REG.NO.:

VIT

Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

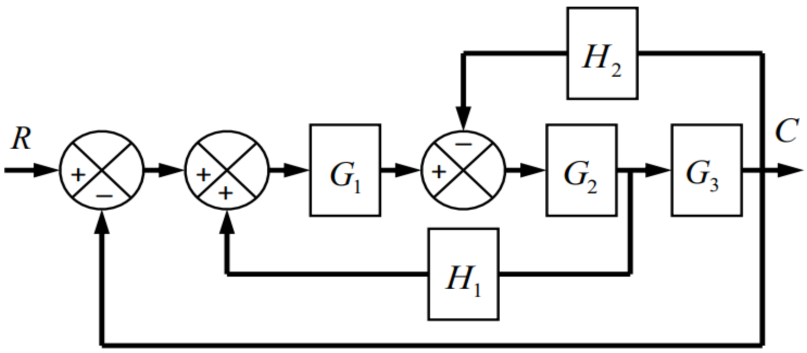
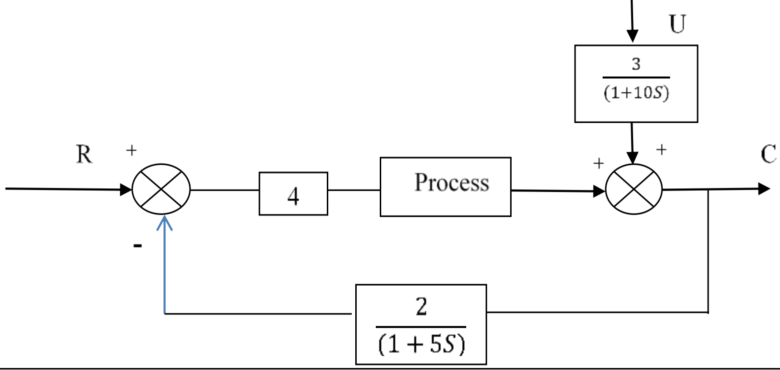
NAME OF THE SCHOOL: SCHEME
CONTINUOUS ASSESSMENT TEST - II
FALL SEMESTER 2024-2025

SLOT: B1+TB1

Programme Name & Branch	:	**B.TECH & Chemical Engineering**
Course Code and Course Name	:	**BCHE305L and Process Dynamics and Control**
Faculty Name(s)	:	**Dr.A. Babu Ponnusami**
Class Number(s)	:	**VL2024250103163**
Date of Examination	:	**14-10-24**
Exam Duration	:	**90 minutes** **Maximum Marks: 50**

<u>General instruction(s):</u>

- Answer All Questions
- M - Max mark; CO – Course Outcome; BL – Blooms Taxonomy Level (1 – Remember, 2 – Understand, 3 – Apply, 4 – Analyse, 5 – Evaluate, 6 – Create)
- Course Outcomes (Type the CO statements covered in this question paper. Use the CO number as per the syllabus copy)
  3. Identify the modes of control action required for closed loop control system and its stability in time domain.

Q. No	Question	M	CO	BL
1.	Obtain the transfer function for the following block diagram using block diagram reduction techniques 	10	3	BL 3
2.	For the control system shown in fig analyse offset values that results due to unit step change in ‘U’ when the process transfer function is (i) $\frac{1}{1+12S}$ and (ii) $\frac{1}{S(1+12S)}$ 	10	3	BL 4

REG.NO.:

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

NAME OF THE SCHOOL: SCHEME
CONTINUOUS ASSESSMENT TEST - II
FALL SEMESTER 2024-2025

SLOT: B1+TB1

3.	a) A PID controller is at steady state with an output pressure of 9 psi . The set point and pen point are initially together. At time t=0, the set point is moved away from the pen point at a rate of 0.5 inch/min. If the knob settings are Kc= 2 psi/inch, τ_i= 1.25 min and τ_D = 0.4 min. Plot the output pressure versus time.	5	3	BL3
	b) A Pneumatic temperature controller has an output range of 3 to 15 psi and a chart calibration of 0-200°C. If the output is 6 psi at 70°C, determine the proportional sensitivity when proportional band is 25% and the output at 100°C.	5		
4.	(a) A unit step change is given to PI controller. If the proportional sensitivity or gain Kc is 4, the integral time τ_I is 2, Obtain the response of the PI controller.	5	3	BL3
	(b) Under what circumstances proportional controller is consider as ON/OFF controller. A pneumatic proportional controller is used to control temperature within the range of 60°F to 110°F. The controller is adjusted so that the input pressure goes from 3 psi (fully open) to 15 psi (fully closed). Measured temperature goes from 76-80°F with set point set as constant. Calculate the gain and proportional band.	5		
5.	A feedback control system has the following transfer functions: Process : $G_p(S) = \frac{5}{[(2s+1)(s+1)]}$ Measurement: $H(s) = \frac{1}{(0.5s+1)}$ Final control element : $G_v(s) = \frac{0.2}{(0.1s+1)}$ Controller : $G_c(s) = K_c$ Using Routh's stability criterion obtain the range of K_c value for which the system is stable.	10	3	BL3

****

REG.NO.:

NAME OF THE SCHOOL: SCHEME
CONTINUOUS ASSESSMENT TEST - II
FALL SEMESTER 2024-2025

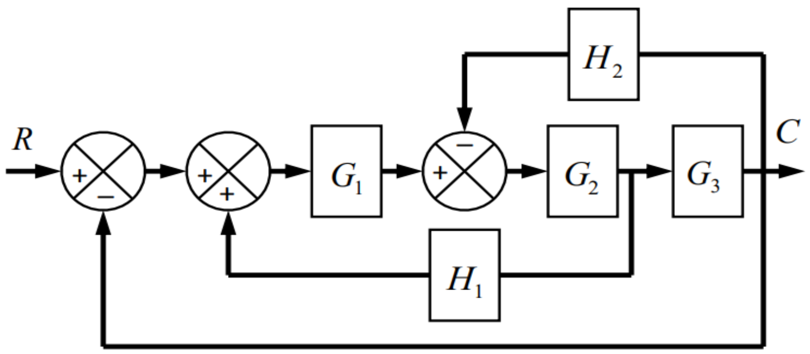
SLOT: B1+TB1

Programme Name & Branch	:	**B.TECH & Chemical Engineering**
Course Code and Course Name	:	**BCHE305L and Process Dynamics and Control**
Faculty Name(s)	:	**Dr.A. Babu Ponnusami**
Class Number(s)	:	**VL2024250103163**
Date of Examination	:	**14-11-24**
Exam Duration	:	**90 minutes**

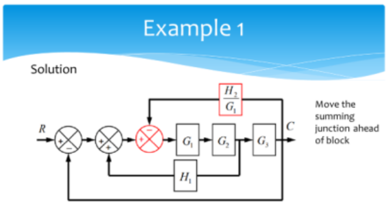
Maximum Marks: 50

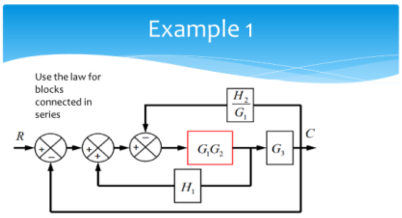
Answer Key

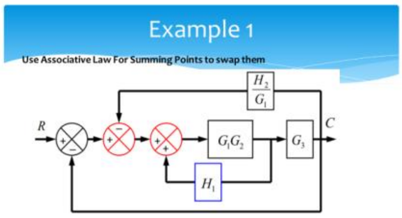
1. Obtain the transfer function for the following block diagram using block diagram reduction techniques

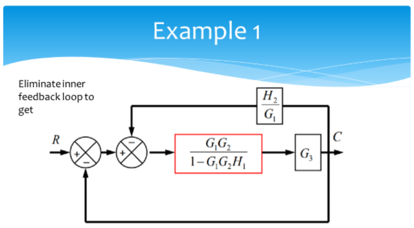


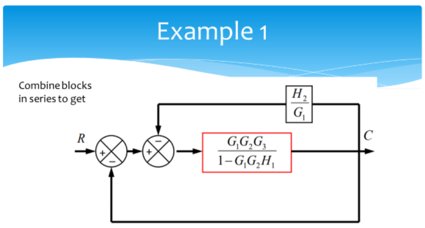
Ans:

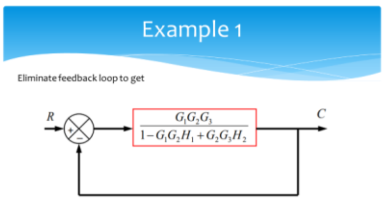


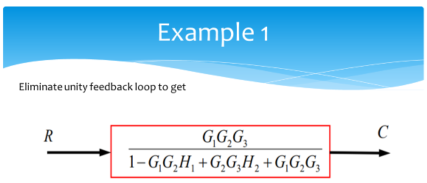












Vellore Institute of Technology

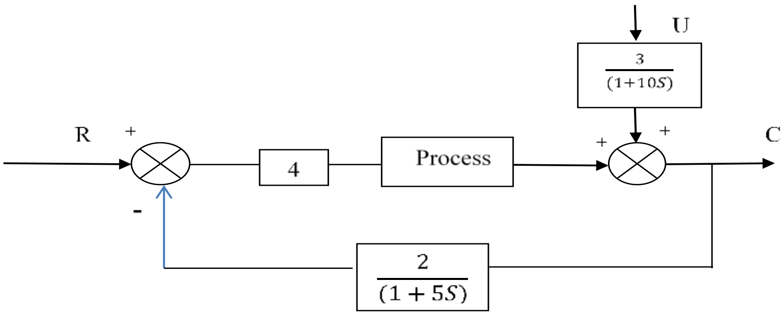
(Deemed to be University under section 3 of UGC Act, 1956)

REG.NO.:

NAME OF THE SCHOOL: SCHEME
CONTINUOUS ASSESSMENT TEST - II
FALL SEMESTER 2024-2025

SLOT: B1+TB1

2. For the control system shown in Fig find the offset that results due to unit step change in 'U' when the process transfer function is (i) $\frac{1}{1+12S}$ and (ii) $\frac{1}{S(1+12S)}$



Ans:

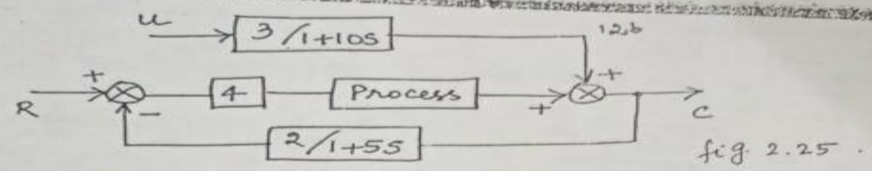
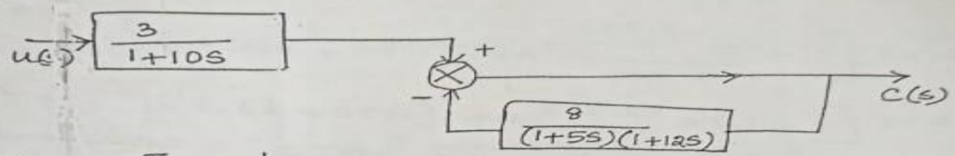


fig 2.25.

i) when the process transfer function is $\frac{1}{1+12s}$ & for a unit step change in u,



$$\frac{c(s)}{u(s)} = \left[\frac{1}{1+\frac{8}{(1+5s)(1+12s)}}\right]\frac{3}{1+10s}$$

$$\frac{c(s)}{u(s)} = \frac{3(60s^2+17s+1)}{(1+10s)(60s^2+17s+9)}$$

for a unit step change in u,

$$c(s) = \frac{3(60s^2+17s+1)}{s(1+10s)(60s^2+17s+9)}$$

$$\therefore \text{offset} = c_{sp}(\infty) - c(\infty)$$

$$\text{where } c(\infty) = \lim_{s\to 0} s\,c(s) = \lim_{s\to 0} \cancel{s}\left[\frac{3(60s^2+17s+1)}{\cancel{s}(1+10s)(60s^2+17s+9)}\right]$$

$$c(\infty) = 3/9 = 1/3$$

$$\therefore \text{offset} = 0 - \frac{1}{3} = -\frac{1}{3}$$

ii) when the process transfer function is $\frac{1}{s(1+12s)}$,

$$\frac{c(s)}{u(s)} = \left[\frac{1}{1+\frac{8}{s(1+5s)(1+12s)}}\right]\frac{3}{1+10s}$$

NAME OF THE SCHOOL: SCHEME
CONTINUOUS ASSESSMENT TEST - II
FALL SEMESTER 2024-2025

SLOT: B1+TB1

12.7

$$\frac{C(s)}{U(s)} = \frac{3s(60s^2+17s+1)}{[s(60s^2+17s+1)+8](1+10s)}$$

$$C(s) = \frac{3\cancel{s}(60s^2+17s+1)}{\cancel{s}[(60s^3+17s^2+s+8)(1+10s)]}$$

$$\therefore \text{offset} = 0 - \lim_{s\to 0} \frac{3s(60s^2+17s+1)}{(60s^3+17s^2+s+8)(1+10s)}$$

$$= 0 - 0 = \underline{\underline{0}}.$$

3. a) A PID controller is at steady state with an output pressure of 9 psi . The set point and pen point are initially together. At time t=0, the set point is moved away from the pen point at a rate of 0.5 inch/min. If the knob settings are Kc= 2 psi/inch, τi= 1.25 min and τD = 0.4 min. Plot the output pressure versus time.

Ans:

Ex. P. 2. A PID control is at steady state with an output pressure of 9 psi. The set point & pen point are initially together. At time $t=0$, the set point is moved away from the pen point at a rate of 0.5 inch/min. If the knob settings are $K_c = 2$ psi/inch, $\tau_i = 1.25$ min & $\tau_D = 0.4$ min. Plot the output pressure Versus time.

Solution:

Given Datas

$p_0 = 9$ psi, $K_c = 2$, $\tau_i = 1.25$, $\tau_D = 0.4$.

$e(t) = 0.5t$

The PID controller equation is,

$$P(s) = K_c\left[1 + \frac{1}{\tau_i s} + \tau_D s\right] E(s)$$

where $E(s) = \frac{0.5}{s^2}$

$$\therefore P(s) = \frac{2\times 0.5}{s^2}\left[1 + \frac{1}{1.25s} + 0.4s\right]$$

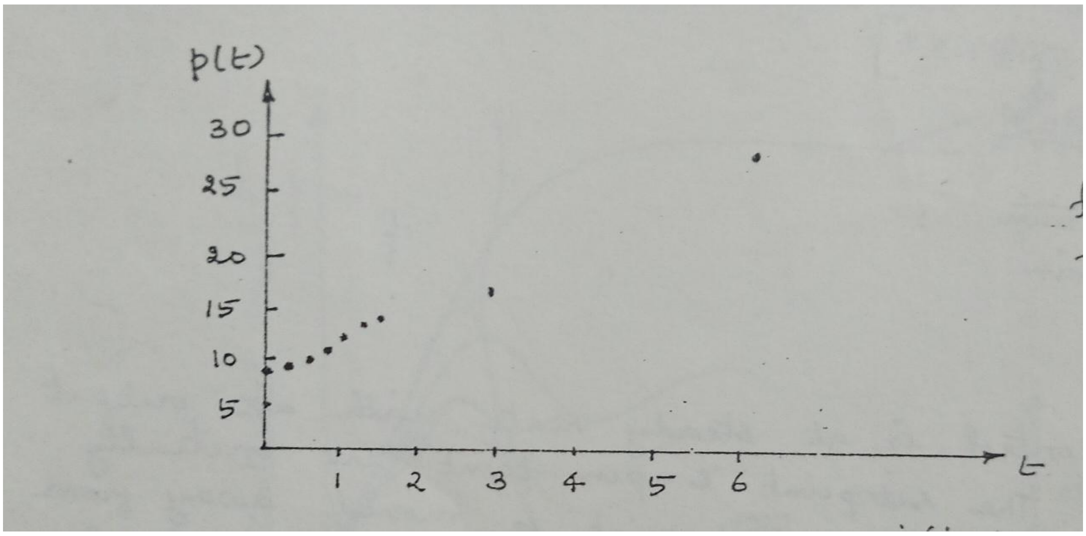
$$P(s) = \frac{1}{s^2} + \frac{1}{1.25s^3} + \frac{0.4}{s}$$

The inversion of above equation results in

$$p(t) = t + 0.4t^2 + 0.4 + 9.$$

The plot of output pressure Versus time is ~~used~~ obtained using table given below & shown in fig. 2.

t	0	0.2	0.4	0.6	0.8	1	1.25	1.5	3	6
$p(t)$	9.4	9.616	9.864	10.14	10.456	10.8	11.27	11.8	16	29.1



b) A Pneumatic temperature controller has an output range of 3 to 15 psi and a chart calibration of 0-200°C. If the output is 6 psi at 70°C, determine the proportional sensitivity when proportional band is 25% and the output at 100°C.

Ans:

Ex. P. 2.15 A pneumatic temp. controller has an o/p range of 3 to 15 lb/in² & a chart calibration of 0-200°c. If the o/p is 6 lb/in² at 70°c, determine the proportional sensitivity when PB is 25% & the o/p at 100°c & 125°c.

Solution:

$$PB = \frac{\text{measured Variable}}{\text{scale range}}$$

0.25×200 = measured Variable (or) temp change)

$\therefore$ temp change = 50

$$\text{sensitivity } (k_p) = \frac{\text{change in o/p}}{\text{temp change}} = \frac{15-3}{50} = 0.24 \text{ psi/°c}$$

The controller eqn. is

$$p = k_p e + p_0$$

$\therefore 6 = 0.24 \times 70 + p_0 \Rightarrow p_0 = -10.8$

Hence o/p pressure at 100°c $= 0.24 \times 100 - 10.8 = 13.2$ psi

4. (a) A unit step change is given to PI controller. If the proportional sensitivity or gain Kc is 4, the integral time τI is 2, Obtain the response of the PI controller.

(b) Under what circumstances proportional controller is consider as ON/OFF controller. A pneumatic proportional controller is used to control temperature within the range of 60°F to 110°F. The controller is adjusted so that the input pressure goes from 3 psi (fully open) to 15 psi (fully closed). Measured temperature goes from 76-80°F with set point set as constant. Find the gain and proportional band.

Ans:

a) $\frac{P(s)}{E(s)} = K_c\left(1+\frac{1}{\tau_I s}\right)$

$G(s) = \frac{1}{s}$

$P(s) = \frac{K_c}{s}\left(1+\frac{1}{\tau_I s}\right)$

Where $K_c=4$, $\tau_I=2$.

$P(s) = \frac{4}{s}\left(1+\frac{1}{2s}\right) \Rightarrow \frac{4}{s}+\frac{2}{s^2}$

$\boxed{P(t) = 4+2t}$

b) At higher values of Proportional gain, Proportional Controller consider as ON/OFF Controller.

Range of Controller 60–110°F

Change in Pressure, ΔP = 3psi – 15psi.

Measured temp range, ΔT = 76 – 80°F

Proportional gain = $\frac{\Delta P}{\Delta T} = \frac{15-3}{80-76} = \frac{12}{4} = 3$ psi/°F

Proportional band = $\frac{80-76}{110-60} = \frac{4}{50} \times 100 = 8\ \%$

5. Process : $G_p(S) = \frac{5}{[(2s+1)(s+1)]}$

Measurement: $H(s) = \frac{1}{(0.5s+1)}$

Final control element : $G_v(s) = \frac{0.2}{(0.1s+1)}$

Controller : $G_c(s) = K_c$

Using Routh's stability criterion range of K_c value for which the system is stable.

Ans:

REG.NO.:

NAME OF THE SCHOOL: SCHEME
CONTINUOUS ASSESSMENT TEST - II
FALL SEMESTER 2024-2025

SLOT: B1+TB1

(4)

$1 + G = 0$, $\quad 1 + G_c \times G_v G_p H = 0$

$$= 1 + \frac{5}{(2s+1)(s+1)} \times \frac{1}{(0.5s+1)} \times \frac{0.2}{(0.1s+1)} K_c = 0$$

$$= 1 + \frac{5/2}{(s+0.5)(s+1)} \times \frac{2}{s+2} \times \frac{2}{s+10} \times K_c = 0$$

$$\Rightarrow 1 + \frac{10K_c}{(s+1)(s+2)(s+0.5)(s+10)} = 0$$

$\rightarrow (s^2+3s+2)(s^2+10.5s+5)$

$\Rightarrow s^4 + 10.5s^3 + 5s^2 + 3s^3 + 31.5s^2 + 15s + 2s^2 + 20.5s + 10$

$= s^4 + 13.5s^3 + 38.5s^2 + 35.5s + 10$

$$\Rightarrow 1 + \frac{10K_c}{s^4 + 13.5s^3 + 38.5s^2 + 35.5s + 10} = 0$$

$\Rightarrow s^4 + 13.5s^3 + 38.5s^2 + 16s + 10 + 10K_c = 0 \quad$ —(4)

$0.1s^4 + 1.35s^3 + 3.85s^2 + 3.6s + (1+K_c) = 0$

s^4	0.1	3.85	$1+K_c$
s^3	1.35	3.6	
s^2	4.83	$1+K_c$	
s^1	$\frac{17.34 - 1.35 - 1.35K_c}{4.83} \Rightarrow (15.99 - 1.35K_c)/4.83$		
s^0	$1+K_c$		

—(4) marks

For the system to be stable, s^1 row & s^0 row > 0

$s^1 \Rightarrow \frac{15.99 - 1.35K_c}{4.83} > 0 \quad 15.99 > 1.35K_c$

$11.84 > K_c$ (or) $K_c < 11.84$

$s^0 \Rightarrow 1 + K_c > 0$

$K_c > -1$ (or) $K_c > 0$

$\therefore \boxed{0 < K_c < 11.84}$ —2 marks