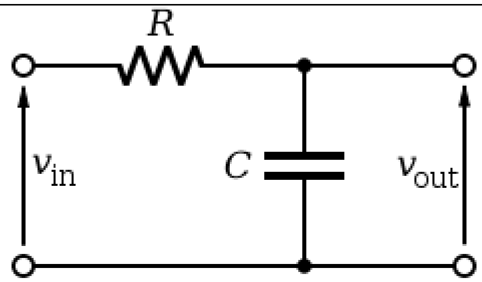
Important Instructions to examiners:

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 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 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)	**Define transfer function. Give three advantages of T.F.**		**04**
Ans.	**Transfer function** is the ratio between the Laplace transform of output to that of LT input under the assumption that all initial conditions are zero. **Advantages** (any 3) 1. It gives mathematical models of all system components 2. As it uses Laplace transform, it converts time domain equations to simple algebraic equations. 3. It relates output to input 4. It describes input-output behavior of the system. 5. It helps in the stability analysis of the system 6. It helps in determining poles, zeros and character equation.	**(1mark)** **3 marks**	
b)	**Define following terms wrt time domain response.** **i) Transient response,** **ii) steady state response,** **iii) steady state error,** **iv) time constant**		**04**
Ans.	**i) Transient response:** Response of the system till it reaches the final steady state. It shows how the system settles down to the final value. OR		

	That part of time response that goes to zero as time becomes very large or infinity. **ii) Steady state response:** Response of the system after the transients dies out. **iii) Steady state error:** The difference between the set point and the final steady state value **iv) Time constant:** Time taken by the system to reach 63.2% of the final value.	**(1mark each)**	
c)	**Define stability. State and explain Routh stability criterion.**		**04**
Ans	**Stable system :-** If the poles are located in 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. **Routh's stability criteria:-** The necessary and sufficient condition for system to be stable is "All the terms in the first column of the Routh's array must have same sign". It is made from the coefficients of characteristic equation. There should not be any sign change in the first column of Routh's array. If there are any sign changes, it indicates that a) System is unstable b) The number of sign changes is equal to the number of the roots lying in the right half of the S-plane.	**01 marks** **03 marks**	
d)	**Define and give significance of following terms w.r.to controller** **i) Neutral zone ii) Offset**		**04**
Ans	**Neutral zone:** it is defined as the range of error over which the controller output remains constant in the On Off controller. It is the range of error through which the signal moves before the switching action takes place. It is designed to avoid frequent chattering or switching of the controller. **Offset:** It is a permanent residual error in proportional controller which is inherent in nature; it is due to one to one correspondence existing between the controller output and error. Since it is the steady state error, it has to be reduced to improve the performance of the controller.	**1 mark** **1 mark** **1 mark** **1 mark**	
B)	**Attempt any one**		**06**
a)	**Find unit step response of first order R.C circuit**		**06**

	 **Fig 1**		
Ans	Input eqn : $$V_i(t) = Ri(t) + \frac{1}{C}\int i(t)dt$$ Output eqn: $$V_0(t) = \frac{1}{C}\int i(t)dt$$ Taking Laplace of i/p and o/p eqns: $$V_i(S) = R\,I(S) + \frac{I(S)}{CS}$$ $$V_O(S) = \frac{I(S)}{CS}$$ TF= $\frac{V_0(S)}{V_i(S)} == \frac{1}{RCS+1} = \frac{C(S)}{R(S)}$ For unit step response, $R(S) = \frac{1}{S}$, therefore, $$C(S) = \frac{1}{S(RCS+1)}$$ Applying partial fraction, $C(S) = \frac{1}{S(RCS+1)} = \frac{A}{S} + \frac{B}{1+RCS}$ A=1, B= -RC, Therefore, $C(S) = \frac{1}{S(RCS+1)} = \frac{1}{S} + \frac{-RC}{1+RCS} =$ $== \frac{1}{S} - \frac{1}{(1/RC)+S}$ Taking Laplace inverse, $C(t) = 1 - e^{-t/RC}$ RC is the time constant τ	**02 marks** **02 marks** **01 mark**	

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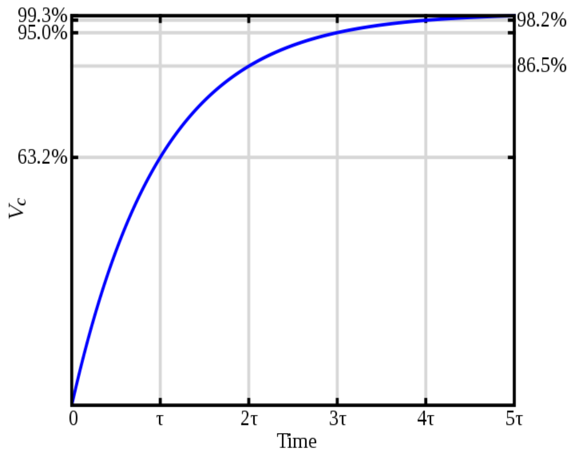
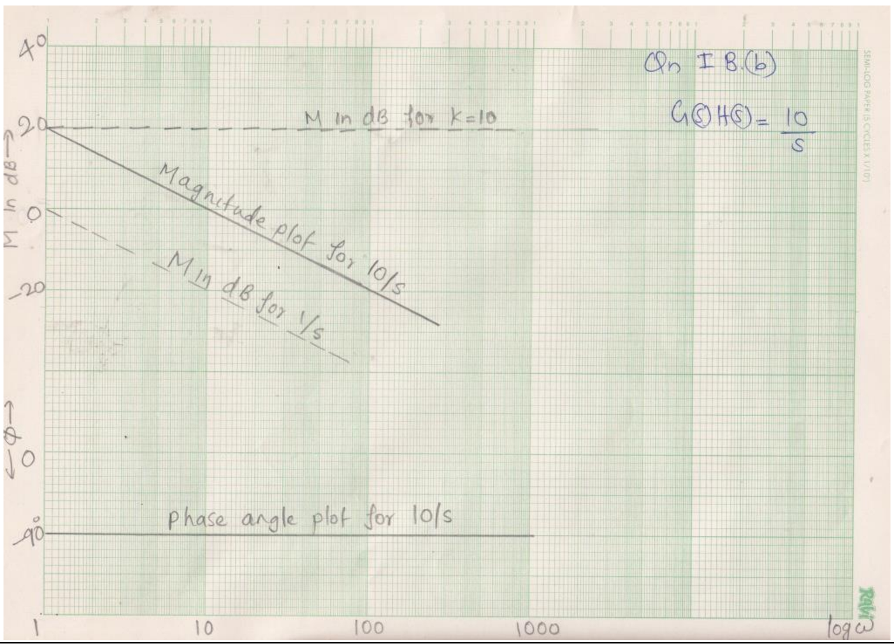
<tr><td></td><td>
</td><td>01 mark</td><td></td></tr>
<tr><td>b)</td><td>Draw bode plot for system with open loop transfer function
$G(S)H(S) = \frac{10}{S}$</td><td></td><td>06</td></tr>
<tr><td>Ans</td><td>Step 1: Convert the given open loop transfer function to time constant form:
It is not needed here.
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
Step 3: Phase angle ϕ :</td><td>02 marks

02 marks</td><td></td></tr>
</table>

Freq $=\omega$	Factor 1 K=10 $\phi_1=$	Factor 2, 1/S $\phi_2=$	Total Phase angle $\phi=\phi_1+\phi_2$
1	0^0	-90^0	-90^0
10	0^0	-90^0	-90^0
1000	0^0	-90^0	-90^0

1000	0^0	-90^0	-90^0

Step 4: Draw the magnitude plot and phase angle plot on semilog paper. **02 marks**



2	**Attempt any two**		**16**
a)	**For the unity feedback system $G(S) = \frac{K}{S(1+0.4S)(1+0.25S)}$, find range of value of K, marginal value of K, and frequency of sustained oscillations.**		**08**

Ans

$$G(S) = \frac{K}{S(1+0.4S)(1+0.25S)}$$

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

$$1 + \frac{K}{S(1+0.4S)(1+0.25S)} = 0$$

$$S(1+0.4S)(1+0.25S) + K = 0$$

$$S + 0.65S^2 + 0.1S^3 + K = 0$$

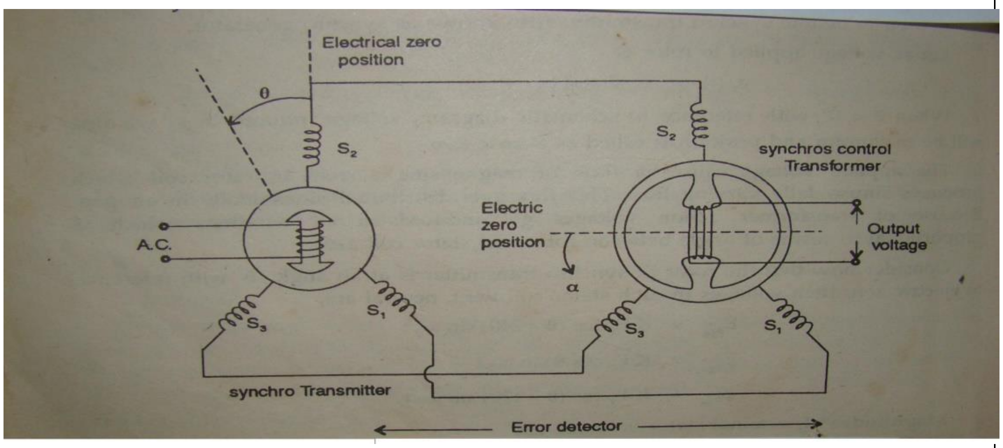
$$0.1S^3 + 0.65S^2 + S + K = 0$$

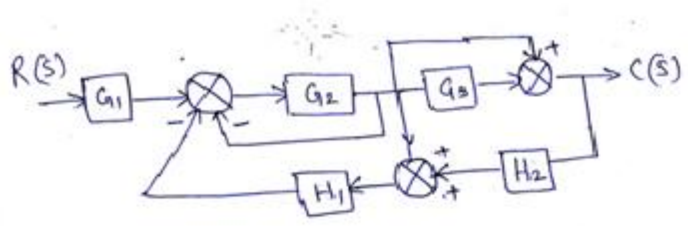
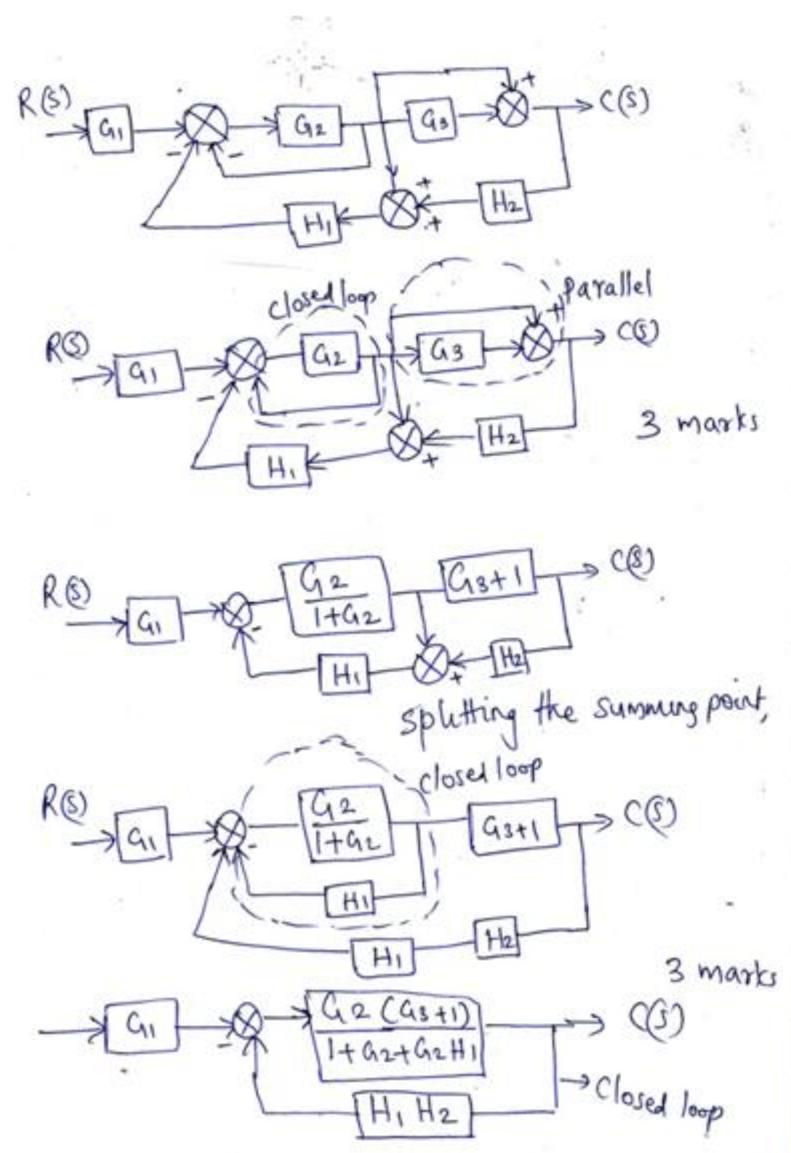
1marks

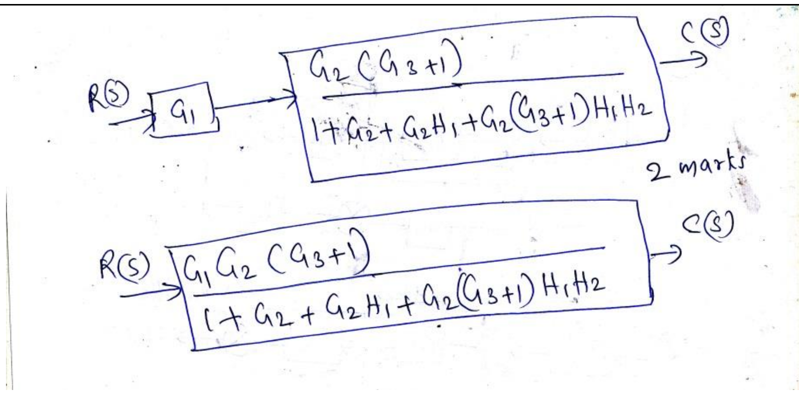
	Routh's array: S^3: 0.1, 1 S^2: 0.65, K S^1: $\frac{0.65-0.1K}{0.65}$, 0 S^0: K, 0 To satisfy the condition for stability, $K > 0,$ $\frac{0.65-0.1K}{0.65} > 0$ Or, $0.65 - 0.1K > 0,\ 6.5 > K$ Therefore, the range of K for the system to be stable is, $\mathbf{0 < K < 6.5}$ **The marginal value of K:** The marginal value of K will be $\boldsymbol{K_{mar} = 6.5}$because for this value, all the elements of third row will become zero which indicates marginal stability. **The frequency of sustained oscillations:** **Find out the roots of the auxiliary equation at marginal value of K (by considering $K = 6.5$),** $\mathbf{0.65S^2 + 6.5 = 0}$ $\mathbf{S^2 + 10 = 0}$ $\mathbf{S^2 = -10}$ $\mathbf{S = \pm j\,3.162}$ Comparing with $\mathbf{S = \pm j\,\omega}$ $\boldsymbol{\omega = frequency\ of\ oscillations = 3.162\ rad/sec}$	**3marks** **2 mark** **1 mark** **1 mark**	
b)	**Describe working of synchro as an error detector with diagram. State its two applications.**		**08**

Routh's array table:

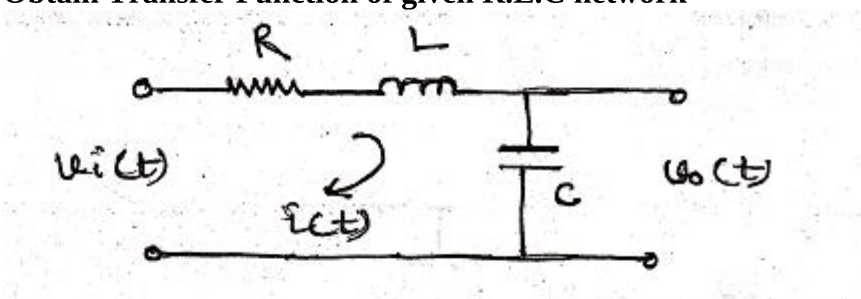
S^3	0.1	1
S^2	0.65	K
S^1	$\frac{0.65-0.1K}{0.65}$	0
S^0	K	0

Ans		**Diagram 2 marks**	
	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: $e(t) = k\, V_r \sin \omega t \, cos\Phi$ Where $V_r \sin \omega t$ is the 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. The error voltage is proportional to the angular difference between the transmitter and control transformer shaft positions.	**04 marks**	
	Applications: as error detector in AC servo system, in military applications for signal transmission	**2 marks**	

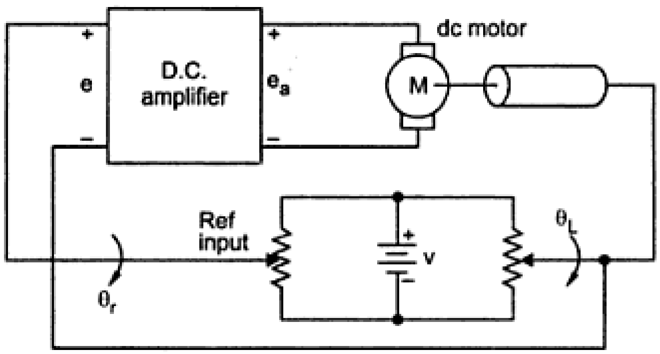
c)	**Reduce the block diagram using reduction rule. Obtain C(S)/R(S)** 		**08**
Ans		**01 mark for each step**	

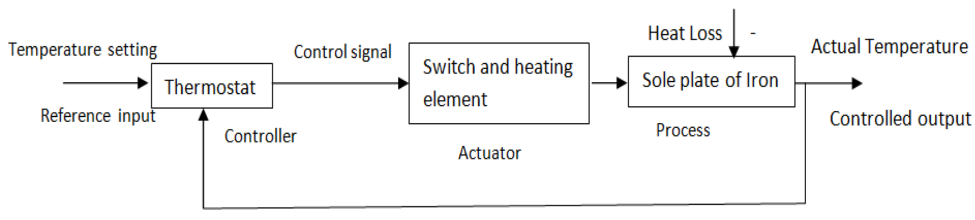
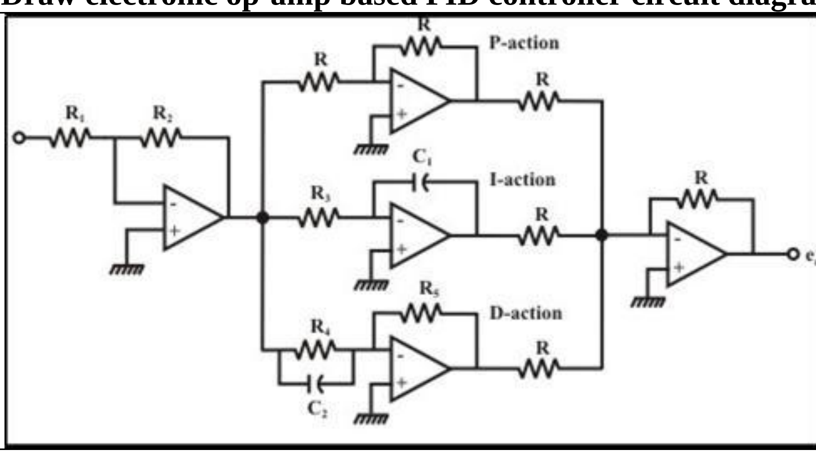


$$TF = \frac{C(S)}{R(S)} = \frac{G_2(G_3+1)}{1+G_2+G_2H_1+G_2(G_3+1)H_1H_2}$$

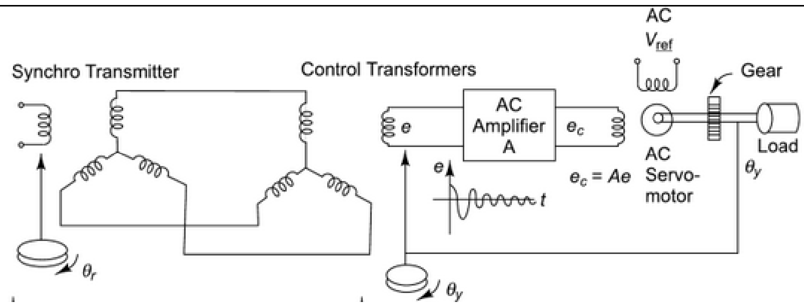
Q.3	**Attempt Any FOUR**		**16**
a)	**Obtain Transfer Function of given R.L.C network**  Figure 3		**04**
Ans	$$Vi(t) = iR + L\frac{di}{dt} + \frac{1}{c}\int idt$$ Taking Laplace transform of the above equation $Vi(s)$ = I (s) [R + sL + 1/ Cs] I(s) / $Vi(s)$ = 1 / [R + sL + 1/sC] ----- (1) $$Vo(t) = \frac{1}{c}\int idt$$ Hence, $Vo(s) = \frac{1}{Cs}I(s)$ I(s) = $Vo(s)\,Cs$------(2)	**Suitable weightage may be given to correct equation and steps.** **01 mark** **01 mark**	

	Substituting value of I (s) in equation 1 $Vo(s)\ Cs/\ Vi(s) = 1/ [R + sL + 1/sC]$ $Vo(s)/\ Vi(s) = 1/ [\ Cs] [R + sL + 1/sC]$ $\therefore \frac{Vo(s)}{Vi(s)} = \frac{1}{[s2\ LC + sRC + 1]}$	**01 mark** **01 mark**	
b)	**Define and give significance of standard test input signal and their Laplace representation**		**04**
Ans	**Definition-**Many signals which are the functions of time; can be used as reference input for various control systems. These signals are square, triangular, step,ramp,sawtooth etc. But practically for the purpose of analysis, those signals which are most commonly used as reference inputs are called as standard test signals. **Significance-** The evaluation of the system can be done on the basis of response given by the system to the standard test input. Once the system behaves satisfactorily to a test input, its response to actual input is assumed to be correct. **Laplace representation of the Standard Test signals** 1) Step Input(for magnitude of A) R(s)= A/s 2) Ramp Input(for slope of A) $R(s)=A/s^2$ 3) Parabolic Input (With slope At) $R(s)= A/s^3$ 4) Impulse Input R(s) = 1	**Definition-1M** **Significance-1M** **Laplace of 4 types of standard test signals-1/2 M each** **Marks may be given if students write Laplace for unit step, ramp or parabolic signal**	
c)	**Determine stability using Routh criterion for given characteristic equation** $S^4+6S^3+ 26S^2+56s+80=0$		**04**
Ans	S^4 | 1 26 80 S^3 | 6 56 0 S^2 | $\frac{6x26-56x1}{6}$ =16.6 $\frac{6x80-0x1}{6}$ =80 S^1 | $\frac{16{,}67x56-80x6}{16.66}$ =27.2 0 1	**4M for correct table and answer. 2M may be given for**	

	S^0 | $\frac{27.21x80-0x16.67}{27.21}$ =80 As there is no sign change in first column of Routh array, system is stable	**correct method even if the answer is not correct**	
d)	**Describe how potentiometer is used as error detector with neat diagram.**		**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 term of the two potentiometers. Output of this differential potentiometer is =Ks[– θL(t)] This is then is fed to DC Amplifier, which is further amplifyin armature current of the DC Motor. The motor, in turn moves and with i shaft connected to the load potentiometer in such a way as to make the ou voltage zero. That is the output (Load) potentiometer shaft moves in accord with the shaft of the input(reference) potentiometer.		
e)	**What is ON-OFF controller? Explain its one application in detail**		**04**
Ans	On- Off Controller :- On-Off control is the simplest form of feedback control. An on-off controller simply drives the manipulated variable from fully closed to fully open depending on the position of the controlled variable relative to the setpoint 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 . **Application (Electric Iron as ON-OFF Controller)** In automatic electric iron, a resistive heating element is used to generate	**2M for definition.** **2M for application.** **Any suitable application may be explained by the candidat**	

	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.  Block diagram of Electric Iron as On-Off Controller	**e.**	
Q.4 A)	**Attempt any THREE**		**12**
a)	**Draw electronic op-amp based PID controller circuit diagram**		**04**
Ans	 	**4M for the correct diagram**	
b)	**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	**2M each for 2 advantages and 2 disadvantages**	

	3. Frequency response test are simple and can be done practically by the readily available laboratory equipment. 4. Without the knowledge of transfer function, the frequency response for stable open loop system can be obtained experimentally. 5. Due to the close relation between frequency response of a system and its step response, idea about step response can be obtained from the frequency response. **Disadvantages:** 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 transfer function by writing differential equations.		
c)	**For given TF determine** **i) Poles** **ii) Zeros** **iii) Characteristic equation** **iv) Order of sys.** **T(s)=**$\frac{2(s+1)^2(s+2)(s^2+2s+2)}{s^3(s+4)(s^2+6s+25)}$		**04**
Ans	i) Poles are s1=0,s2=0,s3=0,s4=-4, s5,s6= , -3$\pm$ 4j ii) Zeros are s= -2, -1, -1, -1$\pm$ j1 iii) The Characteristic equation is $s^3(s+4)(s^2+6s+25)$=0 i.e $s^6+10s^5+49s^4+100s^3$=0 iv) Order of the system is the highest power of s in the characteristic equation Thus, the order of the system is 6	**1 M each for each correct answer**	
d)	**Define servo system. Explain in brief AC servo system with neat diagram**		**04**
Ans	Servo system is defined as automatic feedback control system working on error signals giving the output as mechanical position, velocity or acceleration **AC Servo system**	**1M for definition** **2M for the block**	



As shown above, synchro transmitter and control transformer pair works as error detector. Any difference in the positions of transmitter (θ_r) and control transformer positions (θ_y) causes error voltage to be generated. This output error voltage is amplified and applied to the servo motor which drives the transformer rotor shaft until it is aligned with the transmitter shaft.
The rotor output of control transformer of synchro goes to the amplifier and the output of amplifier is fed to a 2 phase induction servo motor. Servo motor phases are in quadrature. So, the servo motor will always try to rotate in a direction so as to reduce the error voltage. Therefore, θ_y will always follow θ_r until the error voltage is 0.

diagram 1M for blick diagram explanation

B) Attempt any ONE — **06**

1) Give three comparison points between stepper motor and DC servo system — **06**

Ans

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.

2 M each for 3 points

2) A second order system is given by — **06**

$$\frac{C(s)}{R(s)} = \frac{25}{(s^2+6s+25)}$$

Find T_r, T_p, γ.Mp, T_s if subjected to unit step input.

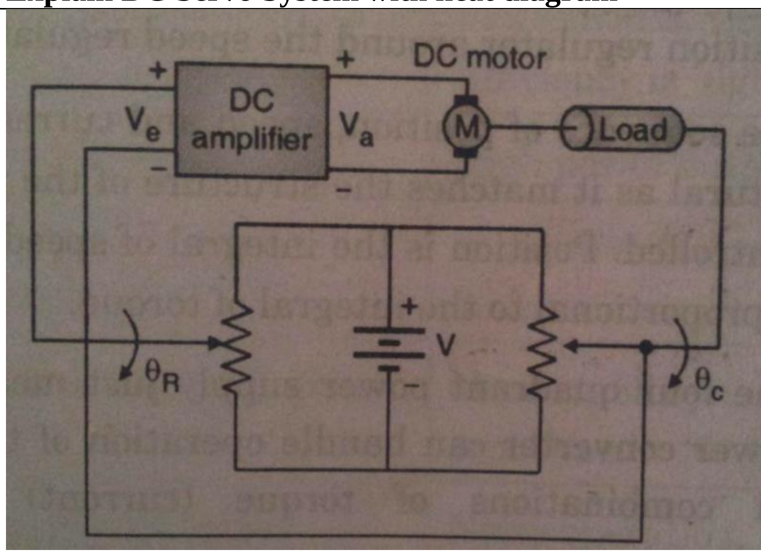
Ans

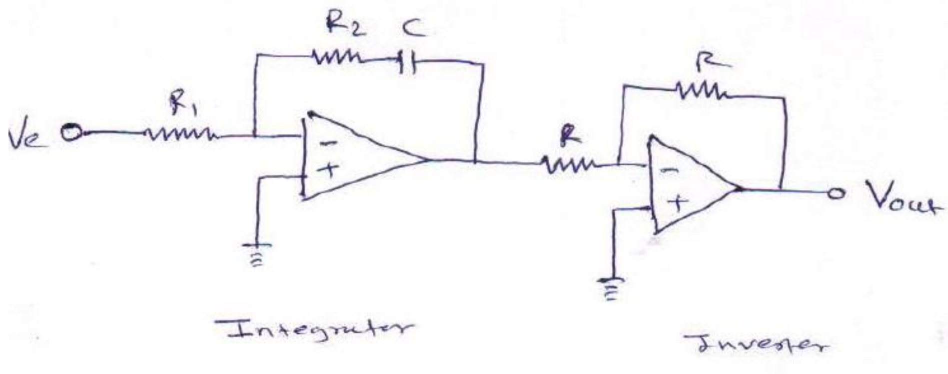
$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{\omega_n^2+2\xi\omega_n s+s^2}$$

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, $\xi=0.6$

1 M each for correct answers of ωn, ξ, Tr, Tp, %Mp,

	$\theta = \tan^{-1}[\sqrt{(1-\xi^2)}/\xi] = 0.9272$ 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-** $\pi\xi/\sqrt{(1-\xi^2)} \times 100 = 9.48\%$	**Ts**	
Q.5	**Attempt any FOUR**		**16**
a)	**Explain DC Servo System with neat diagram**		**04**
Ans	 **Fig: DC Servo Motor** **Explanation** 1) The standard block diagram of servo system consists of error detector, amplifier, motor as controller, load whose position is to be changed. 2) Servo systems is to be divided into two type a) DC servo systems b) AC servo system 3) DC servo system consists of potentiometer as a error detector, DC amplifier, DC motor, DC gear system and the DC load whose position is to be changed. 4) In DC servo system potentiometer has two input i.e one is reference input and another is actual load position. Potentiometer finds the error between two position. The error signal between two position is given to DC amplifier which amplify the error. Output of DC amplifier is given to DC motor & finally Dc motor change the position of DC load. In this way servo system is used to change the load position with help of motor &error detector.	**02 marks for diagram** **02 marks for explanat on**	
b)	**Draw electronic PI Controller. State its advantages, characteristics & write its equation**		**04**

Ans	 Fig:- Electronic PI controller. Analytical equation for PI controller is given as **P=KPKI ∫*Idt+KPEP*** From figure, output equation can be written as $V_{out}=\frac{R1}{R2}V_{in}+\frac{1}{R1C}\int V_{in}dt$ $V_{out}=[\frac{R1}{R2}]V_{in}+[\frac{R1}{R2}][\frac{1}{R2C}].\int V_{in}dt$ **Characteristics of PI Controller** i) When the error is zero, the controller output is fixed at the value that the integral term had when the error want to be zero i.e. $P_I(0)$ ii) If the error is not zero, then the proportional term contributes a correction and the integral term begins to increase or decrease the accumulated value depending on sign of the error and the direction of controlling action. **Advantages of PI Controller (any two)** i) It fully eliminates the steady state error. ii) It has good transient responses. iii) It stabilizes the controller gain. iv) It provides better stability to the system. v) It provides the simplicity and directness.	**01 mark for diagram** **01 mark for equation** **01 mark characteristic** **01 mark for advantages**	
c)	**Define following term w.r.to stability** **i) Relative stable system** **ii) Conditionally stable system**		**04**
Ans	**i) Relative stable system:** • 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. • As the location of the poles move towards left half of S- plane, the settling time becomes smaller and system becomes relatively more	**02 mark for each term**	

stable.

ii) Conditionally stable system:

- A linear time invariant system is called as conditionally stable system if the stability of system depends on certain conditions of parameters of the system.
- In this type of system for some bounded input output is bounded for certain conditions of a particular parameter. If the conditions of the parameter changed then for the same bounded input, the output becomes unbounded.

d) Explain effect of damping on performance of second order 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.

01 mark for each case (maximum 04 marks)

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

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

e) Derive derivation of steady state error on which factor e_{ss} depends. **04**

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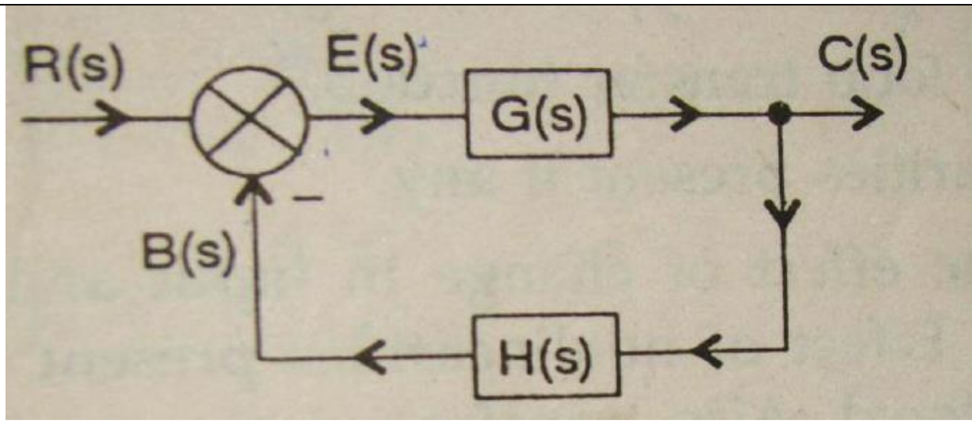
<tr><td>Ans</td><td>

E(s) = R(s) - B(s)

But B(s) = C(s) * H(s)

So, E(s) = R(s) - C(s) H(s)

And C(s) = E(s) * G(s)

Thus, E(s) = R(s) - E(s) G(s) H(s)

i.e. E(s) + E(s) G(s) H(s) = R(s)

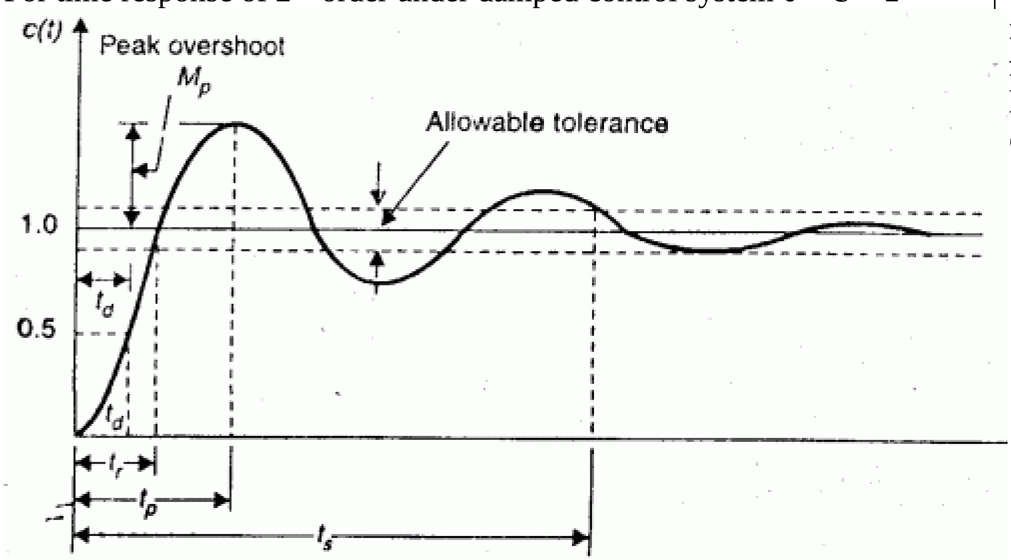
E(s) = R(s)/1+G(s) H(s) for non unity feedback ………………. (1)

E(s) = R(s)/1+ G(s) for unity feedback

Steady State error, ess = $\lim_{t \to \infty} e(t)$
By using final value theorem of Laplace transform,
ess = $\lim_{S \to 0}$ S* E(s) = $\lim_{S \to 0}$ S. R(s)/1+G(s)H(s

Thus steady state response depends on response of R(s), G(s) and H(s)
i) Type of i/p and ii)open loop TF G(s) H(s)</td><td>04 marks</td><td></td></tr>
<tr><td>f)</td><td>State condition of stable, unstable, marginally stable based on gain margin and phase margin</td><td></td><td>04</td></tr>
<tr><td>Ans</td><td>Gain Margin: Greater will the gain margin greater will be the stability of the system. It refers to the amount of gain, which can be increased or decreased without making the system unstable. It is usually expressed in dB.

Phase Margin: Greater will the phase margin greater will be the stability</td><td>04 marks for relevant explanati on</td><td></td></tr>
</table>

	of the system. It refers to the phase which can be increased or decreased without making the system unstable. It is usually expressed in phase. **Stability Conditions of Bode Plots** Stability conditions are given below : 1. **For Stable System :** Both the margins should be positive. Or phase margin should be greater than the gain margin. 2. **For Marginal Stable System :** Both the margins should be zero. Or phase margin should be equal to the gain margin. 3. **For Unstable System :** If any of them is negative. Or phase margin should be less than the gain margin.		
Q.6	**Attempt any FOUR**		**16**
a)	**Draw labeled time response of second order under damped control system**		**04**
Ans	For time response of 2nd order under damped control system **0 < Ɛ < 1**  **Time response of 2nd order under damped control system**	**04 marks for labeled diagram**	
b)	**Define following terms w.r.to Second order system** **i) Settling Time** **ii) Rise Time** **iii) Peak Overshoot** **iv) Delay Time**		**04**
Ans	**i)** **Rise Time:** It is the time required for the response to rise from 10% to 90% of the final value for over damped systems & 0 to 100 % of the final value for under damped systems. It is given by	**01 mark for each definition**	

	$$T_r = \frac{\pi - \theta}{w_d}$$ $$W_d = W_n\sqrt{1-\varepsilon^2} \quad \& \quad \Theta = \tan^{-1}\left(\frac{\sqrt{1-\varepsilon^2}}{\varepsilon}\right)$$ **ii)** **Settling time:** This is defined as the time required for the response to decrease & stay within specified % of its final value . $$T_s = \frac{4}{\zeta w_n}$$ **iii)** **Peak Overshoot:** It is the largest error between reference input & output during the transient period. It is normalized difference of first peak overshoot to final steady state value. $$M_p = e^{\frac{-\pi\varepsilon}{\sqrt{1-\varepsilon^2}}}$$ **iv)** **Delay time:** It is the Time required for the response to reach 50 % of the final value in the first attempt it is given by $$T_d = \frac{1 + 0.7\zeta}{w_n}$$	**(formula is optional)**	
c)	**A unity feedback system has G(s) =** $\frac{40\,(S+2)}{S\,(S+1)(S+4)}$ **. Determine** **i) Type of system** **ii) All error coefficient i.e. Kp, Kv, Ka**		**04**
Ans	1) Comparing the equation in stanadard form: $$G(s)H(s) = \frac{K(1+T1s)+(1+T2s)}{S^j\,(1+Ta\,s)(1+Tb\,s)} \ldots\ldots$$ Where j is type of system $G(s).H(s) = \frac{10\,(S+2)}{S\,(1+S)(1+0.25\,S)}$ …… H(s) = 1 So, This is type – 1 system. 2) $K_p = \lim_{s\to 0} G(s).H(s)$ $K_p = \lim_{s\to 0} G(s) = \lim_{s\to 0} \frac{10\,(S+2)}{S\,(1+S)(1+0.25\,S)} = \infty$ 3) $K_v = \lim_{s\to 0} s.G(s).H(s)$	**01 mark for type of system** **01 mark for Kp,**	

	$K_v = \lim_{s\to0} s.G(s) = \lim_{s\to0} \frac{10\,S\,(S+2)}{S\,(1+S)(1+0.25\,S)}$ = **01 mark for Kp** $\lim_{s\to0} \frac{10\,(S+2)}{(1+S)(1+0.25\,S)} = \frac{20}{1} = 20$ 4) $K_a = \lim_{s\to0} S^2.G(s).H(s)$ $K_a = \lim_{s\to0} S^2.G(s) = \lim_{s\to0} \frac{10\,S\,(S+2)}{(1+S)(1+0.25\,S)} = 0$	**01 mark for Kv** **01 mark for Ka**	
d)	**For given ch**^{r} **eq**^{n}**.** $S^4 + 22S^3 + 10S^2 + S + K = 0$. **Find** K_{max}**.**		**04**
Ans	1) Firstly Find even & odd coefficient from characteristics equation $S^4 + 22S^3 + 10S^2 + S + K$ 2) The routh's array for above characteristics equation is formed as follows S^4 : 1, 10, K S^3 : 22, 1, 0 S^2 : 9.95, K, 0 S^1 : $\frac{9.95-22K}{9.95}$, 0 S^0 : K 3) For stability all elements of 1st column of routh array should be positive. Consider Row s1 … $\frac{9.95-22K}{9.95} > 0$ i.e $K < \frac{9.95}{22}$ i.e. $0 < K < 0.45$ Thus K_{max} is 0.45 for stable system.	**03 marks for rouths array** **01 mark For Kmax**	
e)	**Examine stability by Routh criterion for ch**^{r} **eq**^{n} $S^4 + 10S^3 + 35S^2 + 50S + 24 = 0$		**04**
Ans	1) Firstly Find even & odd coefficient from characteristics equation $S^4 + 10S^3 + 35S^2 + 50S + 24 = 0$ 2) The routh's array for above characteristics equation is formed as follows S^4 : 1, 35, 24	**03 marks for rouths array**	

	S^3 10 50 0 S^2 30 24 0 S^1 42 0 S^0 24 **3)** Conclusion: As in the first column of Routh's array there is NO sign change means all the poles of characteristics equations lie in Left hand of S plane hence system is stable.	**01 mark for conclusion**	