MODEL ANSWER

SUMMER– 18 EXAMINATION

Subject Title: CONTROL SYSTEM **Subject Code: 17538**

Important Instructions to examiners:

1) The answers should be examined by key words 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.	Sub Q.N.	Answer	Marking Scheme
Q.1	A)	**Attempt any THREE :**	**12-Total Marks**
	a)	**Differentiate between open loop and closed loop systems (4 points).**	**4 Marks**
	Ans:		**(any four points each carry 1 Mark)**

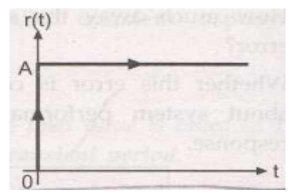
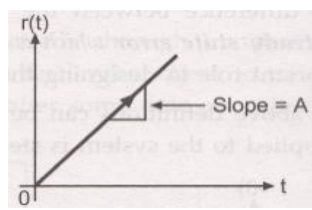
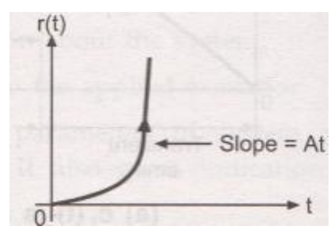
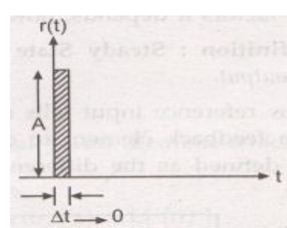
Open loop system	Closed loop system
No Feedback element	Feedback element is present
Error detector is absent	Error detector is present
Less accurate	Accurate
Small bandwidth	Large bandwidth
More stable	Less stable
Simple and low cost	Complex and high cost
It gives low response to the input	It gives fast response to the input
Disturbances occurring in the process are not controllable	Disturbances can be controlled automatically
Any change in output has not effect on the input	Any change in output effects the input

Examples: Automatic toaster, hair dryer, traffic control etc.	Examples : Air conditioning, automatic iron, water level controller, voltage stabilizer etc.

b) **Name the standard test signals. Write the transfer function and draw their response.** **4 Marks**

Ans: The Standard test signals are :

1.Unit Step Input
2.Unit Ramp Input
3.Unit Parabolic Input
4.Unit Impulse Input

Standard test signal	Transfer function	Response
Unit Step Input	$\frac{1}{S}$	
Unit Ramp Input	$\frac{1}{S^2}$	
Unit Parabolic Input	$\frac{1}{S^3}$	
Unit Impulse Input	1	

(Naming of test signals 1Mark,

Transfer functions 1 Mark

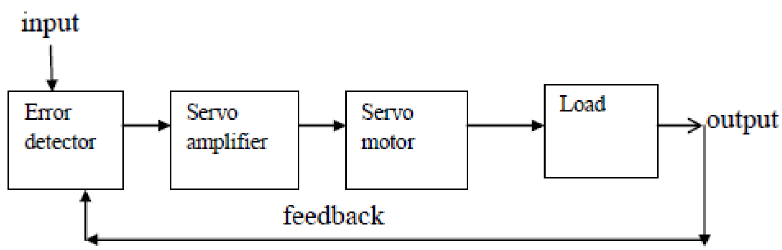
Response 2 Marks)

c) Define servo system. Draw the block diagram of servo system. — **4 Marks**

Ans:

Servo System :- Servo systems are automatic feedback control system which work on error signals with output is the form of mechanical position, velocity or accelerations. The error signals are amplified to drive the motors, which are coupled to the output. — **2 Marks for definition**

Block Diagram:- — **2 Marks For Block diagram**

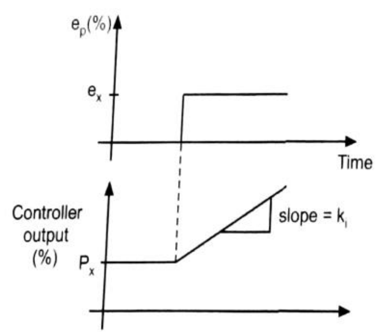


d) Identify the controller which can eliminate the drawback of proportional controller. Draw response graph with equation. — **4 Marks**

Ans:

The controller which can eliminate the drawback of proportional controller is Integral Controller (I-Controller). — **1 Mark for identification,**

Response curve of integral control action — **2 Marks for response,**



Equation of integral controller:- — **1 Mark for equation**

$$P(t) = K_i \int_0^t e(t)dt + P(0)$$

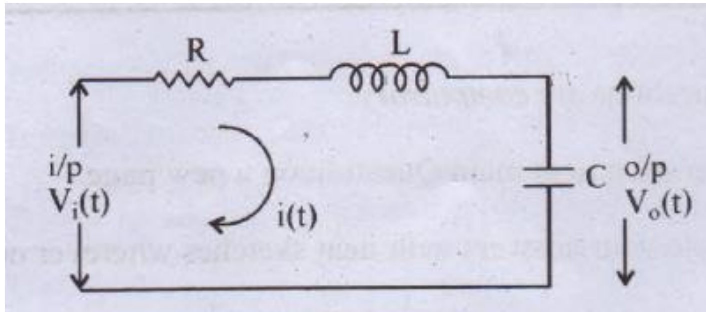
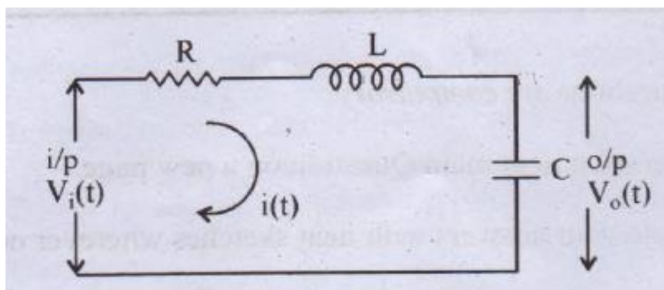
Where P(t) is controller output

K_i is integral gain

P(0) is controller output at t=0

Note: Any relevant equation of I controller may considered.

B)	**Attempt any ONE:**	**6 Marks**
a)	**Define transfer function. Derive the transfer function of the circuit in fig.**	**6 Marks**

			
	Ans:	**Definition:-** **Transfer function:** Transfer function of a linear time invariant system is defined as the ratio of the Laplace transform of the output variable to the Laplace transform of the input variable assuming that all the initial conditions are zero. **Derivation of given Transfer function is**  **Apply KVL to loop.** $$V_i = R_i(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt \quad \text{---------(1)}$$ **Taking L.T.** $$V_i(s) = RI(s) + Ls\,I(s) + \frac{1}{sC}I(s)$$ $$= \left(R + Ls + \frac{1}{sC}\right)I(s)\ldots\ldots\ldots(2)$$ **Output voltage across capacitor is,** $$V_o(t) = \frac{1}{C}\int i(t)dt\ldots\ldots\ldots(3)$$ **Taking L.T.** $$V_o(s) = \frac{1}{sC}I(s)\ldots\ldots\ldots(4)$$	**1 Mark** **1Mark** **1Mark** **1 Mark** **1Mark**

		Take the ratio of **equation (2) and (4),** ∴ Transfer function is, $$TF = \frac{V_o(s)}{V_i(s)}$$ $$TF = \frac{\frac{1}{sC} I(s)}{\left(R + Ls + \frac{1}{sC}\right) I(s)}$$ $$TF = \frac{1}{RCs + LCs^2 + 1}$$	**1 Mark**
	b)	**Draw Bode plot for the system with open loop transfer function** **G(s) H(s) = 20/s (1 + 2s)**	**6 Marks**
	Ans:	Put s =jω, then $G(j\omega)H(j\omega) = \frac{20}{j\omega(1+2j\omega)}$ **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 ω= 1 3. 1/(1+2s) = 1/(1+2jω) T=2 Corner frequency ωc_1 = 1 /T =0.5 rad/sec. The plot is a straight line of constant slope of – 20 dB / dec from corner frequency ωc_1 = 0.5 rad/sec. 4. Resultant : It is calculated by adding algebraically individual magnitudes at origin. Resultant | M | at origin = 26+20+0 = 46 dB It is a straight line of slope -20 dB/dec upto ωc_1 = 0.5 rad/sec. At ωc_1 = 0.5 rad/sec, another line of slope -20 dB/dec is added, so the	**2 Mark for Magnitude plot calculation**

new slope is -20 +(-20) = -40 dB /dec.

Phase plot :-

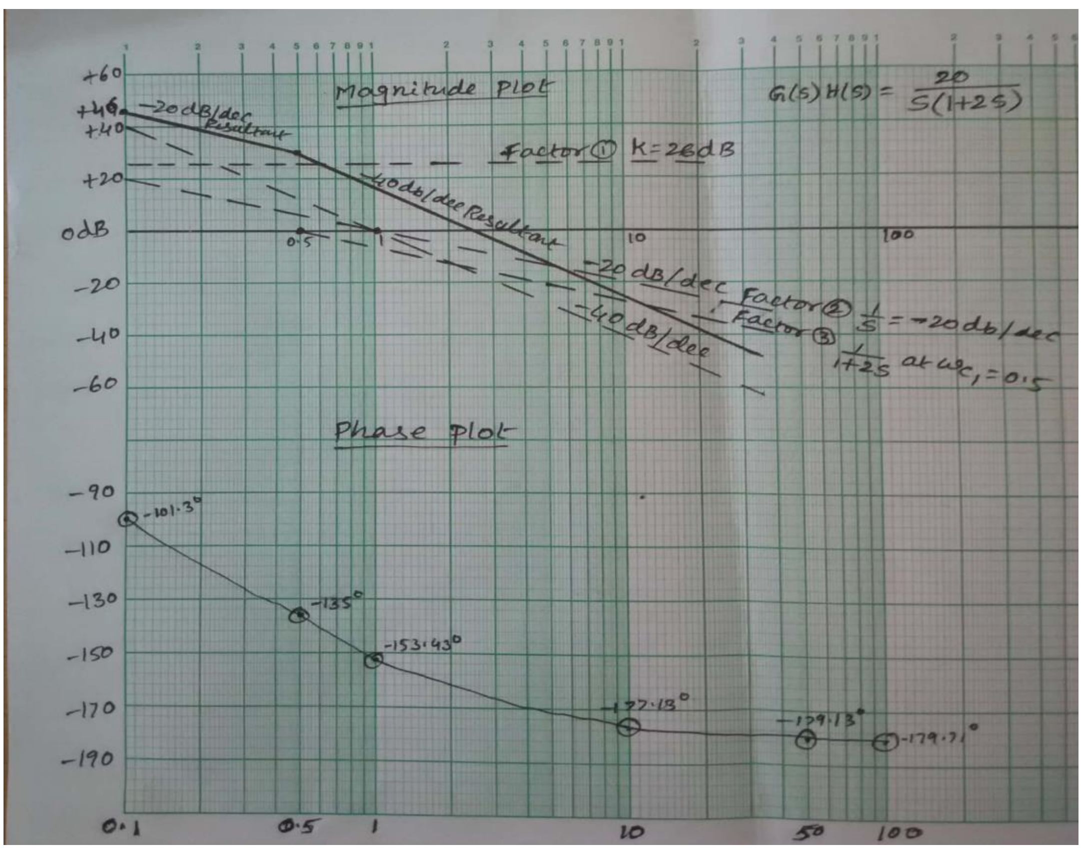
Resultant $\emptyset = \emptyset_1 + \emptyset_2 + \emptyset_3$

$$\boldsymbol{\emptyset_1 = 0^\circ \quad \emptyset_2 = -90^\circ \quad \emptyset_3 = -tan^{-1}(2\omega)}$$

ω	ϕ1	ϕ2	ϕ3	ϕ
0.1	0	-90°	-11.3°	-101.3°
0.5	0	-90°	-45°	-135°
1	0	-90°	-63.43°	-153.43°
10	0	-90°	-87.13°	-177.13°
50	0	-90°	-89.47°	-179.13°
100	0	-90°	-89.71°	-179.71°

2 Mark for Phase plot calculation

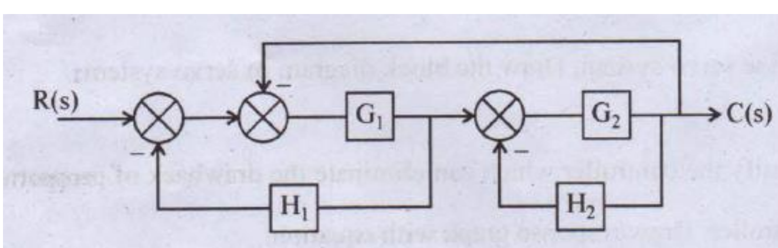
The magnitude and phase plots are as shown below. Bold line indicates the resultant magnitude and phase plot respectively.

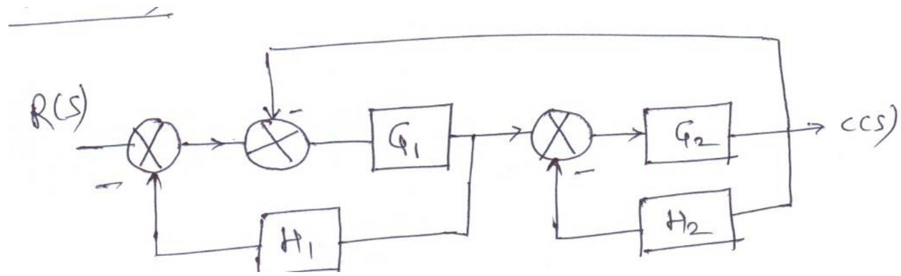
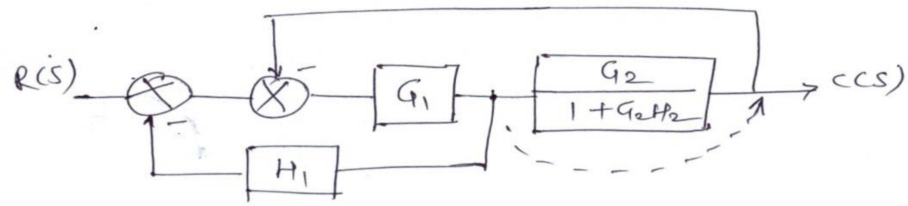
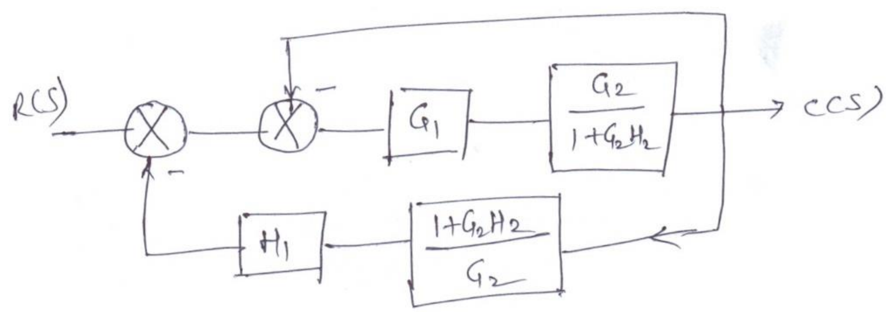
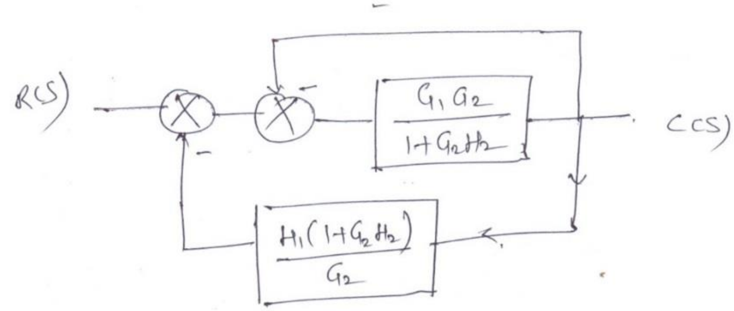


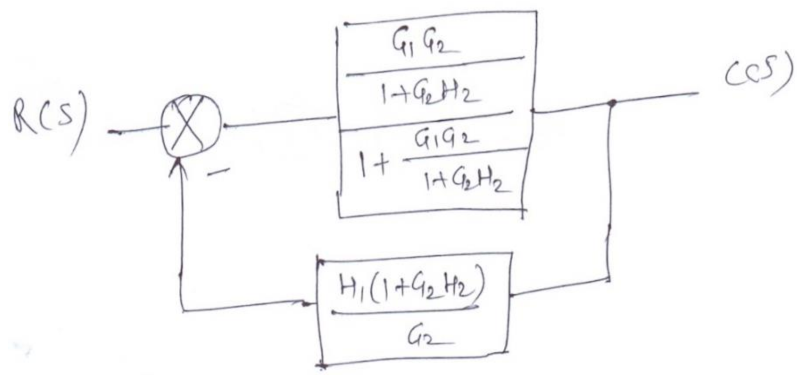
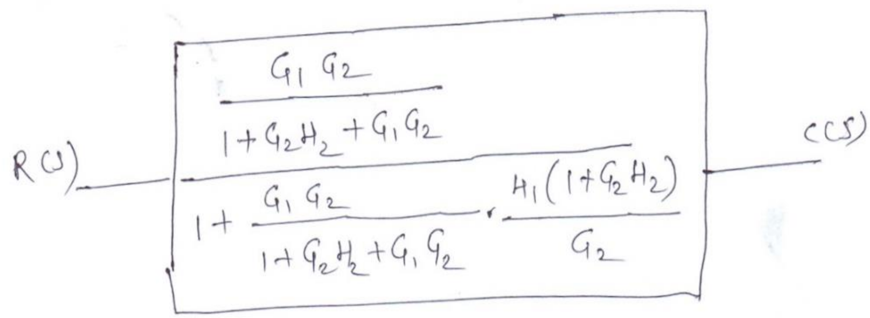
2 Mark for Magnitude and Phase plot

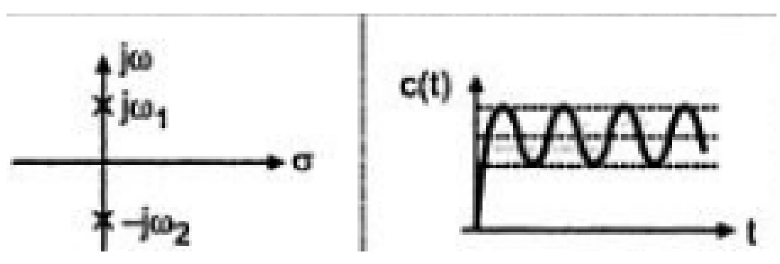
Q 2		**Attempt any TWO :**	**16 Marks**
	a)	**A system has G(s) H(s) $= \frac{K(s+13)}{S(S+3)(S+7)}$. Determine the range of K for which the system is stable.**	**8 Marks**

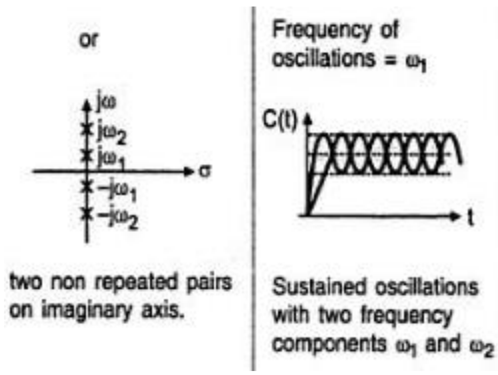
	Ans:	Characteristics Equation: $1 + G(S)H(S) = 0$ $1 + \frac{K(S+13)}{S(S+3)(S+7)} = 0$ $S(S+3)(S+7) + K(S+13) = 0$ $S(S^2+7S+3S+21) + KS + 13K = 0$ $S^3 + 7S^2 + 3S^2 + 21S + KS + 13K = 0$ $S^3 + 10S^2 + (21+K)S + 13K = 0$ S^3	1	(21+K) S^2	10	13K S^1	$\frac{10(21+K)-13K}{10}$	0 S^0	13K For system to be stable there should not be sign change in the first column. from S^0 $13K > 0$ $K > 0$ from S^1 $\frac{10(21+K)-13K}{10} > 0$ $10(21+K) - 13K > 0$ $210 + 10K - 13K > 0$ $210 - 3K > 0$ $210 > 3K$ $\frac{210}{3} > K$ $70 > K$ $\therefore$ Range of K is $0 < K < 70$	**Characteristics equation- 2Marks** **Routh's Array- 4Marks** **Range of K- 2Marks**
	b)	**The transfer function of a system is** $\frac{C(s)}{R(s)} = \frac{25}{s^2 + 6s + 25}$. **Find out Rise time, Peak time, Settling time and Peak overshoot.**	**8 Marks**

	Ans:	Q.2 b) Compare T.F. with the standard form $\frac{W_n^2}{S^2+2\xi W_n S+W_n^2}$ $W_n^2 = 25$ and $2\xi W_n = 6$ $W_n = 5$ rad/sec $\therefore \xi = 0.6$ $\theta = \tan^{-1}\left[\frac{\sqrt{1-\xi^2}}{\xi}\right]$ $= \tan^{-1}\left[\frac{\sqrt{1-0.6^2}}{0.6}\right]$ $= 0.9272$ radians. $W_d = W_n\sqrt{1-\xi^2}$ $= 5\sqrt{1-(0.6)^2}$ $= 4$ rad/sec. Rise time $T_r = \frac{\pi-\theta}{W_d}$ $= \frac{\pi-0.9272}{4}$ $= 0.5535$ Sec. Peak time $(T_p) = \frac{\pi}{W_d}$ $= \frac{\pi}{4}$ $= 0.785$ Sec Setting time $(T_s) = \frac{4}{\xi W_n}$ $= 1.33$ sec Peak overshoot, $\% M_p = e^{-\pi\xi/\sqrt{1-\xi^2}} \times 100$ $= e^{-\pi\times 0.6/\sqrt{1-0.6^2}} \times 100$ $= 9.48\%$.	**Tr-2 Marks** **Tp-2Marks** **Ts-2Marks** **Mp-2Marks**
	c)	**Find out the transfer function of the following system in fig. using block diagram reduction method.**  	**8 Marks**

	Ans:		
			**1Mark**
			**1Mark**
			**2Marks**

			**1Mark**
			**2Marks**
		$$\frac{C(s)}{R(s)} = \frac{G_1 G_2}{1+G_2H_2+G_1G_2+G_1H_1(1+G_2H_2)}$$	**1Mark**
Q. 3		**Attempt any FOUR of the following:**	**16 Marks**
	a)	**Find out the poles and zeros of the following transfer-function :** $$\frac{C(s)}{R(s)} = \frac{s^2+9}{s(s^2+6s+8)}$$	**4 Marks**
	Ans:		

		$\frac{C(s)}{R(s)} = \frac{s^2+9}{s(s^2+6s+8)}$ i) Poles are the roots of the equation obtained by equating denominator to zero i.e. $s(s^2+6s+8)=0$ $s(s^2+6s+8)=0$ $s(s+4)(s+2)=0$ $\therefore$ There are three poles located at $s=0, -4, -2$ Note: For correct Poles 2M & Zeros 2M. ii) Zeros are the roots of the equation obtained by equating numerator to zero i.e. $s^2+9=0$ $s^2=-9$ $s=\sqrt{-9}$ $=\pm j3$ There is two zeros $+j3$ & $-j3$.	**Poles-** **2 Marks** **Zeros-** **2 Marks**
	b)	**State and explain the condition of marginal stability with location of poles on S-Plane.**	**4 Marks**
	Ans:	Marginally stable system: 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, such oscillations of output are called undamped or sustained oscillations. One or more pairs of non-repeated roots are located on imaginary axis.  **OR**	**2 Marks** **1 Mark** **Any one** **2 Marks**



Critically Stable System:

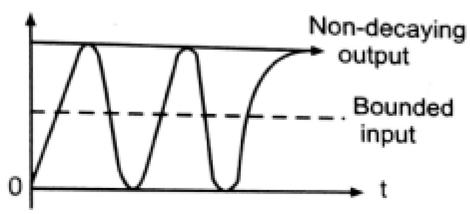
i) The (linear-time invariant) system is said to be critically stable system, if the system output does not go on increasing infinitely nor does it go to zero as time increases, when it is excited by input signal.

ii) The output of a system usually oscillates in a finite range or remains steady at some value. Such systems are not stable as their response does not decay to zero.

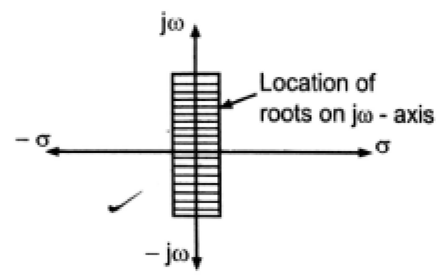
iii) Neither the system is defined as unstable because its output does not go on increasing infinitely.

iv) This system is also called as marginally stable system

v) For critically stable system, the location of poles is on the iw-axis and they are not repeated as shown below



(a) Bounded input producing neither bounded nor unbounded output



(b) Location of roots

c)	**State two advantages and two disadvantages of frequency response analysis.**	**4 Marks**

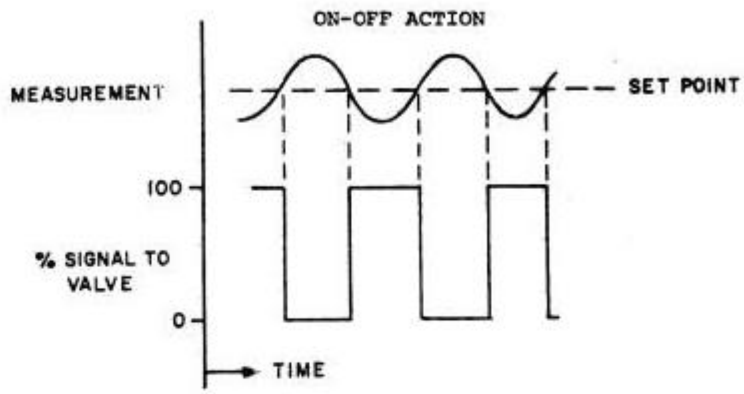
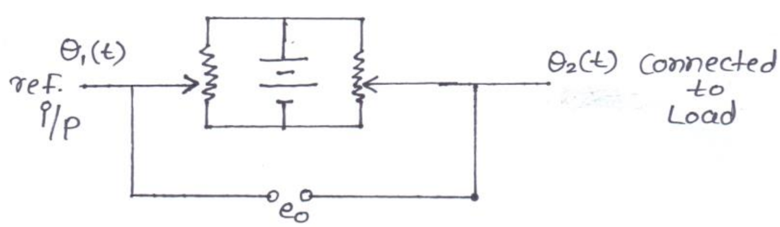
Ans:

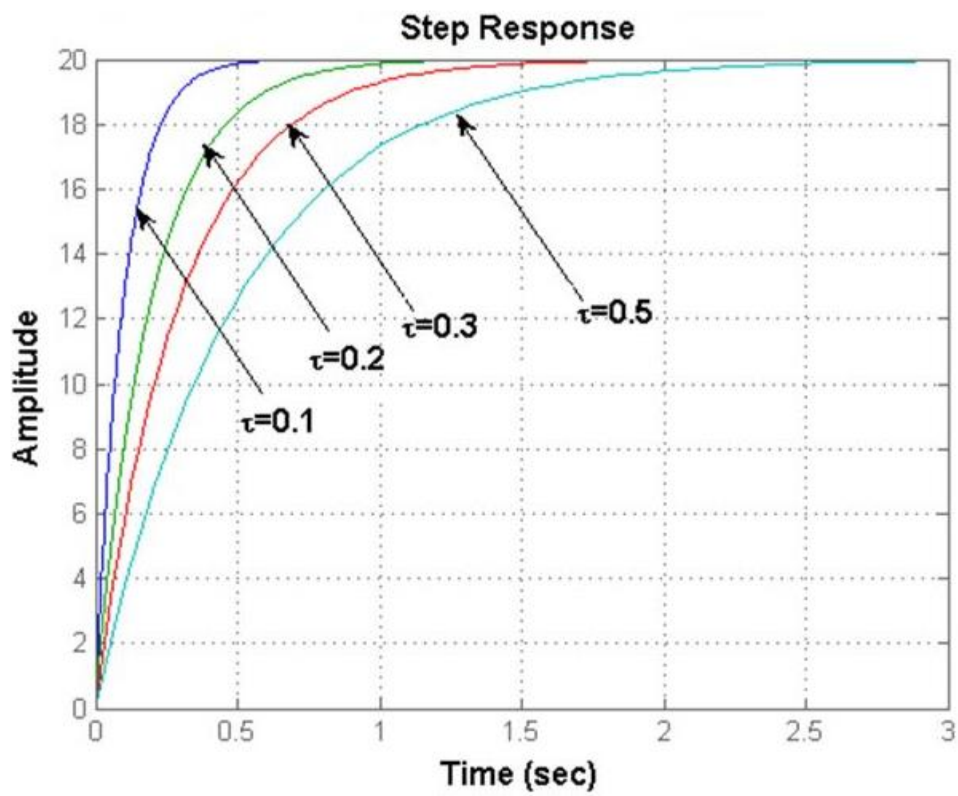
Any two advantages- 1 Mark each

Advantages:-

1. The stability of closed loop system can be found out from the open loop transfer function by using methods such as Nyquist criteria without solving the characteristic equation.
2. Frequency response tests are simple
3. Frequency response tests can be done by using readily available laboratory equipment such as CRO, function generator etc.

Disadvantages:

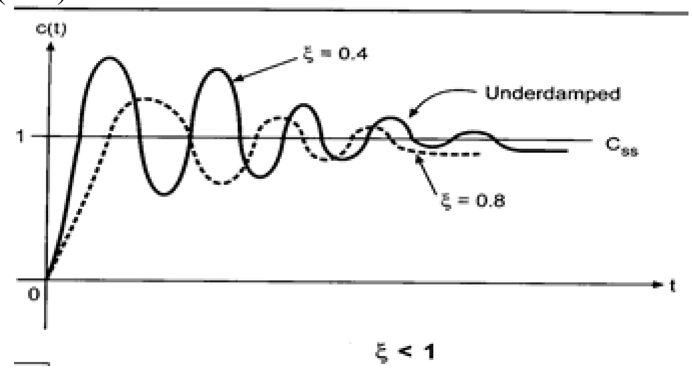
		1. Time consuming 2. Out dated methods compared to digital computation, simulation and modeling. 3. Methods can be applied mainly to linear systems. 4. Not recommended for systems with larger time constants.	**Any two disadvantages -1 Mark each**
	d)	**Explain on-off controller with response graph and equation.**	**4 Marks**
	Ans:	P= 0% $e_p < 0$ = 100% $e_p > 0$ When the measured value is less than the set point, full controller output results. When it is more than the set point, the controller output is zero. The response graph is shown below 	**1.5 Marks for equation** **1 Mark explanation** **1.5 Marks for response graph**
	e)	**Draw and explain the error detector used in DC servo system.**	**4 Marks**
	Ans:	Two pots in parallel is used as error detector. This arrangement allows the comparison of two shaft position thus, giving an o/p voltage proportional to difference in the position of both shaft of pot. One of the pot wiper can be kept constant and the other wiper is connected to the load. As the load change, wiper position change creating a difference in the two wiper positions leading to an error voltage across the two wipers. It is given to the servo amplifier in the servo system. 	**2 Marks for explanation and** **2 Marks for diagram**

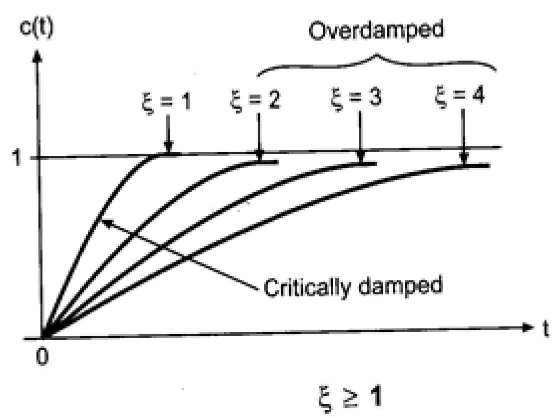
Q. 4	A)	Attempt any THREE :	12 Marks
	a)	**Define time constant. State the effect of it on the response of the system.**	**4 Marks**
	Ans:	Time constant: Time constant of a response signal is that time for which the signal reaches to its 63.2% of its final value. Effect of Time constant on the response of the system: More the time constant, less the speed of response of the system and vice versa. If the time constant of the system is smaller, the response of the system reaches to its steady-state condition faster because the settling time will be smaller. Refer the figure below:  It shows responses of various systems with different time constants τ. From the figure, it is seen that the system reaches the steady state faster if the time constant is smaller because it's settling time is less.	**Defn: 2 Marks** **Effect: 2 Marks**
	b)	**Determine stability by using Routh's criterion for $1+G(s)H(s)=s^4+4s^3+s^2+8s+1=0$**	**4 Marks**
	Ans:		**Array :**

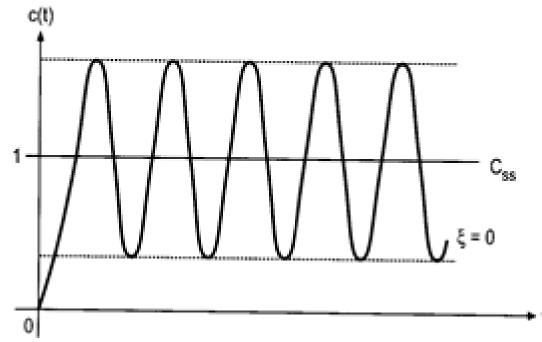
		The Characteristic equation is $S^4 + 4S^3 + S^2 + 8S + 1 = 0$ So, Apply Routh's Array S^4 | 1 1 1 S^3 | 4 8 0 S^2 | -1 1 0 S^1 | 12 0 S^0 | 1 There are two sign changes in first column of the rouths array. So system is unstable with two roots located in right half s-plane.	**2 Marks Stability condition: 2 Marks**
c)		**State the name of the controller which cannot be used alone. State the reasons why it cannot be used alone.**	**4 Marks**
Ans:		**D control action can not be used alone .** 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 Kd % 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	**Name: 1 Marks Reason: 3 Marks**
d)		**Describe the effect of damping for all 4 cases with the help of location of poles and output responses.**	**4 Marks**
Ans:		**Effect of damping in response of 2nd order control system:**	**Effect:1/2 Marks each (4 cases) Response :1/2 Marks each(4 cases)**

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

transient response of second order system for different values of ζ (zeta)



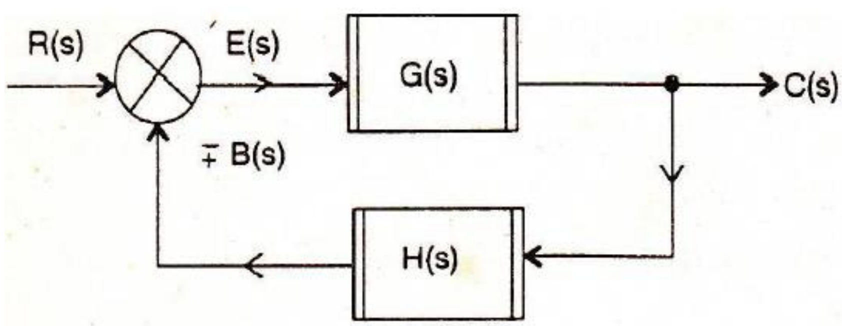




ξ = 0

Un-damped response

	B)	**Attempt any ONE :**	**06 Marks**
	a)	**Derive the Transfer Function of the closed loop system.**	**6 Marks**
	Ans:	(see below)	**Diagram: 1 Marks Derivation:3 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)

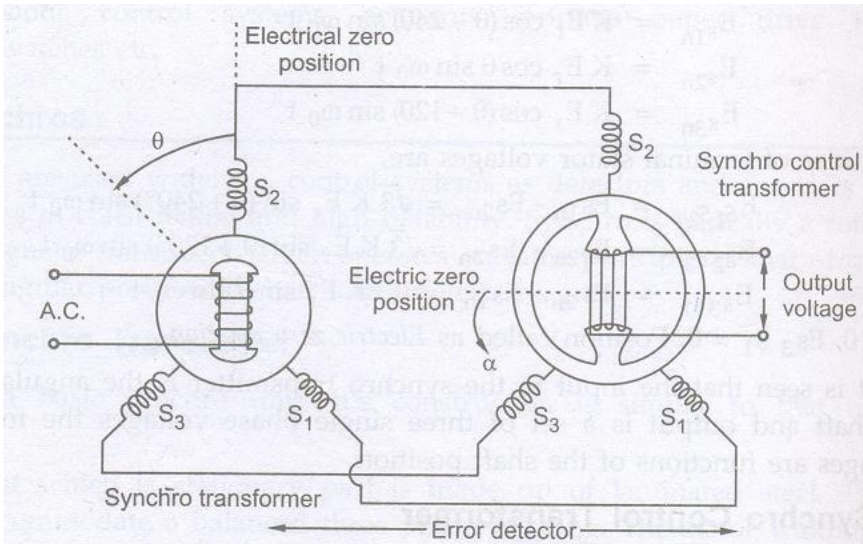
C(s) / G(s) = R(s) + C(s) H(s).

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). which is the Transfer Function.

	b)	**Draw and explain synchro as error detector.**	**6 Marks**
	Ans:	(see below)	**Diagram: 2 Marks** **Eplanation: 2 Marks**



Explanation:
Synchro transmitter along with synchro control transformer is used as error detector . The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap.
The output of the synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils Circulating currents of same phase but different magnitude will flow through both set of stator coils. This establishes an identical flux pattern in the air gap of control transformer. The flux pattern in the air gap of control transformer will have the same orientation as that of transmitter rotor. The voltage induced in the transformer rotor will be proportional to the cosine of angle between the two rotors.
The output equation is given by:
$e_0(t) = V_r Sin(\omega t) + Cos(\phi)$
where $V_r Sin(\omega t)$:input voltage to the transmitter rotor and ϕ is
The angular difference between both rotors.
When $\phi = 90^0$ 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.

Q.5		**Attempt any TWO .**	**16 Marks**

a) **(i) Compare DC Servo motor with stepper motor. (4 points)**
(ii) Draw and explain the constructions of AC servo motor. — **8 Marks**

Ans: **(i)**

4 Marks

(Any 4 points each carry 1 Mark)

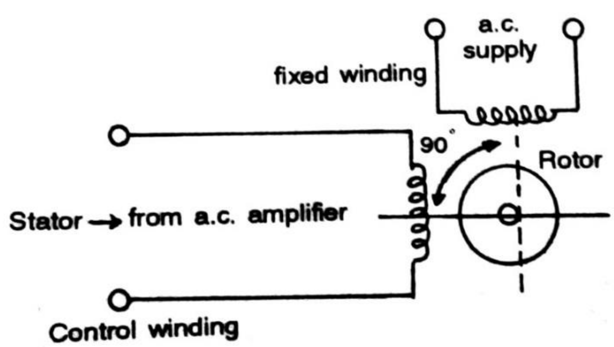
DC Servo Motor	Stepper Motor
Control winding is present	Control winding is absent
Brushes are present	Brushes are absent
Maintenance is high	Maintenance is low
Servomotor is a device which gives angular moment	Stepper motor is electromechanical device which activates a train of pulses of step angular or linear moments
These conditions affect the running current.	Load and no load conditions do not affect the running current of stepper motor.
Speed is controlled by supply voltage	Speed (Stepping rate) is governed by frequency of switching
It gives continuous rotation depending upon control voltage	Number of steps can be precisely controlled

(ii)AC Servo Motor:

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

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

Constructions:- — **4 Marks**



It is mainly divided into two parts. a) Stator b) Rotor

Stator: Stator carries two windings, uniformly distributed and displayed by 90°,in space. One winding is called **main winding** or **fixed winding** or **reference winding**. This is excited by a constant voltage a.c. supply. The other winding is **control**

Winding: It is excited by variable control voltage, which is obtained from a servo amplifier. This voltage is 90°out of phase with respect to the voltage applied to the reference winding. This is necessary to obtain rotating magnetic field. The schematic stator is shown in figure.

Rotor: The rotor is generally of two types. The one is usual squirrel cage rotor. This has small diameter and large length. Aluminum conductors are used to keep weight small. Its resistance is very high to keep torque speed characteristics as linear as possible. Air gap is kept very small which reduces magnetizing current. The other type rotor is drag cup type.

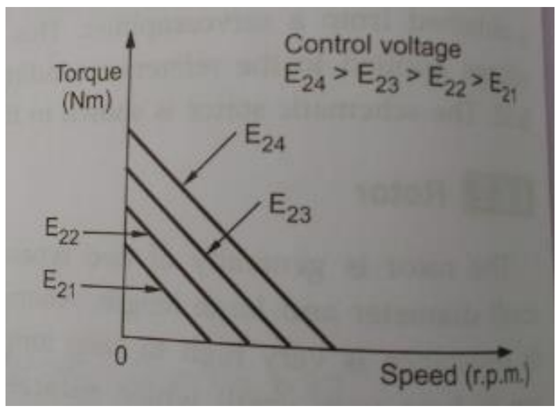
Torque-speed characteristic of AC servo motor :

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.

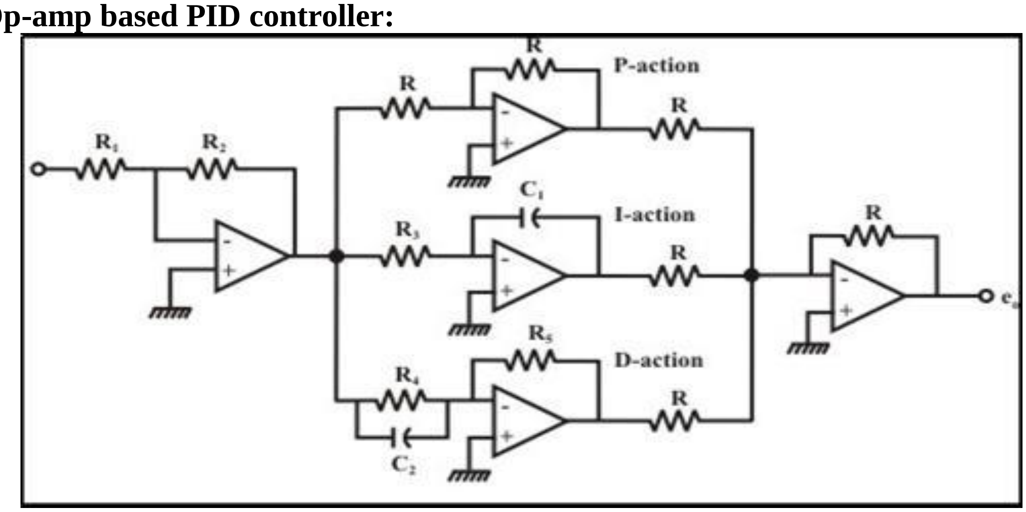
The rotor of the AC servomotor is built with high resistance, so its X/R ratio is small and the torque- speed characteristic is linear.

The torque- speed characteristic of an AC servo motor is as shown below.



b) **Draw op-amp based PID controller. Write its equation. State four advantages of PID controller over other composite controllers.** **8 Marks**

Ans: **Op-amp based PID controller:** **8Marks**



2 Marks for diagram

		Equation:- $$P(t) = K_p e_p + K_p K_i \int_0^t e(t)dt + K_p K_d \frac{d}{dt} e(t) + P(0)$$ **OR** $$V_{out} = \left(\frac{R_2}{R_1}\right) V_e(t) + \left(\frac{R_2}{R_1}\right) \frac{1}{R_1 C_1} \int_0^t V_e(t)\, dt + \left(\frac{R_2}{R_1}\right) R_D C_D \frac{d V_e(t)}{dt} + V_{out}(0)$$ Where K_p= Proportional gain K_d= Derivative gain K_i = Integral gain E_p = Error signal P(t) = Controller output P(0) =Controller output at t=0 **Note: Any relevant equation of PID controller may considered.** **Advantages of PID controller over other composite controllers.** 1. Offset error is eliminated. 2. Settling time is less. 3. Provides a fast response. 4. One of the most powerful mode of controllers. 5. No oscillations 6. Can be used to control all process conditions. 7. Zero steady state error. 8. Eliminates overshoot in the output response of the system.	**2 Marks for equation** **4 Marks for Advantages. (any four)**
	c)	**(i) Derive steady state error and error co-efficient for step input for a type O system.** **(ii) Find out the error co-efficients and steady state errors for a unity feedback system with**	**8 Marks**

$$G(s) = \frac{40(s+2)}{s(s+1)(s+4)}$$

Ans:

(i)Derivation of Steady State Error for step input for type zero system:

4 Marks

Equation for Steady state error

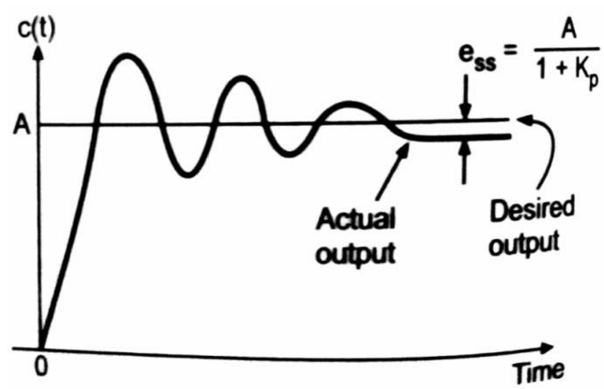
$$e_{ss} = \lim_{s\to 0} \frac{S\,R(s)}{1 + G(s)H(s)}$$

2 Marks for derivation of Steady State Error for step input for type zero system

For a type zero system, $G(S)H(S) = \frac{K}{(1+TS)}$

For step input, r(t) = A

$$R(s) = \frac{A}{s}$$



$$\therefore e_{ss} = \lim_{s\to 0} \frac{s\,R(s)}{1+G(s)H(s)}$$

$$= \lim_{s\to 0} \frac{s\,\frac{A}{s}}{1 + G(s)\,H(s)}$$

$$= \lim_{s\to 0} \frac{A}{1 + G(s)\,H(s)}$$

$$\therefore e_{ss} = \frac{A}{1+\lim\limits_{s\to 0} G(s)H(s)} = \frac{A}{1+\lim\limits_{s\to 0}\frac{\boldsymbol{K}}{(\boldsymbol{1+TS})}} = \frac{A}{1+K} = \frac{A}{1+K_P}$$

Error coefficient for step input for type zero system:

2 Marks for derivation of Error coefficient for step input for type zero system

The equation for steady state for type 0 system= $\frac{A}{1+\lim_{s\to 0} G(s)H(s)}$

$\lim_{s\to 0} G(s)H(s)$ is constant for step input and is called positional error coefficient of the system K_p

$K_p = \lim_{s\to 0} G(s)H(s) =$ Positional error coefficient K

Corresponding steady state error is

$$\therefore e_{ss} = \frac{A}{1+K_p} = \frac{A}{1+K}$$

(ii) error co-efficients and steady state errors for a unity feedback

$$G(s) = \frac{40(s+2)}{s(s+1)(s+4)}$$

4 Marks

Error Coefficients :

2Marks for Error Coefficients

$$K_p = \lim_{s\to 0} G(s)H(s) = \lim_{s\to 0} \frac{40(s+2)}{s(s+1)(s+4)} = \infty$$

$$K_v = \lim_{s\to 0} s\,G(s)H(s) = \lim_{s\to 0} \frac{40(s+2)}{s(s+1)(s+4)} = 20$$

$$K_a = \lim_{s\to 0} s^2 G(s)H(s) = \lim_{s\to 0} \frac{40(s+2)}{s(s+1)(s+4)} = 0$$

Steady state Errors :

2Marks for Steady State Errors

for unit step Input $e_{ss} = \frac{1}{1+K_p} = 0$

for unit Ramp Input $e_{ss} = \frac{1}{K_v} = \frac{1}{20} = 0.05$

for unit parabolic Input $e_{ss} = \frac{1}{K_a} = \frac{1}{0} = \infty$

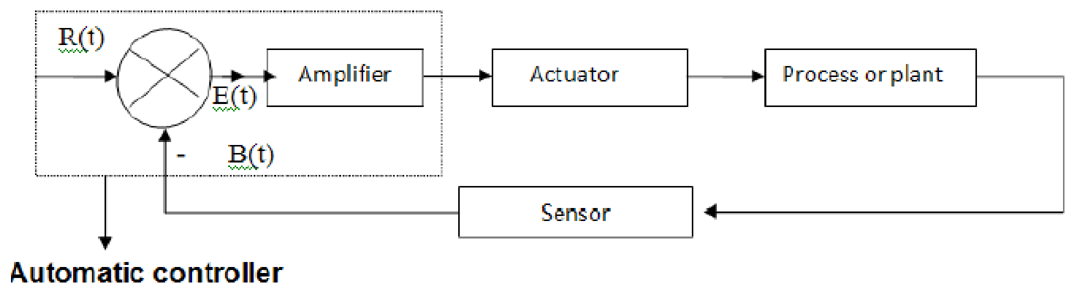
Q.6		**Attempt any FOUR .**	**16 Marks**
	a)	**Define gain margin and phase margin. What should be the values of them for a stable system?**	**4 Marks**
	Ans:	**Gain Margin : -** • It refers to the amount of gain, which can be increased or decreased without making the system unstable. • It is the gain 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 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	**Defn:1 Mark each Effect:1 Mark each**
	b)	**State any two advantages and two disadvantages of Routh's stability criteria.**	**4 Marks**
	Ans:	**Advantages of Routh array:-** i) Simple criterion that enables to determine the number 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.	**Advanages:1 Mark each Disadv: 1 Mark each**

Disadvantages of Routh array: -
i) Cannot find out the value of poles.
ii) It is not a sufficient condition for stability.
iii) Lengthy procedure

c)	**Draw and explain the block diagram of process control system.**	**4 Marks**

Ans:

Block Diagram: 2 Marks
Eplanation: 2 Marks



Explanation :- Process control system consists of process or plant ,sensor, error detector, automatic Controller, actuator or control element.

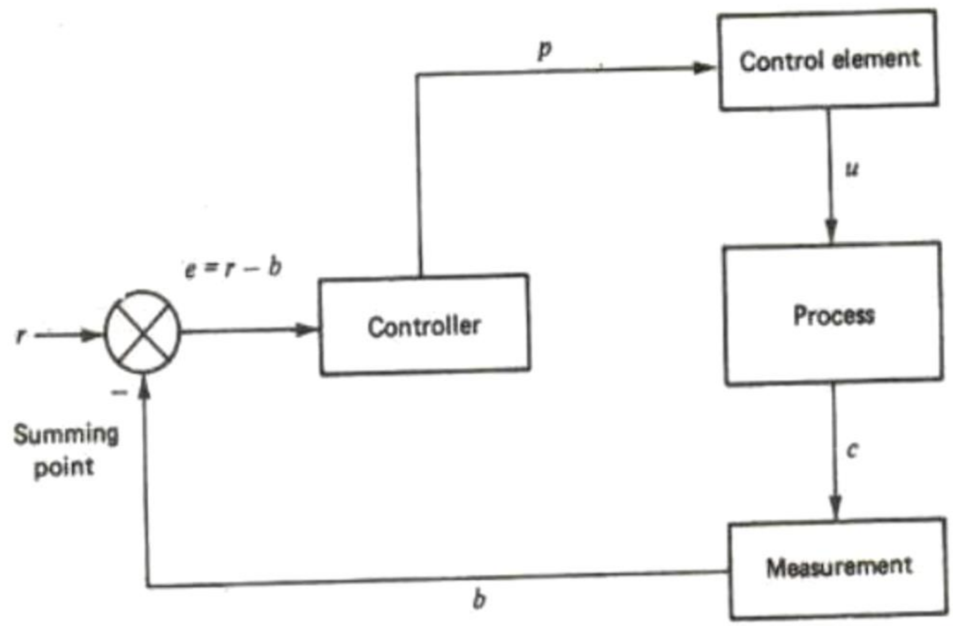
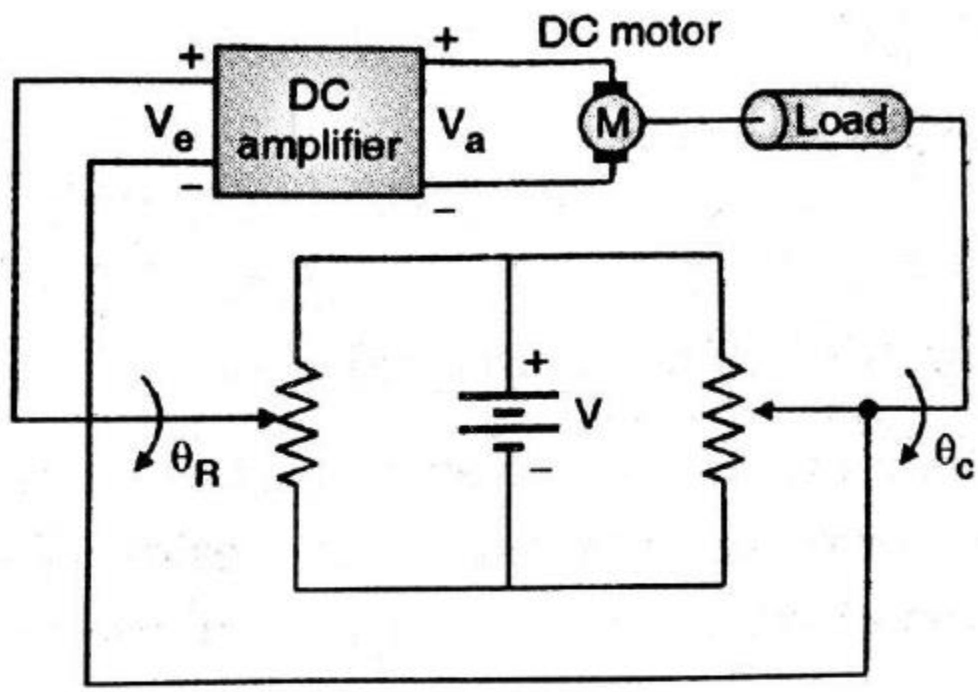
1. **Process or plant-** process means some manufacturing sequence. It has one variable or multivariable output. Plant or process is an important element of process control system in which variable of process is to be controlled.
2. **Sensor/measuring elements –** It is the device that converts the output variable into another suitable variable which can acceptable by error detector Sensor is present in f/b path of close loop system.
3. **Error detector** – Error detector is summing point whose output is an error signal i.e. $e(t) = r(t) - b(t)$ to controller for comparison & for the corrective action. Error detector compares between actual signal & reference i/p i.e. set point.
4. **Automatic controller-** Controller detects the actuating error signal, which is usually at a very low power level, and amplifies it to a sufficiently high level .i.e. means automatic controller comprises an error detector and amplifier.
5. **Actuator or control element** – Actuator is nothing but pneumatic motor or valve, a hydraulic motor or an electric motor, which produces an input to the plant according to the control signal getting from controller.

OR

Explanation : -

The block diagram of process control system consists of the following blocks

1. **Measuring element :** It measures or senses the actual value of controlled variable "c" and converts it into proportional feedback variable b.
2. **Error detector:** It receives two inputs: set point "r" and controlled variable "p". The output of the error detector is given by $e= r-b$. "e" is applied to the controller.
3. **Controller :** It generates the correct signal which is then applied to the final control element. Controller output is denoted by "p".
4. **Final control element :** It accepts the input from the controller which is then transformed into some proportional action performed by the process. Output of control element is denoted by "u".

		5. **Process:** Output of control element is given to the process which changes the process variable. Output of this block is denoted by "u". 	
	d)	**Draw and explain the generalized diagram of DC servo system.**	**4 Marks**
	Ans:	 **Fig:DC ServoSystem**	**Diagram: 2 Marks Explanation :2 Marks**

		Explanation: The standard block diagram of servo system consists of error detector, amplifier, motor as controller, load whose position is to be changed. Servo systems is to be divided into two type a) DC servo systems b) AC servo system 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. 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 positions. The errors between two positions 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	
	e)	**For the given differential equation** $\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 8y(t) = 8x(t)$ **Where y(t)=o/p, x(t)=input** **Find out the transfer function and order of the system.**	**4 Marks**
	Ans:	Taking Laplace for zero initial $S^2Y(s)+4sY(s)+Y(s) = 8X(s)$ $Y(s)[S^2+sY(s)+1] = 8X(s)$ $G(s) = \frac{Y(s)}{X(s)}$ $= \frac{8}{S^2+SY(S)+1}$ $\frac{C(s)}{R(s)} = \frac{8}{S^2+SY(S)+1}$ **which is the Transfer Function.** **Order of the system=2**	**Transfer Function Derivation: 3 Marks** **Order: 1 Marks**