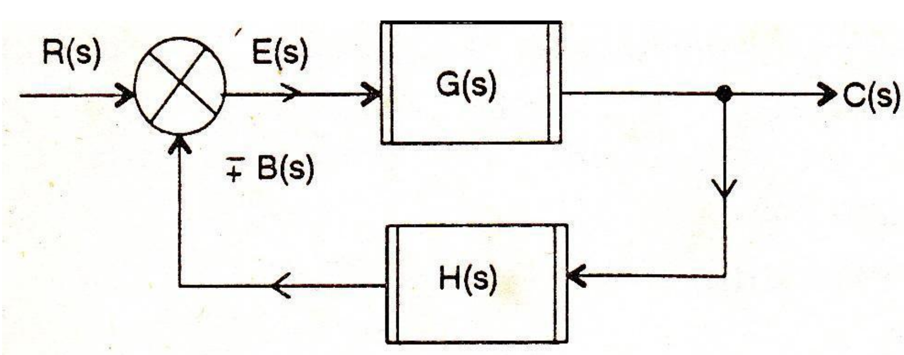
SUMMER – 15 EXAMINATION

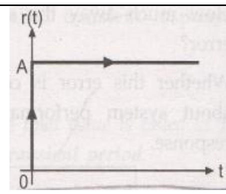
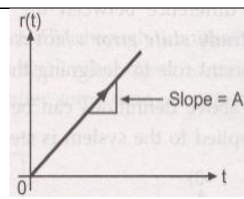
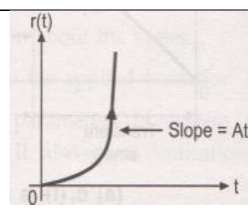
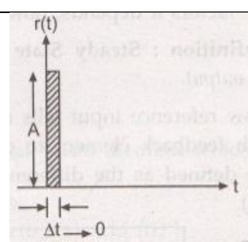
Subject Code: 17538 **Model Answer**

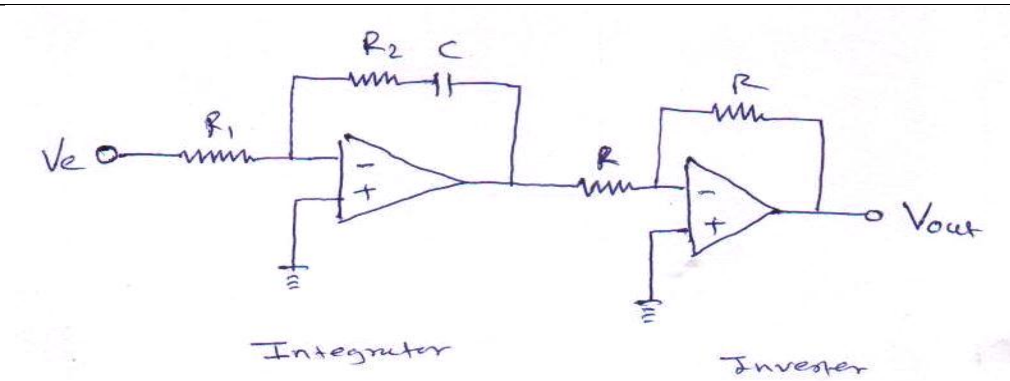
Important Instructions to examiners:

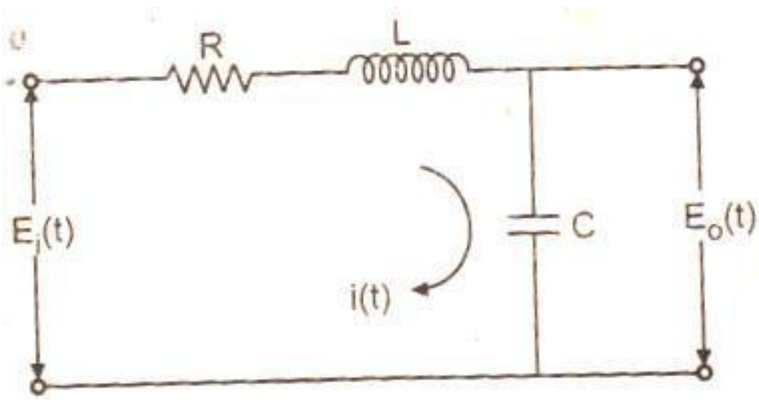
1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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**
i)	**Define transfer function. Derive an expression for transfer function of closed loop system.**		**04**
Ans:	**Definition:** TF is defined as the ratio of Laplace transform of output to that Laplace transform of input under the assumption of zero initial condition Transfer function of closed loop system:- 	**Definition-01 mark, expression -03 marks**	

	R(s) – Laplace of reference i/p R(t). C(s) – Laplace of controlled o/p C(t). E(s) – Laplace of error signal e(t). B(s) – Laplace of feedback signal b(t). G(s) – Equivalent forward path transfer function H(s) – Equivalent feedback path transfer function. Referring to this Fig. E(s) = R(s) + B(s) -----------(1) B(s) = C(s) H(s) -----------(2) C(s) = E(s) G(s) ------------(3) B(s) = C(s) H(s) and substituting in equation (1) E(s) = R(s) +C(s) H(s). E(s) = C(s) / G(s) C(s) / G(s) = R(s) + C(s) H(s). C(s) = R(s) G(s) + C(s) G(s) H(s) Hence, C(s) [1 ± G(s) H(s)] = R(s) G(s) C(s) / R(s) = G(s) / 1± G(s) H(s).		
ii)	**What are different standard test inputs? Draw them and give their laplace transform.**		**04**

<table>
<tr>
<td>Ans:</td>
<td>The different standard test inputsare-
a) Step input b) Impulse input c) Ramp input d) Parabolic input
<table>
<tr><th>Test Signal</th><th>Graphical representation</th><th>Laplace representation</th></tr>
<tr><td>Unit Step Input</td><td>
</td><td>$\frac{1}{s}$</td></tr>
<tr><td>Unit Ramp Input</td><td>
</td><td>$\frac{1}{s^2}$</td></tr>
<tr><td>Unit Parabolic Input</td><td>
</td><td>$\frac{1}{s^3}$</td></tr>
<tr><td>Unit Impulse</td><td>
</td><td>1</td></tr>
</table>
</td>
<td>List of std. i/p-01 mark, Sketches& L.T-03 marks</td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>Define stable, unstable and critically or marginally stable system.</td>
<td></td>
<td>04</td>
</tr>
<tr>
<td>Ans:</td>
<td>STABLE : A linear time invariant system is said to be stable if following conditions are satisfied:</td>
<td></td>
<td></td>
</tr>
</table>

	1.) When the system is excited by a bounded input, output is also bounded and controllable. 2.) In the absence of the input, output must tend to zero irrespective of the initial condition. **UNSTABLE**: A linear time invariant system is said to be unstable if following conditions are satisfied: 1.) If for a bonded input it produces unbounded output. 2.) In absence of the input, output may not return to zero it shows certain output without input. **CRITICALLY STABLE**: A linear time invariant system is said to be critically or marginally stable if for a bounded input its output oscillates with constant frequency and amplitude.	**4-marks for each definition**	
iv)	**Draw electronic PI controller diagram and write its output equation.**		**04**
Ans:	Fig:- Electronic PI controller. **Analytical equation for PI controller is given as** $\mathbf{P=K_PK_I\int Idt+K_PE_P}$ From figure, output equation can be written as,	**Diagram-02 marks, equation-02 marks**	

	$V_{out}=\frac{R1}{R2}V_{in}+\frac{1}{R1C}\int V_{in}dt$ $V_{out} =[\frac{R1}{R2}]V_{in+} [\frac{R1}{R2}][\frac{1}{R2C}]. \int V_{in}dt$		
1.B	**Attempt any One:**		**06**
i)	**Find the transfer function of RLC circuit shown in figure 1**  Figure 1: RLC circuit		
Ans:	Vi = iR + Ldi / dt + 1 / c idt. Take Laplace transform, Vi(s) = I (s) [R + SL + 1/ SC] I(s) / Vi (s) = 1 / [R + SL + 1/ SC] ----- (1) Vo = 1 /C (idt) Hence, Vo (s) = 1 / SC I(s) I(s) = SC Vo(s) -------(2) Substituting value of I (s) in equation 1 SC Vo(s)/ Vi(s) = 1/ [R + SL + 1/ SC] Vo(s) / Vi(s) = 1 / SC[R + SL + 1 /SC]	**04 marks**	

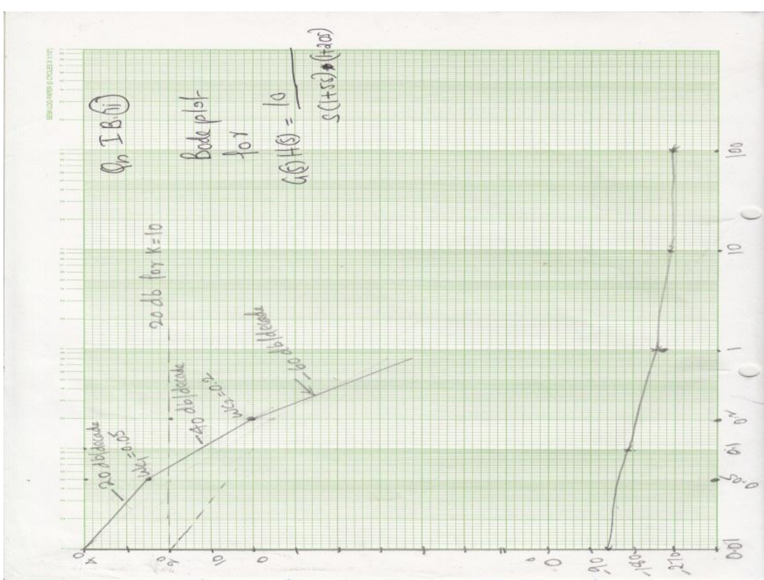
<table>
<tr><td></td><td>$Vo(s) / Vi(s) = 1 / S^2 LC + SRC +1$</td><td></td><td></td></tr>
<tr><td>ii)</td><td>Draw the bode plot for open loop transfer function.
$G(s)H(s) = \frac{10}{s(1+5s)(1+20s)}$</td><td></td><td>06</td></tr>
<tr><td>Ans:</td><td>Step 1: Identify the factors;
1. Open loop gain K=10, M in dB= 20 log 10= 20 dB
2. Pole at origin (1/S) which has a magnitude plot with slope of -20Db/decade. For w=0.01,
M in dB for (1/S) = -20 log0.01= 40 dB
3. First order poles (5S+1) and (20S +1). The corner frequencies of them are w_{c1} = 1/5=0.2, w_{c2} =1/20= 0.05
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 2: Phase angle ϕ:
<table>
<tr><td>Frequency =w</td><td>For Factor1, K=10
ϕ_1=</td><td>For Factor 2, 1/S
ϕ_2=</td><td>For Factor 3, 1/(5S+1)
$\phi_3 = -\tan^{-1} 5w$</td><td>For Factor 3, 1/(20S+1)
$\phi_4 = -\tan^{-1} 20w$</td><td>Total phase angle
$\phi = \phi_1 + \phi_2 + \phi_3 + \phi_4$</td></tr>
</table></td><td>2 mark

2 marks</td><td></td></tr>
</table>

0.01	0^0	-90^0	-28^0	-11.3^0	-129^0
0.05	0^0	-90^0	-14^0	-45^0	-149^0
0.1	0^0	-90^0	-26^0	-63.4^0	-179^0
0.2	0^0	-90^0	-45^0	-75.9^0	-210.9^0
1	0^0	-90^0	-78.6^0	-87.1^0	-255.7^0
10	0^0	-90^0	$-88.8.2^0$	-89.7^0	-267.6^0
100	0^0	-90^0	-89.8^0	-89.9^0	-269.5^0

2mark

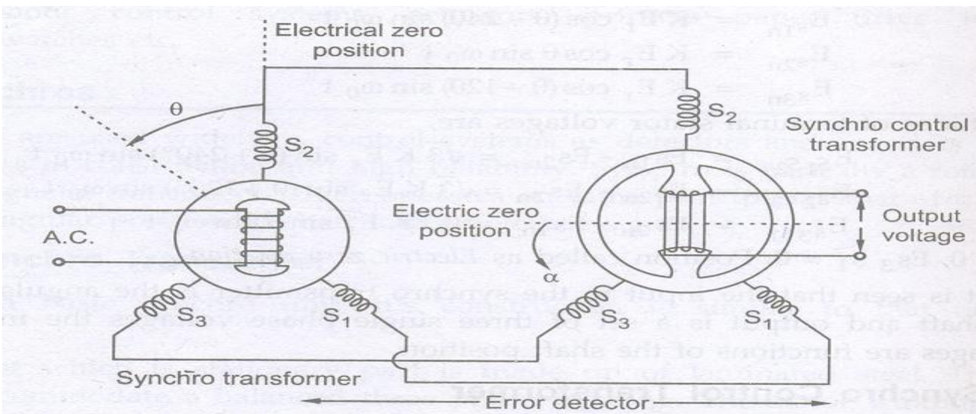
Step 3: Draw the magnitude plot and phase angle plot on semilog paper.



2.	**Attempt any Two:**		**16**
a)	**Using Routh's criteria, determine the range of K values for system to be stable.** $G(s)H(s)=\frac{K}{s(s+2)(s+4)(s+5)}$		**08**
Ans:	Sol: The characteristic eq is $1+G(s)H(s)=0$. $\therefore 1+\frac{K}{s(s+2)(s+4)(s+5)}=0$ $\therefore s(s+2)(s+4)(s+5)+K=0$. $\therefore s^4+11s^3+38s^2+40s+K=0$ is the characteristic eq. Now, the Routh array is s^4 | 1 38 K s^3 | 11 40 0 s^2 | 34.36 K s^1 | $\frac{1374.5-11K}{34.36}$ 0 s^0 | K For stability column 1 should be positive. $\therefore K>0$ —(i) & $\frac{1374.5-11K}{34.36}>0$ —(ii) i.e. $1374.5-11K>0$ or $1374.5>11K$ or $K<124.9$ $\therefore$ Range of K is $K<0<124.9$	**Char. Equation-01 M, Routh's array-2marks,Range-01mark**	

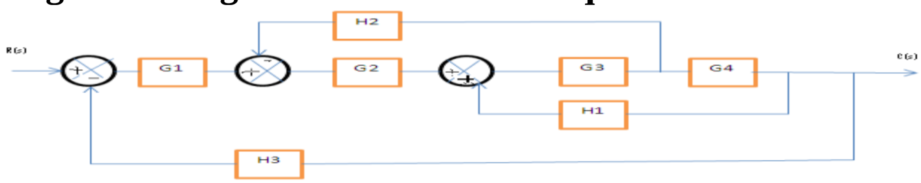
b) **i) Draw a neat sketch of synchro as an error detector.**
ii) Compare DC servomotor with AC servomotor. **08**

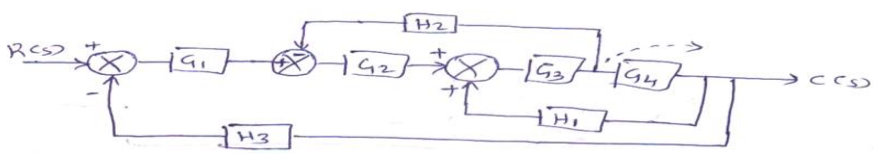
Ans: i) **sketch of synchro as an error detector.** **Diagram-04 marks**

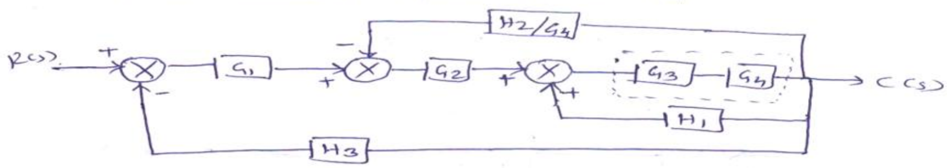


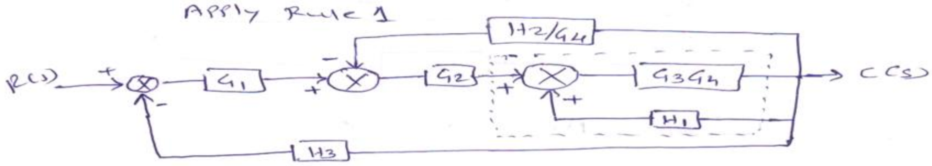
ii) **Compare DC servomotor with AC servomotor.** **Any 4 points-04 marks**

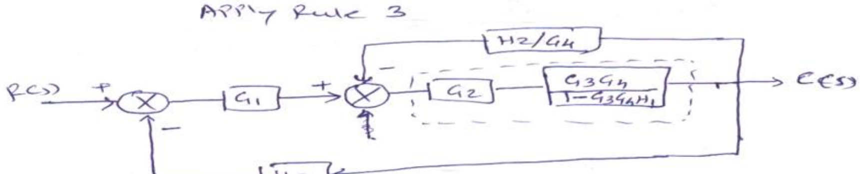
Sr. no	DC servomotor	AC servo motor
1	High power o/p	Low power o/p
2	Maintenance is more maintenance	Maintenance is less
3	Brushes / problem, commutators present	No Brushes / commutators absent
4	Noisy operation	Stable and smooth operation
5	More problem of stability	Less problem of stability
6	Brushes produce RF noise.	No RF noise because of absence of brushes
7	Linear characteristics	Non – linear characteristics
8	Voltage is given through power supply to rotor.	No voltage supply to rotor, Rotor current is supplied inductively by rotating magnetic field of stator.
9	Applications:- high power (machine tools, robotics)	Applications:- low power(computer peripherals, recorders etc.)

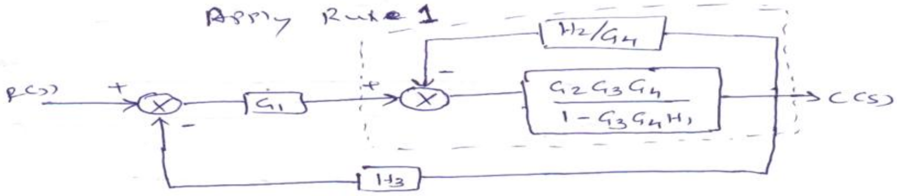
<table>
<tr>
<td>c)</td>
<td>Derive the transfer function of the system shown in Figure below using block diagram reduction techniques.


</td>
<td></td>
<td>08</td>
</tr>
<tr>
<td>Ans:</td>
<td>Soln:


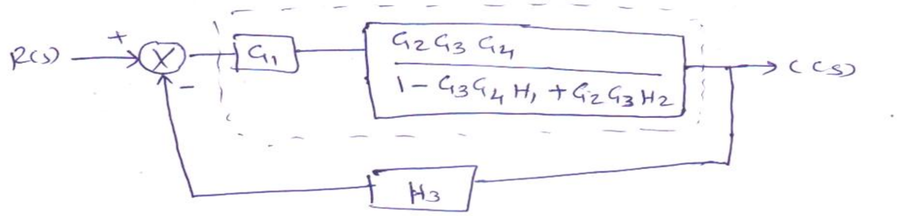
Shift takeoff point after G4


Apply Rule 1


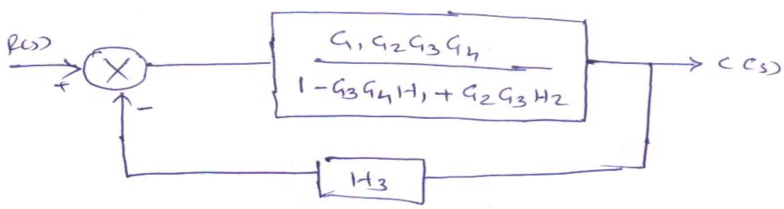
Apply Rule 3


Apply Rule 1


Apply Rule 3
</td>
<td>4 marks</td>
<td></td>
</tr>
</table>



Apply Rule 1



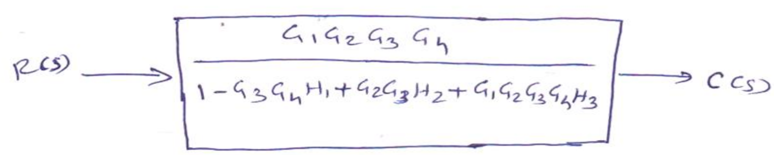
Apply Rule 3

The Gain is

$$\frac{G}{1+GH} = \frac{\frac{G_1G_2G_3G_4}{1-G_3G_4H_1+G_2G_3H_2}}{1+\frac{G_1G_2G_3G_4}{1-G_3G_4H_1+G_2G_3H_2}\cdot H_3}$$

$$= \frac{G_1G_2G_3G_4}{1-G_3G_4H_1+G_2G_3H_2+G_1G_2G_3G_4H_3}$$

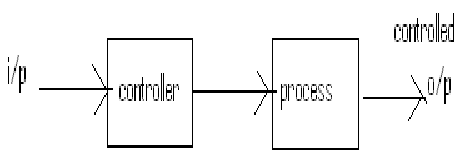
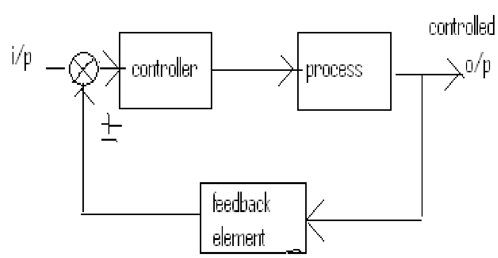
∴



4 marks

3.	**Attempt any four:**		**16**
a)	**Compare open loop and closed loop control system.(any 4 points)**		**04**

Ans:

Open loop	Closed loop
Feedback absent.so any change in o/p does not affect i/p	Feedback present. So changes in o/p affect i/p
It is inaccurate	Highly accurate.
Highly sensitive to disturbances	Less sensitive to disturbances
Simple construction	Complicated design.
Cheaper	Costlier
Stability is more	Stability is less
Smaller bandwidth	Bandwidth is large
	

Any 4 points-01 Mark for each point

b) **Draw neat sketch of unit step response of second order system. Define rise time and settling time.** **04**

Ans:

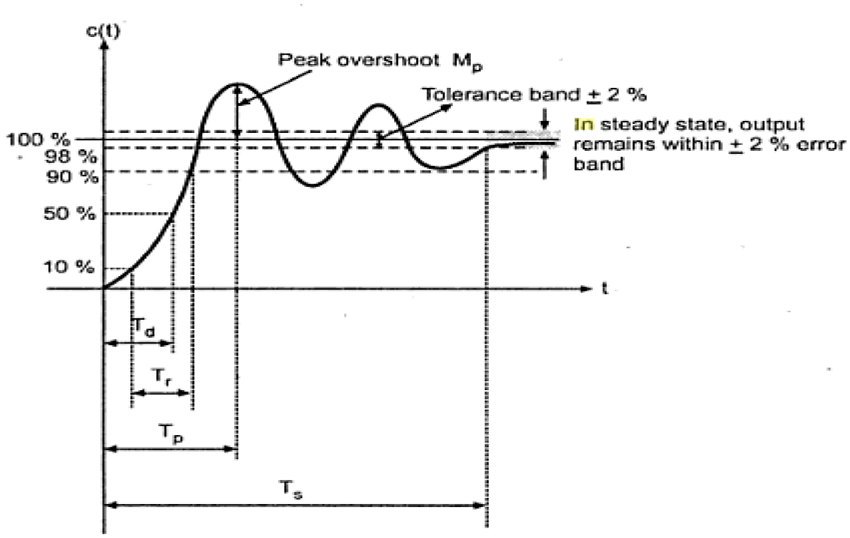
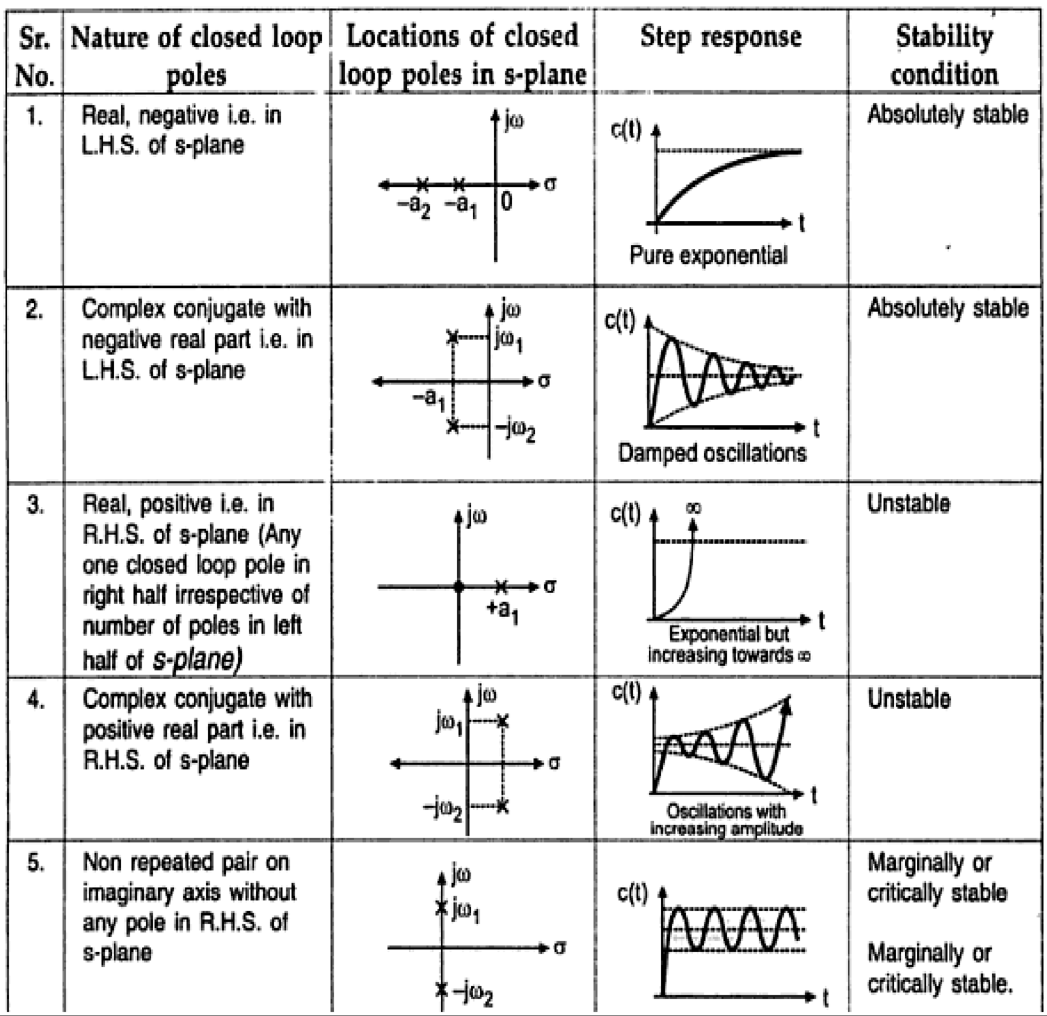


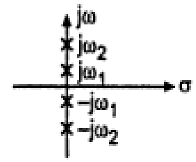
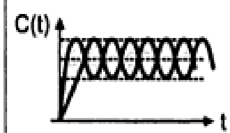
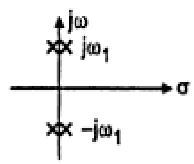
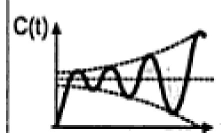
Fig. 2marks

Rise time &settling time 1 mark of each

	Definition: **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%).		
c)	**Draw the diagrams for stability of the system w. r. t root location in s-plane.**		**04**
Ans:	(see table below)	**Ref. table Any 4-points 4 marks**	



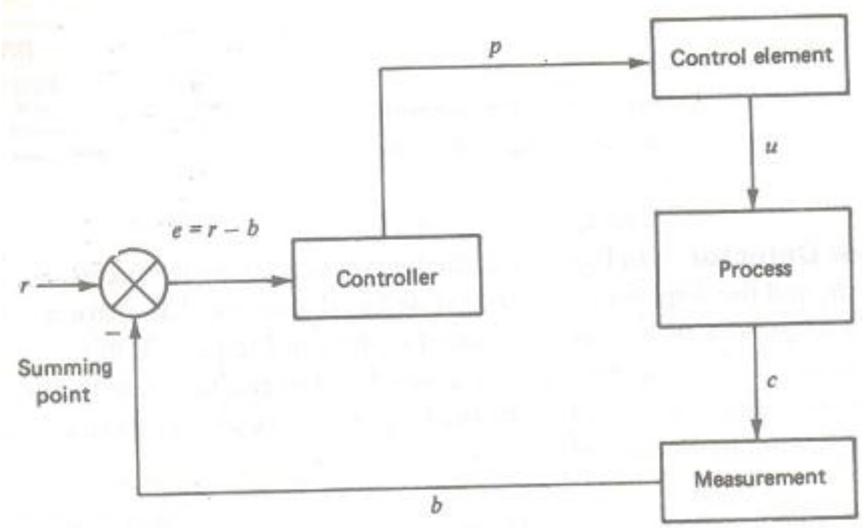
Sr. No.	Nature of closed loop poles	Locations of closed loop poles in s-plane	Step response	Stability condition
1.	Real, negative i.e. in L.H.S. of s-plane	jω, σ, $-a_2$, $-a_1$, 0	c(t), t; Pure exponential	Absolutely stable
2.	Complex conjugate with negative real part i.e. in L.H.S. of s-plane	jω, $j\omega_1$, σ, $-a_1$, $-j\omega_2$	c(t), t; Damped oscillations	Absolutely stable
3.	Real, positive i.e. in R.H.S. of s-plane (Any one closed loop pole in right half irrespective of number of poles in left half of s-plane)	jω, σ, $+a_1$	c(t), ∞, t; Exponential but increasing towards ∞	Unstable
4.	Complex conjugate with positive real part i.e. in R.H.S. of s-plane	jω, $j\omega_1$, σ, $-j\omega_2$	c(t), t; Oscillations with increasing amplitude	Unstable
5.	Non repeated pair on imaginary axis without any pole in R.H.S. of s-plane	jω, $j\omega_1$, σ, $-j\omega_2$	c(t), t	Marginally or critically stable Marginally or critically stable.

		or  two non repeated pairs on imaginary axis.	Frequency of oscillations = ω_1  Sustained oscillations with two frequency components ω_1 and ω_2	
6.	Repeated pair on imaginary axis without any pole in R.H.S. of s-plane		 Oscillations of increasing amplitude	Unstable

Note: Any relevant diagram of s-plane with root location in both plane and imaginary axis may be considered.

d) Compare stepper motor and DC servo motor. **Any 4 points- 4 marks** **04**

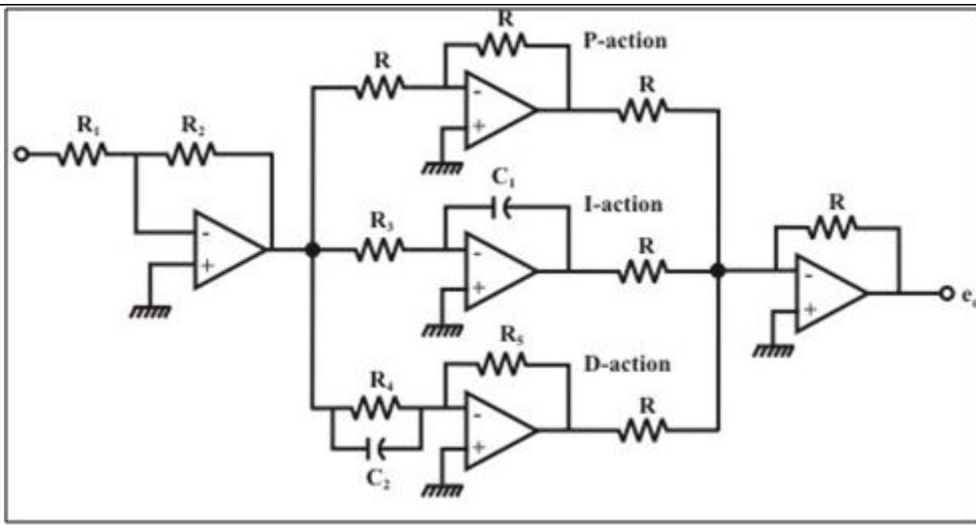
Stepper Motor	DC Servomotor
No control winding	Control winding is present.
Number of steps can be precisely controlled.	It gives continuous rotation.
It is brushless.	It has brushes.
Due to absence of brushes, no wear and tear and hence less maintenance	Maintenance is required
Load and no load condition 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.

<table>
<tr><td>e)</td><td>Draw and describe block diagram of process control system.</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>

Explanation :

The block diagram of process control system consists of the following blocks:-
1) <u>Measuring element</u>: It measures or senses the actual value of controlled variable ‘c’ and converts it into proportional feedback variable b.
2) <u>Error detector</u> : 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) <u>Controller</u>: It generates the correct signal which is then applied to the final control element. Controller output is denoted by ‘ p’.
4) <u>Final control element</u>: 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) <u>Process</u>: Output of control element is given to the process which changes the process variable. Output of this block is denoted by ‘u’.</td><td>2 Marks For diagram

2 Marks For related explainatio n</td><td></td></tr>
</table>

4.A.	**Attempt any three:**		**12**
i)	**Draw electronic PID controller and state its equation.**		**04**
Ans:	 **Equation:** $V = V_S + K_P * E + K_I * \int_0^t E * dt + K_D * \frac{dE}{dt}$ Where: V = Control variable V_S = Output Set point K_P = Proportional gain E = Error (SP-PV) K_I = Integral gain K_D = Derivative gain t = Time	**Diagram-3Marks Equation-1mark**	

	Note: Any relevant equation of PID controller may considered.		
ii)	**Define following terms related with frequency response.** **a) Bandwidth** **b) Cut of frequency** **c) Gain margin** **d) Phase margin**		**04**
Ans:	**Bandwidth:** Range of the frequencies over which the system will respond satisfactorily. It is also defined as range of the frequency over magnitude of closed loop response does not drop by more than 3db from its zero value. **Cut of frequency:** Frequency at which the magnitude of closed loop response is 3db down from its zero frequency value. **Gain margin:** Gain Margin is gain allowable by which the gain can be increased till system reaches on the verge of instability . Mathematically: $\mathbf{GM=-20log_{10}\|G(jw)H(jw)\|w=w_{pc}}$ Where, w_{pc}=phase cross over frequency **Phase margin:**The amount of additional phase lag which can be introduced in the system till system reaches on the verge of instability. Mathematically: $\mathbf{PM=180^0+\|G(jw)H(jw)\|w=w_{gc}}$ Where, w_{gc}=gain cross over frequency	**Each definition 1 mark**	
iii)	**For open loop transfer function** $G(s) = \frac{10}{s(0.5s+1)}$ **Determine:** **a) Damping ratio** **b) Undamped natural frequency** **c) Damped natural frequency** **d) Maximum overshoot**		**04**
Ans:	The closed loop transfer function will be $T(f)=\frac{G(s)}{1+G(s)}$;H(s)=1 (assumed)	**1 mark each**	

$$= \frac{\frac{10}{s(0.5s+1)}}{1+\frac{10}{s(0.5s+1)}}$$

$$= \frac{\frac{10}{s(0.5s+1)}}{\frac{s(0.5s+1)+10}{s(0.5s+1)}}$$

$$T(f) = \frac{10}{0.5s^2 + s + 10} = \frac{10}{0.5(s^2+\frac{s}{0.5}+\frac{10}{0.5})}$$

$$= \frac{20}{s^2+2s+20}$$

Comparing the above transfer function with the standard form

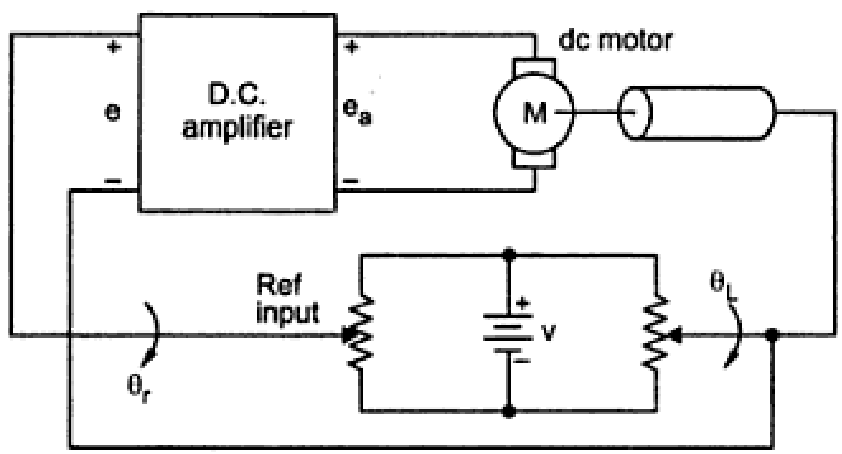
$$T(f)=\frac{w_{n^2}}{s^2+2\xi w_n+w_{n^2}}$$

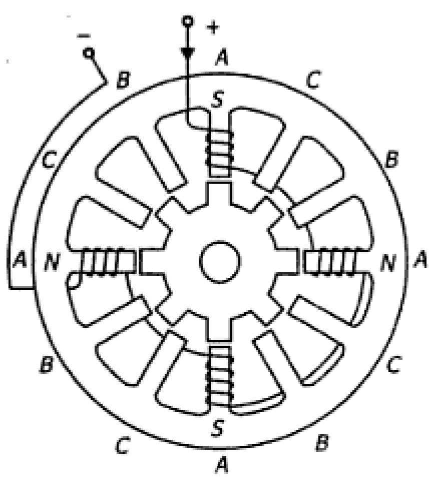
$w_{n^2}=20$ and $2\xi w_n=2$

$w_n = 4.47$ and $\xi = \frac{2}{2\times 4.47}$

$=0.224$

a) **Damping ratio**= $\xi=0.224$

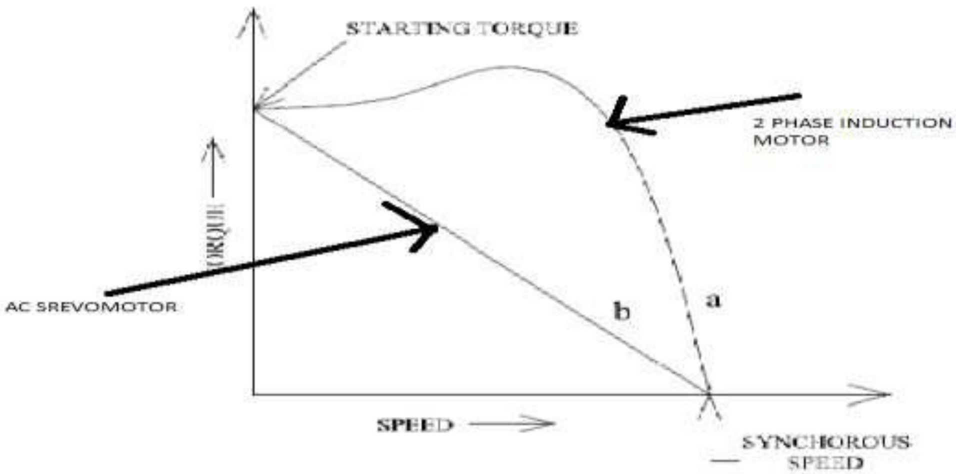
	b) Undamped natural frequency: ω_n=4.47 rad/sec **c) Damped natural frequency:** $\omega d = \omega n\sqrt{(1-\xi^2)} = 4.47\sqrt{(1-0.224^2)} = 4.3563$ rad/sec **d) Maximum overshoot:** $M_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}} * 100$ **=48.4%**		
iv)	**With neat sketch, describe potentiometer as an error detector.**		**04**
Ans:	 **Explanation :** DC Motor control systems potentiometers can be used as position feedback as shown . This type of arrangement allows comparison of two remotely located shaft positions. The output voltage is taken across the variable terminasls of the two potentiometers. Output of this differential potentiometer is =Ks[θ_r(t) – θ_L(t)] This is then is fed to DC Amplifier, which is further amplifying the	**2 marks for diagram** **2marks for explaination**	

	armature current of the DC Motor. The motor, in turn moves and with it the shaft connected to the load potentiometer in such a way as to make the output voltage zero. That is the output (Load) potentiometer shaft moves in accordance with the shaft of the input(reference) potentiometer.		
4.B.	**Attempt any one:**		**06**
i)	**Describe working of variable reluctance type stepper motor with suitable diagram.**		**06**
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.  *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	**Diagram 3 Marks** **Relevant Working 3 marks**	

	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 15^0 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 15^0 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 anti-clockwise rotation, supply should be given in the sequence of ACB.		
ii)	**A second order system is given by** $\frac{C(s)}{R(s)} = \frac{6}{s^2+5s+6}$ **Determine:** **a) Rise time** **b) Peak time** **c) Settling time** **d) Peak overshoot**		**06**
Ans:	Assuming that the second order system is subjected to unit step input. $\frac{C(s)}{R(s)} = \frac{6}{s^2+5s+6}$ Comparing the given equation with the standard form of second order equation, $\frac{C(s)}{R(s)} = \frac{\omega_n{}^2}{\omega_n{}^2+2\xi\omega_n s+s^2}$ we get, $\omega_n{}^2$=6 and $2\xi\omega_n$=5 Therefore, $\omega_n=\sqrt{6}$=2.45 rad/sec and $2*\xi*2.45=5$ Therefore, $\xi=\frac{5}{4.9}$=1.02 approximatly=1	**2 marks for calculating ζ (zeta) &w_n**	

	a) **Rise time:** $T_r = \frac{\pi - \theta}{\omega d}$ $\theta = \tan^{-1}\left(\frac{\sqrt{1-\xi^2}}{\xi}\right) = \tan^{-1}\left(\frac{\sqrt{1-1}}{1}\right) = \tan^{-1}(0) = 0$ $\omega d = \omega n \sqrt{(1-\xi^2)} = 2.45\sqrt{(1-1)} = 0$ rad/sec Hence, $\xi = 1$ System is critically damped & hence no oscillations and no damped Therefore all 4 specifications do not exist on the response of the above system. **Note: Any appropriate answer with formula and suitable assumption may also considered.**	**02 Marks for relevant Justification**	
5.	**Attempt any four:**		**16**
a)	**State how AC servomotor differ from a normal 2-phase induction motor and draw its torque-speed characteristics.**		**04**
Ans:	(see table below)	**Any 3 points: 3 marks, characteristics: 1 marks**	**04**

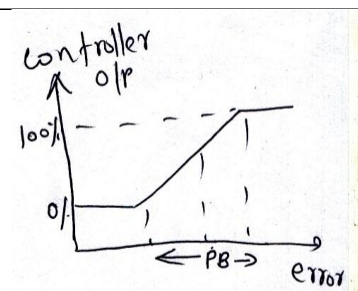
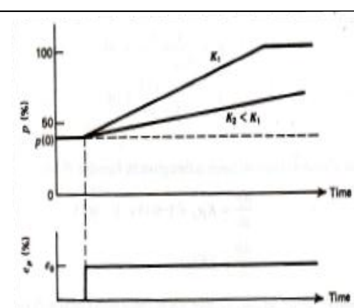
Sr.No	AC servo motor	2 phase induction motor
1	Low inertia	High inertia
2	Linear Torque-speed characteristic	Nonlinear Torque-speed characteristic
3	Less susceptible to low frequency noise	Susceptible to low frequency noise
4	Low power applications	Low and high power applications
5	Diameter of rotor is small	Diameter of rotor is large
6	X/R ratio is less	X/R ratio is more

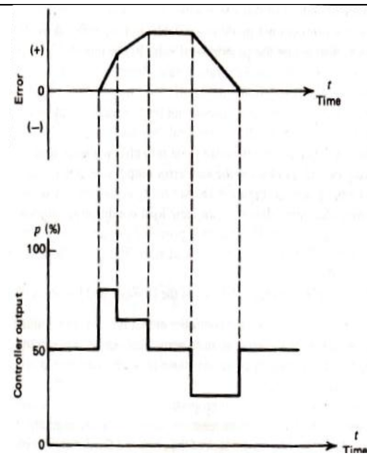


Torque-speed Characteristic

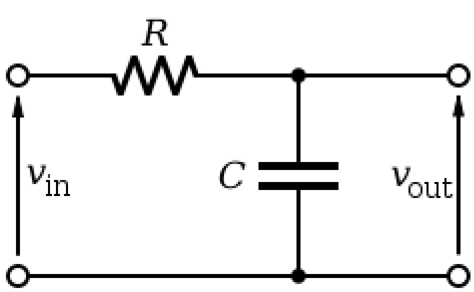
b) Compare P; I and D control actions on the basis of nature of input, response to error, equation and applications. **04**

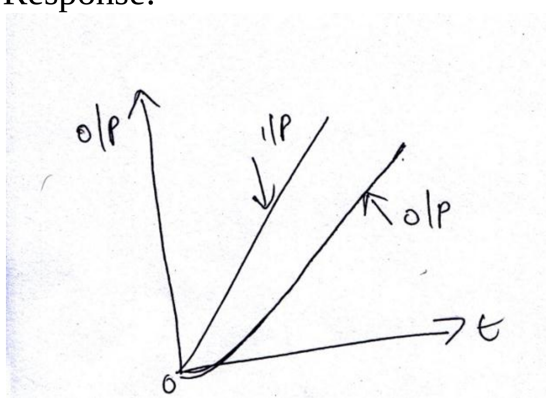
Ans: **Each Point 1 Mark**

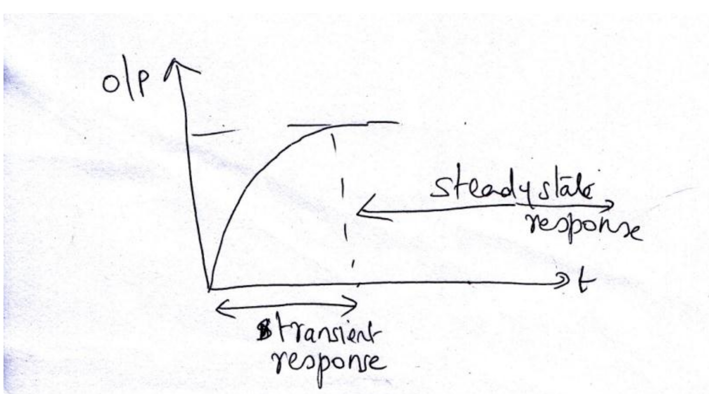
Control Action	Nature of output	Equation	Response of Error	Application
Proportional	Controller output is proportional to error	$K_P E_P + P_0$		Used in processes with medium process lags
Integral	Rate of change of controller output is proportional to error.	$p(t) = K_I \int_0^t e_p \, dt + p(0)$		Used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

				control system
Derivative	Controller output is proportional to derivative of error.	$p(t) = K_D \frac{de_p}{dt}$		Used in processes with large process lags & inertia such as temperature control system

c)	**By means of Routh's criteria determine the stability of the system** $s^4 + 2s^3 + 8s^2 + 4s + 3 = 0$.		**04**
Ans:	Routh's array: S^4 1 8 3 S^3 2 4 0 S^2 6 3 0 S^1 3 0 0 S^0 3 0 0 Conclusion: All the elements in the first column of routh's array are positive, and there is no sign change. Therefore, all the poles are on the left side of S-plane. So the system is stable.	**3 marks For routh's array** **1 mark for conclusion**	
d)	**Define:** **i.) Linear system** **ii.) Nonlinear system** **iii.) Time variant system**		**04**

	iv.) Time invariant system.		
Ans	i) **Linear System**: System which satisfy superposition theorem with additive and homogeneous property is called linear system. ii) **Nonlinear System**: System which do not satisfy superposition theorem is called nonlinear system. iii) **Time Variant System**: system whose parameters change with time irrespective of whether input and output change or not is called time variant system. iv) **Time Invariant System**: system whose parameters do not change with time irrespective of whether input and output change or not is called time invariant system.	**1 Mark for each**	
e)	**Derive an expression for unit ramp response of first order system. Draw its response.**		**04**
Ans:	Consider the first order system below:  Transfer function= output/input= C(S)/R(S)=V_{out}(S) /V_{in}(S) =I(S)/SC/{RI(S)+(I(S)/SC)} =1/(RCS+1) For unit ramp input, R(S)= V_{in}(S) = $1/S^2$ Therefore, C(S)= $1/(RCS+1)*S^2$ Applying partial fraction,	**1 mark** **1 mark**	

	$C(S)=\frac{1}{S(RCS+1)}=\frac{A}{S}+\frac{B}{S^2}+\frac{C}{1+RCS}$ A=1, B= 1 C= -RC, Therefore, $C(S)=\frac{1}{S^2(RCS+1)}=\frac{1}{S}+\frac{1}{S^2}+\frac{-RC}{1+RCS}=$ $==\frac{1}{S}+\frac{1}{S^2}+\frac{1}{(1/RC)+S}$ Taking Laplace inverse, $C(t)= 1+ t-e^{-t/RC}$ (RC is the time constant τ) Response: 	 **1 mark** **1 mark**	
f)	**State two advantages and two disadvantages of frequency response analysis.**		**04**
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	**Any Two – advantage 2 Marks**	

	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. **Dis advantages:** 1. Time consuming 2. Out dated methods compared to digital computation , simulation and modeling. 3. Methods can be applied mainly to linear systems. 4. Not recommended for systems with larger time constants.	**Any Two – disadvantage 2 Marks**	
6.	**Attempt any four:**		**16**
a)	**With a neat diagram define steady state response and transient response of system.**		**04**
Ans:	**Steady state response:** response of the system after the transients die out is called steady state response. **Transient response**: the response which shows how the system settles down to the final steady state is called transient response. It is due to the energy storage elements present in the system. 	**1 mark for each definition** **Diagram 2 marks**	

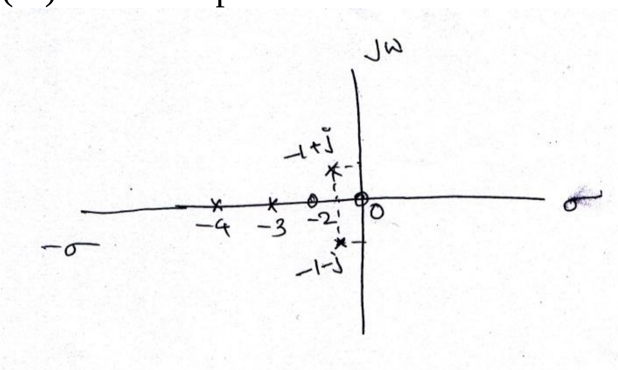
<table>
<tr><td></td><td>Note: Time response of second order system may also considered.</td><td></td><td></td></tr>
<tr><td>b)</td><td>For a given TF $\frac{C(S)}{R(S)} = \frac{S(S+2)}{(S^2+2S+2)\ (S^2+7S+12)}$
Find: i) Pole ii) zero iii) pole zero plot iv) characteristic equation</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>i) poles:

1) $(S^2 + 7S + 12) = 0$ therefore $S = -3, -4$
2) $(S^2 + 2S + 2) = 0$ Which is a quadratic equation.

For the quadratic equation $ax^2+bx+c=0$,
the poles are $= \frac{-b \pm \sqrt{(b^2-4ac)}}{2a}$
$= \frac{-2 \pm \sqrt{(2^2-(4*1*2))}}{2}$
$= \frac{-2 \pm \sqrt{(4-8)}}{2}$
$= \frac{-2 \pm \sqrt{(-4)}}{2}$
$= \frac{-2 \pm j2}{2}$
$= -1 \pm j$ Therefore poles are -1+j & -1-j
The poles are -3,-4, -1+j & -1-j

(ii) Zeroes:
S(S+2)=0
S+2=0, S=0
S= -2, 0
Zeroes= -2,0</td><td>1 mark

1 mark</td><td></td></tr>
</table>

	(iii) Pole zero plot  (iv) Characteristic equation=$(S^2+2S+2)\ (S^2+7S+12)$	1 mark 1 mark	
c)	**A unity feedback control system** $G(S)=\frac{40(S+2)}{S(S+1)\ (S+4)}$ **Find** **i. Type of the system** **ii. Error coefficient**		04
Ans:	**i. Type of the system=type one** **ii. Error coefficient** $K_p = \lim_{S \to 0} G(s)H(s) = \lim_{S \to 0} \frac{40(S+2)}{S(S+1)\ (S+4)} = \infty$ $K_v = \lim_{S \to 0} S\,G(s)H(s) =$ $\lim_{S \to 0} S \frac{40(S+2)}{S(S+1)\ (S+4)} = 20$ $K_a = \lim_{S \to 0} S^2 G(s)H(s) =$ $\lim_{S \to 0} S^2 \frac{40(S+2)}{S(S+1)\ (S+4)} = 0$	1 mark 1mark each for K_p, K_v, K_a	
d)	**State any two advantages and two disadvantages of routh array**		04

<table>
<tr><td>Ans:</td><td>Advantages of Routh array:
i) Simple criterion that enables to determine the no of closed loops which lie in right half of s-plane without factorizing the characteristic equation.
ii) Without actually solving characteristic equation, it tells us whether or not there are positive poles in a polynomial equation
iii) We can judge whether system is stable or not by seeing the sign changes in the first column.
iv) It tells the number of poles present on imaginary axis i.e. it tells about critical stability.

Disadvantages of Routh array:
i) Cannot find out the value of poles.
ii) It is not a sufficient condition for stability.
iii) Lengthy procedure.</td><td>2 points/2 marks

2 points/2 marks</td><td></td></tr>
<tr><td>e)</td><td>Determine the stability of the system by routh's criterion.
$S^5+S^4+2S^3+2S^2+2S+2=0$</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>The Characteristic equation is $S^5+S^4+2S^3+2S^2+2S+2=0$

So, Apply Routh's Array

S^5 | 1 2 2
S^4 | 1 2 2
S^3 | 0 0 0 special case
S^2 | Routh 'array failed
S^1 |
S^0 |</td><td></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 has 2 sign changes which indicate that there are two poles on right side of S-plane. So the system is unstable.	**Upto Auxillary equation 2 marks. Final routh array and conclusion 2 marks.**	