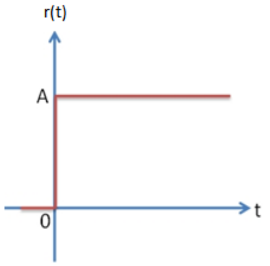
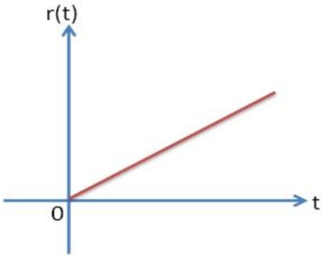
WINTER – 19 EXAMINATION

Subject Name: control system **Model Answer** Subject Code: 22541

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. The figures drawn by candidate and model answer may vary. The examiner may give credit for anyequivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constantvalues may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No .	Sub Q. N.	Answer	Marking Scheme
Q. 1		**Attempt any five of the following:**	**10-Total Marks**
	a)	**Define Linear time invariant control system.**	**2M**
	Ans:	Linear Time Invariant Control System: Linear Time Invariant Control System are those in which parameters of the system are independent of time that is not varying with time and are constants. **OR** A system is said to be Time Invariant if its input output characteristics do not change with time.	**Any one 2M**
	b)	**Draw and express mathematical equation of step and ramp test input.**	**2M**
	Ans:	a) Step input :  Expression: $r(t) = A\ for\ t \geq 0$ $= 0\ for\ t < 0$ OR $R(S) = \frac{A}{S^2}$ Ramp input:	**Diagram and expression 0.5 M each**



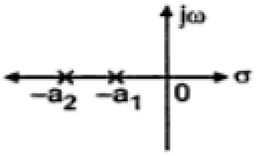
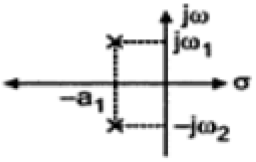
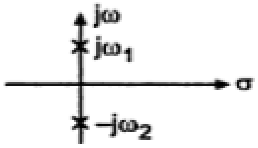
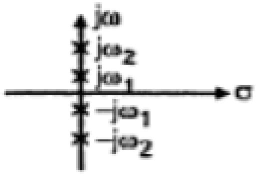
Expression: $r(t) = A.t\ for\ t \geq 0$

$$= 0\ for\ t < 0$$

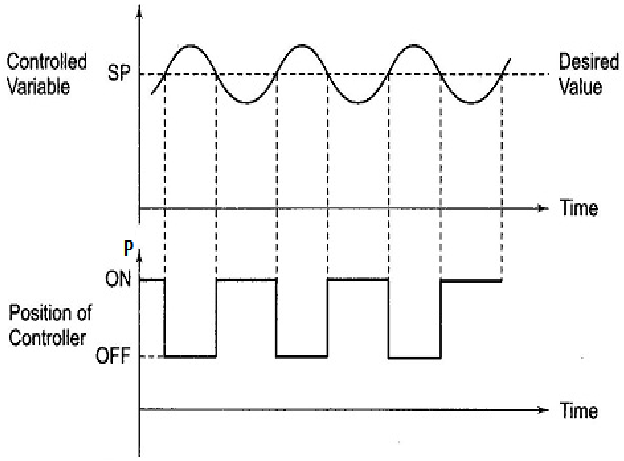
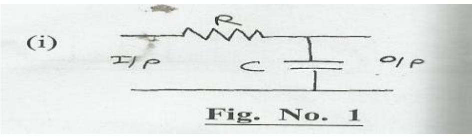
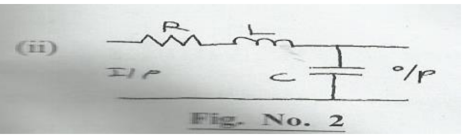
$$OR$$

$$R(S) = \frac{A}{S^3}$$

c)	**Draw the location of poles in S-plane for stable and marginally stable control system.**	**2M**
Ans:	(Note: Any one stable plot and marginally stable plot: 1M each)	**2M**

Stability Condition	**Location of Closed loop poles in S plane**
Absolutely Stable	
Absolutely Stable	
Marginally Stable or Critically Stable	
Marginally Stable or Critically Stable	

d)	**Draw and express the output of ON-OFF controller.**	**2M**
Ans:	Note: Output for any other relevant input can be considered.	**Output-1M**

		 Expression: $P = 100\%\ for\ e > 0$ $= 0\%\ for\ e < 0$	**Expression-1M**
	e)	**Define servo system and list the elements / blocks required in servo ststem.**	**2M**
	Ans:	Servo System: Servo systems are automatic feedback control system which works on error signals with output in the form of mechanical position, velocity or accelerations. Elements/Blocks require: 1. Error detector 2. Servo amplifier 3. Servo motor	**Definition-1M** **Elements/block-1M**
	f)	**Write the order of control system for:**  Fig. No. 1  Fig. No. 2	**2M**
	Ans:	(i) Fig 1 is order 1 (ii) fig 2 is order 2 control system	**1M each**
	g)	**Compare DC motor and DC servo motor.**	**2M**

Ans: **Note: Any 2 relevent point 1M each**

Sr. No.	DC motor	DC servo Motor
1	High Inertia	Low inertia
2	Diameter of the armature is more and its length is less	Diameter of the armature is less and its length is more
3	Comparatively Less torque	High Starting torque
4	Performance in load variation is good	Performance in load variation is poor
5	Less speed accuracy	Speed accuracy is better

2M

Q.2 **Attempt any THREE of the following:** **12-Total Marks**

a) **Find the transfer function of Refer Figure No.3** **4M**

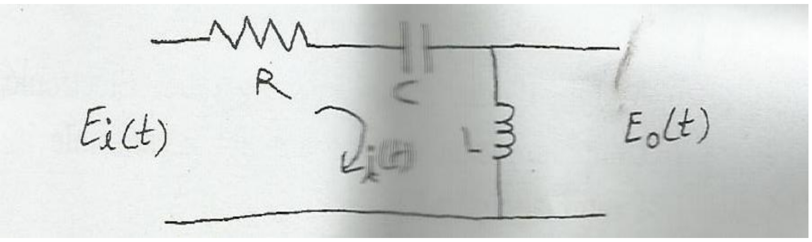


Fig.No. 3

Ans: Apply KVL to input, we get

Ei(t) = i(t)R + [1 / C] ∫[i(t)] dt +L[di(t) / dt].

Take Laplace transform,

Ei(s) = I (s) [R + 1/ SC + SL] ------- (1)

Output across inductor

Eo(t) = L[di(t) / dt].

Take Laplace transform,

Hence, Eo (s) = LS I(s) ------- (2)

Divide equation (2) by (1)

$$\frac{Eo(t)}{Ei(t)} = \frac{\text{LS I(s)}}{\text{I (s)}\left[\text{R} + \frac{1}{\text{SC}} + \text{SL}\right]}$$

$$\frac{Eo(t)}{Ei(t)} = \frac{\text{LS}}{\left[\text{R} + \frac{1}{\text{SC}} + \text{SL}\right]}$$

$$\frac{Eo(t)}{Ei(t)} = \frac{\text{LC S}^2}{[\text{S}^2\text{LC} + \text{RCS} + 1]}$$

Equation1-1M

Equation2-1M

Final Answer-2M

b) **For a given TF, T.F.=** $\frac{(s+4)}{s(s+2)(s+7)}$ **4M**

Find:

(i) Poles,

(ii) Zeroes,
(iii)Type of the system and
(iv)Characteristic equation.

Ans:

I. Poles: We can get poles from equations in the denominator ie

s(s+2)(s+7)=0

Therefore poles are

S=0, s= -2,s= -7

II. Zeros:

We can get zeros from equation in the numerator So for (s+4) equation we can get roots by comparing it with zero. (s + 4) = 0

So zeros i.e. roots of the equation are s= –4

III. Type of the system:

To determine the type of the system, it is require to bring G(s)H(s) into time constant form.

$$G(s)H(s) = \frac{4(1 + 0.25s)}{s * 2 * 7(1 + 0.5s)(1 + 0.14s)}$$

$$G(s)H(s) = \frac{0.286(1 + 0.25s)}{s(1 + 0.5s)(1 + 0.14s)}$$

Comparing it with standard time constant form we get

<u>**Type of the system is 1.**</u>

IV. Characteristic equation:

Standard equation is-1+G(s)H(s)=0

1+s(s+2)(s+7)=0

1+(s^2+2s)(s+7)=0

1+S^3+2s^2+7s^2+14s=0

S^3 + 9s^2 + 14s+1=0

1M each

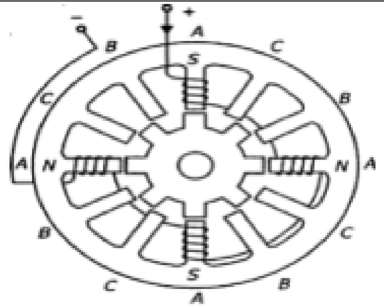
c) Explain the working of variable reluctance type stepper motor with neat diagram. **4M**

Ans:

The variable reluctance stepper motor is characterized by the fact that there is no permanent magnet either on rotor or stator. The rotor is made of soft iron stamping of variable reluctance and carries no windings as shown in the figure. The stator is also made up of soft iron stampings and is of salient poles type and carries stator windings.

Diagram-1.5M

Explanation-2.5M



As shown in the figure, when phase A is energized through supply, the rotor moves to the position in which the rotor teeth align themselves with the teeth of phase A. In this position the reluctance of the magnetic circuit is minimum. After this if phase A is deenergised and phase B is energized by giving proper supply to its winding (not shown in fig.), the rotor will rotate through an angle in a clockwise direction so as to align its teeth with those of phase B. After this, deenergising phase B and energizing phase C will make the rotor rotate by another angle in clockwise direction. Thus, by sequencing power supply to the phases the rotor could be made to rotate by a step of 15^0each time. The direction of rotation could be reversed by changing the sequence of supply to the phase, that is, for anticlockwise rotation, supply should be given in the sequence of ACB.

d) **Obtain the rise time (t_r), damping ratio (ζ), settling time (t_s) and maximum peak overshoot (M_p) for a unity feedback control system with open – loop T.F., G(s)=** $\frac{1}{s(s+1)}$. **4M**

Ans:

Open loop Transfer Function $G(s) = \frac{1}{s(s+1)}$

Standard form of closed loop T.F. $\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$

$$\frac{C(s)}{R(s)} = \frac{\frac{1}{s(s+1)}}{1+\frac{1}{s(s+1)}}$$

$$\frac{C(s)}{R(s)} = \frac{1}{s(s+1)+1}$$

$$\frac{C(s)}{R(s)} = \frac{1}{s^2+s+1}$$

1M each

Standard representation of a TF of a second order system is,

$$\frac{C(s)}{R(s)} = \frac{\omega n^2}{s^2+2\varepsilon\omega ns+\omega n^2}$$

Comparing the two expression

ωn^2=1

$$\omega n = 1$$

$$2\varepsilon\omega n = 1$$

$$\varepsilon = \frac{1}{2}$$

$$\omega d = \omega n\sqrt{1-\varepsilon^2}$$

$$\omega d = 1 * \sqrt{1-0.5^2}$$

$$\omega d = 0.866\, rad/sec$$

$$\theta = \tan^{-1}(\frac{\sqrt{1-\varepsilon^2}}{\varepsilon})$$

$$\theta = \tan^{-1}(\frac{\sqrt{1-0.5^2}}{0.5})$$

$$\theta = \tan^{-1}(\frac{0.866}{0.5})$$

$$\theta = \tan^{-1}(1.73)$$

$$\theta = 59.970^0$$

$$\theta = 1.0466\, rad$$

$$Tr = \frac{\pi-\theta}{\omega d}$$

$$Tr = \frac{\pi-1.0466}{0.866}$$

$$Tr = 2.42 sec$$

$$Ts = \frac{4}{\varepsilon\omega n}$$

$$Ts = \frac{4}{0.5 * 1}$$

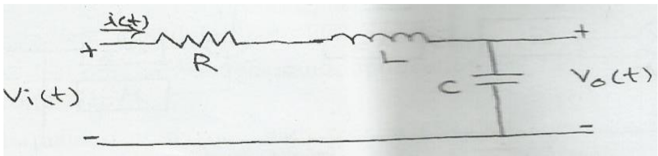
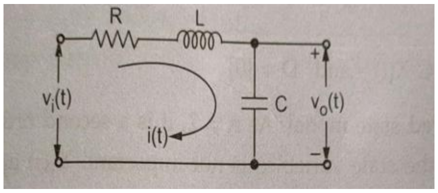
$$Ts = 8 sec$$

$$Mp = e^{\frac{-\pi\varepsilon}{\sqrt{1-\varepsilon^2}}}$$

$$Mp = e^{\frac{-\pi*0.5}{\sqrt{1-0.5^2}}}$$

$$Mp = e^{-1.81}$$

$$Mp = 0.163$$

Q.3		**Attempt any THREE of the following:**	**12-Total Marks**
	a)	**Obtain the differential equation and output equation into standard form of state space representation of the following circuit.** **Refer Figure No.4**  	**4M**
	Ans:	 	

TF = $\frac{V_0(S)}{V_i(S)} = = \frac{1}{LCS^2+RCS+1}$

Taking inverse LT and cross-multiplying,

1 M

$$LC\,\frac{d^2}{dt^2}V_0(t) + RC\frac{d}{dt}\,V_0(t) + V_0(t) = V_i(t)$$

$Input = V_i(t) = u(t)$

$$Output = V_0(t)$$

Therefore, first state variable $x_1 = V_0(t)$

Second state variable $x_2 = \frac{d}{dt}V_0(t) = \dot{x_1}$

$\dot{x_2} = \frac{d^2}{dt^2}V_0(t) = \frac{1}{LC}V_i(t) - (\frac{R}{L})\frac{d}{dt}\,V_0(t) - \frac{1}{LC}V_0(t)$

2M

$$\dot{x_2} = \frac{1}{LC}u(t) - \frac{R}{L}\,x_2 - \frac{1}{LC}\,x_1$$

SSR:

$$\dot{X} = AX + BU$$

$$Y = CX + DU$$

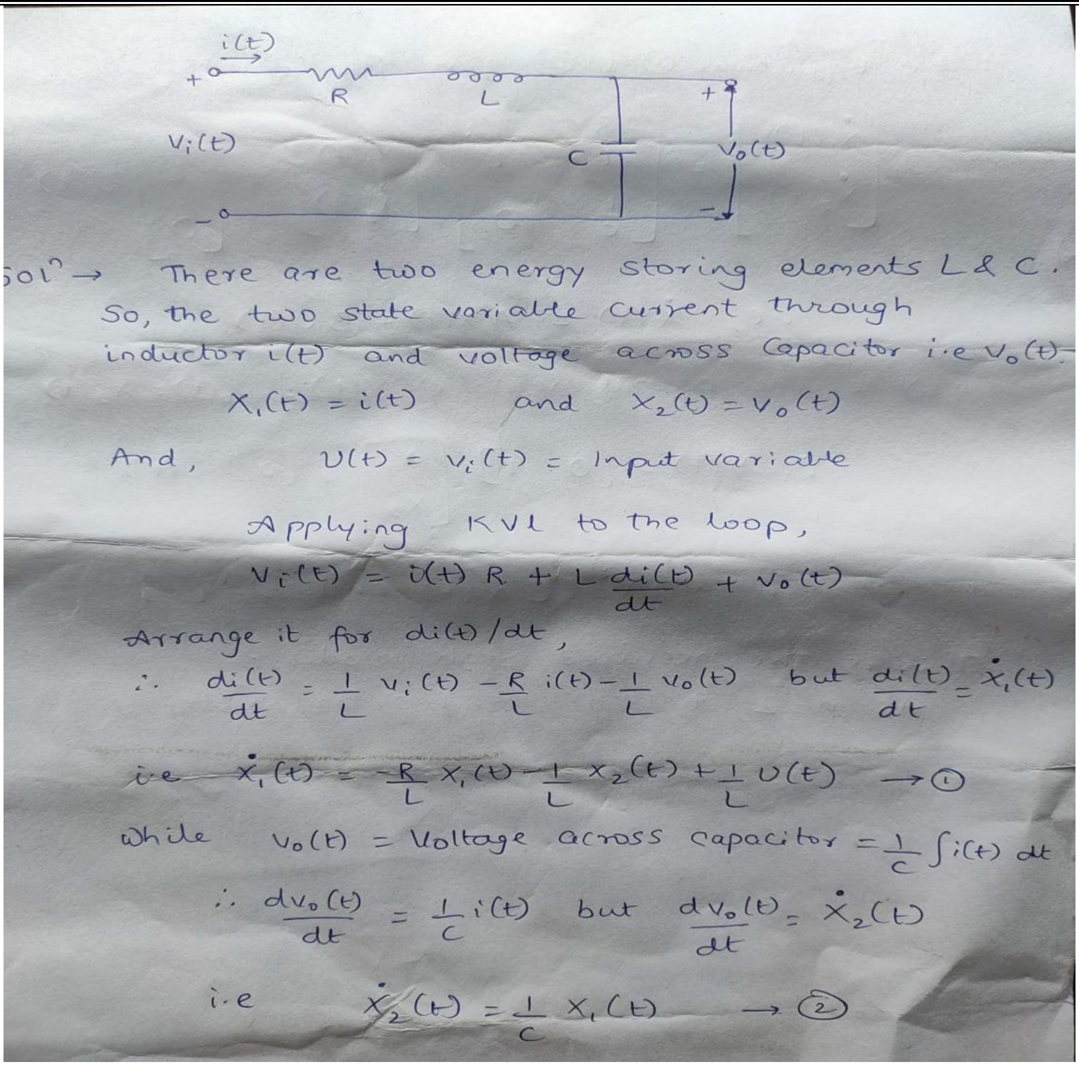
1M

$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -\frac{1}{LC} & -\frac{R}{L} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 & \frac{1}{LC} \end{bmatrix} u$

$$Y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

OR

There are two energy storing elements L and C so the two state variables are current through inductor i(t) and voltage across capacitor i.e. v_0(t).



Sol^n → There are two energy storing elements L & C. So, the two state variable current through inductor i(t) and voltage across Capacitor i.e $v_0(t)$.

$X_1(t) = i(t)$ and $X_2(t) = v_0(t)$

And, $U(t) = v_i(t)$ = Input variable

Applying KVL to the loop,

$$v_i(t) = i(t)R + L\frac{di(t)}{dt} + v_0(t)$$

Arrange it for di(t)/dt,

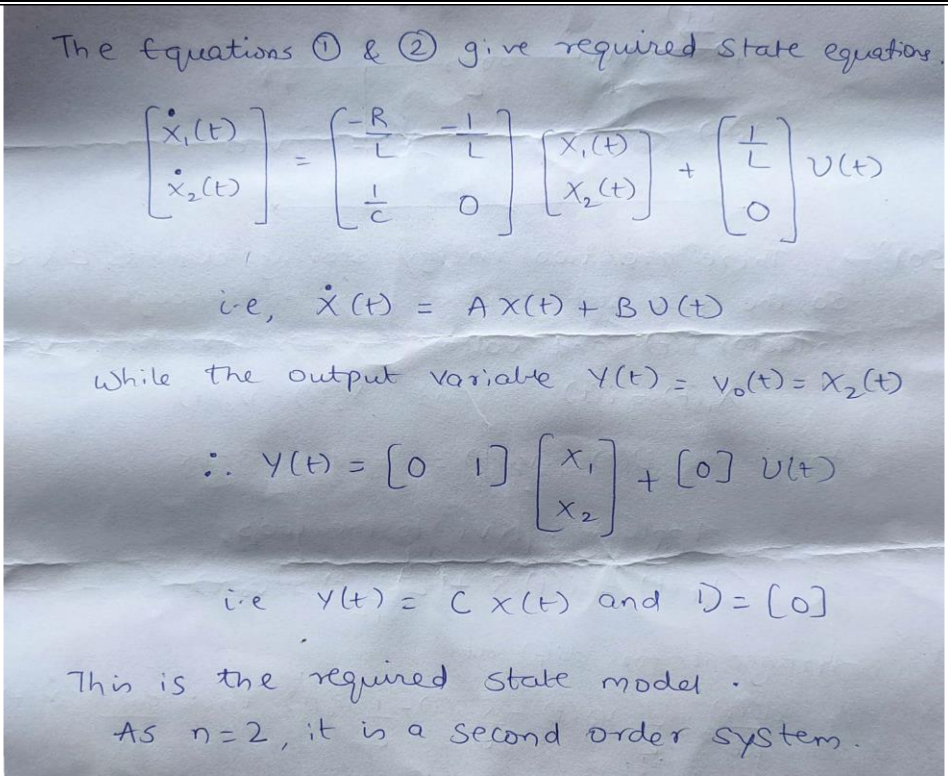
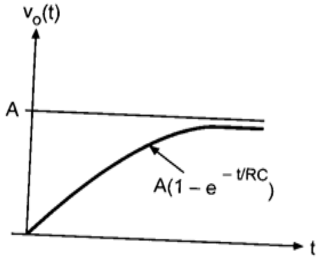
$$\therefore \frac{di(t)}{dt} = \frac{1}{L}v_i(t) - \frac{R}{L}i(t) - \frac{1}{L}v_0(t) \quad \text{but} \quad \frac{di(t)}{dt} = \dot{x}_1(t)$$

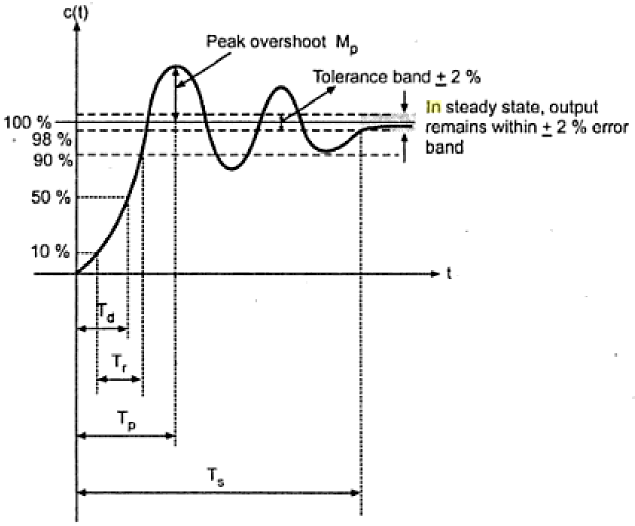
$$\text{i.e} \quad \dot{x}_1(t) = -\frac{R}{L}X_1(t) - \frac{1}{L}X_2(t) + \frac{1}{L}U(t) \rightarrow ①$$

While $v_0(t)$ = Voltage across capacitor $= \frac{1}{C}\int i(t)\,dt$

$$\therefore \frac{dv_0(t)}{dt} = \frac{1}{C}i(t) \quad \text{but} \quad \frac{dv_0(t)}{dt} = \dot{X}_2(t)$$

$$\text{i.e} \quad \dot{X}_2(t) = \frac{1}{C}X_1(t) \rightarrow ②$$

		 The Equations ① & ② give required state equations. $\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix} = \begin{bmatrix}-\frac{R}{L} & -\frac{1}{L}\\ \frac{1}{C} & 0\end{bmatrix}\begin{bmatrix}X_1(t)\\ X_2(t)\end{bmatrix} + \begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}U(t)$ i.e, $\dot{X}(t) = AX(t) + BU(t)$ While the output variable $Y(t) = V_0(t) = X_2(t)$ $\therefore Y(t) = \begin{bmatrix}0 & 1\end{bmatrix}\begin{bmatrix}X_1\\ X_2\end{bmatrix} + [0]\,U(t)$ i.e $Y(t) = C\,X(t)$ and $D = [0]$ This is the required state model. As $n=2$, it is a second order system.	
	b)	**Define time constant. Draw the time response of first order and control system for step input.**	**4M**
	Ans:	**Definition:** Time Constant of a system is defined as the time required by the system output to reach 63.2% of its final value during the first attempt. **Time response of first order control system to a unit step:**  **Time response of second order control system to a unit step:**	**Definitition-2M** **First Order-2M** **Second Order-2M**



c) **Calculate the range of K or values K for stability of feedback control system with T.F.** $\boldsymbol{T(S) = \frac{K}{S^3 + 18S^2 + 77S + K}}$ **4M**

Ans:

Characteristic equation: $1 + G(S)H(S) = 0$

$S^3 + 18S^2 + 77S + K = 0$

Routh's array:

S^3	1	77
S^2	18	K
S	$\frac{1386 - K}{18}$	0
S^0	K	0

Routh's array 3 M

To satisfy the condition for stability,

$$K > 0,$$

$$\frac{1386 - K}{18} > 0$$

Or, $1386 - K > 0,\ 1389 > K$

Therefore, the range of K for the system to be stable is,

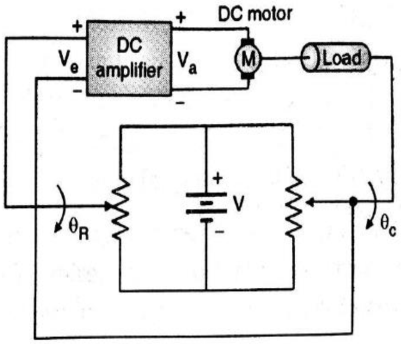
$$\boldsymbol{0 < K < 1386}$$

Range 1 M

d) **Describe the function of D.C. servo system with block diagram.** **4M**

Ans: **Block Diagram of D.C Servo system :** **Diagram-2M**

Explanation-2M



Explanation :

1) The standard block diagram of servo system consists of error detector, amplifier, motor as controller, load whose position is to be changed.

2) Servo systems is to be divided into two type a) DC servo systems b) AC servo system

3) DC servo system consists of potentiometer as error detector, DC amplifier, DC motor, DC gear system and the DC load whose position is to be changed.

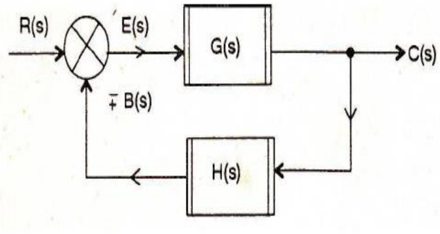
4) In DC servo system potentiometer has two input i.e one is reference input and another is actual load position. Potentiometer finds the error between two positions. The error signal between two positions is given to DC amplifier which amplifies the error. Output of DC amplifier is given to DC motor & finally DC motor changes the position of DC load. In this way servo system is used to change the load position with help of motor & error detector.

Q.4 **Attempt any THREE of the following :** **12-Total Marks**

a) **Derive the transfer function of closed loop control system with negative feedback.** **4M**

Ans: **Diagram-1M**

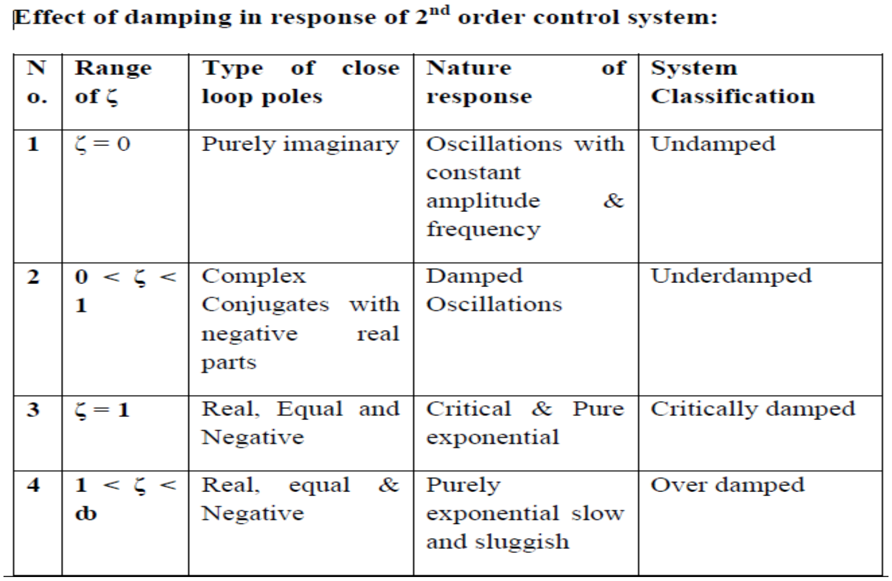
Block diagram: (for negative feedback system)



Derivation-3M

		<u>Derivation:</u> $G(s) = \frac{C(s)}{E(s)}$ $E(s) = \frac{C(s)}{G(s)}$ $C(s) = E(s) \times G(s)$ $B(s) = C(s) \times H(s)$ $E(s) = R(s) - B(s)$ (for negative feedback) ……. [.I.] Substitute for $E(s)$ & $B(s)$ in [.I.] $\frac{C(s)}{G(s)} = R(s) - C(s)\,H(s)$ $C(s) \ \{\frac{1}{G(s)+H(s)}\} = R(s)$ $C(s)\,\frac{[1+G(s)H(s)]}{G(s)} = R(s)$ Transfer Function: $\boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)*H(s)}}$	
	b)	**Describe the effect of damping on second order control system.**	**4M**

Ans:



Effect of damping in response of 2nd order control system:

No.	Range of ζ	Type of close loop poles	Nature of response	System Classification
1	$\zeta = 0$	Purely imaginary	Oscillations with constant amplitude & frequency	Undamped
2	$0 < \zeta < 1$	Complex Conjugates with negative real parts	Damped Oscillations	Underdamped
3	$\zeta = 1$	Real, Equal and Negative	Critical & Pure exponential	Critically damped
4	$1 < \zeta < \infty$	Real, equal & Negative	Purely exponential slow and sluggish	Over damped

Each-1M

c) **Write two advantages and two specifications of frequency response analysis.** **4M**

Ans: **Advantages:**

1. The absolute and relative stabilities of the closed loop system can be found out from the open loop frequency response characteristics by using the methods such as Nyquist stability criteria
2. The transfer function of complicated systems can be found out practically by frequency response test when it is difficult to find transfer function by writing differential equations.
3. Frequency response test are simple and can be done practically by the readily available laboratory equipment.
4. Without the knowledge of transfer function, the frequency response for stable open loop system can be obtained experimentally.
5. Due to the close relation between frequency response of a system and its step response, idea about step response can be obtained from the frequency response.

Any two advantages-2M

Specifications:

1. **Peak Response M_r** : It is defined as the maximum value of magnitude of frequency response.
2. **Resonant Frequency w_r** : This is the frequency at which the resonance peak M_r occurs.
3. **Bandwidth:** It is defined as the range of frequency at which the magnitude of frequency response drops to 70.7% of its zero frequency value or 3 dB from the zero frequency value.
4. **Cut-off Rate**: It is the slope of the log-magnitude curve near the cut-off frequency.
5. **Phase Margin (Φ_{pm}):** The phase margin indicates how much the system angle can be increased to cause the system to become unstable from a stable condition.
6. **Gain Margin:**It is the amount of gain in 'dB' that can be allowed to increase before the system becomes unstable.
7. **Cut off frequency**: It is defined as the frequency at which the magnitude of frequency response is -3 dB.

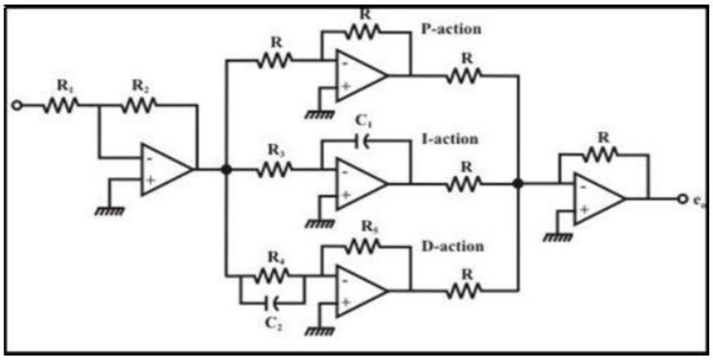
Any two specifications-2M

d) **Draw the circuit of op-amp based PID controller and write the effects of proportional and derivative action on rise time and overshoot.**

Ans:

Circuit of op-amp based PID controller :

Circuit Diagram-2M



Effects of proportional action on rise time and overshoot:

Effects 1M each

1) It reduces the rise time and makes response fast.
2) It increases overshoot.

Effects of derivative action on rise time and overshoot:

1) There is small change in the rise time.
2) It improves the damping and reduces overshoot.

e) **Draw the stability of control system where characteristic equation is given as $s^5+6s^4+15s^3+30s^2+44s+24=0$ using Routh's Stability Criteria.**

4M

Ans:

4M

Characteristic equation: $s^5+6s^4+15s^3+30s^2+44s+24=0$

Routh's array:

S^5	1	15	44
S^4	6	30	24
S^3	10	40	0
S^2	6	24	0
S	0	0	0
S^0			

It is a special case due to the row of zeros. Therefore,
Auxiliary equation: $A(S) = 6S^2 + 24 = 0,$

Taking derivative, $\frac{dA(S)}{dS} = 12S = 0$

By replacing the row of zeros with coefficient of derivative of auxiliary equation, the new Routh array will be:

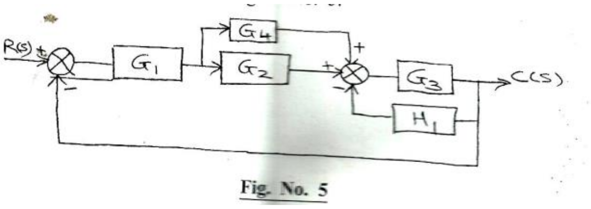
S^5	1	15	44
S^4	6	30	24
S^3	10	40	0
S^2	6	24	0
S	12	0	0
S^0	24	0	0

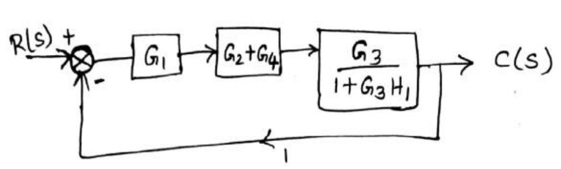
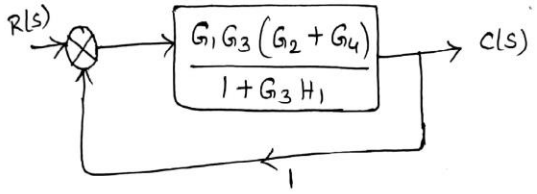
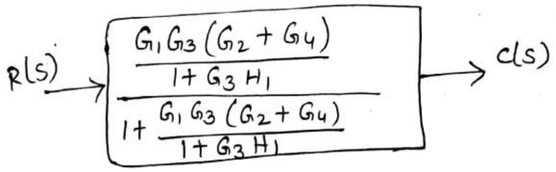
No sign change in the first column , hence no poles on RHS. But to check for marginal stability, solve and get the poles from auxiliary equation.

$$A(S) = 6S^2 + 24 = 0, \quad or\ S^2 + 4 = 0, \qquad or\ S^2 = -4$$

$$or\ S_{1,}S_{2,} = \sqrt{-}4 = \pm 2j$$

It shows that two poles are on the imaginary axis and therefore the system is marginally stable.

Q.5		**Attempt any <u>TWO</u> of the following:**	**12Total M**
	a)	**Derive the transfer function of given system using block reduction rules, Refer Figure No. 5.**  Fig. No. 5	**6M**

	Ans:	5a) sol    After simplification $T(s)=\frac{C(s)}{R(s)}=\frac{G_1G_2G_3+G_1G_3G_4}{1+G_3H_1+G_1G_2G_3+G_1G_3G_4}$	**4marks for block reduction** **2 marks for simplification**
	b)	**Draw the bode plot for -** $G(s).H(s)=\frac{10}{s\,(s+1)\,(s+5)}$ and find the stability based on gain and phase margin.	**6M**
	Ans:	Put s =jω, then $G(j\omega)H(j\omega)=\frac{2}{j\omega(1+j\omega)(1+0.2j\omega)}$ (in time constant form) **Magnitude plot:** Factors: 1. K=20 | M | =20 log 2 =6.02 dB It is a straight line of magnitude 6 dB parallel to X axis(0 dB slope). 2. Pole at origin 1/s : It is a straight line of magnitude +20 dB at origin and a constant slope -20 dB/decade cutting X axis at ω= 1 3. 1/(1+s) = 1/(1+jω) T_1=1 Corner frequency $\omega c_1 = 1/T_1$ =1rad/sec. The plot is a straight line of constant slope of – 20 dB / dec from corner	**3 Marks for explanation**

frequency ωc_1 = 1 rad/sec.

4. 1/(1+0.2s) = 1/(1+0.2jω)

T_2=0.2 Corner frequency ωc_2 = 1 /T_2 =1/0.2 = 5 rad/sec.

The plot is a straight line of constant slope of – 20 dB / dec from corner frequency ωc_2 = 5 rad/sec.

5.Resultant :

It is calculated by adding algebrically individual magnitudes at origin.

Resultant | M | at origin = 6+20+0+0 = 26 dB

6.Resultant Slope at origin

It is a straight line of slope -20 dB/dec upto ωc_1 = 1 rad/sec.

At ωc_1 = 1 rad/sec, another line of slope -20 dB/dec is added, so the new slope is -20 +(-20) = -40 dB /dec.

At ωc_2 = 5 rad/sec, another line of slope -20 dB/dec is added, so the new slope is -40 +(-20) = -60 dB /dec.

Phase plot :

Resultant $\emptyset = \emptyset_1 + \emptyset_2 + \emptyset_3 + \emptyset_4$

$$\boldsymbol{\emptyset_1 = 0^\circ \quad \emptyset_2 = -90^\circ \quad \emptyset_3 = -tan^{-1}(\omega) \qquad \emptyset_4 = -tan^{-1}(0.2\omega)}$$

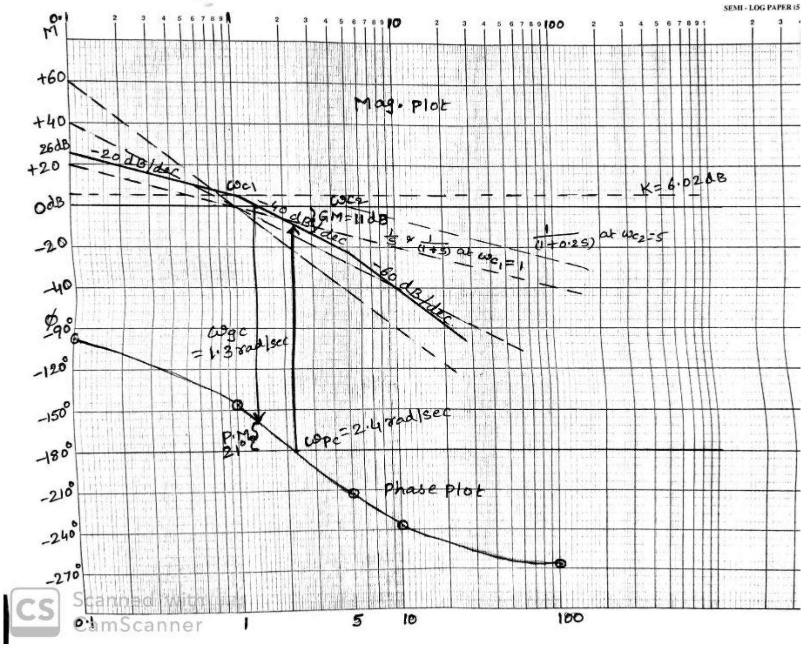
ω	ϕ1	ϕ2	ϕ3	ϕ4	ϕ
0.1	0	-90°	-5.71°	-1.14°	-96.85°
	0	-90°	-45°	-11.3°	-146.3°
5		-90°	-78.69°	-45°	-213.69°
10	0	-90°	-84.28°	-63.4°	-237.68°
100	0	-90°	-89.42°	-87.1°	-266.52°

From the phase plot

ω_{gc} =1.3 rad/sec, ω_{pc} =2.4 rad/sec,

G.M =11dB, PM= 21^0

The system is stable in Nature.

<table>
<tr><td></td><td></td><td>
</td><td>3 Marks for Bode Plot</td></tr>
<tr><td></td><td>(c)</td><td>(i) List the controller of controllers.</td><td>3M</td></tr>
<tr><td></td><td>Ans:</td><td>1. Discontionus Mode
i)ON-OFF controller

2. Continuous Mode
i)Proportional (P)controller
ii)Derivative (D)controller
iii)Integral (I)controller

3. Composite controllers
i)Proportional +Integral (PI)controller
ii)Proportional +Derivative (PD)controller
iii)Proportional +Integral +Derivative (PID)controller</td><td>1M Each</td></tr>
<tr><td></td><td></td><td>(ii) Draw the controller output for give error signal.

1) PID controller

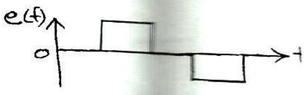


Fig. No. 6

2) PI Controller

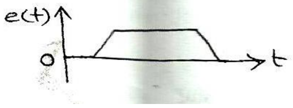
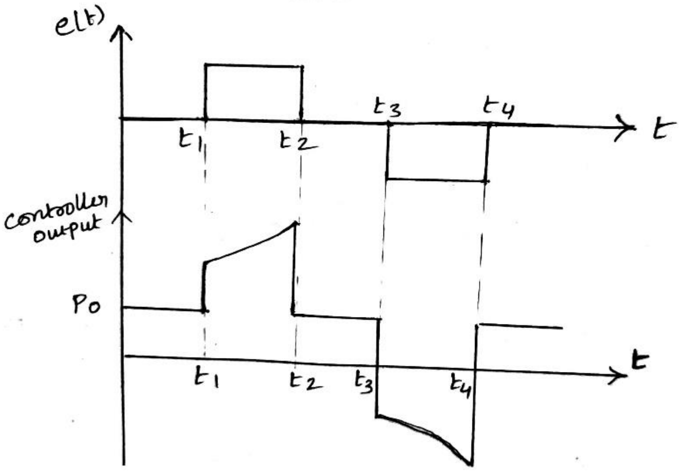
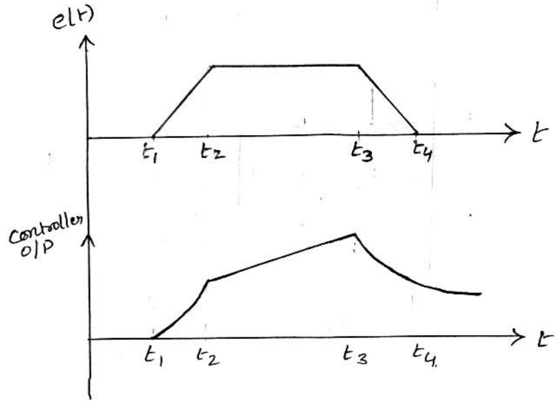


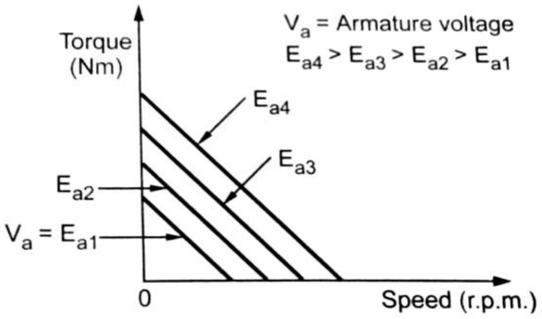
Fig. No.7</td><td>3M</td></tr>
<tr><td></td><td>Ans:</td><td>1) PID controller</td><td>1.5 Marks for PID</td></tr>
</table>

<table>
<tr><td></td><td></td><td>


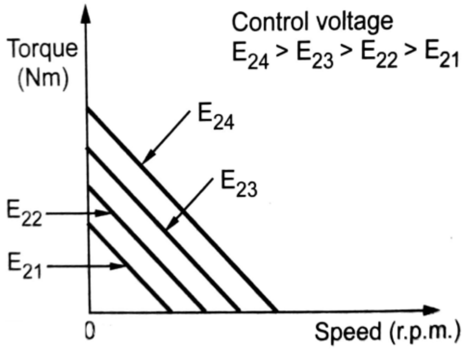
2) PI Controller



</td><td>1.5 Marks for PI</td></tr>
<tr><td>Q.6</td><td></td><td>Attempt any TWO of the following:</td><td>12Total Marks</td></tr>
<tr><td></td><td>(a)</td><td>(i) Draw the characteristics of DC servo motor and AC servo motor.</td><td>3M</td></tr>
<tr><td></td><td>Ans:</td><td>
characteristics of DC servo motor



characteristics of AC servo motor
</td><td>1.5 marks for each characteristics</td></tr>
</table>



Ans: **(ii) Compare AC servo motor and DC servo motor.** **3M**

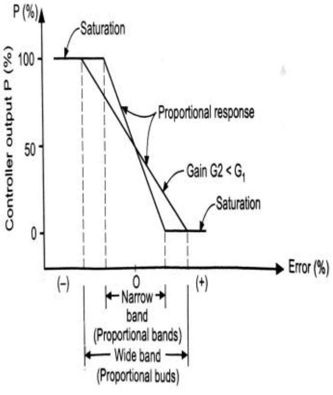
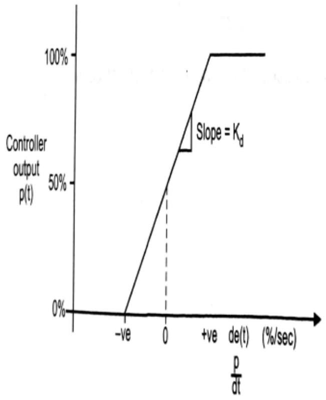
3Marks for any 3 points

Sr.No	**DC servo motor**	**AC servo motor**
1	Deliver High power output	Low power output 1/2W to 100W
2	High efficiency	Efficiency is less about 5 to20%
3	Frequent maintenance required due to commutator.	Due to absence of commutator maintenance is less.
4	More problems of stability.	Less problems of stability.
5	Brushes produce radio frequency noise.	No radio frequency noise.
6	Noisy operation.	Relatively stable and smooth operation.
7	Amplifiers used have a drift.	A.C. Amplifiers used have no drift.
8	Linear response	Non- Linear response
9	Supply is given to armature	Supply is given to stator.

(b) **(i) Compare P and D controller.** **2M**

Ans: **2 marks for any 2 points**

SR.No	**Proportional control action**	**Derivative control action**
1	In P control ,the output is proportional to the error	In D control, output is a function of the rate at which the error is changing
2	If error is Zero, the output	If error is Zero or constant ,

	is a constant equal to Po	output is zero
3	$p(t) = K_p e(t) + p(0)$	$p(t) = K_d \frac{d}{dt} e(t)$
4		
5	Produces offset	Does not produce offset
6	Moderate stability	More stable
7	Moderate response speed	Fast
8	Does not introduce zero at origin of s-plane	Introduces zero at origin of s-plane

		(ii) Write one advantages and application of ON – OFF controller.	**2M**
	Ans:	**Advantage:** 1.Simplest mode of controller 2. Economical 3. Often used if its limitations are well within the tolerance **Application:** Used in , 1.Room heaters 2.Refrigerators 3.Level control of water tanks 4. Air conditioners	**1 M-1 advantage** **1 M-1 Application**
		(iii) Explain neutral zone with plot in ON – OFF controller.	**2M**
	Ans:	**Neutral Zone:** In practical implementation of the two – position controller, there is an overlap as Ep increases through zero or decreases through zero. In this span, no change in controller output occurs and it is called Neutral zone. Fig shows P versus Ep for ON-OFF Controller. Until an increasing error changes by Δ ep above zero, the controller output will not change state. In decreasing it must fall	**1 M -explanation**

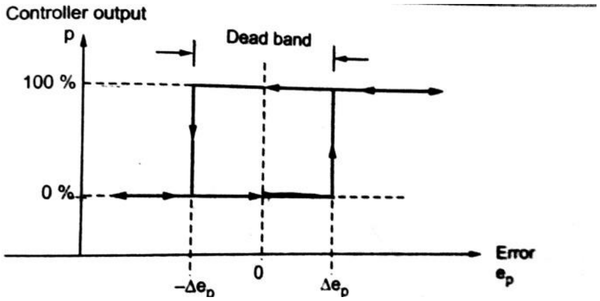
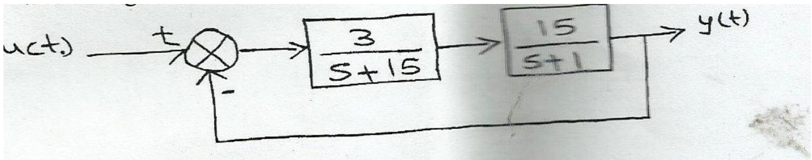
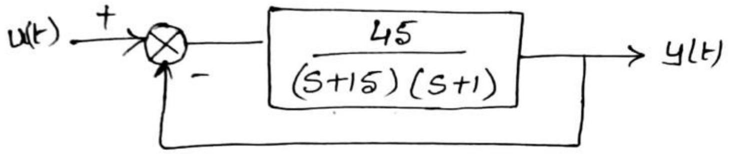
<table>
<tr><td></td><td></td><td>Δ ep below zero before the controller changes to the 0% rating.

 </td><td>1M- plot</td></tr>
<tr><td></td><td>c)</td><td>Calculate the steady state error for unit step input Refer Figure No. 8


Fig. No. 8</td><td>6M</td></tr>
<tr><td></td><td>Ans.</td><td>

$G(s) = \frac{45}{(s+15)(s+1)} = \frac{45}{s^2+16s+15}$
and $H(s) = 1$
As Input is step, $K_p = \lim_{s \to 0} G(s) H(s)$
$\therefore K_p = \lim_{s \to 0} \frac{45}{s^2+16s+15} = \frac{45}{0+0+15}$
$\therefore \underline{K_p = 3}$
∴ Steady state error for unit step Input is
$\therefore e_{ss} = \frac{1}{1+Kp} = \frac{1}{1+3} = \frac{1}{4} = 0.25$
$\therefore \underline{e_{ss} = 0.25}$</td><td>2M -G(S) and H(S) function
2M –Kp
2M for ess
(marks should be given if ess is found out with equation)</td></tr>
</table>