17538

MODEL ANSWER

SUMMER– 19 EXAMINATION

Subject Title:-- Control System 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 anyequivalent 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		**Attempt any THREE of the following:**	12-Total Marks
	a)	**Define control system. List any two practical example.**	4M
	Ans:	**Control System**: It is arrangement of different physical elements connected in such a manner so as to regulate, direct or command itself or some other system. **Example:** 1. If in a class room professor is delivering lecture, the combination becomes a control system. **2.** If lamp is switched ON or OFF using a switch, the entire system is control system. **3.** Stepper motor positioning system **4.** Automatic toaster system. **5.** DC motor speed control **6.** Home automation system.	Definition-2M Example-1M each
	b)	**Differentiate between transient & steady state responses.(four points)**	4M
	Ans:	**Transient response** | **Steady state response**	1M each

The output responseof the system during the time it takes to achieve its final value is called transient response**.**	It is that part of the output response which remains after complete transient vanishes from the system output.	**any 4 points**
The transient response may be exponential or oscillatory.	The steady state response is nearly constant.	
The system reacts against the changes in the inputs, therefore the output response changes during transient period	System will stay in steady state indefinitely until some input changes again.	
Transient signals are random signals that effect a system	Steady state signals are continuous and regular signals that effect a system	
Transient response Specifications are Rise time, delay time, peak time, peak overshoot	Steady state response Specifications are position error constant, velocity error constant and acceleration error constant	

c) **Define:** **4M**

(i) **Settling time**

(ii) **Rise time**

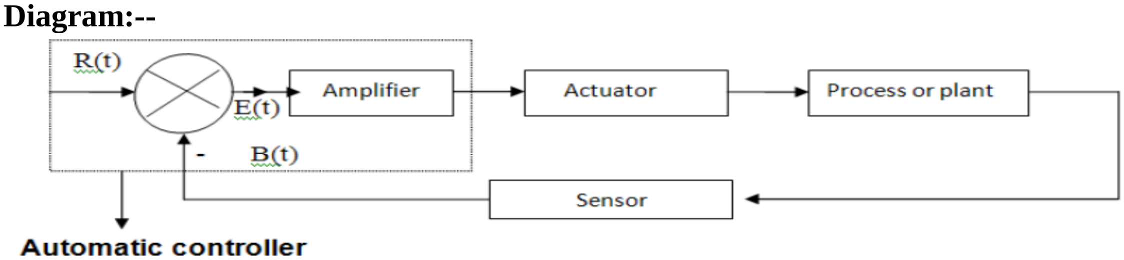
Ans: **2M each**

i) **Settling time:** The time required for the response to reach and stay within specified % of its final value**.**

ii) **Rise time:** It is the time required for the response to rise from 10% to 90% of its final value for over damped system and 1 to 100% of the final value for under damped system.

d) **Draw block diagram of process conytrol system & explain each block.** **4M**

Ans: **Diagram:--** **2M-Block Diagram**



2M-Explanation

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

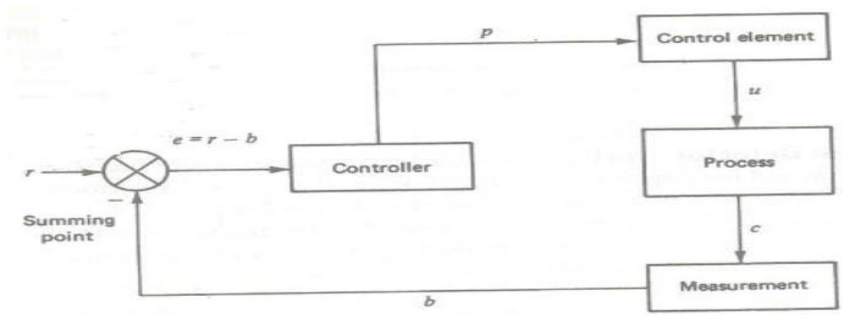
1) Process or plant:process means some manufacturing sequence. It has one variable or multivariable output. Plant or process is an important element of process control system in which variable of process is to be controlled.

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 the subtracting or 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.

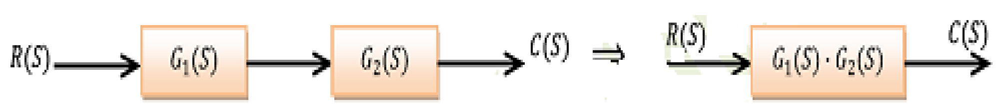
4) Automatic controller: Controller detects the actuating error signal, and takes the corrective action
5) Actuator or control element: Actuator is nothing but pneumatic motor or valve, a hydraulic motor or an electric motor, which produces an input to the plant according to the control signal getting from controller.

OR

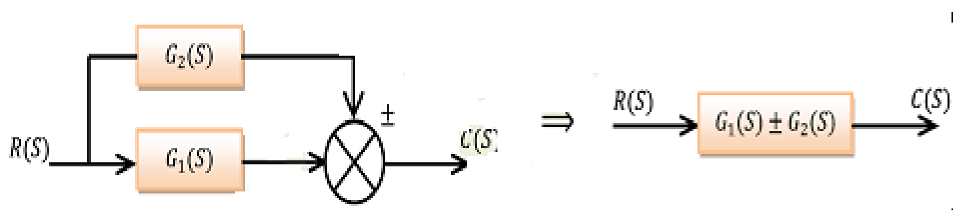


Explanation :
The block diagram of process control system consists of the following blocks:-
1) Measuring element: It measures or senses the actual value of controlled variable “c” and converts it into proportional feedback variable b.
2) Error detector: It receives two inputs: set point “r” and controlled 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”.

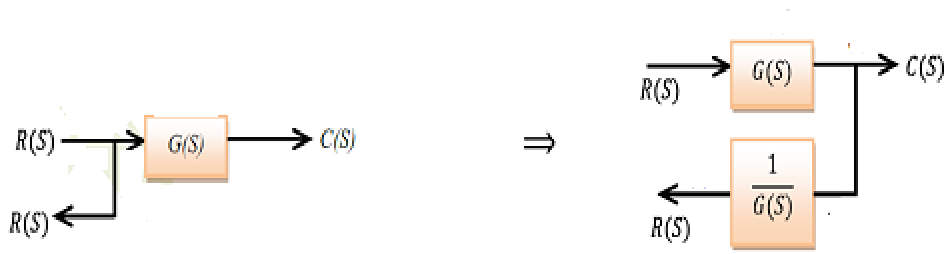
(B)		**Attempt any ONE of the following :**	**6-Total Marks**
	a)	**List & explain any three rules for block reduction technique.**	**6M**
	Ans:	i) Combining a block in cascade: When two or more blocks are Connected in series, their overall transfer function is the product of individual block transfer function.	**Rules-2M each**



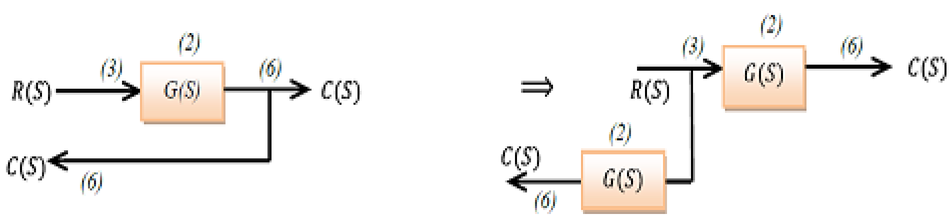
ii) Combining two blocks in parallel: When two or more blocks are connected in parallel, their overall transfer function is the addition or difference of individual transfer function.



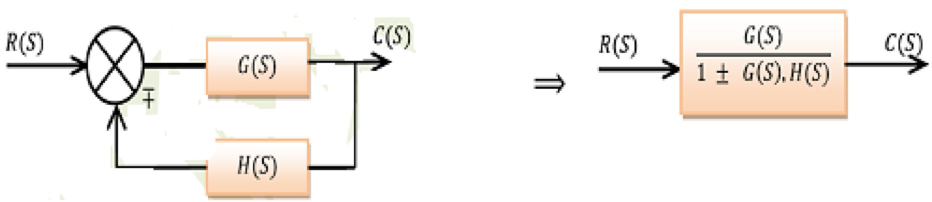
iii) Shifting a take off point after a block: To shift take off point after a block, we shall add a block with transfer function 1/G in series with signal having taking off from that point.



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

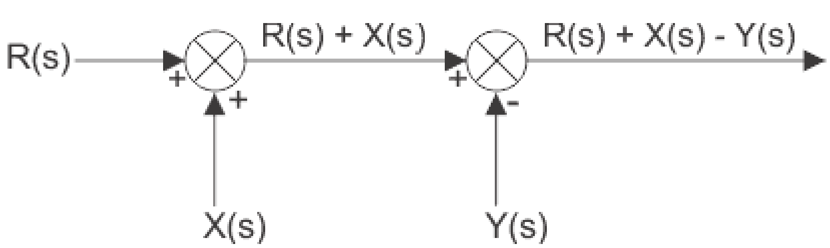


v) Eliminating Feedback Loop:

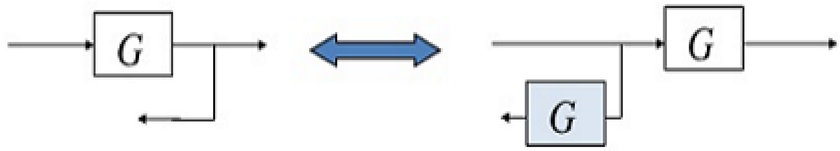


$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s).H(s)}$$

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.



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) **Draw bode plot for the system with open loop transfer function:** **6M**

$G(S)H(S) = 1/S(S+1)(S+5)$ ...

Ans:

Step 1: Convert the given open loop transfer function to time constant form: **2M**

.

$$G(S)H(S) = \frac{0.2}{S(1+S)(1+0.2S)}$$

Step 2: **Identify the factors;**

1. Open loop gain K=0.2, Magnitude in dB= 20 log K= 20 log 0.2 = -13.98dB **2M**

2. Pole at origin (1/S) which has a magnitude plot with slope of -20dB/decade.
For ω=1, and 0 dB magnitude.

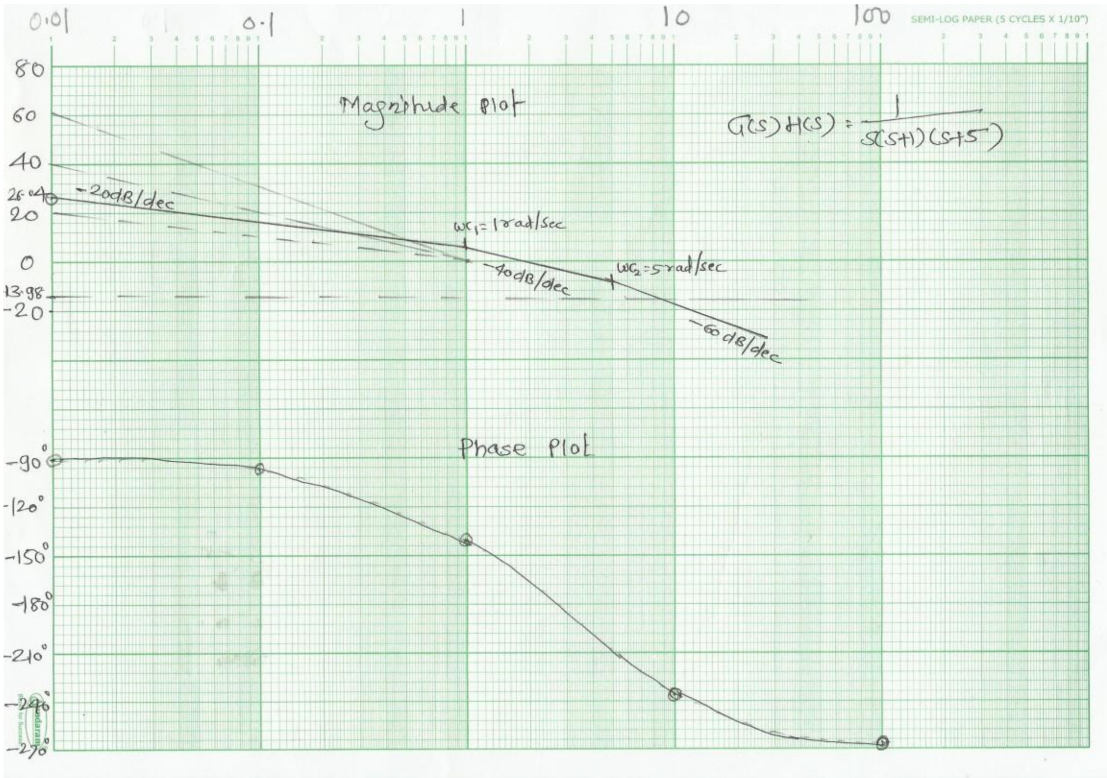
For ω= 0.01, Magnitude in dB for (1/S) = - 20 log 0.01= 40 dB

3. First order pole (1+ S). The corner frequency is ω_{c1} =1 rad/sec. Till this corner frequency the magnitude plot's slope will be -20 dB/decade due to Pole at origin (1/S) and from the corner frequency ω_{c1} it changes to -40 dB /decade
4. First order pole (1+ 0.2S). The corner frequency is ω_{c2} =1/0.2= 5 rad/sec. Till this corner frequency the magnitude plot's slope will be -40 dB/decade due to Pole at origin (1/S) and First order pole (1+ S). From the Corner frequency ω_{c2} it changes to -60 dB /decade.

Step 3: **Phase angle plot** **2M**

Frequency (ω) rad/sec	**Factor 1 K=0.2 Θ_1**	**Factor 2 1/S Θ_2**	**Factor 3 1/(1+S) Θ_3= -**	**Factor 4 1/(1+0.2S) Θ_4= -**	**Total $\Theta = \theta_1 + \theta_2 + \theta_3 + \theta_4$**

			$\tan^{-1}\omega$	$\tan^{-1}0.2\,\omega$	
0.01	**0^0**	**-90^0**	**-0.5729**	**-0.1145**	**-90.6874**
0.1	**0^0**	**-90^0**	**-5.7106**	**-1.1457**	**-96.8563**
1	**0^0**	**-90^0**	**-45**	**-11.3099**	**-146.3099**
10	**0^0**	**-90^0**	**-84.2894**	**-63.4349**	**-237.7243**
100	**0^0**	**-90^0**	**-89.4271**	**-87.1375**	**-266.5646**



Q.2		**Attempt any TWO of the following:**	**16-Total Marks**
	a)	**For unity feedback system $S^4+3S^3+3S^2+2S+K=0$, determine K_{max} for system to be stable.**	**4M**

Ans:

$$s^4 + 3s^3 + 3s^2 + 2s + K = 0$$

s^4	1	3	K
s^3	3	2	0
s^2	2.33	K	0
s^1	$\frac{4.66-3K}{2.33}$	0	0
s^0	K		

For system to be stable there should not be sign change in the first column.

$\therefore$ $K > 0$ from s^0

and $\frac{4.66-3K}{2.33} > 0$ from s^1

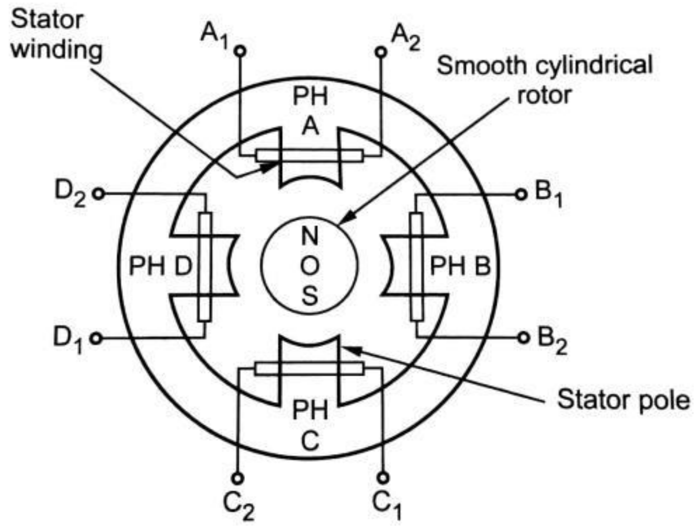
$$4.66 - 3K > 0$$
$$4.66 > 3K$$
$$1.55 > K$$

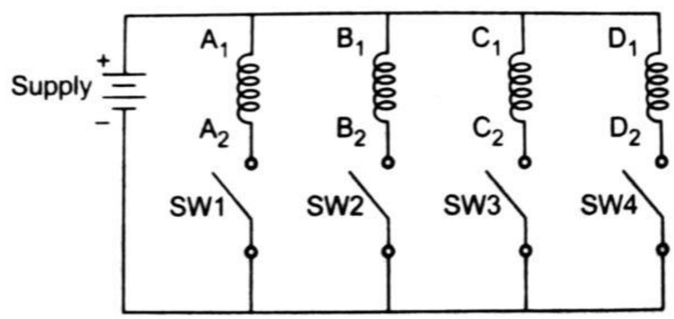
Range of K is $0 < K < 1.55$

$$\therefore K_{max} = 1.55$$

4M

b)(i)	**Describe the working of Permanent magnet stepper motor with neat diagram.**	**4M**
Ans:	**Diagram:--** **Four phase permanent magnet stepper motor**	**Diagram-3M** **Working-3M**





Drive circuit

Explanation:

The stator of this type of motor has four poles. Around the poles exciting coils are wounded (A, B, C, D)

Rotor may be salient or smooth cylindrical type. It is made up of ferrite material and permanently magnetized.

Working:

When voltage pulses are applied to various phases with the help of drivingcircuit, the rotor makes 90o revolution called step for each input voltage pulse

It can be explained as under :

1) When switch SW1 is closed exciting the phase A, we have a North pole in phase A due to this excitation. An electromechanical torque is developed and rotorrotates to adjust its magnetic axis with the magnetic axis of the stator.

2) Next phase B is excited with switch SW2 after disconnecting phase A. Due tothis, rotor further rotates to adjust its magnetic axis with north pole of phase B.

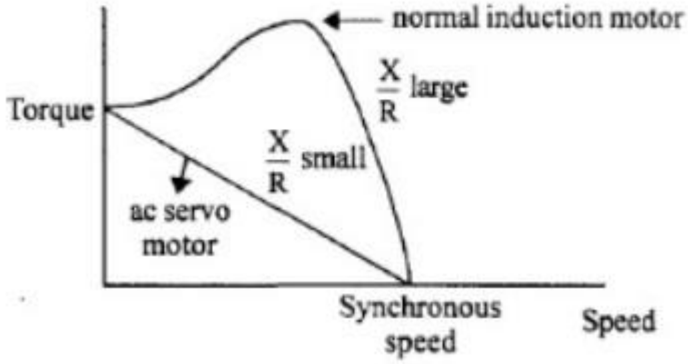
Hence it rotates through 90o called step.

3) Similarly when phase C and phase D are sequentially excited, the rotor tends torotate through 90o in clockwise direction, every time when such sequence isrepeated.

	(ii)	**Draw charavcterristics of AC servo motor. In what way is it different from normal 2 phase induction motor?**	**4M**

Ans:

Characteristics-2M



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

Any two point-2M

c) **Compare PI, PD,& PID controller.(four points)** **4M**

Ans:

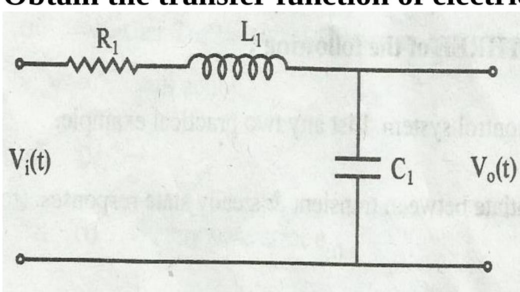
Parameter	**PI**	**PD**	**PID**
Offset	Eliminates	Doesnot eliminate	Eliminates
Speed of response	Less compared to PD and PID	Fast	Fast
Settling time	Large settling time	Less settling time	Less settling time
Overshoot	More	Less	Less
Stability	Less	Improves Stability	Improves Stability
Response to error input	Considers the magnitude of the system error signal and the integral of this error	Considers the magnitude of the system error and the derivative of this error	Considers the magnitude of the system error, integral and the derivative of this error

2M each for any 4 points

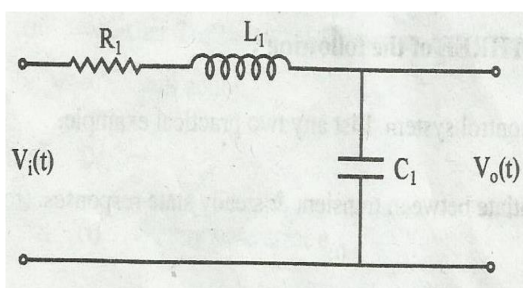
Equation	$P(O) = K_P E_P + K_I \int E_P dt + p_o$	$P(O) = K_P E_P + K_D \frac{dE_P}{dt} + p_o$	$P(O) = K_P E_P + K_I \int E_P dt + K_D \frac{dE_P}{dt} + p_o$
Application	Process systems with less time lag	Process systems with more time lag	Suitable for Process systems with a range of time lag

Q.3 **Attempt any FOUR of the following:** **16- Total Marks**

a) **Obtain the transfer function of electrical circuit:** **4M**



Ans: (**1mrk** for equation 1 ,**1mark** for equation 2 **1mark** for equation 3&4 **1mark** for transfer function)



Derivation of given Transfer function is:--

Apply KVL to loop, we get the equation as

$$V_i = R_i(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt \qquad \text{---------(1)}$$

Taking L.T.

$$V_i(s) = RI(s) + Ls\,I(s) + \frac{1}{sC}I(s)$$

$$= \left(R + Ls + \frac{1}{sC}\right) I(s) \qquad \text{.........(2)}$$

Output voltage across capacitor is,

$$V_o(t) = \frac{1}{C}\int i(t)dt \qquad \text{.........(3)}$$

Taking L.T.

$$V_o(s) = \frac{1}{sC} I(s) \qquad \text{.........(4)}$$

Take the ratio of equation (2) and (4),

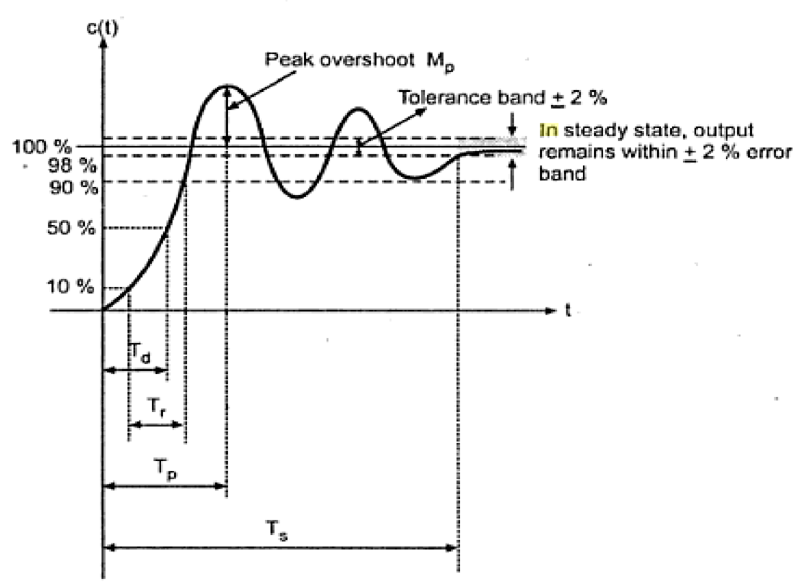
∴Transfer function is,

$$G(s) = \frac{V_o(s)}{V_i(s)}$$

$$G(s) = \frac{\frac{1}{sC} I(s)}{\left(R + Ls + \frac{1}{sC}\right) I(s)}$$

$$G(s) = \frac{1}{RCs + LCs^2 + 1}$$

b)	**Draw transient response of second order system for a unit step input.**	**4M**
Ans:	**Diagram of Transient response second order:--**	**2 M for response** **2 M for labeling**



c)	**Determine stability by using Routh's Criterion $S^5+6S^4+3S^3+2S^2+S+1$.**	**4M**

Ans:

3c)

$$s^5+6s^4+3s^3+2s^2+s+1=0$$

s^5	1	3	1
s^4	6	2	1
s^3	2.66	0.833	0
s^2	0.121	1	0
s^1	-21.15	0	
s^0	1		

∵ There are two sign changes.
system is unstable and two roots in R.H.S

3 M for Routh's criterion

1mark M for condition

d) Draw variable reactance type of stepper motor & explain its working. **4M**

Ans:

(Note:-- Any one type)

Variable reluctance stepper motor:

2M for diagram

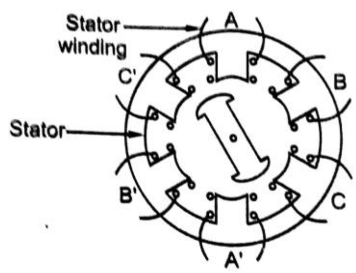


Figure:1

The stator in the stepper motor is usually wound for three phases. It has six salient poles (teeth) with concentrated exciting windings around each one of them. The rotor is made out of slotted steel laminations and has two salient poles (or teeth) without any exciting windings as shown in the figure 1. The basic drive circuit is shown in figure 2.

2marks M for explanation

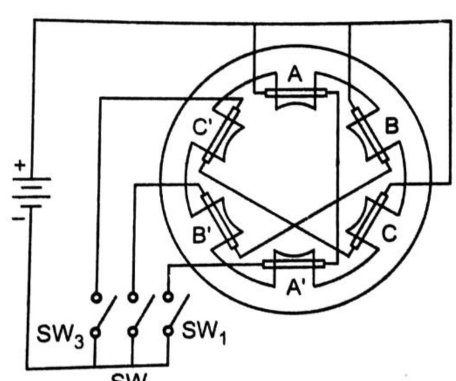


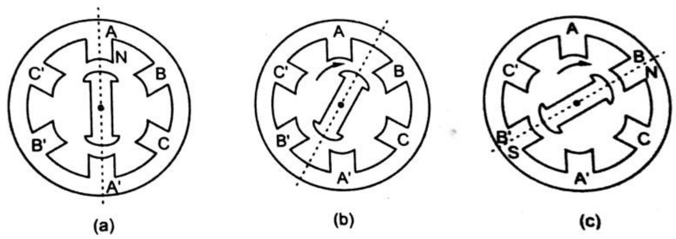
Figure:2

Explanation: The coils wound around diametrically opposite poles are connected in series and the three phases are energized from a DC source with the help of switches.

i) When the phase A-A' is excited with switch SW1 closed with A forming N Pole and A' as S Pole, the rotor tries to adjust itself in a minimum reluctance position between stator and rotor as shown in the fig.a.

ii) When the phase B-B' is also excited with switch SW2 closed, keeping A-A' energized the magnetic axis of stator moves 30^0 in clockwise direction and hence rotor also rotates through 30^0 step in clockwise direction to attain new minimum reluctance position as shown in fig.b.

iii) After that the excitation of AA' is disconnected and only BB' is kept energized. Rotor further moves through 30^o step to adjust itself in new minimum reluctance position as shown in fig.c.



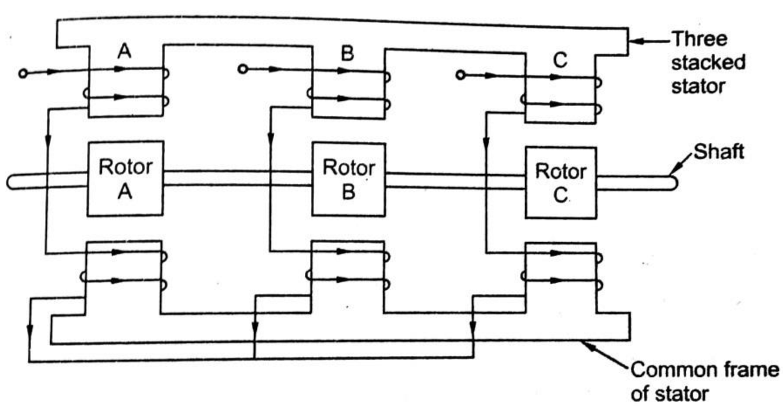
By successively exciting three phases in the specific sequence, the motor takes twelve steps to make one complete revolution.

OR

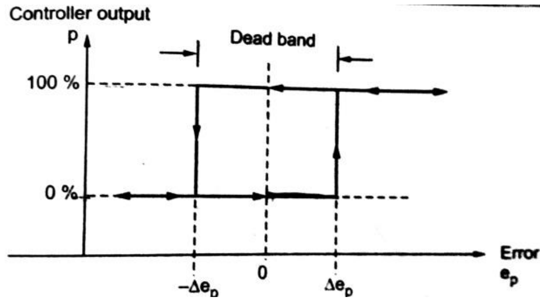
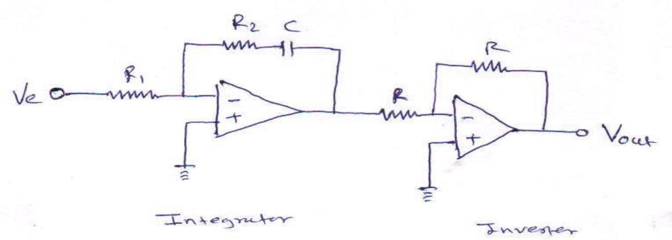
Mult tack variable reluctance stepper motor:

In this type, the windings are arranged in different stacks. The figure represents a three stack stepper motor. The three stacks of the stator have a common frame. The rotors have a common shaft. The stator stacks and rotors have toothed structure with same teeth size. The stators are pulse excited and rotors are unexcited. When the stator is excited, the rotor gets pulled to the nearest minimum reluctance position where the stator and rotor teeth are aligned. The stator teeth of various stacks are arranged to have a progressive angular displacement of :

$\alpha = 360^0/(q\ T)$ where q = number of stacks, T = number of teeth .



e)	**State the concept of neutral tone & proportional band.**	**4M**
Ans:	**Neutral Zone:** In all the practical implementation of the ON-OFF controller, there is an	**2marks**

		overlap, as the error increases through zero or decreases through zero. Such an overlap creates a span of error in which there is no change in the controller output. This span is called **neutral zone**, **dead zone** or **dead band**.  Fig shows P verses ep for ON-OFF Controller. As the error changes by Δ ep, there is no change in the controller output. **Proportional Band:** Proportional band is defined as the amount of change in the controlled variable required to drive the proportional controller output from 0 to 100%. In a controller the manipulating variable is proportional to the control deviation within the proportional band. The gain of the controller can be matched to the process by altering the proportional band. If the proportional band is set to zero, the controller action is ineffective. Proportional Band significance - The range of error to cover the 0% to 100% controller output is called proportional band. It specifies the percentage error that results in a 100% change in the controller output. PB = 100/Kp where Kp is proportional gain	**2marks**
Q.4	**(A)**	**Attempt any THREE of the following :**	**12-Total Marks**
	a)	**Draw the circuit diagram of PI controller using op-amp & explain how offset is removed using integral action.**	**4M**
	Ans:	Circuit diagram of PI controller using op-amp:  Fig:: Electronic PI controller. This is a composite control mode obtained by combining the proportional mode and the integral mode.	**2M**

		Analytical equation for PI controller is given as $$P(O) = K_P E_P + K_I \int E_P dt + p_o$$ The important advantage of this control is that the one to one correspondence of proportional mode is available while the offset gets eliminated due to integral mode. The integral part of such a composite control provides a reset of the zero error output after load change occurs. The load changes occurs at t = t1 due to which error varies as shown in the fig.1. The controller output changes suddenly by amount of Vp due to the proportional action. After that the controller output changes linearly with respect to time at a rate of Kp/Ti. The reset state is defined as the reciprocal of Ti.	**2M**

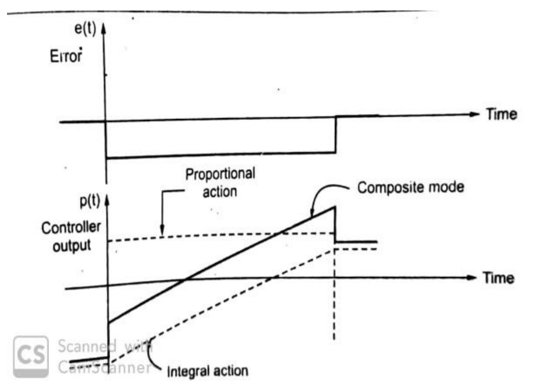


Fig.1

The response shown in the fig.1 is for the direct action of the controller. The response of composite PI control mode for the reverse action is shown in fig.2.

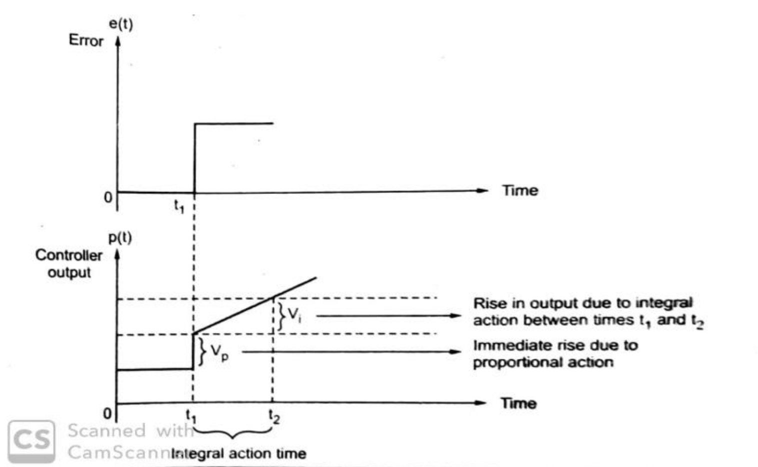


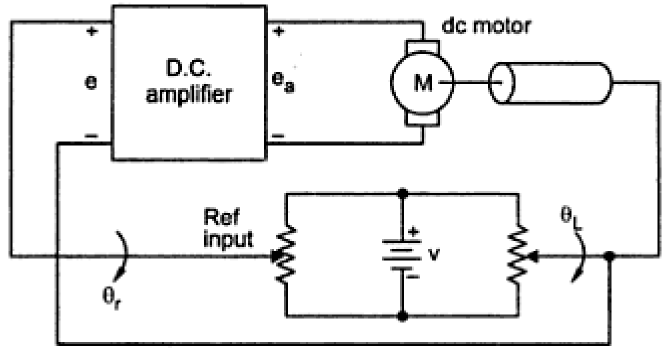
Fig.2

In the reverse action the proportional part is the image of the error. The sum of Proportional plus integral action finally leaves the error to zero.

	b)	**List & define any four frequency response specifications.**	**4M**
	Ans:	**Frequency response specifications:**	

		• Band width • Cut off frequency • Cutoff rate • Resonant peak • Resonant Frequency • Gain cross over frequency • Phase cross over frequency • Gain Margin • Phase Margin	**2 marks For any four Listing**
		Bandwidth: It is defined as the range of the frequencies over which the system will respond satisfactorily. It is also defined as range of the frequency over magnitude of closed loop response does not drop by more than 3db from its zero frequency value. **Cut off frequency:** Frequency at which the magnitude of closed loop response in 3db down from its zero frequency value is called as cut off frequency. **Cut off rate: The** slope of the resultant magnitude curve near the cut off frequency is called as cut off rate. **Resonant Peak:** It is the maximum value of the magnitude of the closed loop frequency response. **Resonant Frequency:** Frequency at which resonant peak takes place in the system response. **Gain cross over frequency: The** frequency at which magnitude of G(jω) H(jω) is unity is called gain cross over frequency. **Phase cross over frequency: The** frequency at which phase angle of G(jω) H(jω) is -180° is called as phase cross over frequency. **Gain Margin:** The Margin in gain allowable by which gain can be increased till system reaches on the verge of instability is called as Gain Margin **Phase Margin:** The amount of additional phase lag which can be introduced in the system till the system reaches on the verge of instability is called as Phase Margin.	**2 marks for Any four definition**
	c)	**For Unity feedback system having open loop, find** **T.F. $G(S)=K(S+2)/S(S^3+7S^2+12S)$** **(i) Type ofsystem.** **(ii) All error co-efficient**	**4M**

	Ans:	$G(s) = \frac{K(s+2)}{s(s^3+7s^2+12s)}$ ∵ unity feedback sys. $H(s)=1$ $= \frac{K(s+2)}{s^2(s^2+7s+12)}$ → If we compare this T.F with standard T.F then type of the system is <u>TYPE 2</u> → Error coefficients $K_p = \lim_{s\to 0} G(s)\,H(s)$ $= \lim_{s\to 0} \frac{K(s+2)}{s^2(s^2+7s+12)} = \frac{K(0+2)}{0(0+0+12)} = \infty$ $K_p = \infty$ $K_v = \lim_{s\to 0} s\,G(s)\,H(s)$ $= \lim_{s\to 0} s \cdot \frac{K(s+2)}{s^2(s^2+7s+12)} = \infty$ $K_v = \infty$ $K_a = \lim_{s\to 0} s^2\,G(s)\,H(s)$ $\lim_{s\to 0} s^2 \frac{K(s+2)}{s^2(s^2+7s+12)} = \frac{K(0+2)}{0+0+12}$ $= \frac{2K}{12} = \frac{K}{6}$ $K_a = \frac{K}{6}$	**1 mark for type of system** **3marks of error coefficients**
	d)	**Define potentiometer, draw circuit diagram of potentiometer as an error detector.**	**4M**
	Ans:	**Circuit diagram:--**	**2M**



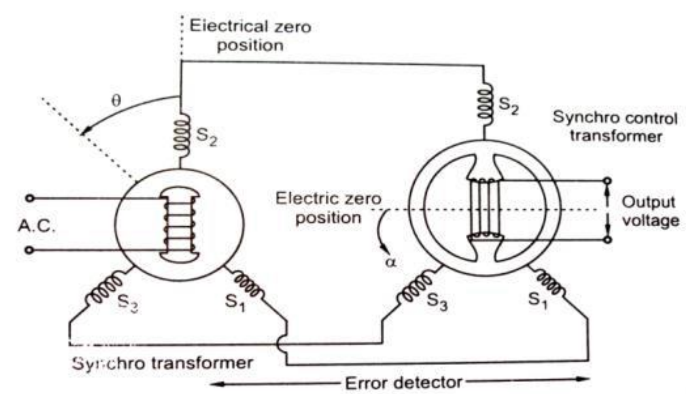
Explanation:--

Potentiometer: It is an electro mechanical transducer that converts mechanical energy into an electrical energy. The input to the device is in the form of mechanical displacement either linear or rotational. When the voltage is applied across the fixed terminals of the potentiometer, the output voltage, which is measured across the variable terminals, will be proportional to the input displacement either linear or according to some non linear relation. **2M**

(B)		**Attempt any ONE:**	**6-Total Marks**
	a)	**Which servo component can be used as error detector in ac servo system? Draw & explain it.**	**6M**

Ans:

Synchro transmitter along with synchrocontrol transformer is used as error detectors in ac servo system. **1M**



2M

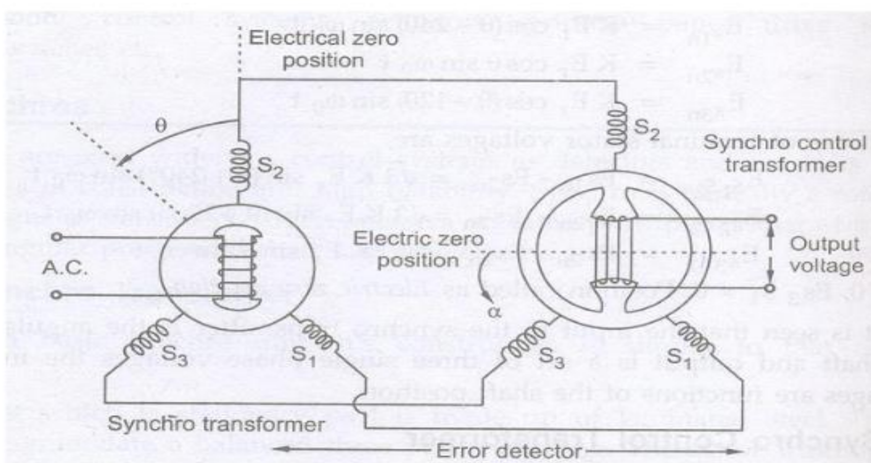
Explanation :

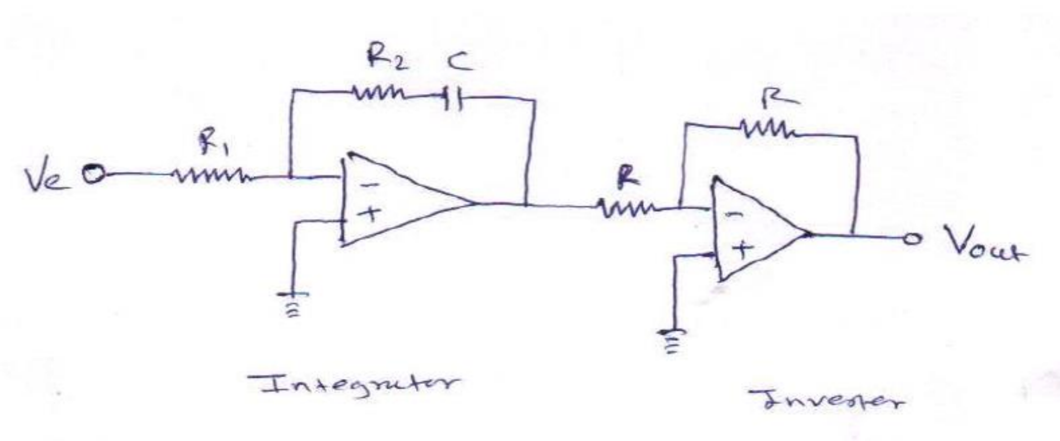
Synchro transmitter along with synchro control transformer is used as error detector. The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap.

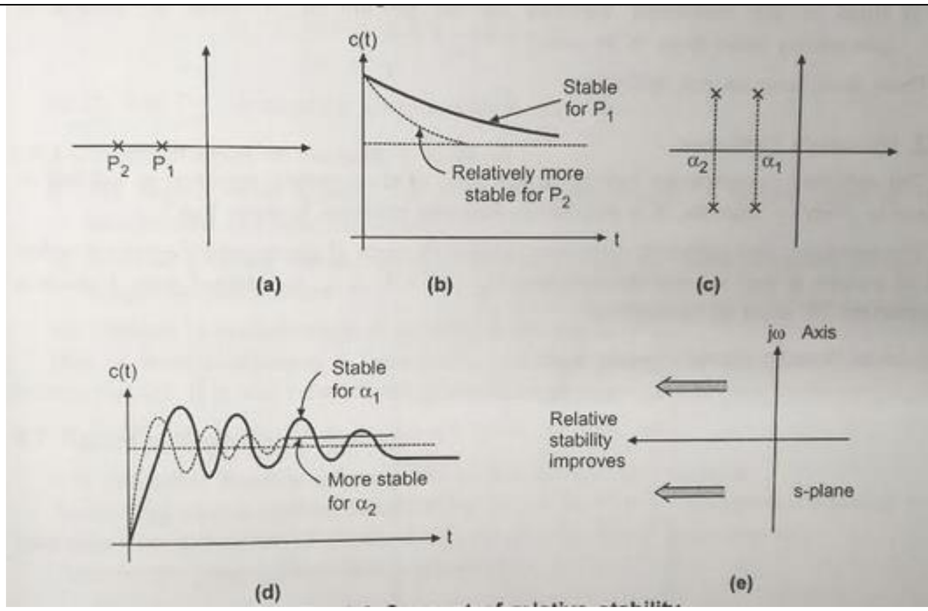
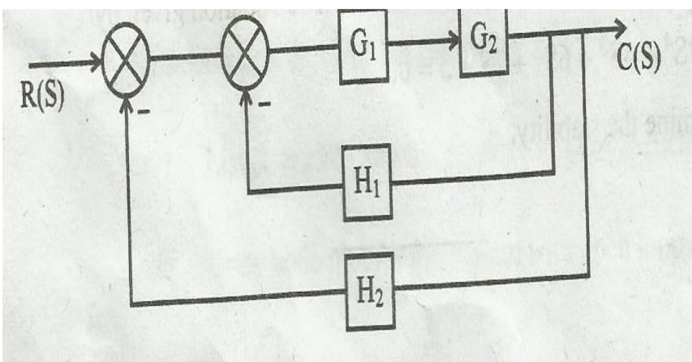
The output of the Synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils. Circulating currents of same phase but different magnitude will flow through both set of stator coils.

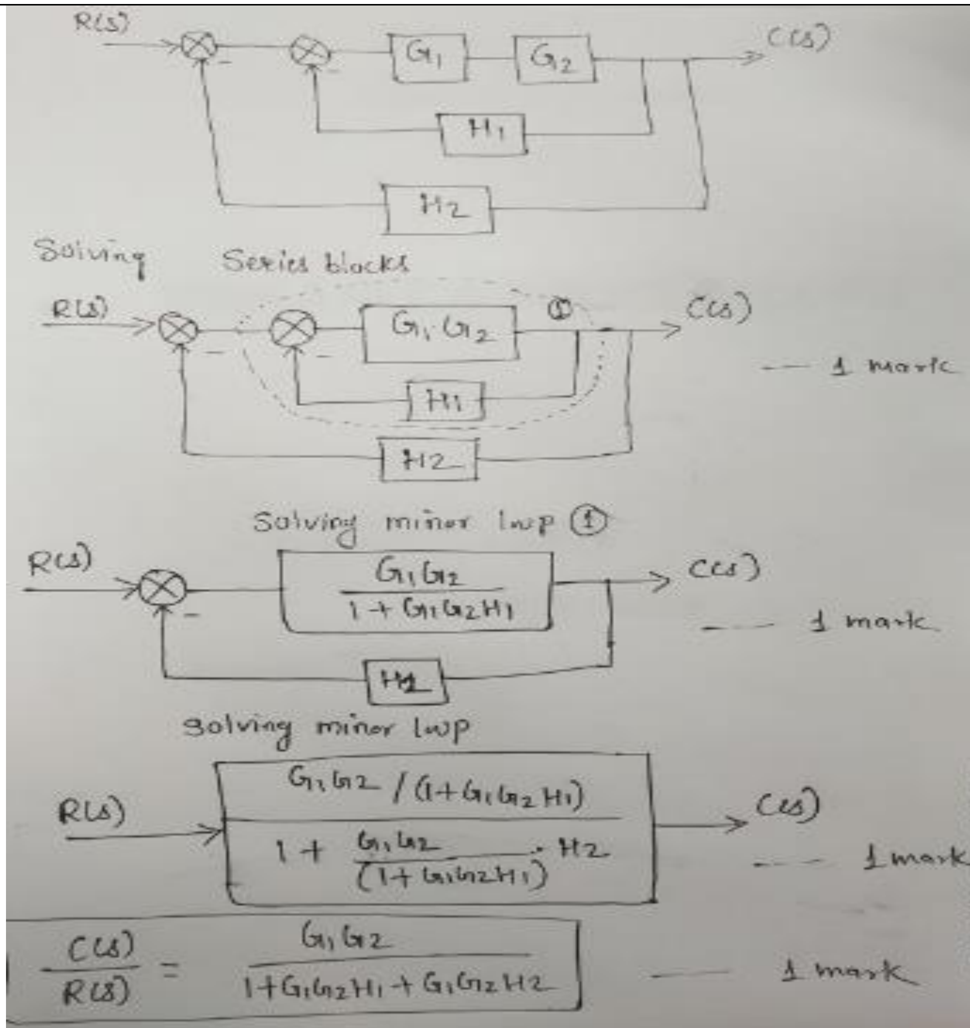
This establishes an identical flux pattern in the air gap of control transformer. **3M**

		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 : $$e_0(t) = v_r Sin\omega t + cos\emptyset$$ Where V_r Sinωt =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.	
	b)	**Find all time domain specifications for unity feedback system having** $\boldsymbol{G(S) = 25/S(S+6)}$**with unit step input.**	**6M**
	Ans:	$G(s) = \frac{25}{s(s+6)}$, ∵ unity feedback $H(s) = 1$ $\therefore T.F = \frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$ $= \frac{\frac{25}{s(s+6)}}{1+\frac{25}{s(s+6)}} = \frac{25}{s^2+6s+25}$ Compare the T.F. with the standard form $\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} = \frac{25}{s^2+6s+25}$ Here, $\omega_n^2 = 25$ and $2\xi\omega_n = 6$ $\therefore \omega_n = 5$ $\quad \xi = \frac{6}{2\times5} = 0.6$ → damped natural frequency $\omega_d = \omega_n\sqrt{1-\xi^2}$ $= 5\sqrt{1-0.6^2} = 4$ rad/sec. → Rise time $T_r = \frac{\pi-\theta}{\omega_d}$, $\theta = \tan^{-1}\left[\frac{\sqrt{1-\xi^2}}{\xi}\right]$ $= \tan^{-1}\left[\frac{\sqrt{1-0.6^2}}{0.6}\right] = 0.927$ rad $\therefore T_r = \frac{\pi-0.927}{4} = 0.553$ sec. → Peak time $T_p = \frac{\pi}{\omega_d} = \frac{\pi}{4} = 0.785$ sec. → Delay time $T_d = \frac{1+0.7\xi}{\omega_n} = \frac{1+(0.7\times0.6)}{5} = 0.28$ sec.	**1M for TF** **1M for ω_d** **1M for T_r** **1M for T_p**

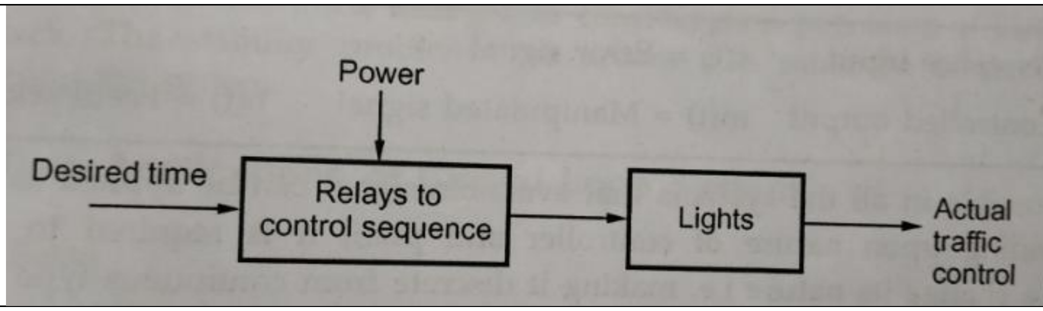
		→ Peak over shoot M_P $\% M_P = e^{-\pi \xi / \sqrt{1-\xi^2}} \times 100$ $= e^{-\pi \times 0.6 / \sqrt{1-0.6^2}} \times 100$ $= 9.48\%$ → $T_S = \frac{4}{\xi \omega_n} = \frac{4}{0.6 \times 5} = 1.33$ sec **(Note: T_d is optional)**	**1M for M_p** **1M for T_s**
	Q.5	**Attempt any FOUR of the following**	**16 Total Marks**
	(a)	**Draw and explain the working of Synchro as error detector.**	**4M**
	Ans:	 **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: e0(t) =VrSin (ωt) +Cos(ϕ) whereVrSin (ωt):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	**2M** **2M**

		output voltage is zero.This position is called electrical zero and is used as referenceposition.	
	(b)	**Draw electronic PI controller. State the components used and write equation.**	**4M**
	Ans:	 **Components used: Op-amp, resistors and capacitors** **Equation:** Analytical equation for PI controller is given as $$P(O) = K_P E_P + K_I \int E_P dt + p_o$$ From figure, output equation can be written as, $$V_{out} = \frac{R1}{R2} V_{in} + \frac{1}{R1C} \int V_{in} dt$$ $$V_{out} = [\frac{R1}{R2}] V_{in} + [\frac{R1}{R2}][\frac{1}{R2C}]. \int V_{in} dt$$	**Diagram: 2 M** **Components: 1 M** **Equation: 1M**
	(c)	**What is Relative stability? Draw the neat sketch to represent it on S plane.**	**4M**
	Ans:	**Relative Stability:** The system is said to be relatively more stable on the basis of settling time. i.)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. ii)As the location of the poles move towards left half of S-plane, the settling time becomes smaller and system becomes relatively more stable.	**2M**

<table>
<tr><td></td><td></td><td>
</td><td>2M</td></tr>
<tr><td></td><td>d)</td><td>Find transfer function of given block diagram:

</td><td>4M</td></tr>
</table>

	Ans:		**4M**
	e)	**For a system having T.F.64/S^2+5S+64 for unit step input, determine:** **(i) Natural frequency of oscillation W_n** **(ii) Damping Ratio €** **(iii) Damping frequency** **(iv) Time for peak overshoot T_p.**	**4M**

	Ans:	$T.F. = \frac{64}{s^2+5s+64}$ Comparing this with standard T.F. of 2nd order system $\frac{\omega_n^2}{s^2+2\xi\omega_n+\omega_n^2}$ $\therefore \omega_n^2 = 64$ $\omega_n = 8$ rad/sec — (1) mark $2\xi\omega_n = 5$ $\xi = \frac{5}{2\times\omega_n}$ $\quad \xi = \frac{5}{2\times 8}$ $\xi = 0.3125$ — (1) mark $\omega_d = \omega_n\sqrt{1-\xi^2}$ $\omega_d = 8\sqrt{1-(0.3125)^2}$ $\omega_d = 7.59$ rad/sec — (1) mark $T_p = \frac{\pi}{\omega_d}$ $T_p = \frac{\pi}{7.59}$ $T_p = 0.413$ sec — (1) mark	**1M each**
	f)	**State the condition of stable, unstable, marginal stable based on gain margin & phase margin.**	**4M**
	Ans:	For stable system, gain margin & phase margin should be positive. For unstable system, gain margin & phase margin should be negative. For marginally stable system, gain margin & phase margin should be zero. .	**4M**
Q.6		**Attempt any FOUR of the following:**	**16 Marks**
	(a)	**Whether Traffic signal is open or closed loop system. Justify it with the help of control action.**	**4M**
	Ans:	Traffic signal is open loop system. A traffic flow control system used on road is time dependent. The traffic on the road becomes mobile or stationary depending on the duration and the sequence of lamp glow. The sequence and duration are controlled by relays which are predetermined and not dependent on the rush on the road.	**2mark** **Justification: 2marks**

		 	
	(b)	**Define:** **(i) Steady state error $e_{(t)}$** **(ii) Steady state error co-efficient e_{ss}**	4M
	Ans:	**(i)Steady state error $e_{(t)}$:** Steady state error is defined as the error in the steady state of the system after the transient die out as time t→∞. **(ii)Steady state error co-efficient e_{ss}:** The response that remains after the transient response has died out is called steady state response. The steady sate response is important to find the accuracy of the output. The difference between steady state response and desired response gives the steady state error. The control system has following steady state errors for change in positions, velocity and acceleration. • **K_p** = Positional error constant • **K_v**= Velocity error constant • **K_a** = Acceleration error constant These constants are called static error coefficient. They have the ability to minimize the steady error.	2M 2M
	(c)	**Derive the unit step response of first order system.**	4M
	Ans:	(Stepwise marking) The T.F. of First order system is , $\frac{Vo(s)}{Vi(s)} = \frac{1}{1+sRC}$ For Unit Step Input, $Vi(s) = \frac{1}{s}$	1M 1M

		So, $Vo(s) = \frac{1}{s(1+sRC)} = \frac{A}{s} + \frac{B}{1+sRC}$ Where A= 1 & B = –RC So, $Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC}$ Taking Laplace inverse, we get $Vo(t) = 1 - e^{-\frac{t}{RC}} = C_{ss} + C_t(t)$ $C_{ss} = 1$ and $C_t(t) = -e^{-\frac{t}{RC}}$	1M 1M
	(d)	**Explain why derivate action cannot be used alone.**	**4M**
	Ans:	Derivative control action responds to the rate at which the error is changing The equation for D controller is: $P_o = K_D \frac{dE_p}{dt}$ It shows that the controller output will be zero if i) error Ep is zero ii) if error is constant. Therefore D controller is not used alone.	**4M**
	(e)	**Consider 5th order system with characteristics equation given by $S^5+2S^4+4S^3+6S^2+2S+5=0$ Determine the stability.**	**4M**

	Ans:	Given characteristic equation is $s^5+2s^4+4s^3+6s^2+2s+5=0$ Find odd and even coefficient from given characteristic equation and make Routh's array $a_0=1,\ a_1=2,\ a_2=4,\ a_3=6,\ a_4=2,\ a_5=5$ Make Routh's array. $\begin{array}{c\|ccc} s^5 & 1 & 4 & 2 \\ s^4 & 2 & 6 & 5 \\ s^3 & 1 & -0.5 & 0 \\ s^2 & 7 & 5 & 0 \\ s^1 & -1.21 & 0 & \\ s^0 & 5 & & \end{array}$ $b_0=\frac{(2\times4)-(1\times6)}{2}=1$ $b_1=\frac{(2\times2)-(5\times1)}{2}=-0.5$ $c_0=\frac{(1\times6)-(-0.5\times2)}{1}=7,\ c_1=\frac{(1\times5)-(2\times0)}{1}=5$ $d_0=\frac{(7\times-0.5)-(1\times5)}{7}=-1.21$ $e_0=\frac{(-1.21\times5)-(7\times0)}{-1.21}=5$ As there are two sign changes so system is Unstable two roots are in R.H.S.		**3 M or Routh's array** **1M for stability statement**