: [2]

$$\frac{3s}{(s^2+1)(s^2+4)}$$

2. For the reactor (CSTR) shown in the figure below, determine the transfer function that relates the exit concentration from the reactor to changes in the feed concentration. If we instantaneously double the feed concentration from 1 to 2 mol/L, what is the new exiting concentration 1 min later? What is the new steady state reactor concentration? The rate constant is k = 2 $(mol/L)^{-1}(min)^{-1}$.
The reaction rate law is $-r_A = kC_A^2$, where r_A is the production rate of A in moles per liter per minute. [8]

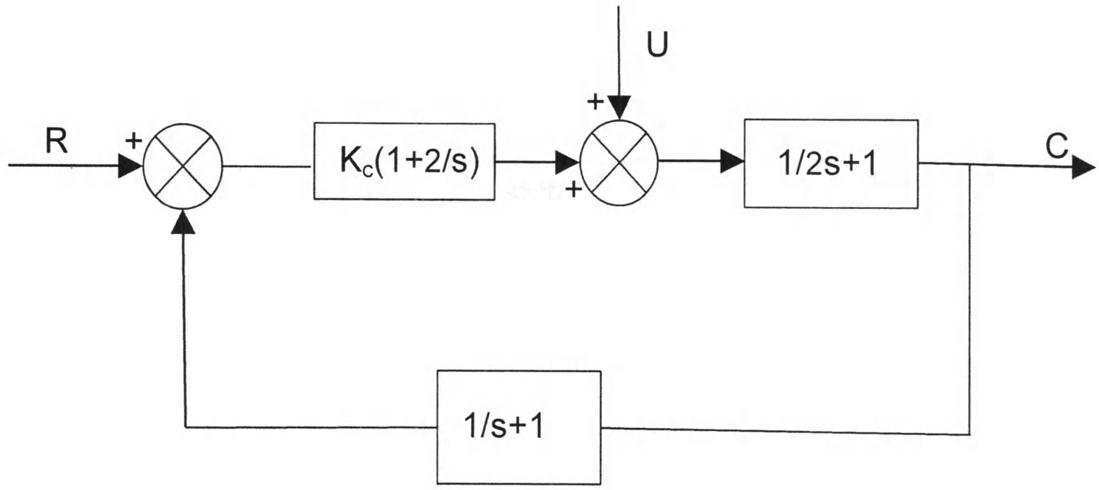


3. For the control system shown below

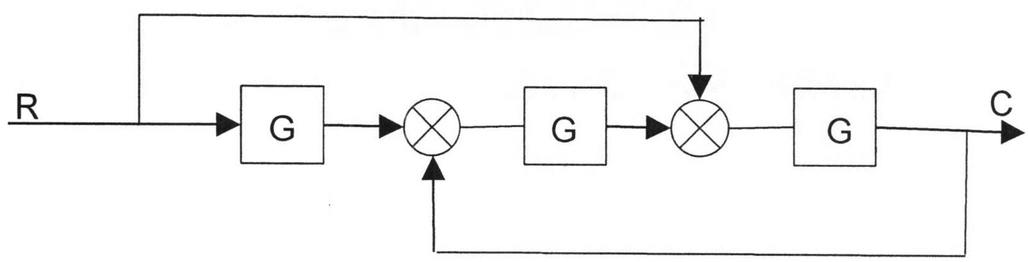
a. Write the characteristic equation. [2]

b. Use the Routh test to determine if the system is stable for $K_c = 4$ [2]

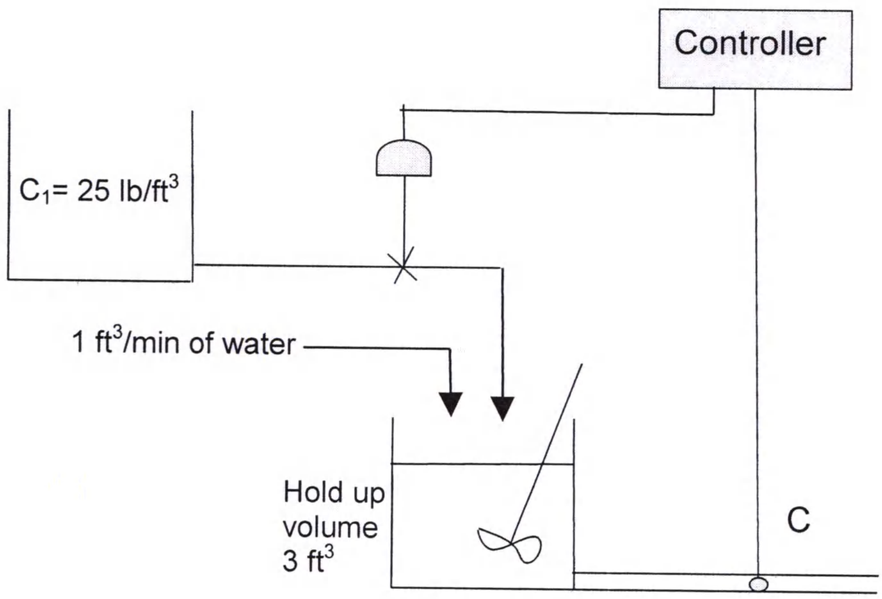
c. Determine the ultimate value of Kc above which the system is unstable [2]



4. Determine the transfer function C(s) / R(s) for the control system shown below. Express the results in terms of G_a, G_b and G_c. Show all the steps for full credit. [4]



5. The system shown in the Figure below is controlled by a proportional controller. The concentration of salt in the solution leaving the tank is controlled by adding a concentrated solution through a control valve.



The following data apply:

Concentration of concentrated salt solution $C_1 = 25$ lb salt/ft^3 solution.

Controlled concentration C = 0.1 lb salt/ft^3 solution.

Control valve: The flow through the control valve varies from 0.002 to 0.006 ft^3/min with a change of valve top pressure from 3 to 15 psi. This relationship is linear.

Distance velocity lag: It takes 1 min for the solution leaving the tank to reach the concentration measuring element at the end of the pipe. Neglect lags in the valve.

a. Draw a block diagram of the control system. Place in each box the appropriate transfer function. Calculate all the constants and give the units. [6]

b. Using a rough frequency-response diagram and the Ziegler-nichols rules, determine the settings for the controller. [4]

c. Using the controller settings in part (b), calculate the offset when the set point is changed by 0.02 unit of concentration. [4]

OR

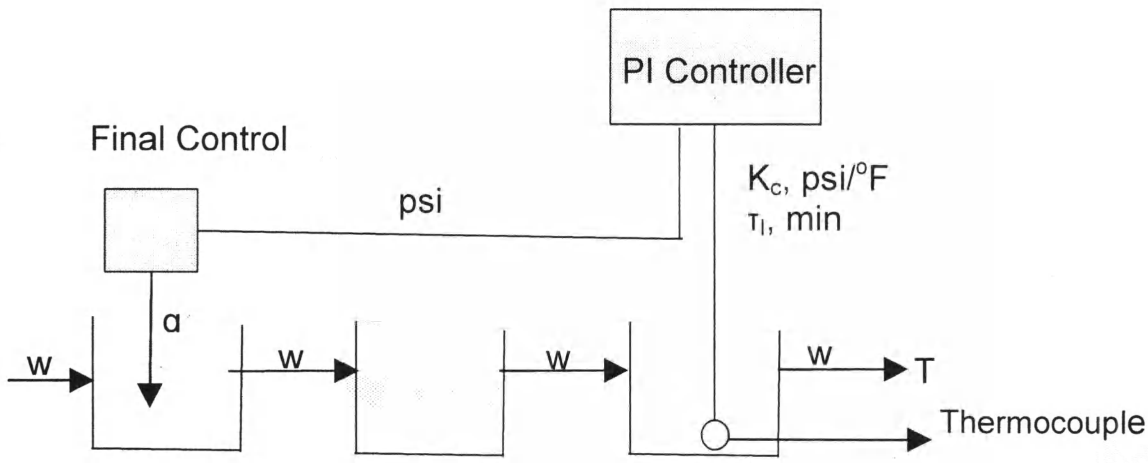
The stirred tank heater system shown in the figure below is controlled by a PI controller. The following data apply:

Flow rate ω of liquid through the tanks: 250 lb/min

Holdup volume of each tank: 10 ft^3

Density of liquid: 50 lb/ft^3

Final control element: A change of 1 psi from the controller changes the heat input q by 100 Btu/min. The final control element is linear.



a. Draw a block diagram of the control system. Show in detail such things as units and numerical values of the parameters. [6]

b. Determine the controller settings by Ziegler-Nichols rules. [4]

c. If the control system is operated with proportional mode only, using the value of K_c found in part (b), determine the flow rate w at which the system will be on the verge of instability and oscillate continuously. What is the frequency of this oscillation? [4]

III-I. CHEG-302 — Table MAR 05 2018

TABLE 2.1

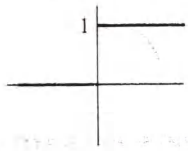
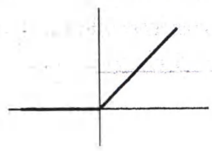
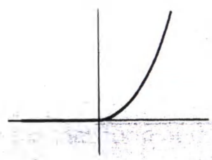
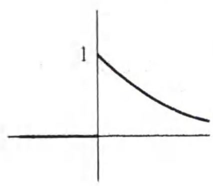
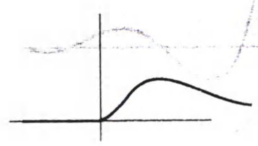
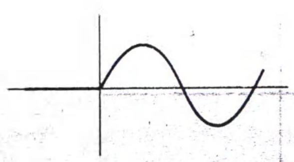
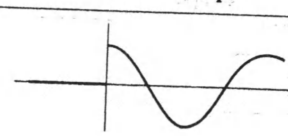
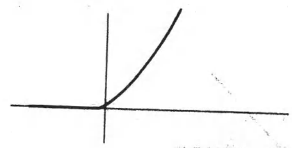
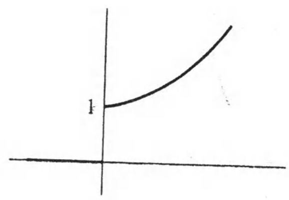
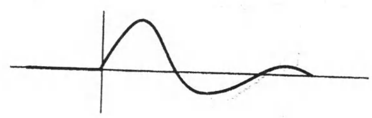
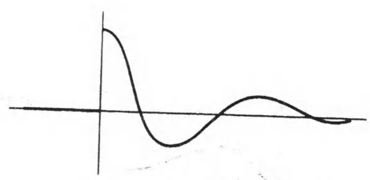
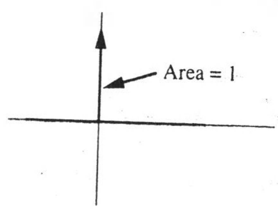
Function	Graph	Transform
$u(t)$		$\frac{1}{s}$
$tu(t)$		$\frac{1}{s^2}$
$t^n u(t)$		$\frac{n!}{s^{n+1}}$
$e^{-at}u(t)$		$\frac{1}{s+a}$
$t^n e^{-at}u(t)$		$\frac{n!}{(s+a)^{n+1}}$
$\sin kt\, u(t)$		$\frac{k}{s^2+k^2}$

TABLE 2.1 *(Continued)*

Function	Graph	Transform
$\cos kt\, u(t)$		$\frac{s}{s^2 + k^2}$
$\sinh kt\, u(t)$		$\frac{k}{s^2 - k^2}$
$\cosh kt\, u(t)$		$\frac{s}{s^2 - k^2}$
$e^{-at} \sin kt\, u(t)$		$\frac{k}{(s + a)^2 + k^2}$
$e^{-at} \cos kt\, u(t)$		$\frac{s + a}{(s + a)^2 + k^2}$
$\delta(t)$, unit impulse		1

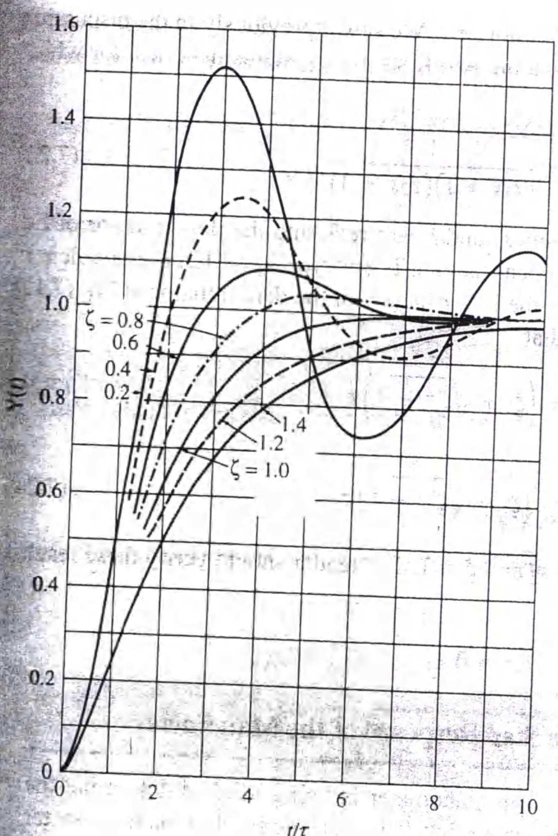


FIGURE 7–3
Response of a second-order system to a unit-step forcing function.

CASE III STEP RESPONSE FOR $\zeta > 1$. For this case, the inversion of Eq. (7.17) gives the result

$$Y(t) = 1 - e^{-\zeta t/\tau}\left(\cosh\sqrt{\zeta^2 - 1}\,\frac{t}{\tau} + \frac{\zeta}{\sqrt{\zeta^2 - 1}}\sinh\sqrt{\zeta^2 - 1}\,\frac{t}{\tau}\right) \tag{7.21}$$

where the hyperbolic functions are defined as

$$\sinh a = \frac{e^a - e^{-a}}{2}$$

$$\cosh a = \frac{e^a + e^{-a}}{2}$$

The procedure for obtaining Eq. (7.21) is parallel to that used in the previous cases.

The response has been plotted in Fig. 7–3 for several values of ζ. Notice that the response is nonoscillatory and becomes more "sluggish" as ζ increases. This is known as an *overdamped* response. As in previous cases, all curves eventually approach the line $Y = 1$.