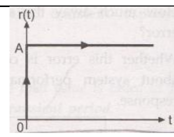
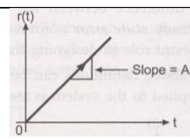
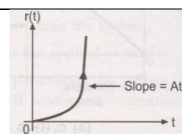
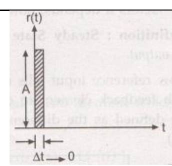
Important Instructions to examiners:

1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values 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 judgments 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.

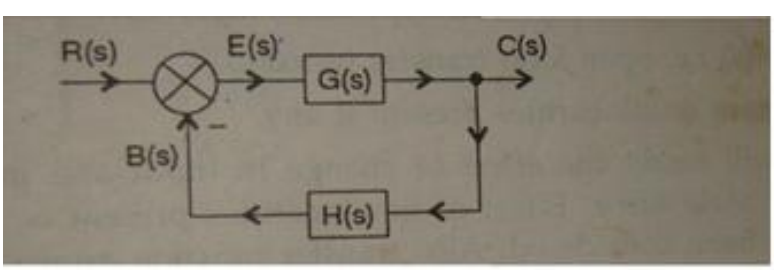
Q. No.	Question & Model Answer	Remark	Total Marks
1.A	**Attempt any Three:**		12
a)	**Distinguish between open and closed loop system (any four points)**		04
Ans:	(table below)	1 mark for each point (relevant 4 points only)	

Sr.No	Open loop	Closed loop
1	No Feedback element	Feedback element is present
2	Error detector is absent	Error detector is present
3	Inaccurate	Accurate
4	Small bandwidth	large bandwidth
5	More stable	less stable
6	Simple construction	Complex construction
7	Less costly	more costly
8	Affected by non linearity	not affected by non-linearity
9	Sensitive to disturbance	not sensitive to disturbance

b)	**Draw graphical representation of the following test signal and give their Laplace representation.** **i.) Step input** **ii.) Impulse input** **iii.) Ramp input** **iv.) Parabolic input**		**04**
Ans:	(see table below)	**1 mark for each input graphical representation and LT**	

Test Signal	Graphical representation	Laplace representation
Unit Step Input		$\frac{1}{s}$
Unit Ramp Input		$\frac{1}{s^2}$
Unit Parabolic Input		$\frac{1}{s^3}$
Unit Impulse		1

c)	**Define the term stability and relative stability.**		**04**
Ans:	Stability: A linear time invariant system is set to be stable if following conditions are satisfied. i.)When the system is excited by a bounded input the output is also bounded and controllable. ii.) In the absence of input output must tend to zero irrespective of the initial conditions. Relative Stability: The system is said to be relatively more stable on the basis of settling time. i.)If the settling time for a system is less than that of another system then the former system is said to be relatively more stable than the	**2 marks each**	

	second one. ii)As the location of the poles move towards left half of S- plane, the settling time becomes smaller and system becomes relatively more stable.		
d)	**Define ON –off controller. Give 2 examples.**		**04**
Ans:	On- Off Controller :- It has only two fixed positions such as on (1) and off (0). The output signal P remains either 0% or 100% depending upon whether the error is negative or positive. P = 100% (ON) for positive error P = 0% (OFF) for negative error . Consider a practical example of temperature control system with Set Point "x". When the temperature is more than "x" the on - off controller will be off and when it is less than "x" ,on - off controller will be on. Example:- Relays, Thermostat	**02 marks For definition and** **02 marks for any relevant examples**	
1.B	**Attempt any One:**		**06**
a)	**Define transfer function. Derive the equation of transfer function for closed loop system.**		
Ans:	Transfer Function is defined as the ratio of Laplace transform of Output to that of Laplace transform of input under the assumption of zero initial condition. Block diagram: (for negative feedback system) 	**1 mark for defination** **1mark For BD**	

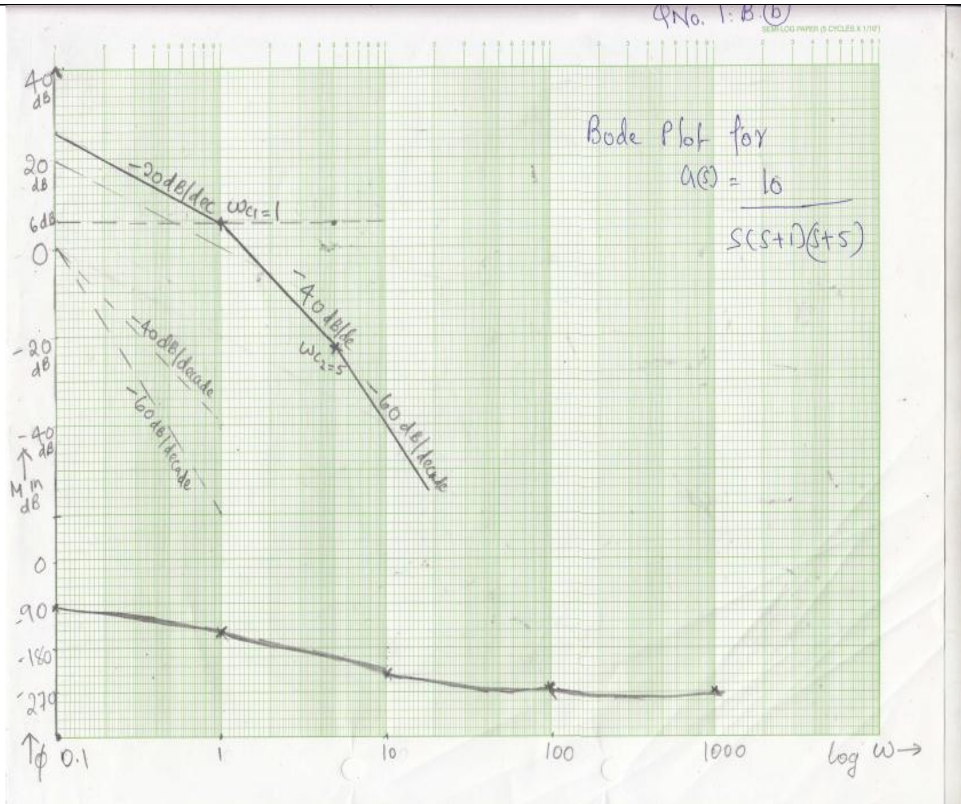
	Derivation: $G(s) = \frac{C(s)}{E(s)}$ $E(s) = \frac{C(s)}{G(s)}$ C(s) = E(s) x G(s) B(s) = C(s) x H(s) E(s) = R(s) - B(s) (for negative feedback) ……. [.I.] Substitute for E(s) & B(s) in [.I.] $\frac{C(s)}{G(s)}$ = R(s) - C(s) H(s) C(s) $\{\frac{1}{G(s)+ H(s)}\}$ = R(s) C(s) $\frac{[1+ G(s)H(s)]}{G(s)}$ = R(s) Transfer Function: $\boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)* H(s)}}$	**4 marks for Derivation**	
b)	**For the unity feed back control system :** $\mathbf{G(S) = \frac{10}{S(S+1)(S+5)}}$ **Sketch the bode plot.**		**06**

Ans:	Step 1: Convert the given open loop transfer function to time constant form: $G(s)H(s) = \frac{10}{5s\,(s+1)\left(\frac{s}{5}+1\right)} = \frac{2}{s\,(s+1)(0.2s+1)}$ Step 2: Identify the factors: 1. Open loop gain K=2, Magnitude in dB= 20 log K= 20 log 2 = 6.02 dB 2. Pole at origin $(\frac{1}{s})$ which has a magnitude plot with slope of -20 dB/ decade. For ω=0.1, M in dB for $(\frac{1}{s})$ = -20 log 0.1= 20 dB 3. First order poles (s+1) and (0.2s +1). The corner frequencies of them are: ωc_1=1, $\omega c_2 = \frac{1}{2}$ = 5; Till the corner frequencies the magnitude plot's slope will be 0 dB /decade and from the corner frequencies it changes to -20dB /decade. Step 3: Phase angle ϕ:	**1 mark** **2 marks** **1mark**	

Frequency $=\omega$	For Factor1, K=2 ϕ1=	For Factor 2,($\frac{1}{s}$) ϕ2=	For Factor 3, ($\frac{1}{s+1}$) ϕ3 = -$\tan^{-1}\omega$	For Factor 3, $\frac{1}{0.2s+1}$ ϕ4= -$\tan^{-1}0.2\,\omega$	Total phase angle ϕ= ϕ1+ϕ2 +ϕ3+ϕ4
0.1	00	-900	-5.70	-1.10	-96.80
1	00	-900	-450	-11.30	-146.30
10	00	-900	-84.20	-63.40	-237.60
100	00	-900	-89.40	-87.10	-266.50
1000	00	-900	-89.90	-89.70	-269.60

2marks

Step 4: Draw the magnitude plot and phase angle plot on semilog paper.

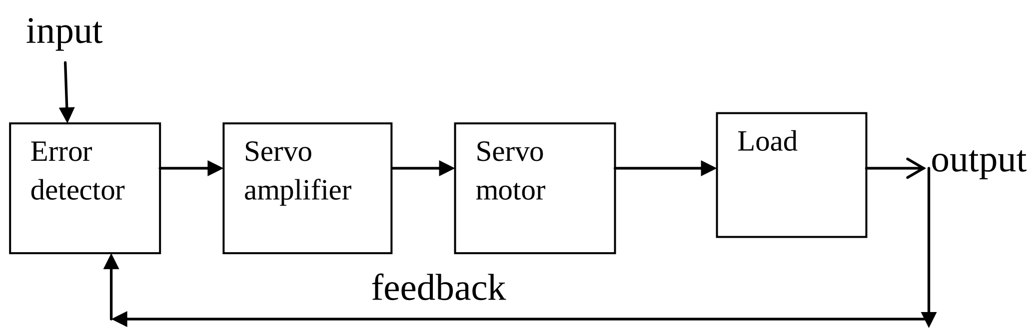
			
2.	**Attempt any Two:**		**16**
a)	**Consider fifth order system with characteristics equation given by:** $S^5 + S^4 + 2S^3 + 2S^2 + 3S + 5 = 0$. **Determine stability using Routh's criterion.**		**08**
Ans:	S^5 1 2 3 S^4 1 2 5 S^3 0 -2 0 special case S^2 ∞ -- -- Routh 'array failed S S^0 Substitute a small positive number ε in place of 0 occurred as a first element in a row. Complete the array with this number ε. Then examine the sign change by taking $\lim_{\varepsilon \to 0}$.	**Initial Rouths Array: 2 mark,**	

	S^5 1 2 3 S^4 1 2 5 S^3 ε -2 0 S^2 $\frac{2\varepsilon+2}{\varepsilon}$ 5 0 S $\frac{(-2(2\varepsilon+2))/\varepsilon - 5\varepsilon}{\frac{2\varepsilon+2}{\varepsilon}}$ 0 0 S^0 5 To examine sign change $\lim_{\varepsilon\to 0} \frac{2\varepsilon+2}{\varepsilon} = 2 + \lim_{\varepsilon\to 0} 2/\varepsilon = 2 + \infty = \infty$ (sign is positive) $\lim_{\varepsilon\to 0} \frac{(-2(2\varepsilon+2))/\varepsilon - 5\varepsilon}{\frac{2\varepsilon+2}{\varepsilon}} = \lim_{\varepsilon\to 0} \frac{-4\varepsilon - 4 - 5\varepsilon^2}{2\varepsilon+2} = \frac{0-4-0}{0+2}$ = -2 (sign is negative) Final Rouths Array: S^5 1 2 3 S^4 1 2 5 S^3 $\boxed{\varepsilon}$ -2 0 S^2 ∞ 5 0 S -2 0 0 S^0 5 Routh's stability criteria states that the elements of 1st column of	**Modified Rouths Array: 4 marks,**	

	Routh's array should not have any sign change for the system to be stable. The number of sign changes in the 1st column indicates the number of Poles on RHS which makes the system unstable. Here, 2 sign changes in the 1st column indicate 2 RHS poles. Therefore system is unstable. (Note:- Alternative method of Rouths Array by replacing S with $\frac{1}{z}$ in the original equation also can be considered n .)	**Conclu sion – 02 marks**	
b)	**Define servo system. Draw block diagram of it. Compare AC Servo motor with DC servomotor. (any 4 points)**		**08**
Ans:	<u>Definition</u>: Servo system is defined as automatic feedback control system working on error signals giving the output as mechanical position, velocity or acceleration.	**2 marks**	

Ans:

Block diagram:



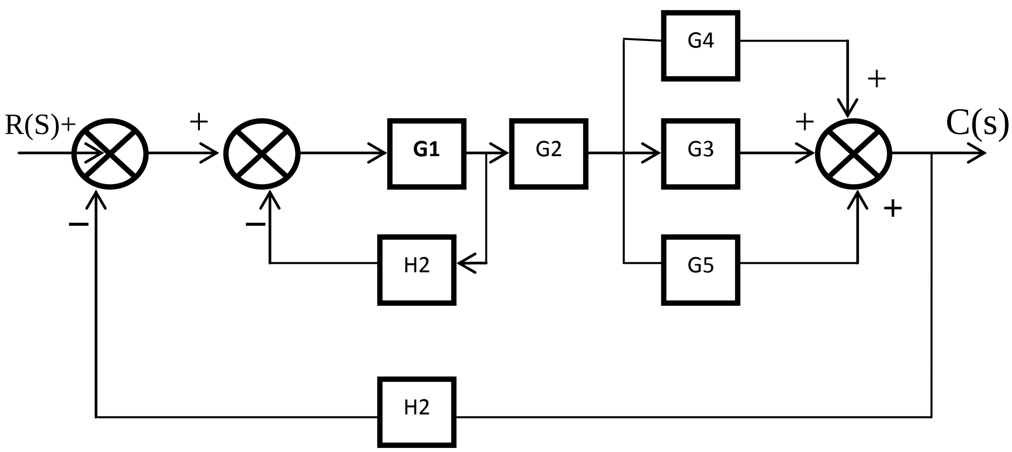
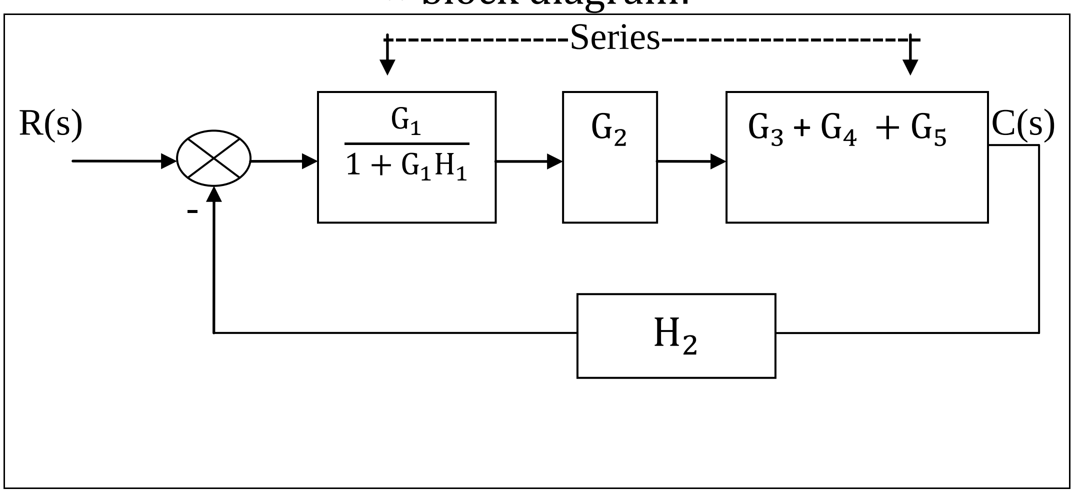
2 marks for BD

Compare AC servomotor with DC servomotor :

AC servomotor	DC servo motor
Less maintenance	More maintenance
Control voltage is applied to stator	Control voltage is applied to armature
No RF noise	RF noise is present
Brushes and commutators are not present	Brushes and commutators are present
Nonlinear response	Linear response
Low power application	High power application
Poor efficiency	Better efficiency
Economical, less costly	costly

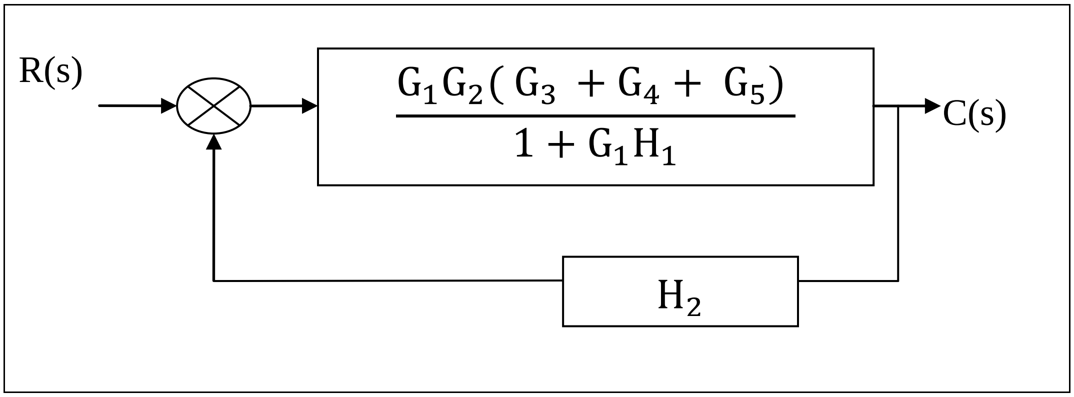
any 4 points

4 marks

c)	**Find transfer function of given block diagram.** 		08
Ans:	Step 1 and 2: Consider the closed loop system with G_1 and H_1 and reduce it to: $\frac{G_1}{1+G_1H_1}$ Consider the parallel blocks with $G_{3,}$ G_4, G_5 and reduce it to $G_3 + G_4 + G_5$ ∴ block diagram: 	4 marks	

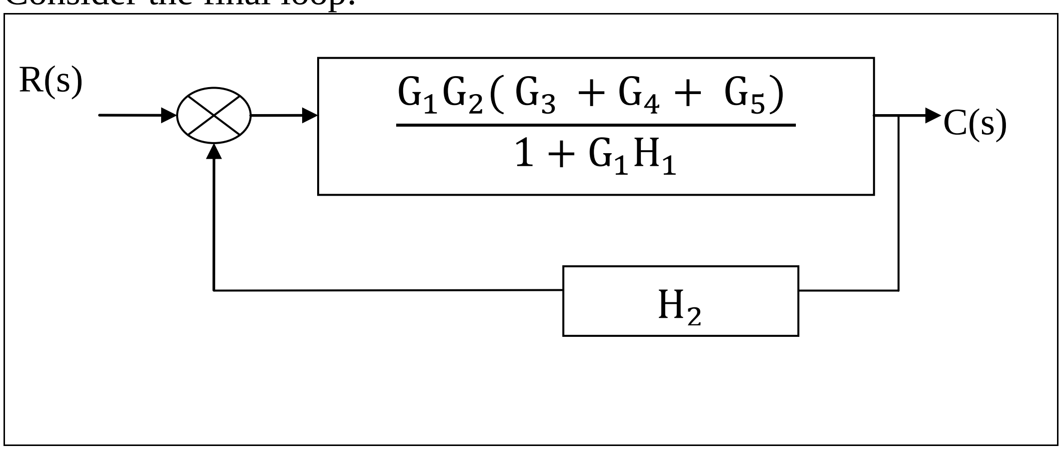
2 marks

Step 3:
Reduce the blocks in series :

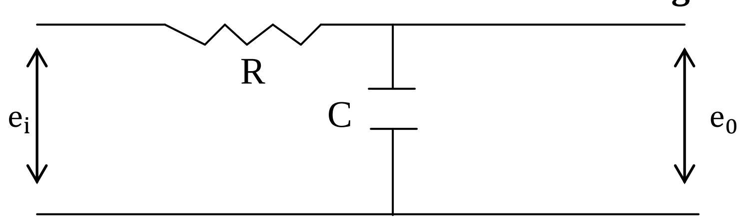


Step 4:
Consider the final loop:

1 mark



Closed loop:

	T.F = $\dfrac{\dfrac{G_1G_2(G_3+G_4+G_5)}{1+G_1H_1}}{1+\dfrac{G_1G_2(G_3+G_4+G_5)}{1+G_1H_1}H_2}$ T.F = $\dfrac{G_1G_2(G_3+G_4+G_5)}{G_1H_1+[G_1G_2(G_3+G_4+G_5)H_2]}$ Block diagram $R(s) \longrightarrow \boxed{\dfrac{G_1G_2(G_3+G_4+G_5)}{G_1H_1+[G_1G_2(G_3+G_4+G_5)H_2]}} \longrightarrow C(s)$	**1 mark**	
3.	**Attempt any four:**		**16**
a)	**Find the transfer function of the network given in figure:** 		**04**
Ans:	Applying KVL we get the following equations: $R\,i(t)+\frac{1}{c}\int i(t)\,dt=e_i(t)$	1 Mark	

	$\frac{1}{c}\int i(t)\,dt = e_o(t)$ Taking Laplace transform, we get $R\,I(s) + \frac{1}{sC} I(s) = E_i(s)$ $\frac{1}{sC} I(s) = E_o(s)$ Transfer function $T(s) = \frac{Eo(s)}{Ei(s)} = \frac{\frac{1}{sC} I(s)}{R\,I(s) + \frac{1}{sC} I(s)}$ On simplifying: $\boxed{\text{Transfer function } T(s) = \frac{1}{1+sCR}}$	1 Mark 1Mark 1 Mark	
b)	**For given transfer function :** **T.F =** $\frac{40(S+2)}{S(S+1)(S+4)}$**, find :** **i.) poles** **ii.) zeros** **iii.) characteristic equation**		**04**
Ans:	i)Poles are obtained by making denominator of the transfer function =0 There are three poles at s = 0, s = -1 and s = - 4 ii) Zeros are obtained by making numerator of the transfer function = 0 There is one zero at s = -2 iii) Characteristic equation: It is given by s(s+1) (s+4) = 0 On simplifying we get: $\boxed{\text{Characteristic equation} = s^3+5s^2+4s=0}$	1 Mark 1Mark 2 Marks	

c)	**State routh's stability criterion. How will you determine whether system is stable or unstable?**		**04**

Ans:

Statement:

Routh's stability criterion:

The necessary and sufficient condition for a system to be stable is **"All the terms in the first column of Routh's array must have same sign.There should not be any change in the first column of Routh's array."**

If there are any sign changes then,

a) The system is unstable.

b) The number of sign changes is equal to the number of roots lying in the right half of s- plane.

2 Marks

Determination of whether system is stable or unstable:

To apply Routh's stability criterion, consider the system whose characteristic equation is given by:

$$F(s) = a_0 s_n + a_1 s_{n-1} + a_2 s_{n-2} + \text{----------} + a_n = 0.$$

The coefficients of the characteristic equation of the given system are arranged in an array called Routh's array in the following way:

Method of forming an array :

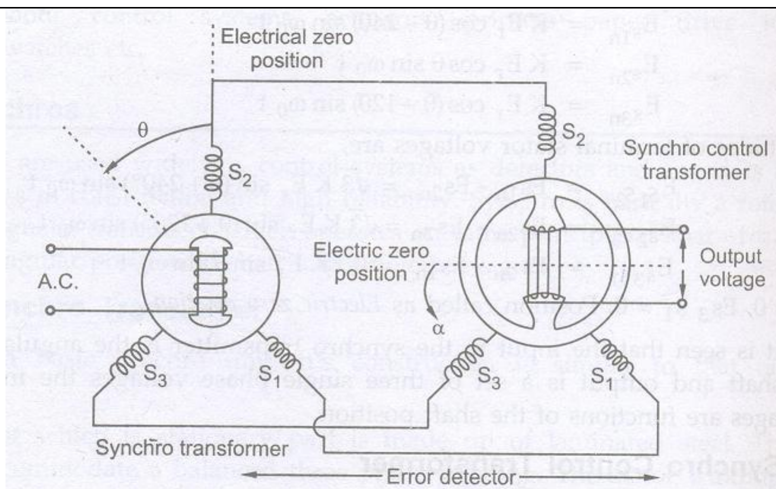
$$\begin{array}{c|cccc}
s^n & a_0 & a_2 & a_4 & a_6 \\
s^{n-1} & a_1 & a_3 & a_5 & a_7 \\
s^{n-2} & b_1 & b_2 & b_3 & \\
s^{n-3} & c_1 & c_2 & c_3 & \\
: & : & : & : & \\
s^0 & a_n & & &
\end{array}$$

The values of b_1, b_2, c_1, c_2 etc are obtained as follows:

2 Marks (forming routh array is optional)

<table>
<tr><td></td><td>$b_1 = \frac{a_1a_2 - a_0a_3}{a_1}$; $b_2 = \frac{a_1a_4 - a_0a_5}{a_1}$; $b_3 = \frac{a_1a_6 - a_0a_7}{a_1}$

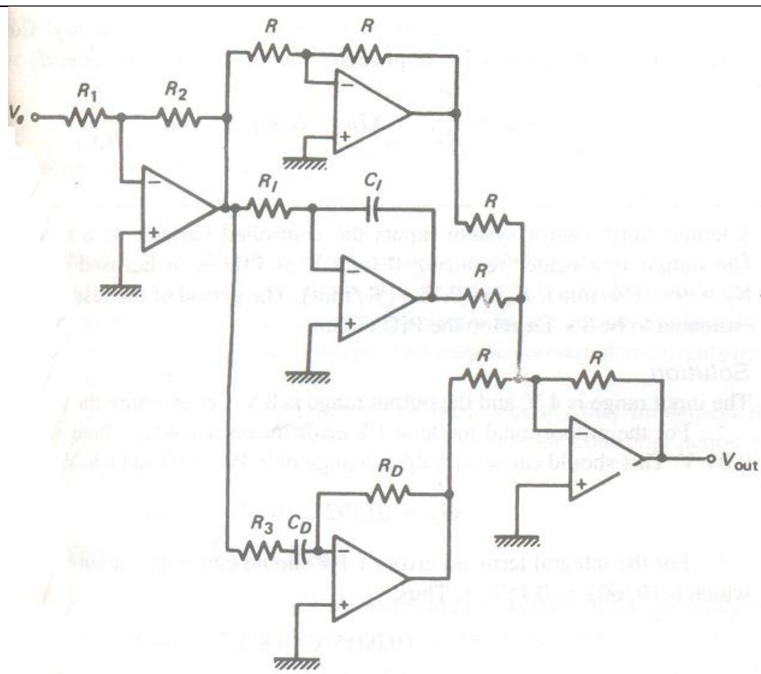
$c_1 = \frac{b_1a_3 - a_1b_2}{b_1}$; $c_2 = \frac{b_1a_5 - a_1b_3}{b_1}$
The process is continued till the coefficient for s_0 is obtained which will be a_n. From this array, the stability of the system is predicted.</td><td></td><td></td></tr>
<tr><td>d)</td><td>Explain synchro as error detector with diagram.</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>

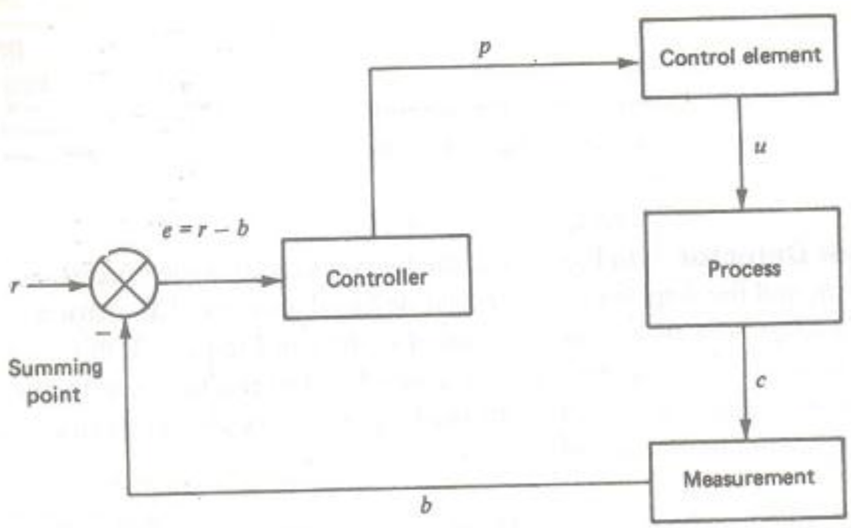


<u>Explanation</u>:

Synchro transmitter alongwith synchro control transformer is used as error detector . The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap.
The output of the synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils Circulating currents of same phase but</td><td>2 Marks For diagram

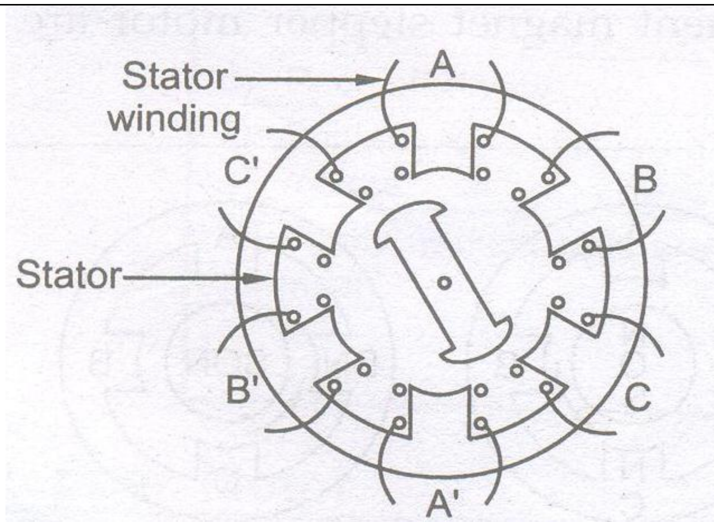
2 Marks For related explanation</td><td></td></tr>
</table>

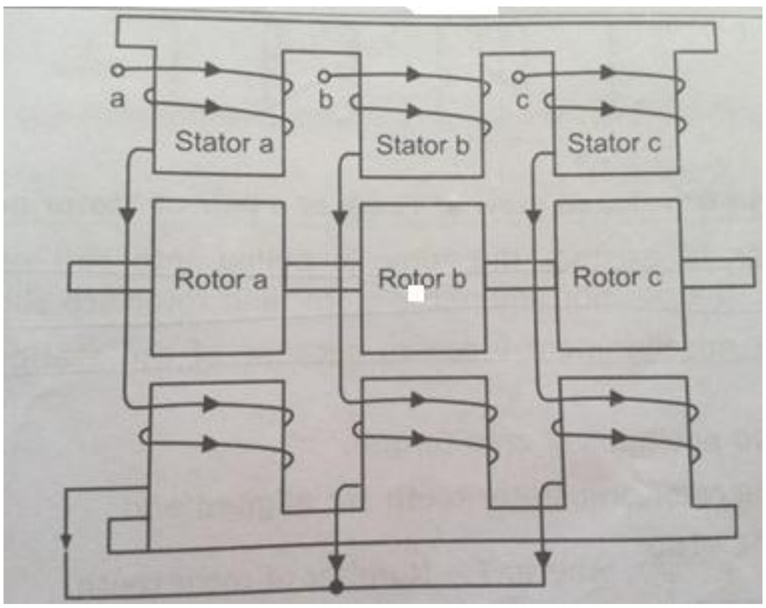
	different magnitude will flow through both set of stator coils. This establishes an identical flux pattern in the air gap of control transformer. The flux pattern in the air gap of control transformer will have the same orientation as that of transmitter rotor. The voltage induced in the transformer rotor will be proportional to the cosine of angle between the two rotors. The output equation is given by: $e_0(\text{t}) = V_r \sin\omega t + \cos\phi$ where: $V_r \sin\omega t$: input voltage to the transmitter rotor and ϕ is the angular difference between both rotors. When ϕ=90° both rotors are perpendicular to each other and the output voltage is zero.This position is called electrical zero and is used as reference position.		
e)	**Draw the neat diagram of electronics PID controller using Op-amp . List two advantages.**		**04**
Ans:	 Any 2 advantages: Advantages of electronic PID controller: 1) It is the most powerful mode of controllers	**03 Marks for diagram** **01 Marks For any relevant advantage**	

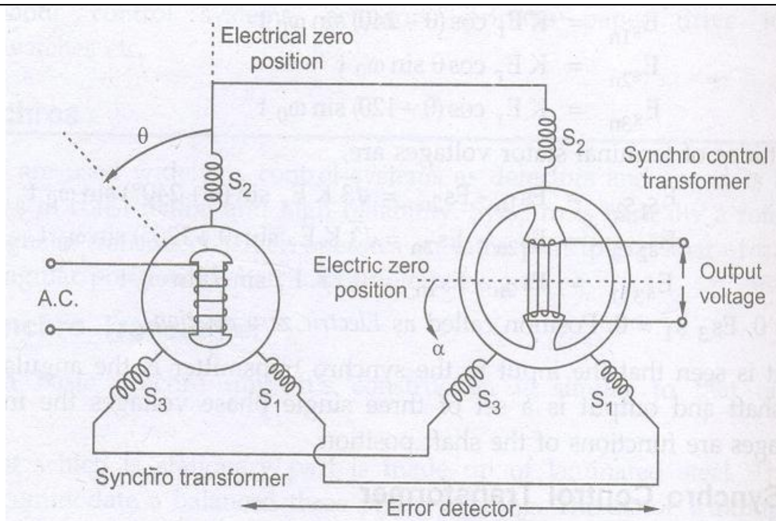
	2) It eliminates offset		
4.A.	**Attempt any four:**		**16**
a)	**Draw block diagram of process control system and explain each block.**		**04**
Ans:	**Block diagram of process control system**  **Explanation :** The block diagram of process control system consists of the following blocks:- 1) Measuring element: It measures or senses the actual value of controlled variable 'c' and converts it into proportional feedback variable b. 2) Error detector : It receives two inputs: set point 'r' and controlled variable 'p'. The output of the error detector is given by e= r-b. 'e' is applied to the controller. 3) Controller: It generates the correct signal which is then applied to the final control element. Controller output is denoted by ' p'. 4) Final control element: It accepts the input from the controller which is then transformed into some proportional action performed by the process. Output of control element is denoted by 'u'. 5) Process: Output of control element is given to the process which	**2 Marks For diagram** **2 Marks For related explanation**	

	changes the process variable. Output of this block is denoted by ‘u’.		
b)	**List ant two advantages and two disadvantages of frequency response analysis.**		**04**
Ans:	**Advantages:** 1) The absolute and relative stabilities of the closed loop systems can be found out from open loop frequency response characteristics by using methods like Nyquist stability criteria. 2) The transfer functions of complicated systems can be found out practically by frequency response method when it is difficult to determine using differential equations. 3) Frequency response tests are simple and can be easily performed using by using equipments available in laboratories. 4) Without the knowledge of transfer function, the frequency response of a stable open loop control system can be obtained experimentally. 5) Due to close relationship between frequency response and step response of a system, idea about step response can be obtained from its frequency response. **Disadvantages:** 1) Obtaining frequency response practically is time consuming. 2) It is applicable to linear systems only. 3) The methods are considered to be old and outdated as compared to methods like digital computer simulation and modelling. 4) It is not recommended for systems with large time constants.	**2 Marks for any 2 advantages** **2 marks for any two disadvantages**	
c)	**Transfer function of second order system is given by** **:** $\frac{C(S)}{R(S)} = \frac{10(S+1)}{S^2+6S+25}$ **Find Tr, Tp, Ts and % Mp for unit step input.**		**04**
Ans:	Comparing the given equation with the standard form of second order equation,	**(1 Mark for**	

	$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{\omega_n^2+2\xi\omega_n s+s^2} = \frac{25}{s^2+6s+25}$ we get, ω_n^2=25 Therefore, $\omega_n = 5 rad/sec$ $2\xi\omega_n$=6 , ξ=0.6 $\theta = \tan^{-1}(\frac{\sqrt{1-\xi^2}}{\xi}) = \tan^{-1}(\frac{\sqrt{1-0.6^2}}{0.6})$= 0.9272rad $\omega d = \omega n\sqrt{(1-\xi^2)} = 5\sqrt{(1-0.6^2)}$ = 4 rad/sec $T_r = \frac{\pi-\theta}{\omega d} = \frac{\pi-0.9272}{4}$ = 0.5535sec $T_p = \frac{\pi}{wd} = \frac{\pi}{4}$ = 0.785sec $T_s = \frac{4}{\xi w_n}$ = 1.33sec $\%M_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}} * 100$ = 9.48%	each parameter Means for Tr,Tp, Ts,and %Mp)	
d)	**Explain construction of variable reluctance stepper motor with diagram.**		**04**

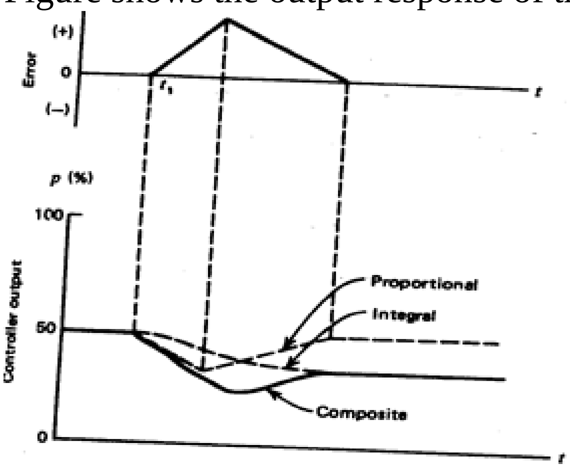
Ans:	 **Explanation :** The figure above represents a variable reluctance stepper motor with single stack whose stator is wound for 3 phases. The stator has six salient poles or teeth with concentrated exciting windings around each one of them. The rotor is made up of slotted steel laminations. It has 2 salient poles without any exciting windings. The coils of the driving circuit are wound around opposite poles such that they are connected in series. The three phases are energized from a DC source with the help of switches. When any one phase is excited by the closing of the switch in series, the corresponding poles act as north and south poles. The rotor between them adjusts itself in minimum reluctance position between stator and rotor. When the next phase is excited by the closing of the second switch keeping the previous phase excited, the magnetic axis of the stator shifts by 30 degrees. So the rotor will also rotate through 30 degree step to attain the new minimum reluctance position. By successively exciting the three phases in specific sequence, the motor is made to complete one revolution. **(OR)** **Multi Stack variable reluctance stepper motor**	**02 marks For Diag.** **2 Marks For relevant Explaination**	

		**02 marks For Diag.**	
	In this type, the windings are arranged in different stacks. The figure represents a three stack stepper motor. The three stacks of the stator have a common frame. The rotors have a common shaft. The stator stacks and rotors have toothed structure with same teeth size. The stators are pulse excited and rotors are unexcited. When the stator is excited, the rotor gets pulled to the nearest minimum reluctance position where the stator and rotor teeth are aligned. The stator teeth of various stacks are arranged to have a progressive angular displacement of : $\alpha = \frac{360}{qT}$ where q = number of stacks, T = number of teeth	**2 Marks For relevant Explanation**	
4.B.	**Attempt any one:**		**06**
a)	**Identify which servo component can be used as error detector in AC servo system .draw and explain it.**		**06**
Ans:	A pair of synchro transmitter along with control transformer acts as error detector in AC servo system	**1 Marks**	

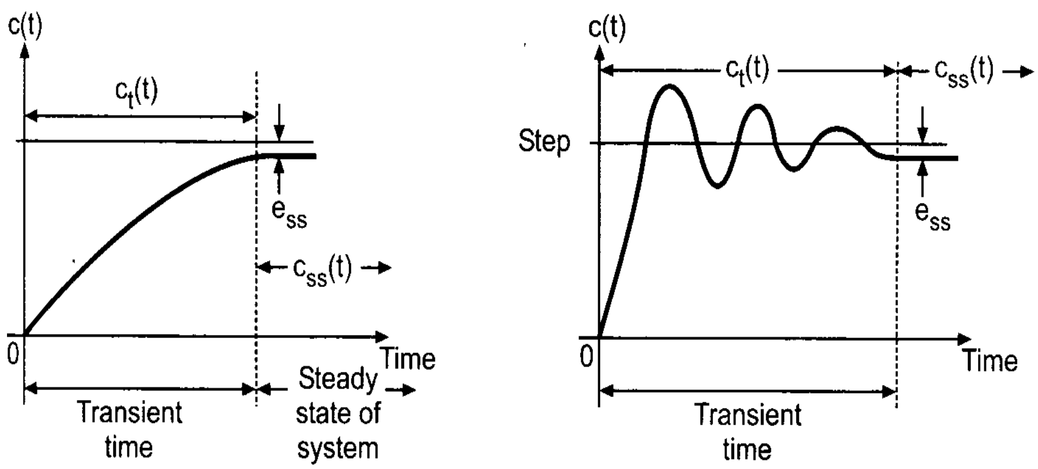
	 	**2 Marks For Diagram**	
	Explanation : Synchro transmitter along with synchro control transformer is used as error detector . The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap. The output of the Synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils Circulating currents of same phase but different magnitude will flow through both set of stator coils. This establishes an identical flux pattern in the air gap of control transformer. The flux pattern in the air gap of control transformer will have the same orientation as that of transmitter rotor. The voltage induced in the transformer rotor will be proportional to the cosine of angle between the two rotors. The output equation is given by : $e_0(t) = V_r \sin \omega t + \cos\phi$ where $V_r \sin \omega t$ =input voltage to the transmitter rotor and ϕ is the angular difference between both rotors. When ϕ=90°both rotors are perpendicular to each other and the output voltage is zero This position is called electrical zero and is used as reference position.	**3 Marks For Explaination**	

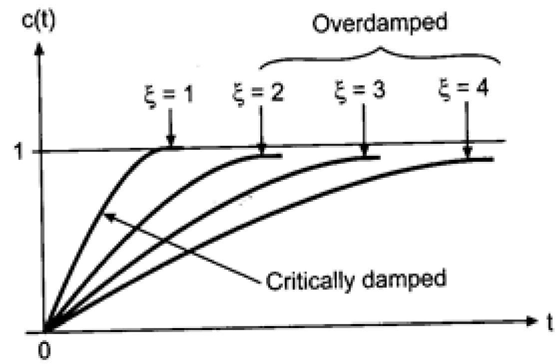
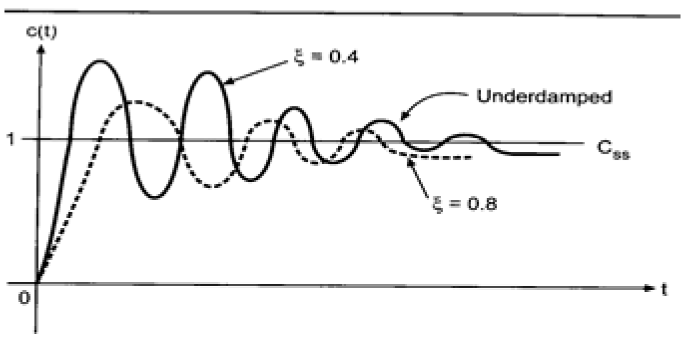
b)	**A unity feedback system has** **G(s) =** $\frac{10(s+1)}{s^2(s+2)(s=10)}$ **find error coefficient Kp,Kv, Ka**		**06**
Ans:	$G(s)=\frac{10(s+1)}{s^2\,(s+2)(s+10)}$,H(s)=1 $K_p=\lim_{s\to 0} G(s)\,H(s) = \lim_{s\to 0}\frac{10(s+1)}{s^2\,(s+2)(s+10)}*1=\infty$ $K_v=\lim_{s\to 0} s\,G(s)\,H(s) = \lim_{s\to 0}\frac{s\,10(s+1)}{s^2\,(s+2)(s+10)}*1=\infty$ $K_a=\lim_{s\to 0} s^2\,G(s)\,H(s) = \lim_{s\to 0}\frac{s^2 10(s+1)}{s^2\,(s+2)(s+10)}*1$ $=\lim_{s\to 0}\frac{10(s+1)}{(s+2)(s+10)}=\frac{10(0+1)}{(0+2)(0+10)}=\frac{10}{20}=0.5$ **Kp** = ∞ **Kv** = ∞ **Ka = 0.5**	2 Marks 2 Marks 2 Marks	
5.	**Attempt any four:**		**16**
a)	**Explain how AC servomotor is different from two phase induction motor.**		**04**

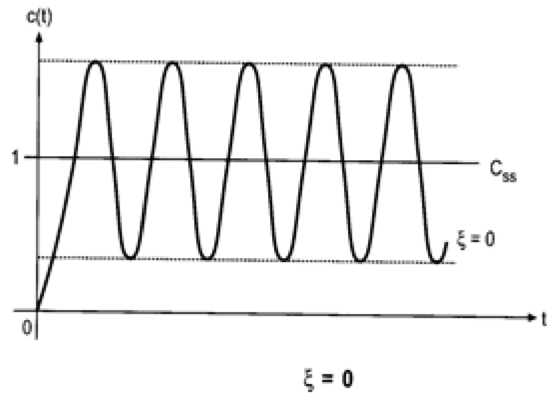
Ans:	<table><tr><th>Two Phase Induction Motor</th><th>AC Servomotor</th></tr><tr><td>In these motor the current flows through rotor due to principle of induction</td><td>In these motors, signal error is converted in to angular velocity to correct the error.</td></tr><tr><td>Two phase induction motor are type of AC motor where power is supplied to the rotor by means of electromagnetic induction, rather than a Commutator or slip rings.</td><td>A servomotor is a rotary actuator that allows for precise control of angular position.</td></tr><tr><td>These motor are widely used in high power industrial drives.</td><td>Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.</td></tr><tr><td>Speed of the induction motor is controlled by the number of poles pairs and the frequency of the supply voltage.</td><td>Servomotors are controlled by microcontrollers.</td></tr><tr><td>Torque producing capacity is high</td><td>Torque speed characteristic is linear.</td></tr></table>	**1 mark each point**	**04**
b)	**Illustrate PI control action with output equation and nature of output response.**		**04**
Ans:	This Control Mode is a combination of the Proportional mode and the integral mode. The output equation of this controlling mode is given by , $P=K_p\ e_p+K_p\ k_i\ \int_0^t e_p\ dt+\ p_i\,(0)$ where $p_i\,(0)$ = Integral term value at t = 0 The main advantage of this composite control mode is that the one to one correspondence of the proportional mode is available and the integral mode eliminates inherent offset.	**2 marks for relevant explanation** **1 mark equation**	

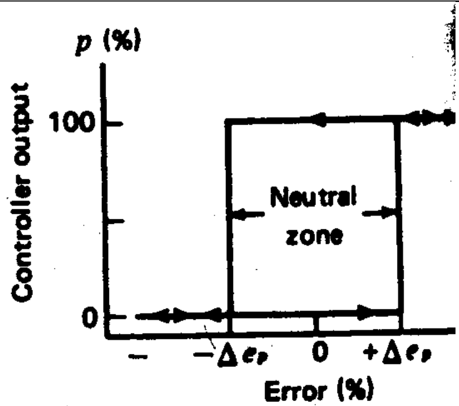
	Figure shows the output response of the PI mode controlling action.  	**1 mark for output respons e**	
c)	**For unity feedback system G(S) =** $\mathbf{\frac{K}{S(1+0.4S)(1+0.25S)}}$ **Find range of values of 'K'. Calculate marginal values of K.**		**04**
Ans:	Characteristic equation: 1 + G(s) H(s) = 0 and H(s) = 1. $\therefore\ 1 + \frac{K}{S(1+0.4S)(1+0.25S)} = 0$ $\therefore\ s(1 + 0.65s + 0.1s^2) + k = 0$ $\therefore\ 0.1s^3 + 0.65\,s^2 + s + k = 0$ $\begin{array}{c\|ccl} S^3 & 0.1 & 1 & \text{for } s^0,\ k > 0 \\ S^2 & 0.65 & k & \text{for } s^1 \\ S^1 & \frac{0.65-0.1k}{0.65} & 0 & 0.65 - 0.1k > 0 \\ & & & \therefore\ 0.65 > 0.1k \\ & & & \therefore\ 6.5 > k \\ S^0 & k & & \end{array}$	**2 marks for value of 'K'** **2**	

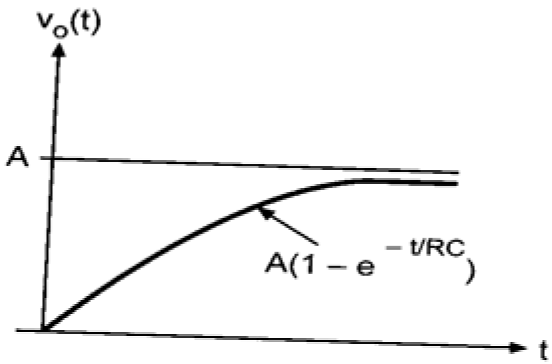
	$\therefore$ Range of values of K: $0 < k < 6.5$ The marginal value of 'K' is a value which makes any row other than s^0 as row of zeros. $\therefore$ $0.65 - 0.1\,K_{mar} = 0$ $\therefore$ $K_{mar} = 6.5.$	**Marks for marginal value of ' K'**	
d)	**A second order system is given by $\frac{C(S)}{R(S)} = \frac{25}{S^2+6S+25}$, find:** **i.) Damping ratio** **ii.) Natural frequency** **iii.) Peak time** **iv.) Settling time**		**04**
	Comparing T.F. with Standard Form $\frac{\omega_n^2}{S^2 + 2\zeta\,\omega_n\,s + \omega_n^2}$ $\omega_n^2 = 25$ and $2\zeta\,\omega_n = 6$ • so , ω_n =5rad/sec and • $\zeta = 0.6$ $\theta = \tan^{-1}\sqrt{1-\frac{\zeta^2}{\zeta}} = 0.9272$ rad. $\omega_d = \omega_n \sqrt{1-\zeta^2} = 5\sqrt{1-(0.6)^2} = 4$ rad/sec. • $T_p = \frac{\Pi}{\omega d} = \frac{\pi}{4} = 0.785$ sec • $Ts = \frac{4}{\zeta\omega_n} = 1.33$ sec	**1 Mark for calculating value for each point**	
e)	**Define transient response and steady state response.**		**04**

Ans:	Transient Response: The output variation during the time, it takes to achieve its final value is called as transient response. Steady state Response: It is that part of the time response which remains after complete transient response vanishes from the system output. It is also define as response of the system as time approaches infinity from the time at which transient response completely dies out.  **(a) $c_t(t)$ is exponential (b) $c_t(t)$ is oscillatory**	**2 marks for each definati on with respons e**	
f)	**Define gain margin and phase margin.**		**04**
Ans:	• Gain Margin: The Margin in gain allowable by which gain can be increased till system reaches on the verge of instability. G.M. = -20 $\text{Log}_{10} \mid G(j\omega)\, H(j\omega) \mid_{\omega = \omega_{pc}}$ • Phase Margin: The amount of additional phase lag which can be introduced in the system till system reaches on the verge of instability is called as phase margin.	2 marks for gain margin 2 marks for phase margin	

	P.M. = $180^0 \pm G(j\omega) H(j\omega)_{\omega = \omega_{gc}}$		
6.	**Attempt any four:**		**16**
a)	**Draw the transient response of second order system for different values of ζ (zeta)**		**04**
Ans:	 $\xi \geq 1$  $\xi < 1$	**1 mark for each response**	

	 ξ = 0 Un-damped response **Note: Marks can be given for relevant explanation too**		
b)	**What is ON – OFF controller? Explain the neutral zone in ON OFF controller.**		**04**
Ans:	ON-OFF controller is a two position discontinuous controlling mode. The mathematical equation of ON-OFF Controller is shown below : P = 0 %, e_p <0 100 % e_p >0 Neutral Zone: In virtually any practical implementation of the two – position controller, there is an overlap as e_p increases through zero or decreases through zero, In this span, no change in controller output occurs. Fig shows p versus e_p for ON-OFF Controller. Until an increasing error changes by Δe_p above zero, the controller output will not change state. In decreasing it must fall Δ $e_p$below zero before the controller changes to the 0% rating.	**2 marks for relevant explanation of ON OFF controller** **2 marks for explanation of neutral**	

		zone	
c)	**Derive the unit step response of first order system.**		**04**
Ans:	The T.F. of First order system is , $\frac{V_0(s)}{V_i(s)} = \frac{1}{1 + sRC}$ For Unit Step input $V_i(s) = \frac{1}{s}$ So, $V_0(s) = \frac{1}{s(1+sRC)} = \frac{A'}{s} + \frac{B'}{1+sRC}$ Where : A' = 1 and B' = - RC $Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC} = \frac{1}{s} - \frac{1}{s} + \frac{1}{RC}$ Taking Laplace inverse, $Vo(t) = 1 - e^{\frac{-t}{RC}} \Rightarrow Css + ct(t)$ $Css = 1$ and $ct(t) = - e^{\frac{-t}{RC}}$	**01 Mark for TF.** **01 Mark for Value of A And B** **01 M for ILT**	

	The Response is shown in fig. 	**01 M for final answer and Response**	
d)	**List any 4 applications of PID controller.**		**04**
Ans:	1) Temperature, Level Controller 2) Flow Controller 3) Uses in Satellite Communication 4) Used in Closed loop Control System **Note: Marks could be given for any other relevant application**	**1 mark for each relevant application.**	
e)	**Determine the stability of a system having characteristics equation**		**04**

	as $S^4 + 4S^3 + S^2 + 8S + 1 = 0$		
Ans:	The Characteristic equation is **$S^4 + 4S^3 + S^2 + 8S + 1 = 0$** So, Apply Routh's Array $$\begin{array}{c\|ccc} S^4 & 1 & 1 & 1 \\ S^3 & 4 & 8 & 0 \\ S^2 & -1 & 1 & 0 \\ S^1 & 12 & 0 & \\ S^0 & 1 & & \end{array}$$ There are two sign changes in first column of the rouths array. So system is <u>unstable</u> with two roots located in right half s-plane.	**03 mark for Routh array and** **01 Mark for conclusion**	