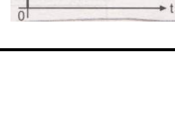
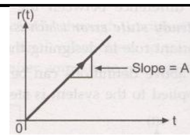
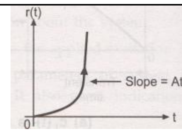
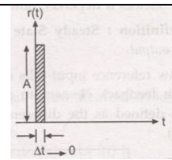
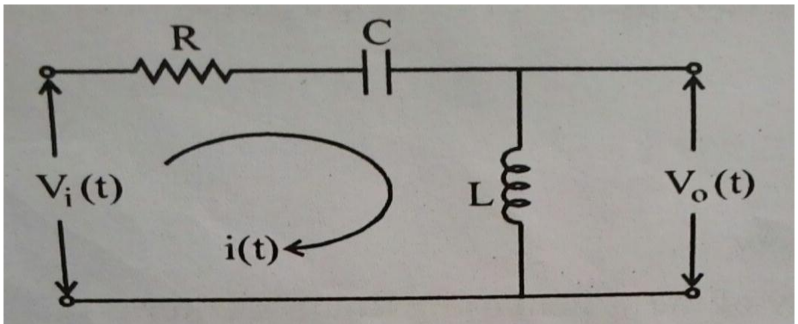
Important Instructions to examiners:

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 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 judgment 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 & its Answer	Remark	Total Marks
1.A	**Attempt any THREE**		**12**
a)	**Compare time variant and time invariant system.**		**04**
Ans.	**Time Variant System:** system where parameters of the system are changing / varying with time irrespective of whether input and output changes or not is called time variant system. Ex: rocket launching system, space shuttle/vehicle **Time Invariant System**: system in which parameter of system are not changing/varying with time irrespective of whether input and output changes or not is called time invariant system. Ex: RC, RLC networks, different electrical network.	**2marks** **2marks**	
b)	**Draw graphical representations of following test I/P and give their Laplace transform.** **i) Step input ii) Ramp input iii) Parabolic input iv) Impulse input**		**04**
Ans			

Test Signal	Graphical representation	Laplace representation	Remark	Total Marks
			1mark each for test input	
Unit Step Input		1/s		

	Unit Ramp Input		$1/s^2$		
	Unit Parabolic Input		$1/s^3$		
	Unit Impulse		1		
c)	**Define stability and explain different types of stability.**				**04**
Ans	**Stability:**If the poles of the system are located on the left half of the s-plane system is said to be stable. **OR** When the system is excited by a bounded input, the output is also bounded and controllable.In the absence of the input, output must tend to zero irrespective of the initial condition. **Types of stability:** When the system is excited by a bounded input, the output is unbounded. **i) <u>Critical stability</u>:-** If the poles (non repeated) are located purely on imaginary axis of s-plane, system is said to be critically stable. **ii)<u>Conditional stability</u>:-** If the Stability of system depends on condition of parameter of the system, such a system is called conditionally stable system. **iii)<u>Relative Stability</u>:** The system is said to be relatively more stable on the basis of settling time.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 second one.			**01 mark definition** **03 marks for explanation of types of stability**	
d)	**Why D control action is not used alone, Justify& give advantages & disadvantages of the same.(any two)**				**04**
Ans	The equation for D controller is: $$P_o = K_D \frac{dE_p}{dt}$$ It shows that the controller output will be zero if i) error $E_p$is zero ii) if error is constant. Therefore D controller is not used alone.			**2 marks**	

	Advantages: fast and stabilizes system **Disadvantages:** cannot eliminate offset, cannot be used alone. **Note. Any two relevant advantage and disadvantage may consider.**	**1 mark** **1 mark**	
B	**Attempt any ONE**		**06**
a)	**Derive transfer function of the given electrical network** **Diagram**  **Fig. 1**		**06**
Ans	Input equation : $V_i(t) = Ri(t) + \frac{1}{C}\int i(t)dt + L\frac{di(t)}{dt}$ Output equation: $V_0(t) = L\frac{di(t)}{dt}$ Taking Laplace of i/p and o/p equations: $V_i(S) = RI(S) + \frac{I(S)}{CS} + LSI(S)$ $V_O(S) = LSI(S)$ TF= $\frac{V_0(S)}{V_i(S)} = \frac{LSI(S)}{RI(S)+\frac{I(S)}{CS}+LSI(S)} = \frac{LCS^2}{LCS^2+RCS+1}$	**1 mark** **1 mark** **1 mark** **1 mark** **2 marks**	
b)	**For unity feedback system with Transfer Function** $G(S) = \frac{40(S+5)}{S(S+10)(S+2)}$ **. Draw the bode plot.**		**06**
Ans	Step 1: Convert the given open loop transfer function to time constant form:	**1 mark**	

$$G(S)H(S) = \frac{40\times 5(\frac{S}{5}+1)}{20S(\frac{S}{10}+1)(\frac{S}{2}+1)} = \frac{10(0.2S+1)}{S(0.1S+1)(0.5S+1)}$$

2 mark

Step 2: Identify the factors;

1. Open loop gain K=10, M in dB= 20 log K= 20 log 10=20dB
2. Pole at origin (1/S) which has a magnitude plot with slope of

-20dB/decade. For w=1, M in dB for (1/S) = -20 log 1=0 dB

3. First order poles (0.1S+1) and (0.5S +1). The corner frequencies of them are w_{c1} =1/0.1=10, w_{c2} =1/0.5=2. Till the corner frequencies the magnitude plot's slope will be
   0 dB/decade and from the corner frequencies it changes to
   -20dB /decade.
4. First order zero (0.2S+1).The corner frequency isw_c =1/0.2=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.

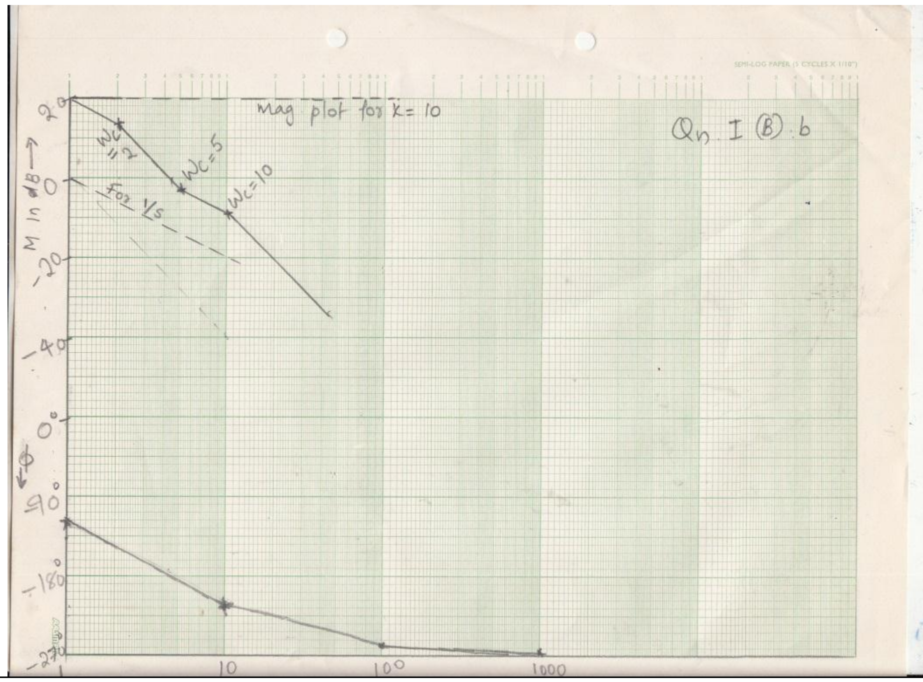
1 mark

Step 3: Phase angle ϕ :

Freq $=\omega$	Factor1 K=10 ϕ_1=	Factor 2, 1/S ϕ_2=	Factor 3, 1/(0.1S+1) $\phi_3 =$ $-\tan^{-1}(0.1\omega)$	Factor 4, 1/(0.5S+1) ϕ_4= $-\tan^{-1}(0.5\omega)$	Factor 4, (0.2S+1) ϕ_5= $\tan^{-1}(0.2\omega)$	Total Phase angle $\phi=\phi_1+\phi_2+\phi_3+\phi_4+\phi_5$
1	0^0	-90^0	-5.7^0	-26.56^0	11.3^0	-122.26^0
10	0^0	-90^0	-45^0	-78.69^0	63.43^0	-213.69^0
100	0^0	-90^0	-84^0	-88.85^0	87.13^0	-262.85^0
1000	0^0	-90^0	-89.42^0	-89.88^0	89.71^0	-269.3^0

2marks

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



Q. 2	**Attempt any TWO**		**16**
a)	**Determine stability system with characteristic equation** **$S^6+4S^5+3S^4-16S^2-64S-48=0$**		**08**
Ans.	Routh's array:	**2marks**	

S^6	1	3	-16	-48
S^5	4	0	-64	0
S^4	3	0	-48	0
S^3	0	0	0	

Because of row of all zeros, form auxiliary equation: **2marks**

$$A(S) = 3S^4 - 48 = 0,$$

$$\frac{dA}{dS} = 12S^3$$

New Routh's array: **3marks**

S^6	1	3	-16	-48
S^5	4	0	-64	0
S^4	3	0	-48	0
S^3	12	0	0	0
S^2	[ε] 0	-48	0	0
S	$\frac{576}{\varepsilon}$	0	0	0
S^0	-48			

$$\lim_{\varepsilon \to 0} \frac{576}{\varepsilon} = +\infty$$

Since there is one sign change in the first column of RA, system is unstable. **1 mark**

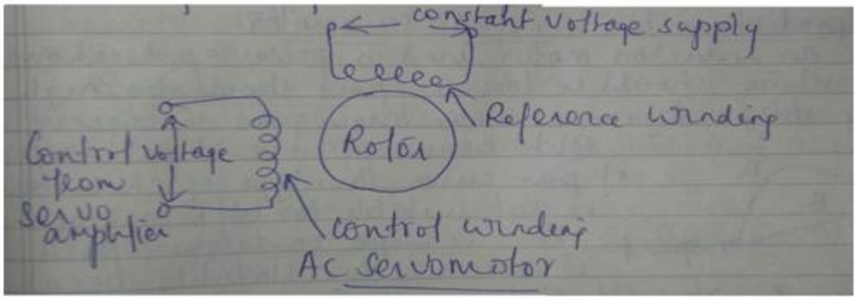
b) **Explain AC servo motor operation with neat diagram. Compare AC servo motor with normal induction motor.(any 4 points)** **08**

Ans **Explanation:** **4 marks**

AC servo motor is similar to induction motor. It consists of 2 stator windings known as reference and control windings uniformly distributed and displaced by 90^0 .Rotor and stator are made of electromagnetic material. The rotor has windings in it which makes short-circuited paths. No external voltage is applied to rotor.

The stator reference winding is excited by a constant AC supply. The stator control winding is excited by a variable error voltage which is obtained from servo amplifier. This results in field currents which give rise to a rotating magnetic field of stator. When it sweeps over the rotor, voltages are induced in rotor windings. This produces currents in the rotor winding which in turn produces a magnetic field in rotor. The rotating magnetic field of stator interacts with rotor magnetic field and this produces torque which causes the rotor to rotate.

Diagram:



Comparison of ACservomotor and normal Induction motor: (any 4 points)

Sr.No	AC servo motor	Normal induction motor
1	Low inertia	High inertia
2	Linear Torque-speed characteristic	Nonlinear Torque-speed characteristic
3	Diameter of rotor is small	Diameter of rotor is large
4	X/R ratio is less	X/R ratio is more
5	Less susceptible to low frequency noise	Susceptible to low frequency noise
6	Low power applications	Low and high power applications
7	Can be used where noise disturbance create problems	Cannot be used in such application.

4 marks

c) **Obtain the transfer function of the following system by using block diagram reduction techniques.** **08**

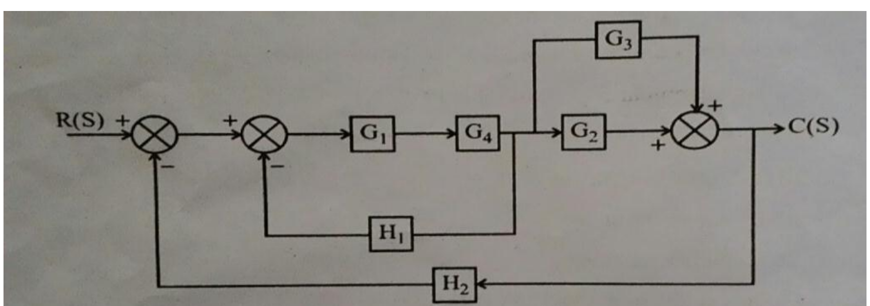
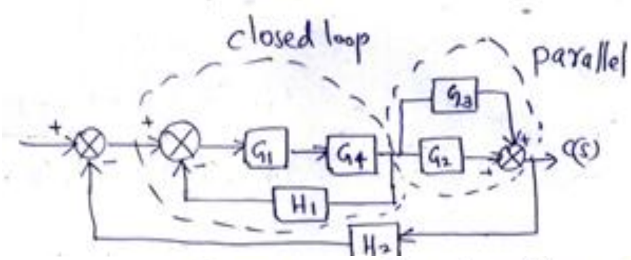
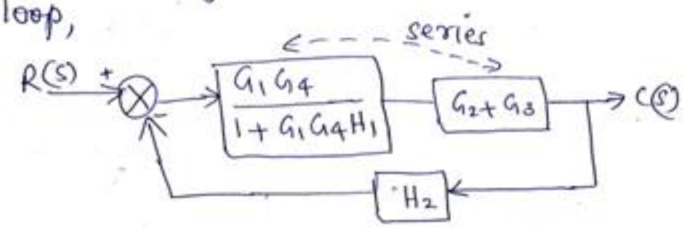
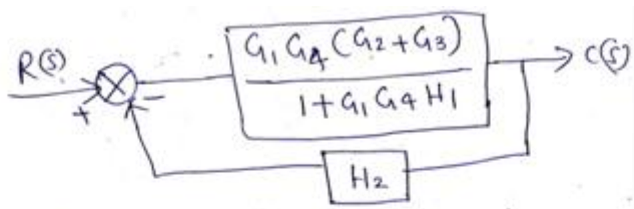
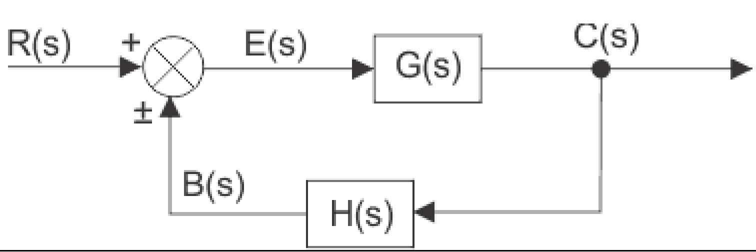
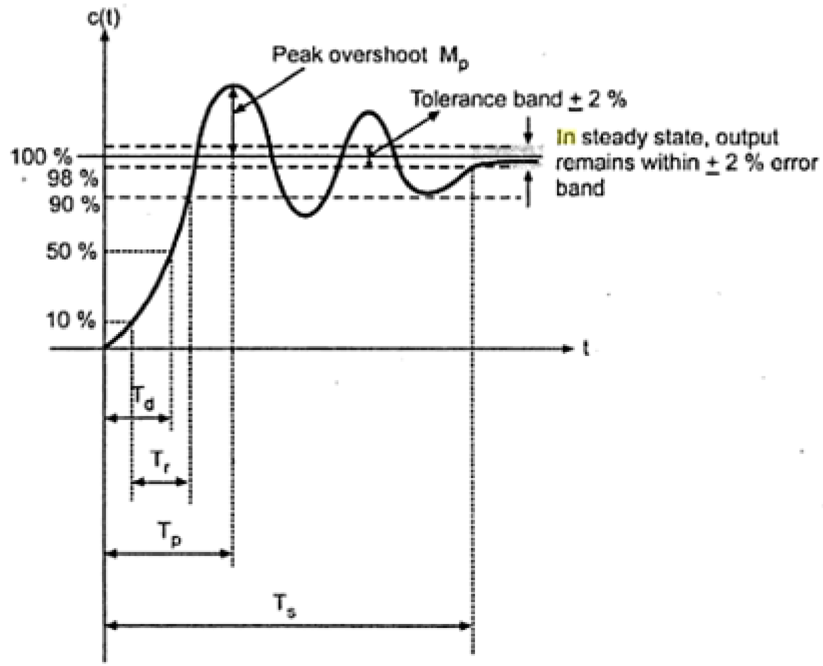


Fig. 2

Ans

	 Considering the closed loop and parallel loop, 	**4 marks**	
	 Considering the above closed loop,	**2marks**	
	$TF = \frac{C(s)}{R(s)} = \frac{G_1 G_4 (G_2+G_3)}{1+G_1G_4H_1+G_1G_4(G_2+G_3)H_2}$	**2marks**	
Q. 3	**Attempt any FOUR**		**16**
a)	**Derive transfer function of closed loop control system.**		**04**
Ans.	**Block diagram: (for negative feedback system)** 	**diagram 1 Mark**	

	Where, G (s) is the transfer function of forward path H (s) is the transfer function of feedback path C (s) is the Controlled output R (s) is the reference input B (s) is the feedback signal E (s) is the Error signal **Derivation:** E(s) = 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: $\boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)*H(s)}}$	**Derivati on 3Marks**	
b)	**Draw labeled time response of 2nd order control system & define i)Delay time ii) Rise time iii)Setting time iv) Peak overshoot**		**04**

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

Delay Time:It is the time required by the response to reach 50% of the final value in first attempt.

Rise Time: Time required for the response to rise from 10% to 90% of the final value for overdamped systems and 0% to 100% of the final value for underdamped systems.

Settling time: Time required for the response to decrease and stay within specified percentage of if final value and within tolerance band (usually 2%).

Peak Overshoot:It is the largest error between reference input and output during the transient period. It can also be defined as the amount by which output overshoots its reference steady state value during the first overshoot.</td><td>diagram 2Marks

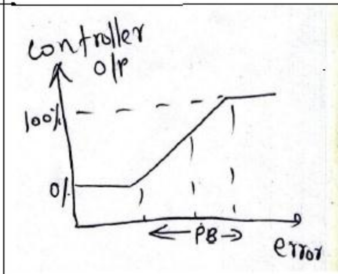
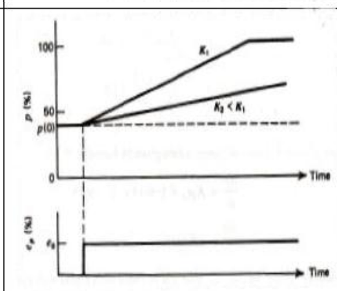
Each definition-1/2 (half) marks</td><td></td></tr>
<tr><td>c)</td><td>Determine stability of the system using Routh'scriterian
$S^5+S^4+2S^3+2S^2+2S+2=0$</td><td></td><td>04</td></tr>
<tr><td>Ans</td><td>Arranging and solving the Routh Array

$$\begin{array}{l|llll}
S^5 & 1 & 2 & 2 & \\
S^4 & 1 & 2 & 2 & \\
S^3 & 0 & 0 & 0 & \text{special case} \\
S^2 & & & \text{Routh 'array failed} & \\
S^1 & & & & \\
S^0 & & & &
\end{array}$$</td><td>1 Mark for forming the Routh Array</td><td></td></tr>
</table>

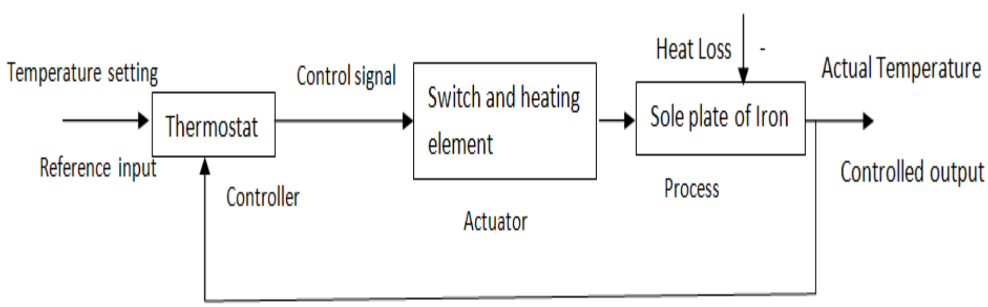
	Auxiliary equation: $A(S)= S^4+2S^2+2=0$ Taking derivative, $dA(S)/dS= 4S^3+4S=0$ By replacing the row of zeros with coefficient of derivative of auxiliary equation, the new routh array will be: S^5 1 2 2 S^4 1 2 2 S^3 4 4 0 S^2 1 2 0 S -4 0 0 S^0 2 0 0 The first column in routh's array has 2 sign changes which indicate that there are two poles on right side of S-plane. So the system is unstable	**1 Mark for forming and solving the auxiliary equation** **1 Mark for completing the Routh Array** **1 Mark for commenton the stability**	
d)	**Compare stepper motor and DC servo motor(any 4 points).**		**04**
Ans	see table below	**1 Mark for each point (any 4 points)**	
e)	**Compare proportional and integral controller on the basis of** **(i) Nature of output**		**04**

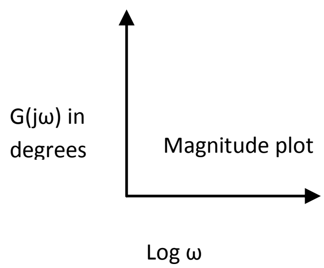
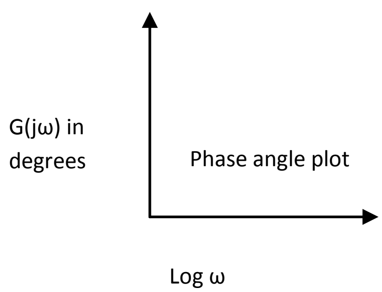
Stepper Motor	**DC Servomotor**
No control winding	Control winding is present.
Number of steps can be precisely controlled.	It gives continuous rotation.
It is brushless.	It has brushes.
Due to absence of brushes, no wear and tear and hence less maintenance	Maintenance is required
Load and no load condition does not affect the running current of stepper motor	These conditions affect the running current
Speed(stepping rate) is governed by frequency of switching	Speed is controlled by supply voltage.

	(ii) Response of error **(iii) Output equation** **(iv) Application**		
Ans	(see table below)	**1 Mark each for the specific points**	

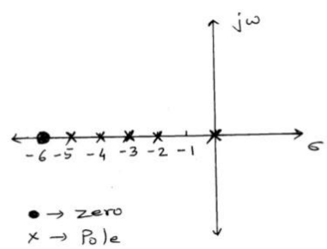
Control Action	Nature of output	Equation	Response of Error	Application
Proportional	Controller output is proportional to error	$K_P E_P + P_0$		Used in processes with medium process lags
Integral	Rate of change of controller output is proportional to error.	$p(t) = K_I \int_0^t e_p\, dt + p(0)$		Used in processes with small process lags & small capacitance such as flow & level control system

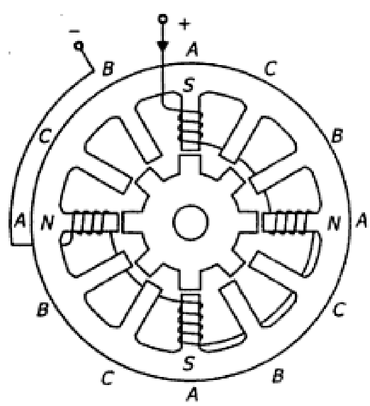
Q.4 A	**Attempt any THREE**		**12**
a)	**Describe principle of automatic electric iron as ON-OFF controller with its standard equation**		**04**
Ans	ON-OFF controller is a two position discontinuous controlling mode. The mathematical equation of ON-OFF Controller is shown below : **Output Equation** P = 0 %, e_p <0 100 % e_p >0 Where, P is the controller output and e_p is the error signal. **OR** ON-OFF controller – it is simplest and cheapest type of discontinuous type of controller. In this controller when measured value is less than SP full controller output results. When it is more than SP controller output is zero.	**1 mark** **1 Mark**	

	Explanation: In automatic electric iron, a resistive heating element is used to generate heat. A thermostat is used as controller to control the temperature. The reference input is the desired temperature setting on the thermostat. The controlled output is the actual temperature of the electric iron. When the output temperature is less than the thermostat reference setting, the thermostat is actuated which, in turn, switches on the heating element. As a result, the temperature increases, and when it exceeds the thermostat setting (desired value of temperature) by a small amount, the heating element is turned off. The temperature then starts decreasing. When it falls below the thermostat setting by a small amount, the heating element is once again switched on. The heating cycle is thus repeated. The sole plate of the iron of which the temperature is to be controlled is the Process. The actuator is the heating element and the thermostat acts as the error detector and controller. Disturbance to the system is the heat loss due to radiation. **Diagram of Electric Iron as On-Off Controller:**  Block diagram of Electric Iron as On-Off Controller (Any other relevant diagram should be considered)	**1 Mark** **1 mark for figure**	
b)	**Give need of bode plot & describe straight line magnitude plot & Phase angle plot.**		**04**
Ans	**Need Of Bode Plot:** 1) To find the stability of control system 2) The experimental determination of transfer function is easier if frequency response data is presented in the form of logarithmic plot. Such plot shows both low and high frequency characteristics in the same diagram. **Magnitude Plot**: The magnitude plot is expressed in its logarithmic values by finding out the value $20 \log_{10} \lvert Gj(\omega) \rvert$ dB. Such decibel values are plotted against $\log_{10} \omega$.	**1 mark (any relevant 1 point)** **1.5 marks**	

	 **The Angle Plot**: In this, the angle of Gj(ω) is expressed in degrees which is plotted against log10 ω.  	**1.5 marks**	
c)	**For the given close T.F.** $\frac{C(s)}{R(s)} = \frac{10(s+6)}{s(s+2)(s+5)(s^2+7s+12)}$ **Determine. (i)Poles (ii)Zener (iii)Characterstic equation (iv) Pole-Zero plot on S-Plane**		**04**
Ans	**i) Poles** $s(s+2)(s+5)(s^2+7s+12)=0$ **Therefore, poles are 1) s=0** **2) (s+2)=0 i.e s=-2** **3) (s+5)=0 i.e. s=-5** **4)** $(s^2+7s+12)=0$ **It is a quadratic equation whose roots are** $\frac{-7\pm\sqrt{(7^2-4x1x12)}}{2x1} = \frac{-7\pm\sqrt{(49-48)}}{2}$ $= \frac{-7\pm\sqrt{1}}{2} = -4,-3$ **Therefore, poles are 0,-2,-5,-4,-3** **ii) Zeros** **(s+6)=0 i.e s=-6** **iii) Characteristics equation**	**1 Mark for each correct answer**	

<table>
<tr><td></td><td>iv)

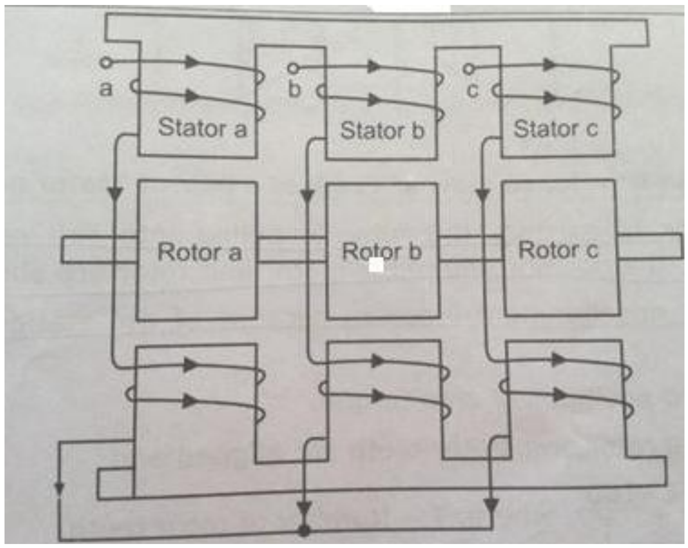
$$s(s+2)(s+5)(s^2+7s+12)=0$$

</td><td></td><td></td></tr>
<tr><td>d)</td><td>Describe variable reluctance type stepper motor with neat sketch</td><td></td><td>04</td></tr>
<tr><td>Ans</td><td>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.

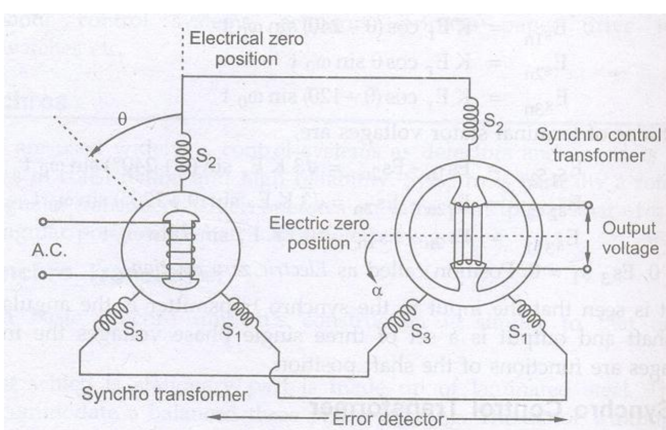


Schematic diagram of a three-phase single stack variable reluctance stepper motor. Only the 'A' phase windings are shown for clarity.

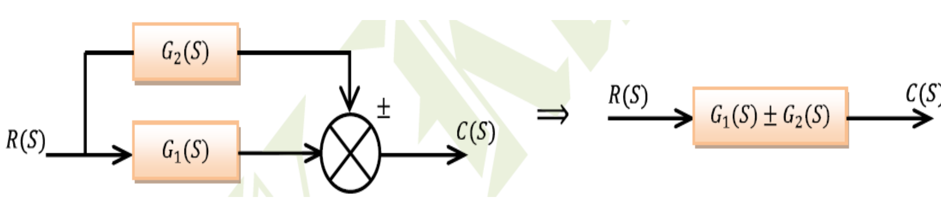
As shown in the figure, when phase A is energized through supply, the rotor moves to the position in which the rotor teeth align themselves with the teeth of phase A. In this position the reluctance of the magnetic circuit is minimum. After this if phase A is deenergised and phase B is energized by giving proper supply to its winding (not shown in fig.), the rotor will rotate through an angle of 150 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 150 in clockwise direction.. Thus, by sequencing power supply to the phases the rotor could be made to rotate by a</td><td>Sketch-
2 Marks

Descrip
tion-2
Marks</td><td></td></tr>
</table>

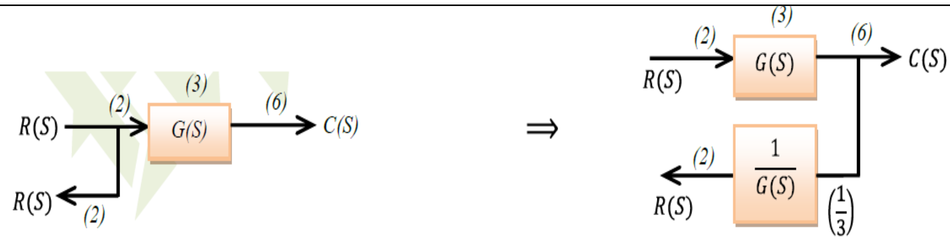
	step of 150each time. The direction of rotation could be reversed by changing the sequence of supply to the phase, that is, for anti-clockwise rotation, supply should be given in the sequence of ACB **OR**  In this type, the windings are arranged in different stacks. The figure represents a three stack 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 : $\alpha = 360/qT$ where q = number of stacks, T = number of teeth		
(B)	**Attempt any ONE**		**06**
a)	**For given transfer function.** $\frac{C(s)}{R(s)} = \frac{25}{(s^2+6s+25)}$ **Determine. Tr, Ts, Tp, %Mp for unit step I/p**		**06**
Ans	Comparing the given equation with the standard form of second order	**1 Mark**	

	equation $$\frac{C(s)}{R(s)}=\frac{\omega_n^2}{\omega_n^2+2\xi\omega_n s+s^2}$$ we get, $\omega_n^2 = 25$ $2\xi\omega_n = 6$ Therefore, $\omega_n = \sqrt{25} = 5$ rad/s And $2*\xi*5=6$, therefore, $\xi=0.6$ $\theta = \tan^{-1}[\sqrt{(1-\xi^2)}/\xi] = 0.9272$ radians $\omega_{d==}\omega_n\sqrt{(1-\xi^2)} = 4$ rad/s **Rise Time. Tr=** $\pi - \theta/\omega_d$ $= (\pi-0.9272)/4 = 0.5535$ sec **Settling Time**, **Ts=4/** $\xi\,\omega_n = 1.33$ sec (for a tolerance band of + 2%) **Peak Time**, **Tp=** $\pi/\omega_d = \pi/4 = 0.785$ sec **% Peak overshoot,%Mp= e**$^{-\pi\xi/\sqrt{(1-\xi 2)}}$x100=9.48%	**for finding ωn.** **1 mark for finding ξ.** **1 mark for each correct answer of parameters. (Tr,Ts, Tp,Mp)** **(Due consideration should be given to correct formula)**	
b)	**Identify with servo component can be used as error detector in AC servo system. Draw and explain it.**		**06**
Ans	Usually, synchos are used as error detector in AC servo systems. **Diagram of Synchro as error detector**  **Explanation :**	**1 Mark for identification** **3 Marks for labeled diagram**	

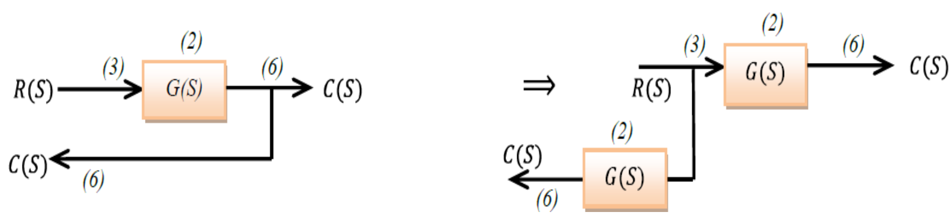
<table>
<tr><td></td><td>Synchro transmitter along with synchro control transformer is used as error detector . The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap.
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.</td><td>**2 Marks for the explanation**</td><td></td></tr>
<tr><td>**Q.5)**</td><td>**Attempt any FOUR**</td><td></td><td>**16**</td></tr>
<tr><td>**a)**</td><td>**Draw and explain block diagram reduction rules. (Any four)**</td><td></td><td>**04**</td></tr>
<tr><td>**Ans.**</td><td>**i) Combining a block in cascade:** When two or more blocks are connected in series, their overall transfer function is the product of individual block transfer function.


ii) Combining two blocks in parallel: When two or more blocks are connected in parallel, their overall transfer function is the addition or difference of individual transfer function.


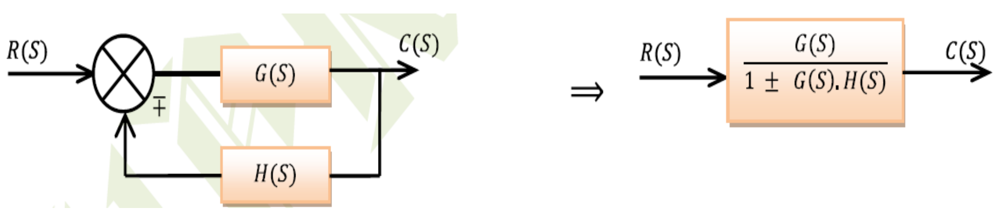
iii) Shifting a take **off point after a block:** To shift take off point after a block, we shall add a block with transfer function 1/G in series with signal having taking off from that point.</td><td>**01 Mark for each (any 04 correct rules)**</td><td></td></tr>
</table>



iv) Shifting a take off **point before a block:** To shift take off point before a block, we shall add a block with transfer function G in series with signal having taking off from the take off point

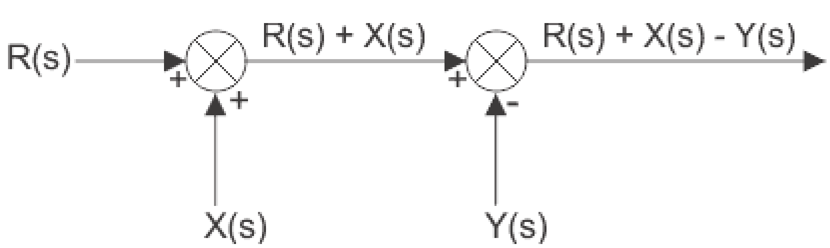


v) Eliminating Feedback Loop:

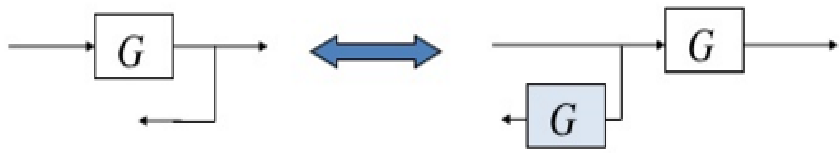


$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s).H(s)}$$

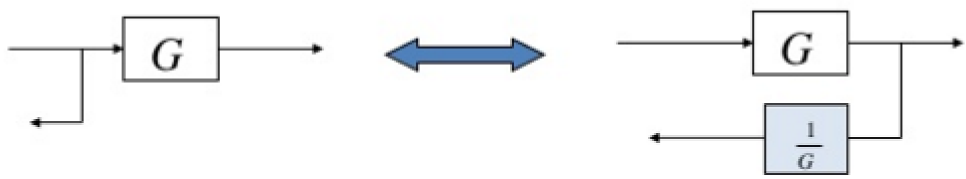
vi) **Interchanging Summing Points:** The order of summing points can be interchanged, if two or more summing points are in series and output remains the same.



vii) **Moving Take off point before a summing point:** To shift a take off point before summing point, add a summing point in series with take off point.



viii) **Moving Take off point after a summing point:** To shift a take off point after summing point, one more summing point is added in series with take off point.



ix) Moving summing point after a block: To shift summing point after a block, another block having transfer function G is added before the summing point.

x) Moving summing point before a block: To shift summing point before a block, another block having transfer function 1/G is added before the summing point.

b)	**Find all error coefficients & steady state error for following differential equation** $$\frac{d^2y}{dx} + 4\frac{dy}{dx} + 8\,y(t) = 8\,x(t)$$		**04**

Ans. Taking Laplace for zero initial

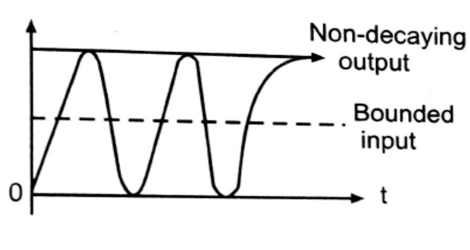
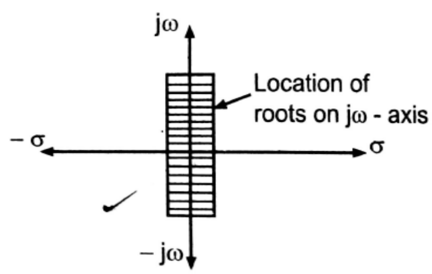
$$s^2.Y(s) + 4.s.Y(s) + 8.Y(s) = 8.X(s)$$

$$\text{Y(s)}\,[s^2 + 4.s + 8\,] = 8.X(s)$$

$$G(s) = \frac{Y(s)}{X(s)} = \frac{8}{(s^2 + 4.s + 8\,)}$$

i) Positional error coefficient (K_p) is given by,
$K_p = \lim_{s\to 0} G(s).H(s)$

	Assuming unity feedback system i.e. H(s) = 1, we will get $K_p = \lim_{s\to 0} G(s) = \lim_{s\to 0} \frac{8}{(s^2+4.s+8)}$ $K_p = \frac{8}{8} = 1$ ii) Velocity error coefficient (K_v) is given by, $K_v = \lim_{s\to 0} s.G(s).H(s)$ Assuming unity feedback system i.e. H(s) = 1, we will get $K_v = \lim_{s\to 0} s.G(s)$ $Kv = \lim_{s\to 0} s.G(s) = \lim_{s\to 0} \frac{8.s}{(s^2+4.s+8)}$ $K_v = 0$ iii) Acceleration error coefficient (K_a) is given by, $K_a = \lim_{s\to 0} S^2.G(s).H(s)$ Assuming unity feedback system i.e. H(s) = 1, we will get $K_a = \lim_{s\to 0} S^2.G(s) = \lim_{s\to 0} \frac{8.S^2}{(s^2+4.s+8)}$ i.e. $K_a = 0$ iv) Steady State Error is given as, $ess = \lim_{s\to 0} \frac{s\ .\ X(s)}{1+G(s).H(s)}$ Assuming H(s) = 1 & X(s) = $\frac{1}{s}$ for unit step input, we get $ess = \lim_{s\to 0} \frac{s\ .\ X(s)}{1+G(s)}$ $ess = \lim_{s\to 0} \frac{s*1/s}{1+\frac{8}{(s^2+4.s+8)}} = \lim_{s\to 0} \frac{(s^2+4.s+8)}{8+(s^2+4.s+8)}$ $ess = \frac{(0+0+8)}{8+(0+0+8)} = \frac{8}{16}$	**Kp – 01 Mark** **Kv – 01 Mark** **Ka – 01 Mark** **Ess – 01 Mark**	

	ess = 0.5 or $\frac{1}{2}$		
c)	**What do you mean by stability? Define critically stable system.**		**04**
Ans.	**Stability:** i) The system is said to be stable if it produces bounded output for a bounded input. ii) It is used to define usefulness of the system. iii) The stability implies that the system performance should not change even if there are small changes in system input. iv) Any control system must be stable. v) The system is stable if poles of the system lie on left half of s-plane vi) The system can be classified into six types based on stability. i.e. stable system, unstable system, limitedly stable system, absolutely stable system, critically stable system, conditionally stable system and relatively stable system. **Critically Stable System:** i) The (linear-time invariant) system is said to be critically stable system, if the system output does not go on increasing infinitely nor does it go to zero as time increases, when it is excited by input signal. ii) The output of a system usually oscillates in a finite range or remains steady at some value. Such systems are not stable as their response does not decay to zero. iii) Neither the system is defined as unstable because its output does not go on increasing infinitely. iv) This system is also called as marginally stable system v) For critically stable system, the location of poles is on the iw-axis and they are not repeated as shown below  **(a) Bounded input producing neither bounded nor unbounded output**  **(b) Location of roots**	**2 Mark for meaning of stability** **2 Mark for relevant definition of critically stable system**	
d)	**Give four advantages and four disadvantages of bode plot.**		**04**
Ans.	**Advantages of bode plot:** i) It is based on the asymptotic approximation, which provides a simple	½	

	method to plot the logarithmic magnitude curve. ii) The multiplication of various magnitude appears in the transfer function can be treated as an addition, while division can be treated as subtraction as we are using a logarithmic scale. iii) With the help of this plot only we can directly comment on the stability of the system without doing any calculations. iv) Bode plots provides relative stability in terms of gain margin and phase margin. v) It also covers from low frequency to high frequency range. **Disadvantages of bode plot:** i) Absolute of only minimum-phase system can be determine from bode plot. ii) Relative stability of only minimum-phase system can be determine from bode plot. iii) If the phase margin is measure below the -180 degree axis, the phase margin is negative and the system is unstable. **iv)** It is not so easy to carry out the design of controller by referring to the bode plot.	**mark each (any four advantages)** ½ **mark each (any four disadvantages)**	
e)	**Define damping. Show effect of damping in response of 2nd order control system.**		**04**
Ans.	**Damping :** i) Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations. ii) The damping ratio is a dimensionless measure describing how oscillations in a system decay after a disturbance. iii) The damping ratio is generally denoted by zeta (ζ) iv) The damping ratio is a measure of describing how rapidly the oscillations decay from one bounce to the next. **OR** **Damping:** Every system has a tendency to oppose the oscillatory behavior of the system which is called damping. **OR** Damping ratio/factor explain us how much dominant the opposition from	**01 Mark**	

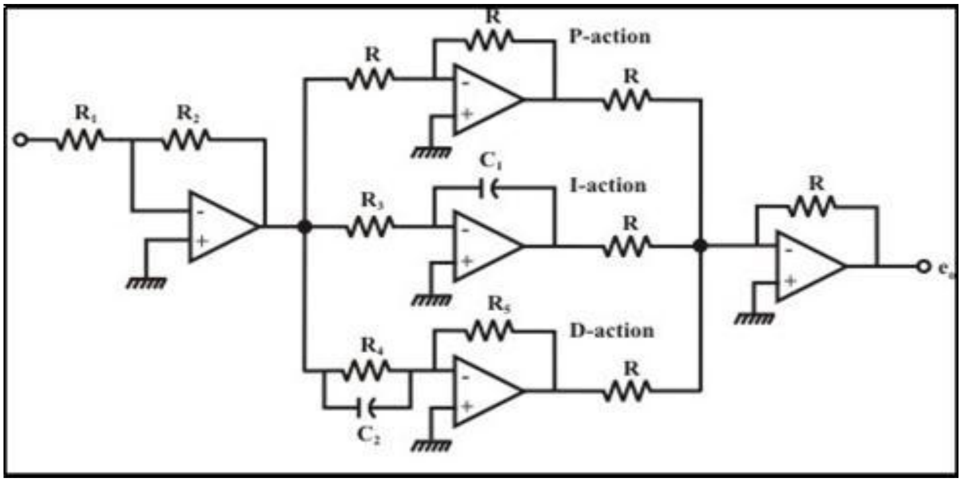
system is to the oscillation in the output.

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

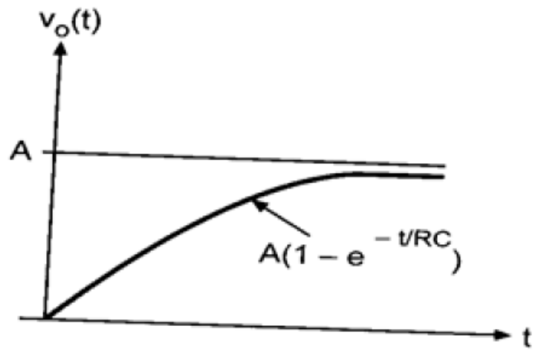
No.	Range of ζ	Type of close loop poles	Nature of response	System Classification
1	$\zeta = 0$	Purely imaginary	Oscillations with constant amplitude & frequency	Undamped
2	$\mathbf{0 < \zeta < 1}$	Complex Conjugates with negative real parts	Damped Oscillations	Underdamped
3	$\mathbf{\zeta = 1}$	Real,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

03 marks

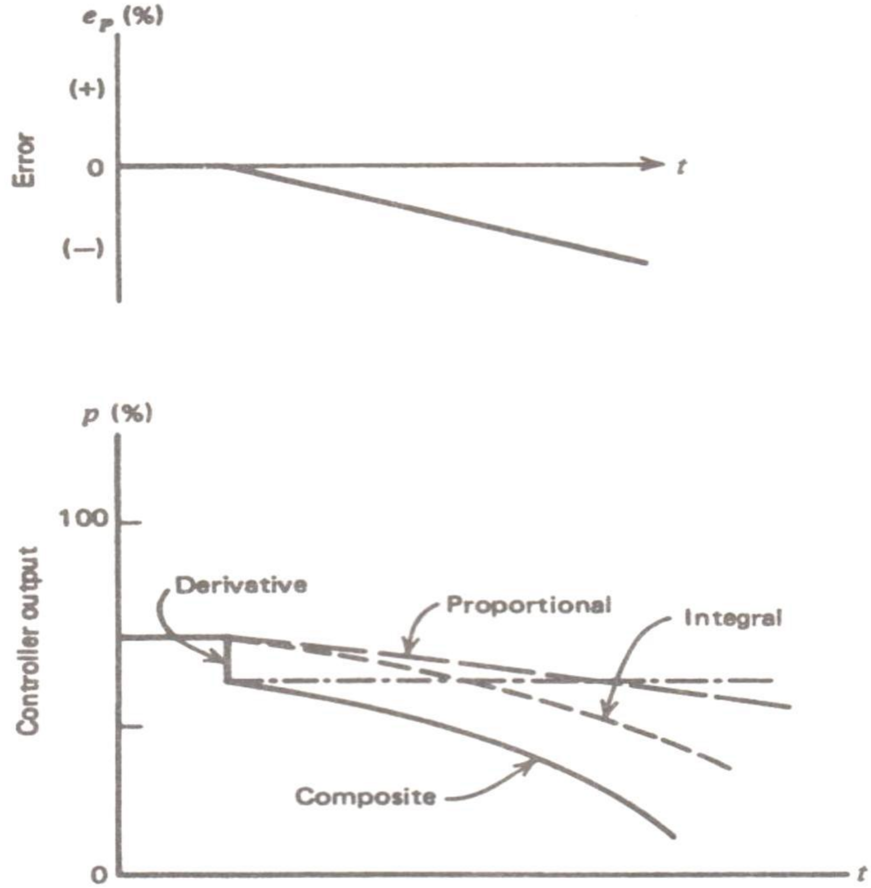
f)	**Draw neat labelled diagram of PID controller & Define (1) Proportional Band (2) Offset.**		**04**

Ans.		**02 Marks**	
	Proportional Band: Proportional band is defined as the amount of change in the controlled variable required to drive the loop output from 0 to 100%. In a controller the manipulating variable is proportional to the control deviation within the proportional band. The gain of the controller can be matched to the process by altering the proportional band. If the proportional band is set to zero, the controller action is ineffective.	**01 Mark**	
	Offset: A common characteristic of proportional control is an error between the set point and control point, which is referred to as offset or droop. As the system load and/or proportional band increases, so does throttling range. Offset is an undesirable characteristic of proportional only control action and is easily eliminated by adding Integral Action.	**01 Mark**	
Q. 6	**Attempt any FOUR**		**16**
a)	**Give advantages and Disadvantages of Frequency Response Analysis (four each)**		**04**
Ans.	**Advantages of Frequency Response Analysis** i) It is easy to get a frequency response in laboratory with good accuracy ii) It is useful to determine the transfer function of complicated system, which can not be determined by analytical technique. iii) The signal generators and precise measuring instruments for generation of sinusoidal signals of various ranges of frequency and amplitude are readily available. iv) The absolute stability and relative stability of closed loop control system can be estimated from the knowledge of open loop frequency response. v) The design and parameter adjustment of the open loop transfer	**½ mark each (any four advantages)**	

	function of a system for a specified closed loop performance can be carried out easily. vi) The effect of noise disturbance and parameter variations can be easily visualized and assessed. vii) The transient response of a system can be obtained from its frequency response. viii) It can be extended to certain non-linear systems ix) There is no need to evaluate the roots of the characteristics equation. x) It can give more quickly the design and analysis specification of the control system having multiple loops and poles. **Disadvantages of Frequency Response Analysis** i) It cannot be used for linear systems having large time constant. ii) It cannot be used for non-interruptible systems. iii) It gives only indirect indication of the nature of the time response of the system which is always the final aim of studying system behavior. iv) It can give approximate results only, as it is graphical method. v) With the increased use of digital computers and available software's, it is not used for analysis.	**½ mark each (any four disadvantages)**	
b)	**Derive expression of output response of 1st order system for unit step input.**		**04**
Ans.	The T.F. of First order system is , $$\frac{Vo(s)}{Vi(s)} = \frac{1}{1+sRC}$$ For Unit Step Input $V_i(s) = \frac{1}{s}$ So, $Vo(s) = \frac{1}{s(1+sRC)} = \frac{A'}{s} + \frac{B'}{1+sRC}$ Where A' = 1 & B' = –RC So, $Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC}$ Taking Laplace inverse, we get $Vo(t) = 1 - e^{\frac{-t}{RC}} => C_{ss} + C_t(t)$ $C_{ss} = 1$ and $C_t(t) = -e^{\frac{-t}{RC}}$	**01 Mark for TF.** **01 Mark for Value of A And B** **01Mark for Inverse LT**	

	The Response is shown in fig. 	**01 Mark for final answer and Response**	
c)	**For unity feedback system** **Find G(s) =** $\frac{50}{(1+0.1s)(1+2s)}$ **Find Kp, Kv, Ka.**		**04**
Ans.	i) Here system is unity feedback system so, H(s) = 1 So, $G(s).H(s) = \frac{50}{(1+0.1s)(1+2s)} = \frac{50}{\left(1+\frac{s}{10}\right)(1+2s)} = \frac{500}{(s+10)(1+2s)}$ $G(s) = \frac{250}{(s+10)(s+0.5)}$ ii) Positional error coefficient (K_p) is given by, $K_p = \lim_{s\to 0} G(s).H(s)$ As, H(s) = 1, we will get $K_p = \lim_{s\to 0} G(s) = \lim_{s\to 0} \frac{250}{(s+10)(s+0.5)}$ $K_p = \frac{250}{5} = 50$ iii) Velocity error coefficient (K_v) is given by, $K_v = \lim_{s\to 0} s.G(s).H(s)$ As, H(s) = 1, we will get $K_v = \lim_{s\to 0} s.G(s)$ $Kv = \lim_{s\to 0} s.G(s) = \lim_{s\to 0} \frac{250.s}{(s+10)(s+0.5)}$ $K_v = 0$ iv) Acceleration error coefficient (K_a) is given by, $K_a = \lim_{s\to 0} S^2.G(s).H(s)$	**01 Mark** **Kp – 01 Mark** **Kv – 01 Mark** **Ka – 01 Mark**	

	As, H(s) = 1, we will get $K_a = \lim_{s\to 0} S^2.G(s) = \lim_{s\to 0} \frac{250.S^2}{(s+10)(s+0.5)}$ i.e. $K_a = 0$		
d)	**Describe PID control action with neat sketch.**		**04**
Ans.	**Explanation:** i) The combination of proportional control action, derivative control action and integral control action is called as PID controller action. ii) The combined action has advantage of the three individual control actions. The proportional controller stabilizes gain but produces steady state error. iii) The integral action reduces the steady state error. The derivative action reduces the rate of change of error. iv) PID controller is a band pass or band attenuate filter, depending on the values of the controller parameters. v) The response characteristics of PID controller is shown in figure. The proportional part of the control action repeats the change of deviation. vi) The derivative action of the control action adds on increment of manipulated variables so that the proportional plus derivative control action is shifted ahead in time. vii) The integral part of the control action adds a further increment of manipulated variable.	**Explanation 02 Mark**	

		**Diagram 02 Marks**	
e)	**Find range of values of K so that system with following characteristics equation will be stable,** **$F(s) = s (s^2 + s + 1) (s + 4) + K = 0$**		**04**
Ans.	The characteristics equation is given by, $s (s^2 + s + 1) (s + 4) + K = 0$ $(s^3 + s^2 + s) (s + 4) + K = 0$ i.e. $s^4 + 5. s^3 + 5. s^2 + 4. s + K = 0$	**01 Mark for Equation**	**04 Marks**

	The routh's array for above characteristics equation is formed as follows S^4 1 5 4 S^3 5 4 0 S^2 4.2 K 0 S^1 $\frac{16.8-5K}{4.2}$ 0 S^0 K For stability all elements of 1st column should be positive. i.e. $\frac{16.8-5K}{4.2} > 0$ for S^1 row i.e. $K < \frac{16.8}{5}$ i.e. $0 < K < 3.36$ This is range of K for stable system.	**Array solving 02 Marks** **K value 01 Mark**	