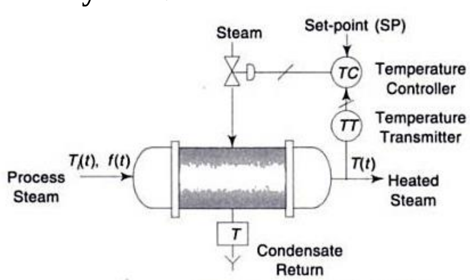
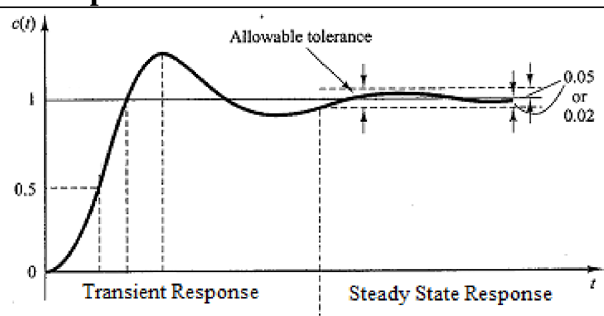
Important Instructions to examiners:

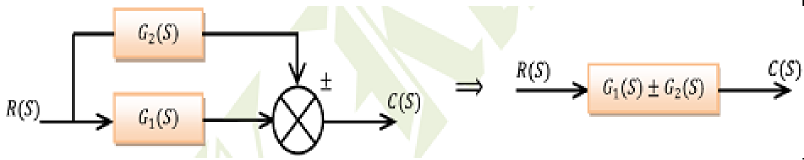
1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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 judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Question & its Answer	Remark	Total Marks
01 (A)	**Attempt any THREE:**		**12**
(a)	**Define control system and explain it with the help of suitable example.**		**04**
Ans.	**Control system:** A control system is a system of devices or set of devices, that manage, commands, directs or regulates the behavior of other device(s) or system(s) to achieve desired results. OR **Control system:** Any quantity of interest in a machine, mechanism or other equipment is maintained or altered in accordance with a desired manner. **Temperature Control System:**  *Heat Exchanger Control System* **Description:** This heat exchanger is used to heat the process fluid from some inlet temperature T(i) up to a desired outlet temperature T(t). The energy gained by the process fluid is provided by the latent heat of condensation of the superheated steam. There are number of variables in	**01 mark Definition** **1½ marks Diagram** **1½ marks Explanation**	

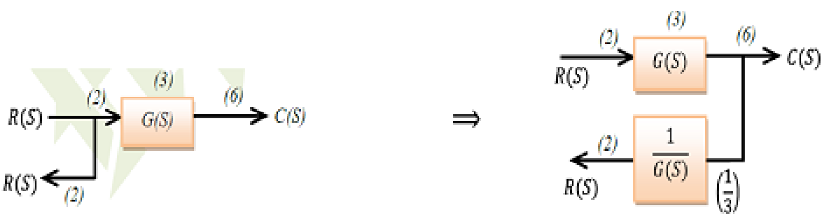
	this process that can change causing the outlet temperature to deviate from its desired value. Therefore, action must be taken to correct any deviation so as to maintain the outlet process temperature at its desired value T(t). It can be achieved by measuring the outlet temperature T(t) & correcting any deviation by comparing it to desired (set point) value. The steam valve can be manipulated (by throttling & opening the steam flow) to correct the deviation. The outlet temperature T(t) is measured by a sensor & transmitted by transmitter (TT) to a temperature controller(TC). Temperature controller (TC) compares this measured value with the desired value and depending upon the signal it sends the signal to the final control element (FCE) which manipulates the steam flow by opening or closing the valve. **(NOTE: Any relevant example of CS with neat diagram & brief explanation may considered)**		
(b)	**Define** **i) Transient Response** **ii) Steady State Response**		**04**
Ans.	 Transient and Steady-State Response Analyses **i) Transient response:** whenever the systems with energy storage are subjected to the inputs or disturbances, often it exhibits the damped oscillations before reaching to final steady output such a response of system is called as transient response. OR The output variations during the time, it takes to achieve its final value is called as Transient response. OR It is defined as that part of the time response which decays to zero after some time as system output reaches to its final value. **ii) Steady State Response:** It is defined as that part of the time response which remains after complete transient response vanishes from the system output. **Transient response** corresponds to the system close loop poles and **steady state response** corresponds to the excitation poles or poles of the input function.	**02 marks each**	
(c)	**Define Stability. Explain the importance of stability in a system.**		**04**

Ans.	**Stability:** A system is said to be a stable if its output remains bounded irrespective of the changes in parameters or disturbances. **OR** When a linear time invariant 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. **Importance of stability:** The concept of stability in common and engineering sense reflects necessity to keep response of a disturbed system within acceptable limits. If deviations describing response of the system from a given regime (e.g. state of equilibrium) lie within the prescribed limits, the system is called stable. Otherwise, the system is called unstable. Disturbances, response, and prescribed limits can be specified in each case in different ways. The stability of a control system is often extremely important and is generally a safety issue in the engineering of a system. An example to illustrate the importance of stability is the control of a nuclear reactor. An instability of this system could result in an unimaginable catastrophe or in case of a robot arm controller that is unstable may cause the robot to move dangerously. Also, systems that are unstable often incur a certain amount of physical damage, which can become costly. The stability of a system relates to its response to inputs or disturbances. A system which remains in a constant state unless affected by an external action and which returns to a constant state when the external action is removed can be considered to be stable.	**01 mark Definition** **03 marks for Importance**	
(d)	**Explain why derivative action cannot be used alone.**		**04**
Ans.	The equation for D controller is: $$p(t) = K_d \frac{de(t)}{dt}$$ For a given rate of change of error signal, there is a unique value of the controller output. When the error is zero, the controller output is zero. When the error is constant i.e. rate of change of error is zero, the controller output is zero. When the error is changing, the controller output changes by K_d % for even 1 % per second rate of change of error. When the error is zero or a constant, the derivative controller output is zero. Hence, it is never used alone. Its gain should be small because faster rate of change of error can cause very large sudden change of controller output. This may lead to instability of the system.	**04 marks for relevant Explanation**	
(B)	**Attempt any ONE:**		**06**
(a)	**Explain any three rules of the block diagram reduction technique.**		**06**
Ans.	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.		

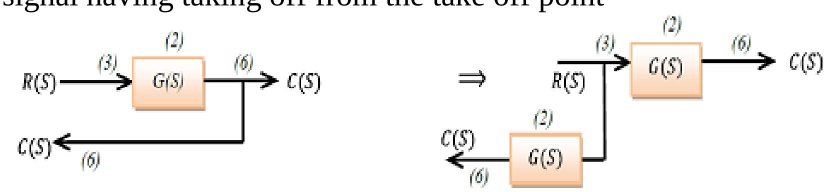
ii) Combining two blocks in parallel: When two or more blocks are connected in parallel, their overall transfer function is the addition or difference of individual transfer function.



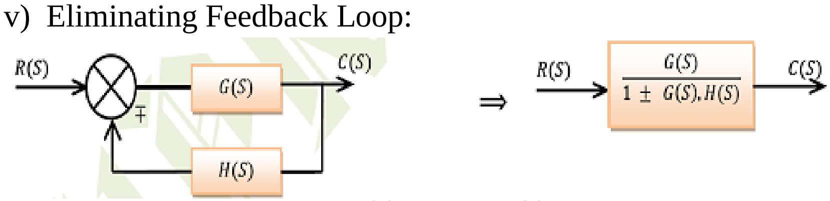
iii) Shifting a take off point after a block: To shift take off point after a block, we shall add a block with transfer function 1/G in series with signal having taking off from that point.



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



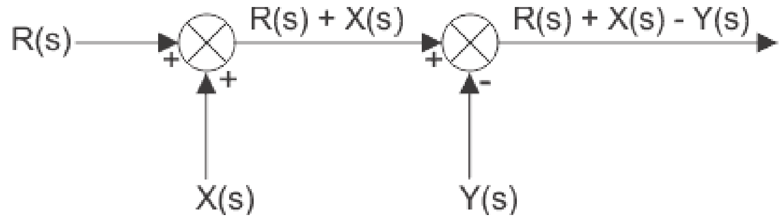
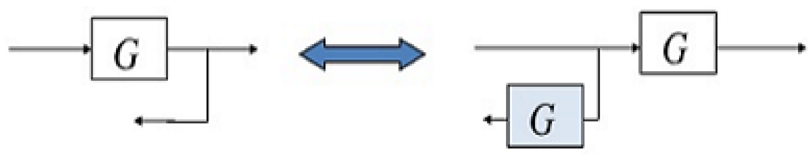
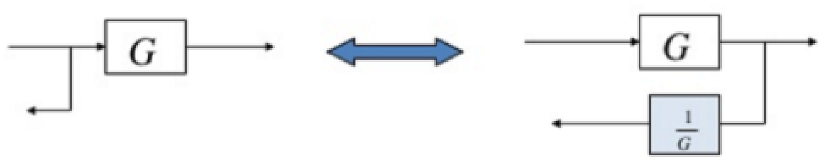
v) Eliminating Feedback Loop:



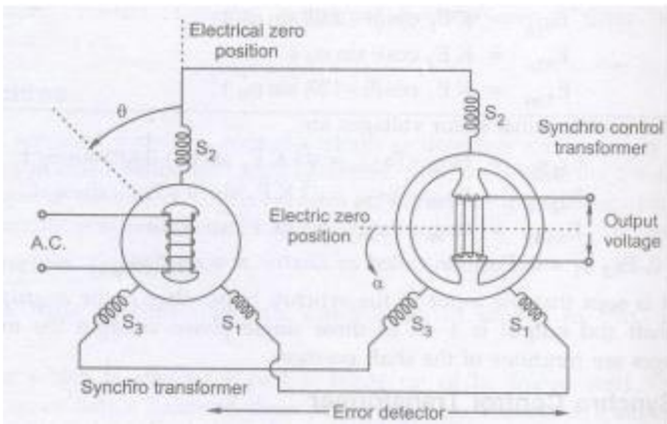
$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s).H(s)}$$

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.

06 marks (Any three rules with neat diagram & explanation)

	 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)	**What is Frequency Response Analysis? State its advantages.(any four)**		**06**
Ans.	**Frequency Response Analysis:** The steady state response of a system to a purely sinusoidal input [r(t)= A sinw ωt] is defined as frequency response. In frequency response analysis the input sinusoidal signal [r(t)= A sinw ωt] is varied over certain range of frequency, keeping amplitude constant, and the resulting response [c(t)= B sin (ωt+Φ)] of system is studied. **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 cannot be determined by analytical technique. iii) The signal generators and precise measuring instruments for generation of sinusoidal signals of various ranges of frequency and	**02 marks (Frequency response)** **04 marks (Any four advantages)**	

	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 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.		
2	**Attempt any TWO:**		**16**
(a)	**A system has $G(s)H(s) = \frac{K}{s(s+2)(s+4)(s+8)}$ where K is positive. Determine the range of K for stability.**		**08**
Ans.	The characteristic equation is given by 1+G(s)H(s)=0 $1+\frac{K}{S(S+2)(S+4)(S+8)}=0$ S(S+2)(S+4)(S+8)+K=0 i.e. $S^4+14S^3+56S^2+64S+K=0$ The routh's array for above characteristics equation is formed as follows S^4 1 56 K S^3 14 64 0 S^2 51.42 K 0 S^1 $\frac{3291.42-14K}{51.42}$ 0 0 S^0 K For system to be stable elements in first column of Routh array must have the same sign i.e. no sign change.	**02 marks (Deriving correct characteristic equation)** **04 marks (Preparing Routh's array)**	

	Hence $\frac{3291.42-14K}{51.42} > 0$ and $K > 0$ i.e. 3291.42-14K > 0 i.e. 14K < 3291.42 K < 235.10 Hence range is 0 < K < 235.10	**02 marks (Range with explanation)**	
(b)	**Draw and explain synchro as error detector. State its applications.**		**08**
Ans.	**Synchro as error detector:**  **Explanation:** Synchro transmitter along with synchro control transformer is used as error detector . The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap. The output of the Synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils circulating currents of same phase but different magnitude will flow through both set of stator coils. This establishes an identical flux pattern in the air gap of control transformer. The flux pattern in the air gap of control transformer will have the same orientation as that of transmitter rotor. The voltage induced in the transformer rotor will be proportional to the cosine of angle between the two rotors. The output equation is given by : $e_0(t) = V_r \sin \omega t + \cos\phi$ where Vr sinwt = 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	**03 marks for Diagram** **03 marks for relevant Explanation**	

<table>
<tr><td></td><td>position is called electrical zero and is used as reference position.
Applications:
1. Torque Transmission.
2. Error detection in position control.
3. Adding and subtracting rotory angles.</td><td>**02 marks (Any two applications)**</td><td></td></tr>
<tr><td>**(c)**</td><td>**Obtain the transfer function for system in fig(1) using block reduction technique.**

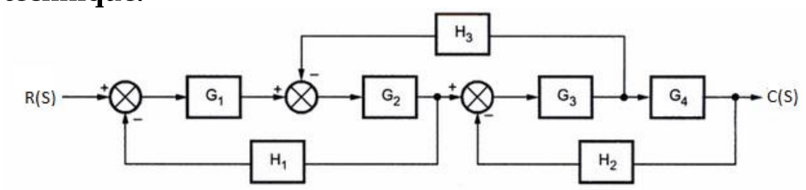
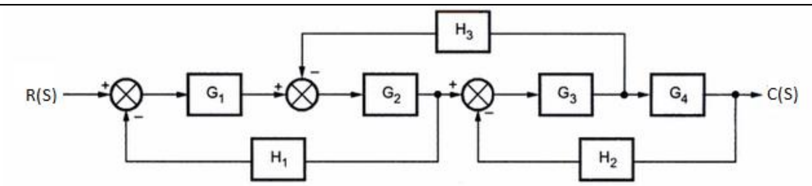
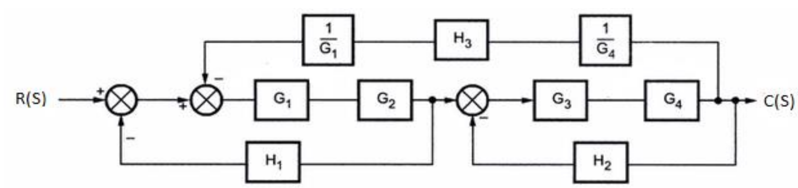
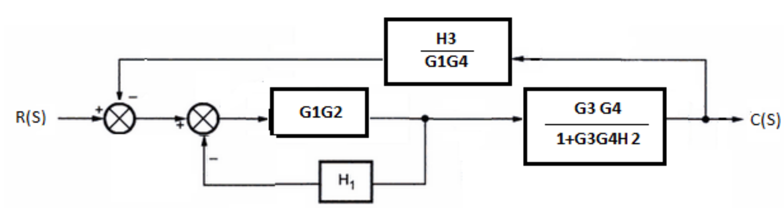


Fig. (1)</td><td></td><td>**08**</td></tr>
<tr><td>**Ans.**</td><td>

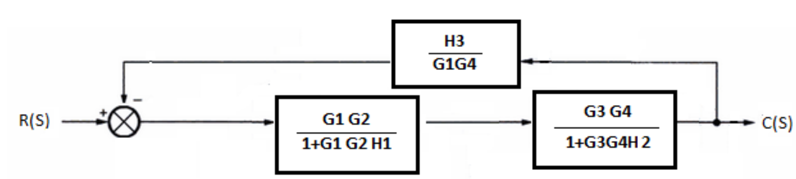
Step1:



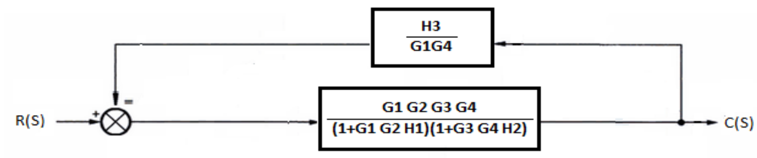
Step2:



Step3:


</td><td>**06 marks (Step 1 to Step 4)**</td><td></td></tr>
</table>

Step4:



Step5:

$$\frac{C(S)}{R(S)} = \frac{G1G2G3G4}{(1 + G1G2H1)(1 + G3G4H2)G2G3H3}$$

02 marks (Step 5 and Step 6)

Step6:

$$\frac{C(S)}{R(S)} = \frac{G1G2G3G4}{1 + G1G2H1 + G3G4H2 + G1G2G3G4H1H2 + G2G3H3}$$

3 **Attempt any FOUR:** **16**

(a) **Compare open loop and closed loop control system (Four points)** **04**

Ans.

No.	**Open Loop Control System**	**Close Loop Control System**
1	It is simple and economical	It is complex and costlier
2	It is easier to construct, as it requires less number of components	It is not easy to construct, as it requires more number of components
3	It consumes less power	It consumes more power
4	It is more stable	It is less stable
5	It does not require feedback path element	It requires feedback path element
6	It has poor accuracy	It has better accuracy
7	It does not give automatic correction for external disturbances	It gives automatic correction for external disturbances
8	It is more sensitive to noise	It is less sensitive to noise
9	It is dependent on operating condition	It is not dependent on operating conditions
10	Its operation is degraded if non linearity is present	Its operation is not independent on conditions
11	It has slow response	It has fast response
12	It has high bandwidth	It has low bandwidth

01 mark (Any four points)

(b) **What is damping? Explain the effect of damping on the response 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

01 Mark for definition

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.

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

03 Marks for Effects (any three)

(c) Determine stability of a system using Routh's criterion. **04**

$$S^5 + S^4 + 2S^3 + 2S^2 + 3S + 5 = 0$$

Ans.

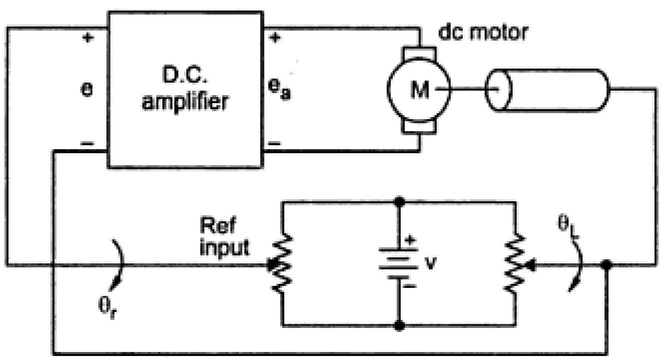
1) Firstly Find even & odd coefficient from characteristics equation $S^5 + S^4 + 2.S^3 + 2.S^2 + 3.S + 5 = 0$

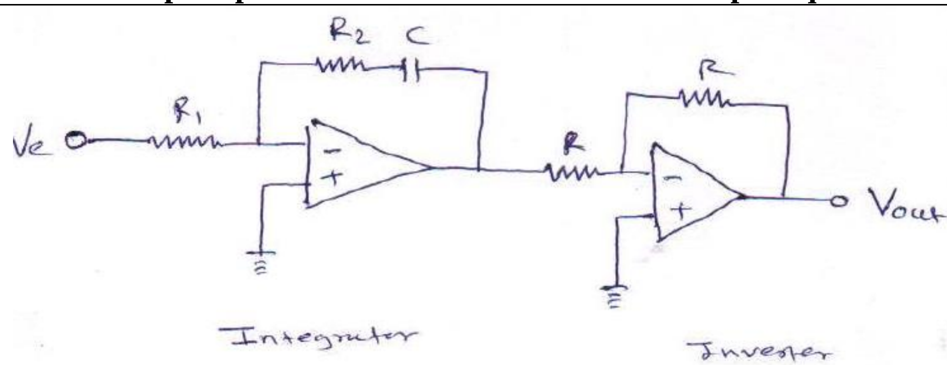
2) The routh's array for above characteristics equation is formed as follows

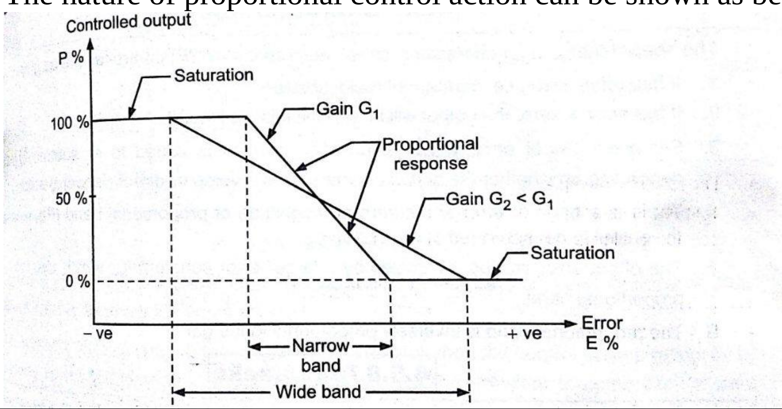
S^5	1	2	3	
S^4	1	2	5	
S^3	0	-2	0	special case I
S^2	∞			

01 Mark (Routh Array Formation)

	S^1 S^0 Substitute a small positive number ε in place of 0 occurred as a first element in a row. Complete the array with this number ε. Then examine the sign change by S^3 taking $\lim_{\varepsilon \to 0}$		
	S^5 1 2 3 S^4 1 2 5 S^3 ε -2 0 S^2 $(2\varepsilon + 2)/\varepsilon$ 5 0 S^1 $(-4\varepsilon - 4 - 5\varepsilon^2)/2\varepsilon + 2$ 0 S^0 5 To examine sign change $\lim_{\varepsilon \to 0} \frac{2\varepsilon + 2}{\varepsilon} = 2 + \lim_{\varepsilon \to 0} 2/\varepsilon = 2 + \infty = \infty$ (sign is positive) $\lim_{\varepsilon \to 0} (-4\varepsilon - 4 - 5\varepsilon^2)/2\varepsilon + 2$ $= 0-4-5(0)/2$ $= -4/2$ $= -2$	**02 Marks (Solving Special Case)**	

	Final Rouths Array: s^5 1 2 3 s^4 1 2 5 s^3 ε -2 0 s^2 ∞ 5 0 s -2 0 0 s^0 5 1) Conclusion – Routh"s stability criteria states that the elements of 1st column of Routh"s array should not have any sign change for the system to be stable. The number of sign changes in the 1st column indicates the number of Poles on RHS which makes the system unstable. Here, 2 sign changes in the 1st column which indicate 2 RHS poles. Therefore system is unstable. **(Note:- Alternative method of Rouths Array by replacing S with 1/Z in the original equation also may be considered.)**	**01 Mark (Final Ans & Conclusion)**	
(d)	**Draw and explain 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 terminals of the two potentiometers. Output of this differential potentiometer is =Ks[θr(t) – θL(t)] This is then is fed to DC Amplifier, which is further amplifying the 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.	**02 Marks Diagram** **02 Marks Explanation**	

(e)	**Draw the op-amp based PI Controller. Derive its output equation.**		**04**
Ans.	 Fig:. Electronic PI controller. Analytical equation for PI controller is given as **P=KP KI** $\int I\,dt + KP\,EP$ 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. $P_I(0)$ 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 of sign of the error and the direction action	**02 Marks Diagram** **02 Marks output Equation**	
4 (A)	**Attempt any THREE:**		**12**
(a)	**Explain proportional controller. Draw its response graph.**		**04**
Ans.	• Proportional controller is a device that produces an output signal proportional to the deviation. • The proportional control action is a multi position type of controller action in which position of the correcting element is directly proportional to the deviation. It is called as P control action. • This action responds to the size and sign of deviation. For each value of deviation, there is a specific value of controller output of controller output that correlates with a specific value opening. • The proportional band is the range of deviation, in percent scale; that corresponds to the full range of deviations. It is dependant on the gain. • The proportional controller amplifies the error signal by Kp. Also,	**03 Marks P Controller Explanation**	

	introduction of the controller on the system increases the gain by amount Kp. • Mathematically the controller output Po for proportional controller is expressed as, Po = Kp.ep + Pn Where Kp is proportional constant, Pn is controller output with no error ep is error expressed as percentage of span • The nature of proportional control action can be shown as below,  	01 Marks for Graph with neat labeling	
(b)	**What is gain margin & phase margin? What should be the values of gain margin & phase margin for a good system?**		**04**
Ans.	**Gain Margin :** • It refers to the amount of gain, which can be increased or decreased without making the system unstable. • It is the gain which can be varied before the system becomes just stable (i.e, after varying the gain up to a certain threshold, the system becomes marginally stable & then further variation of gain leads to unstability) • Gain Margin occurs at phase cross over frequency is the frequency at which the phase angle G(s)H(s) -180^o • Gain margin acts as a safety factor for model uncertainty. • Greater will the **gain margin** greater will be the stability of the system. It is usually expressed in dB. • Gain margin should always be chosen as greater than one (GM>1) to ensure stability. **Phase margin:** • It refers to the phase which can be increased or decreased without making the system unstable. It is usually expressed in phase. • It is the phase that can be varied before the system becomes just	**01Mark (Gain Margin)** **01Marks (Phase Margin)**	

<table>
<tr><td></td><td>stable(i.e, after varying the phase up to a certain threshold, the system becomes marginally stable and then further variation of phase leads to unstability).
• Phase margin occurs at Gain Cross over frequency(Gain cross over frequency is the frequency at which the magnitude of the G(s)H(s) becomes 1)
• Greater will the phase margin greater will be the stability of the system.

Stability conditions are given below :
• For Stable System: Both the margins should be positive. Or phase margin should be greater than the gain margin.
• For Marginal Stable System: Both the margins should be zero. Or phase margin should be equal to the gain margin.
• For Unstable System: If any of them is negative. Or phase margin should be less than the gain margin.</td><td>02Marks(Values of GM, PM)</td><td></td></tr>
<tr><td>(c)</td><td>A unity feedback system has G(s) = $\frac{40\,(S+2)}{S\,(S+1)\,(S+4)}$.

Determine:
(i) Type of system
(ii) All static error coefficient</td><td></td><td>04</td></tr>
<tr><td>Ans.</td><td>1) Comparing the equation in standard 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)
$K_p = \lim_{s\to 0} G(s).H(s)$

$K_p = \lim_{s\to 0} G(s) = \lim_{s\to 0} \frac{10\,(S+2)}{S\,(1+S)\,(1+0.25\,S)} = \infty$</td><td>01 Mark (Type of system)

01 Mark each(Kp,Kv,Ka)</td><td></td></tr>
</table>

$K_v = \lim_{s \to 0} s.G(s).H(s)$

$K_v = \lim_{s \to 0} s.G(s) = \lim_{s \to 0} \frac{10\,S\,(S+2)}{S\,(1+S)\,(1+0.25\,S)} = \lim_{s \to 0} \frac{10\,(S+2)}{(1+S)\,(1+0.25\,S)}$

$= \frac{20}{1} = 20$

$K_a = \lim_{s \to 0} S^2.G(s).H(s)$

$K_a = \lim_{s \to 0} S^2.G(s) = \lim_{s \to 0} \frac{10\,S\,(S+2)}{(1+S)\,(1+0.25\,S)} = 0$

(d) Compare stepper Motor with DC Servo Motor. (Any Four Points) — **04**

Ans.

No.	Stepper Motor	DC Servo Motor
1	Control winding is absent	Control winding is present
2	Number of steps can be precisely controlled	It gives continuous rotation
3	It is brushless.	It has brushes.
4	Due to absence of brushes no wear and tear. Hence no maintenance.	Maintenance is required
5	Load and no load condition does not affect the running current of stepper motor	These conditions affect running current
6	Speed is governed by frequency of switching	Speed is controlled by supply voltage

01Mark (Any four points)

(B) Attempt any ONE: — **06**

(a) Explain the characteristics of D.C.servomotor. — **06**

Ans.

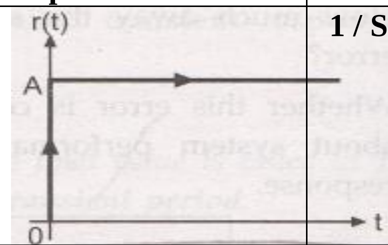
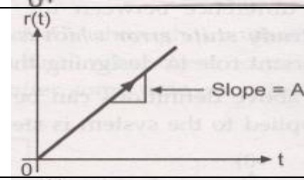
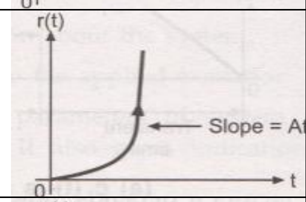
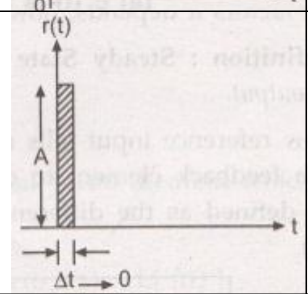
- It has linear characteristics
- It has low inertia
- It is light in weight
- It has low cost hence economical
- It is easier to control
- It has high torque to inertia ratio
- It has higher operating speed i.e fast response due to low electrical and mechanical time constants
- It gives high power output.

01 Mark each(Any six points with brief explanation)

(b) Explain the different standard input test signal. Give their laplace transform. — **06**

Ans. The different standard test inputs are-

a) Step input b) Impulse input c) Ramp input d) Parabolic input

Test Signal	Graphical Representation	Laplace Transform
Unit Step Input		**1 / S**
Unit Ramp Input		**$1 / S^2$**
Unit Parabolic Input		**$1 / S^3$**
Unit Impulse		**1**

$1^{½}$ Mark each (Graphical representation ½ mark & L.T. 01 mark)

5	**Attempt any FOUR:**		**16**
(a)	**What is AC servomotor? Explain its torque speed characteristics.**		**04**

Ans. An AC servomotor is basically a two phase induction motor which has certain special design features which makes it suitable for servo applications.

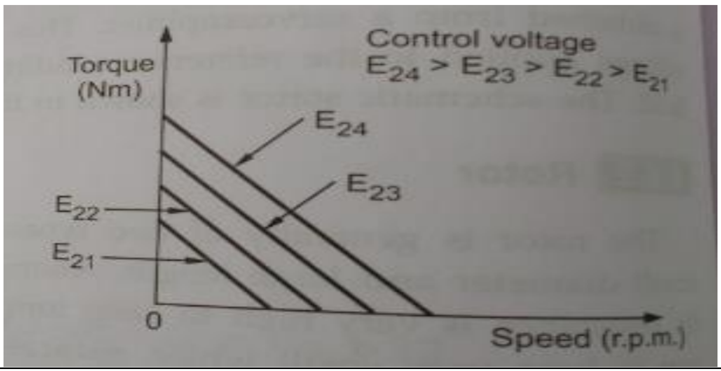
01 Mark for definition

It is driven by the amplified error signal from the output of a servo amplifier.

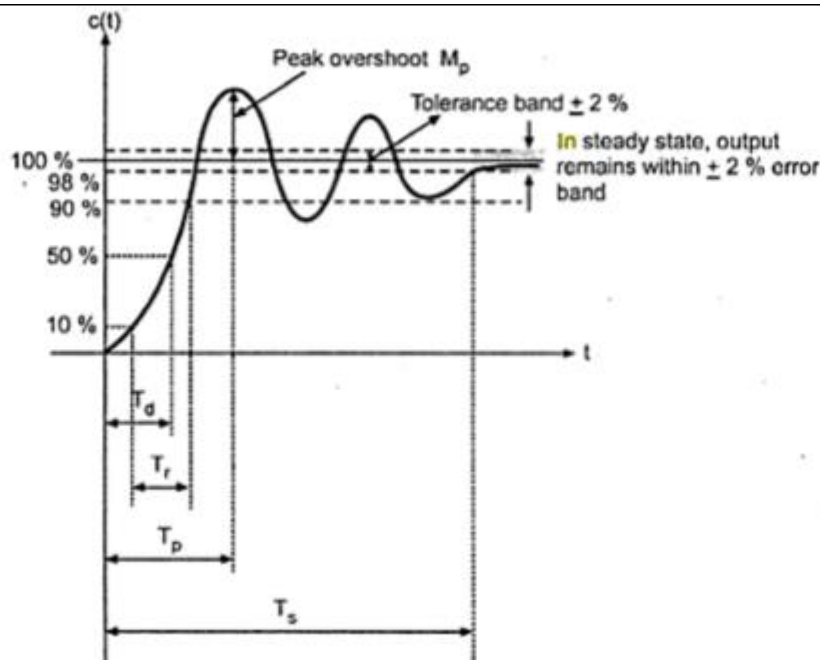
Torque-speed characteristic of AC servo motor :

One of the basic requirements of a servo motor is that its torque- speed characteristic should be linear.

This characteristic depends upon the ratio of reactance to resistance. If X/R

	ratio is small, the characteristic becomes linear. The rotor of the AC servomotor is built with high resistance, so its X/R ratio is small and the torque- speed characteristic is linear. The torque- speed characteristic of an AC servo motor is as shown below.  	**02 Marks for explanation** **01 Mark for graph**	
(b)	**What is a composite controller? State their applications.**		**04**
Ans.	Composite controllers are those controllers that are obtained by combining continuous mode controllers like proportional, integral and derivative controller in different ways. The applications of various types of composite controllers are : 1. Proportional-Integral or (PI)controller : This controller eliminates the offset problem of P controller, so it is suitable for systems which have large or frequent load changes. But the systems should have relatively slow changes in load to prevent oscillations. 2. Proportional- Derivative or(PD) controller : This is used for those industrial processes having fast load changes where offset error is tolerable. 3. Three mode controller or Proportional Integral and Derivative(PID) controller: As it has the advantages of P,I and D modes it is suitable for all types of process conditions where precise control is required. **(NOTE: Marks can be given for relevant application.)**	**01 Mark for definition** **01 Mark for each application.**	
(c)	**$S^3+4S^2+S+6=0$, state how many roots are in right half of s- plane.**		**04**

Ans.	The Routh's Array is formed as below: s^3 1 1 s^2 4 6 s^1 - 0.5 0 s^0 6 **Conclusion:** As there are 2 sign changes in the Routh's Array, it means there are 2 poles or roots on theright half of s- plane. Hence System is unstable.	**0 2 Marks Routh's Array** **02 Marks**	
(d)	**A second order system is given by :** $\frac{C(s)}{R(s)} = \frac{25}{S^2+6S+25}$. **Find its** **(i) wn (ii) wd (iii) Rise time (iv) Peak time**		**04**
Ans.	Comparing the above equation with the standard form below, $\frac{C(s)}{R(s)} = \frac{\omega_n{}^2}{\omega_n{}^2+2\xi\omega_n s+s^2}$ we have $w_n{}^2 = 25$, i) $w_n = \sqrt{25} = 5$ rad/sec. $2\xi w_n s = 6$ $2\xi * 5 = 6$ $\xi * 10 = 6$ $\xi = 6/10$ $\therefore \xi = 0.6$	**01 Mark for each calculation**	

	ii) $w_d = w_n\sqrt{(1-\xi^2)} = 4$ rad/s iii) Rise Time $T_r = (\pi - \theta)/w_d = (\pi - 0.9272)/4 = 0.5535$ sec iv) Peak Time $T_p = \pi/w_d = \pi/4 = 0.785$ sec **Ans:** **i) w_n = 5 rad/sec. ii) w_d= 4 rad/s iii) T_r= 0.5535 sec** **iv) T_p= 0.785 sec**		
(e)	**Define (i) peak overshoot (ii) settling time of a second order system and label it on time domain response.**		**04**
Ans.	 **Peak Overshoot M_p :** It is defined as 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	**02 Marks for neat labeled response**	

	reference steady state value during the first overshoot. **Settling time T_s:** It is defined as the time required for the response to decrease and stay within specified percentage of its final value and within tolerance band.	**01 Mark for each definition**	
(f)	**Draw bode plot for the system with open loop transfer function:** **$G(S)H(S) = \frac{20}{S(1+2S)}$**		**04**
Ans.	Put s =jw, then$G(jw)H(jw) = \frac{20}{jw(1+2jw)}$ **Magnitude plot:** Factors: 1. K=20 | M | =20 log 20 =26.02 dB It is a straight line of magnitude 26 dB parallel to X axis(0 dB slope). 2. Pole at origin 1/s : It is a straight line of magnitude +20 dB at origin and a constant slope -20 dB/decade cutting X axis at w= 1 3. 1/(1+2s) = 1/(1+2jw) T=2 Corner frequency w_{c1} = 1 /T =0.5 rad/sec. The plot is a straight line of constant slope of – 20 dB / dec from corner frequency w_{c1} = 0.5 rad/sec. 4. Resultant : It is calculated by adding algebrically individual magnitudes at origin. Resultant | M | at origin = 26+20+0 = 46 dB It is a straight line of slope -20 dB/decupto w_{c1} = 0.5 rad/sec. .At w_{c1} = 0.5 rad/sec, another line of slope -20 dB/dec is added, so the new slope is -20 +(-20) = -40 dB /dec.	**01 Mark Magnitude plot calculation**	

Phase plot :

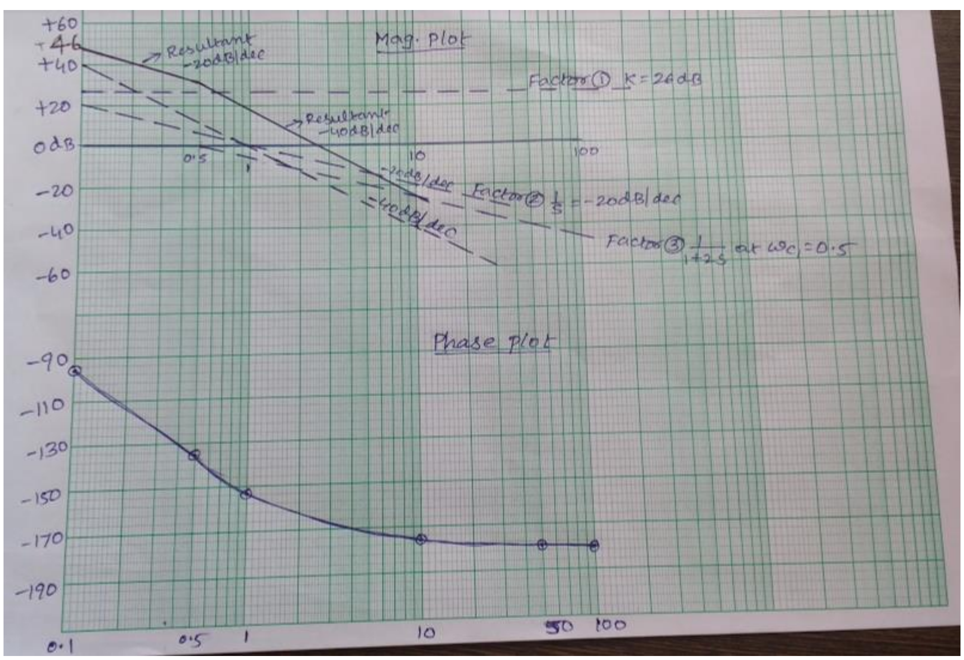
Resultant $\phi = \phi_1 + \phi_2 + \phi_3$

$\phi_{1} = 0^{o}$ $\phi_2 = -90^{o}$ $\phi_3 = -\tan^{-1} 2w$

w	ϕ_1	ϕ_2	ϕ_3	ϕ
0.1	0	- 90^{o}	-11.3^{o}	-101.3^{o}
0.5	0	-90^{o}	-45^{o}	-135^{o}
1	0	-90^{o}	-63.43^{o}	-153.43^{o}
10	0	-90^{o}	-87.13^{o}	-177.13^{o}
50	0	-90^{o}	-89.47^{o}	-179.42^{o}
100	0	-90^{o}	-89.71^{o}	-179.71^{o}

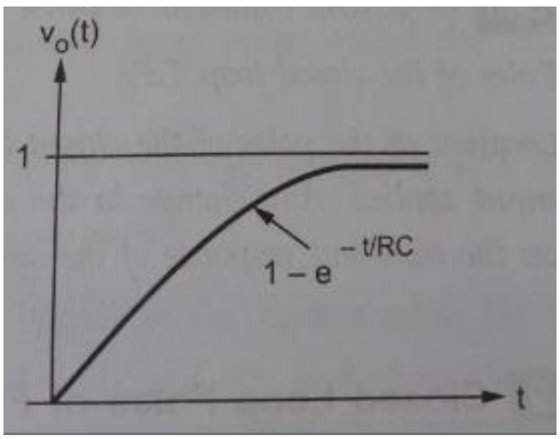
01 Mark for Phase plot table

The magnitude and phase plots are as shown below. Bold line indicates the resultant magnitude and phase plot respectively.



02 Marks for magnitude plot and phase plot

6	**Attempt any FOUR:**		**16**
(a)	**Define poles and zero. How system stability is affected by location of poles and zeros in s-plane?**		**04**
Ans.	**Definition :** **Poles :** The values of 's' which makes the transfer function infinity after substitution in the denominator of a transfer function are called poles of the transfer function. **Zeros :** The values of 's' which makes the transfer function zero after substitution in the numerator of a transfer function are called zeros of the transfer function. System stability is determined from the location of closed loop poles in the s- plane. If the poles are located on the left half of s-plane, then such system is absolutely stable. If the poles are located on the right half of s-plane, then such system is unstable. If one or more pairs of non- repeated roots are located on the jwaxis, then the system is critically stable or marginally stable	**01 Mark for each definition** **02 Marks for relevant explanation**	
(b)	**Analyze the first order system for an unit step function.**		**04**
Ans.	Consider a simple first order system be excited by a unit step input. The T.F. of first order system is given by , $\frac{Vo(s)}{Vi(s)} = \frac{1}{1+sRC}$ For unit step input, $v_i(t) = 1, \quad \text{for} t \geq 0$ $= 0, \quad \text{for } t < 0.$ The Laplace equivalent is $Vi(s) = \frac{1}{s}$ $\therefore Vo(s) = \frac{1}{s(1+sRC)} = \frac{A^1}{s} + \frac{B^1}{1+sRC}$ Using Partial fraction method we get: $A^1 = 1$ & $B^1 = -RC$	**01 Mark for T.F.** **02 marks**	

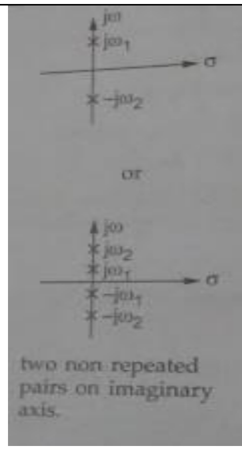
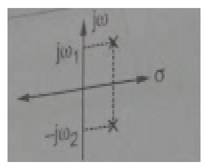
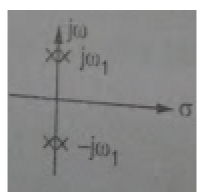
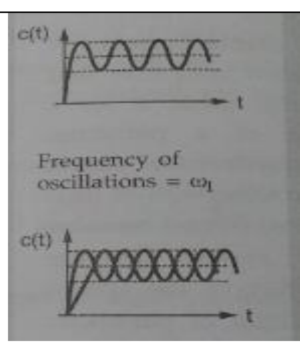
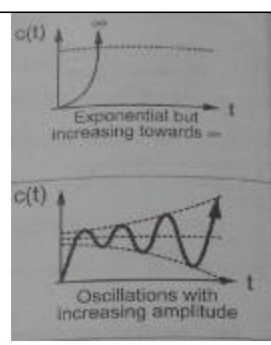
	Substituting the values of A^1 and B^1, we get $\therefore Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC}$ Taking Laplace inverse, we get $v_o(t) = 1 - e^{-\frac{t}{RC}} \Rightarrow C_{ss} + c_t(t)$ The steady state response $C_{ss} = 1$ and transient term $c_t(t) = - e^{-\frac{t}{RC}}$ The output waveform is as shown.  	01 Mark	
(c)	**What is Type O system? Derive the steady state error and error coefficients for step input.**		04

Ans.	Type of a system means the number of poles present at the origin of open loop transfer function G(s)H(s) of the system. Hence a type 0 system is a system which does not have any pole at the origin of its open loop transfer function. **Derivation of steady state error and error coefficients for step input for a type 0 system:** Consider a step input of magnitude A applied to the system. $r(t) = A$ $R(s) = \frac{1}{s}$ The steady state error is given by $e_{ss} = \lim_{s\to 0} \frac{sR(s)}{1+G(s)H(s)} = \lim_{s\to 0} \frac{s\frac{A}{s}}{1+G(s)H(s)}$ $= \lim_{s\to 0} \frac{A}{1+G(s)H(s)}$ $e_{ss} = \frac{A}{1+\lim_{s\to 0} G(s)H(s)} = \frac{A}{1+Kp}$ where $Kp = \lim_{s\to 0} G(s)H(s)$ is called positional error coefficient. Steady state error $e_{ss} = \frac{A}{1+Kp}$ The open loop transfer function G(s)H(s) of a type 0 is given by : $G(s)H(s) = \frac{K(1+T1s)(1+T2\,s)\ldots\ldots}{(1+Tas)(1+Tbs)\ldots\ldots\ldots}$ For step input , $Kp = \lim_{s\to 0} G(s)H(s) = K$	**01 Mark for definition** **03 Marks for Derivation**	

	Steady state error $e_{ss} = \frac{A}{1+Kp} = \frac{A}{1+K}$ $\therefore K_p = K$ Steady state error $e_{ss} = \frac{A}{1+K}$ Similarly $Kv = \lim_{s\to 0} sG(s)H(s) = \lim_{s\to 0} \frac{sK(1+T1s)(1+T2\ s)\ldots\ldots}{(1+Tas)(1+Tbs)\ldots\ldots} = 0$ $e_{ss} = A/K_v = A/0 = \infty$ $Ka = \lim_{s\to 0} s2G(s)H(s) = \lim_{s\to 0} \frac{s2K(1+T1s)(1+T2\ s)\ldots\ldots}{(1+Tas)(1+Tbs)\ldots\ldots} = 0$ $e_{ss} = A/K_a = A/0 = \infty$		
(d)	**What is the difference between critically stable and unstable system .**		**04**

Ans.

	Critically stable	**Unstable system**	**02 Marks each (Any two)**
1.Definition	For a bounded input,it produces an output which oscillates with constant frequency and amplitude.	For a bounded input, it produces an unbounded output. In the absence of input the output may not return to zero.	
2.Nature of closed loop poles	Will have one or morenon repeated pair of poles on the jw axis with no pole in the R.H.S. of s-plane.	1.The roots are real and positive, located in R.H.S of s- plane. 2. complex conjugate roots with positive real part. 3. It can also have repeated pair of poles on the jw axis with	

				no pole in the R.H.S. of s-plane.		
		3.Location of closed loop poles in s plane		 1.Real and positive 2 complex conjugate roots with positive real part  3. Repeated pair on jw axis. 		
		4. Step response				

(e)	**For a unity feedback system G(s) = $\frac{K}{S(1+0.4S)(1+0.25S)}$. Find marginal value of K.**		**04**
Ans.	Characteristic equation = 1+G(s)H(s) = 0 G(s) = $\frac{K}{s(1+0.4s)(1+0.25s)}$, H(s) = 1 $1 + \frac{K}{s(1+0.4s)(1+0.25s)} = 0$ $\frac{s(1+0.4s)(1+0.25s+K}{s(1+0.4s)(1+0.25s} = 0$ $0.1\,s^3 + 0.65s^2 + s + K = 0$ 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 From s^0, K > 0 From s^1, $(0.65-0.1K) > 0$ 0.65 > 0.1 K $\therefore$ 6.5 > K The value of K which makes any row of Routh's Array other than s^0row , zero is called marginal value of K. Hence marginal value of K is a value which makes row of s^1 as row of zeros. $0.65 - 0.1\,K_{mar} = 0$ $\therefore$ $\mathbf{K_{mar} = 6.5}$	**02 Marks** **02 Marks Routh's array & marginal value of K**	

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	