MODEL ANSWER

WINTER– 18 EXAMINATION

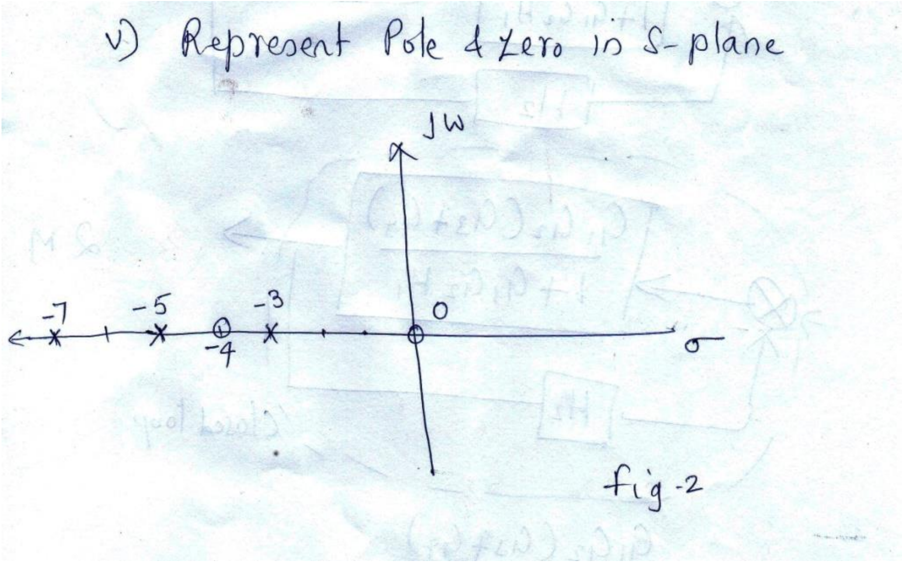
Subject Title: Control System Subject Code: 17538

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		**Attempt any THREE :**	**12-Total Marks**
	a)	**Define Linear time variant and Linear tin invariant control system with examples**	**4M**
	Ans:	**<u>Linear time variant system:</u>** A **linear time variant system** is defined as a control system in which parameters of the system are varying with time that means as time passes parameters varies. **<u>OR</u>** A system is said to be Time variant if its input output characteristics change with time. Ex: rocket launching system, space shuttle/vehicle. **<u>Linear time in-variant system</u>** A **linear time in-variant system** is defined as a control system in which parameters of the system does not vary with time. **<u>OR</u>** A system is said to be Time Invariant if its input output characteristics do not change with time. Ex: RC ,RLC networks, different electrical network.	**2M each**

	b)	**Define steady state error. Derive equation for steady state error for type - 0 system.**	**4M**
	Ans:	Steady state error is defined as the error in the steady state of the system after the transient die out as time t→0. **Equation for steady state error for type' 0' system**: Steady state error $e_{ss} = \lim_{s\to 0} \frac{S\,R(S)}{1+G(S)H(S)}$ For type '0' system, $G(S)H(S) = \frac{K}{(1+T_P\,S)}$ For unit step input, $R(S) = \frac{1}{S}$, $e_{ss} = \lim_{s\to 0} \frac{S\times\frac{1}{S}}{1+G(S)H(S)} = \frac{1}{1+K_P} = K$ For unit ramp input, $R(S) = \frac{1}{S^2}$, $e_{ss} = \lim_{s\to 0} \frac{S\times\frac{1}{S^2}}{1+G(S)H(S)} = \infty$ For unit parabolic input, $R(S) = \frac{1}{S^3}$, $e_{ss} = \lim_{s\to 0} \frac{S\times\frac{1}{S^3}}{1+G(S)H(S)} = \infty$	**1M** **3M**
	c)	**State Routh's stability criterion. List advantages and limitation of it. (any two)**	**4M**
	Ans:	**Routh's stability criterion:** If there is no sign change in the first column of Routh's array which is made from the coefficients of characteristic equation, the system is stable. The number of sign changes indicates the number of right side poles in the 'S'plane which makes the system unstable. **Advantages of Routh array:-** i) Simple criterion that enables to determine the number of closed loop poles which lie in right half of S-plane without factorizing the characteristic equation. ii) Without actually solving characteristic equation, it tells whether or not there are positive poles in a polynomial equation iii) By seeing the sign changes in the first column, it can be analyzed whether system is stable or not. iv) It tells the number of poles present on imaginary axis i.e. it tells about critical stability. **Disadvantages of Routh's array: -** i) Cannot find out the value of poles. ii) It is not a sufficient condition for stability. iii) Lengthy procedure	**2M** **1M(any two)** **1M(any two)**
	d)	**State need of Bode plot. Define Gain margin and phase margin. Write he condition of gain margin and phase margin for stable system.**	**4M**
	Ans:	**Need of Bode plot:** it is a logarithmic plot which represents the sinusoidal transfer function; it consists of magnitude plot and phase angle plot. It is used to determine stability. **Gain Margin : -** • It refers to the amount of gain, which can be increased or decreased without making the system unstable.	**1M** **1M**

		• 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 instability) . **Phase margin: -** • It refers to the phase angle which can be increased or decreased without making the system unstable. • 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 instability). **Condition of gain margin and phase margin for stable system.** For Stable System Both the margins should be positive.	**1M** **1M**
	B)	**Attempt any ONE :**	**6**
	a)	**For system whose transfer function equation is** $\frac{C(S)}{R(S)} = \frac{S(S+4)}{(S+5)(S^2+10S+21)}$ **Find value of** **i) Poles** **ii) Zero's** **iii) Characteristics equation** **iv) Order of system** **v) Represent pole and zeros in S-plane**	**6M**
	Ans:	i) Poles = -5, -3,-7 ii) Zeros = 0,-4 iii) Characteristics equation , $(S+5)(S^2+10S+21) = 0$ iv) Order of system = 3 v) Represent pole and zeros in S-plane **Fig 2**  	**1M** **1M** **1M** **1M** **2M**

b) **Draw Bode plot for system whose open loop transfer function is,** **6M**

$$G(S)\,H(S) = \frac{10}{S\,(1+5S)\,(1+20S)}$$

Ans: **Step 1**: Convert the given open loop transfer function to time constant form:
Given equation is already in time constant form

Step 2: Identify the factors;

1. Open loop gain K=10, Magnitude in dB= 20 log K= 20 log 10 = 20dB

2. Pole at origin (1/S) which has a magnitude plot with slope of -20dB/decade.
   For ω=1, Magnitude in dB for (1/S) = -20 log 1= 0 dB
   For ω= 0.01, Magnitude in dB for (1/S) = -20 log 0.01= 40 dB **2M**

3. First order pole (1+ 20S). The corner frequency is ω_{c1} =1/20= 0.05rad/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

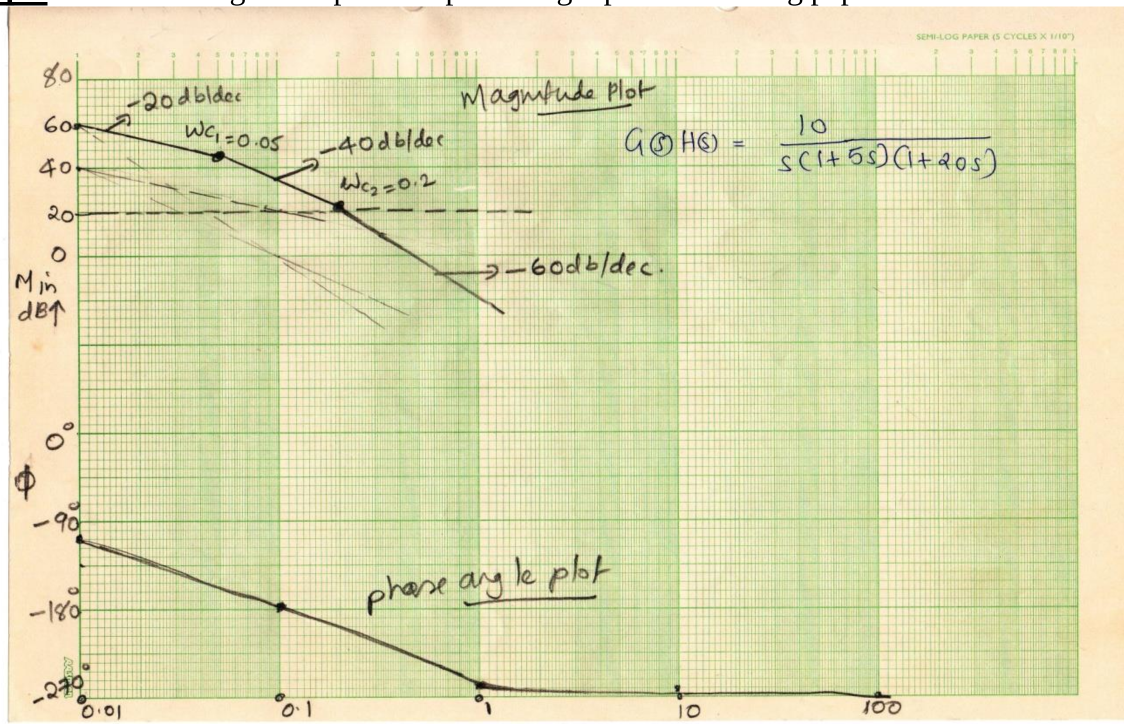
4. First order pole (1+ 5S). The corner frequency is ω_{c2} =1/5= 0.2rad/sec. Till this corner frequency the magnitude plot's slope will be -40 dB/decade due to Pole at origin (1/S) and First order pole (1+ 20S). From the Corner frequency ω_{c2} it changes to -60 dB /decade.

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

Frequency ω (rad/sec)	**Factor 1; K=10, θ_1**	**Factor 2; 1/S, θ_2**	**Factor 3; 1/(1+5S), $\theta_3 = -\tan^{-1} 5\omega$**	**Factor 4; 1/(1+20S), $\theta_4 = -\tan^{-1} 20\omega$**	**Total $\theta = \theta_1 + \theta_2 + \theta_3 + \theta_4$**
0.01	0^0	-90^0	-2.86^0	-11	-103.86
0.1	0^0	-90^0	-26.56^0	-63	-179
1	0^0	-90^0	-78.6	-87	-255.6
10	0^0	-90^0	-88.85	-89	-268
100	0^0	-90^0	-89.88	-90	-270

2M

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



Q 2		Attempt any TWO:	16-Total Marks
	a)	**Determine stability of system using Routh's criterion whose characteristics equation is** $S^5 + 2S^4 + 2S^3 + 4S^2 + 11S + 10 = 0$	8M

Ans:

S^5	1	2	11
S^4	2	4	10
S^3	0	6	0
S^2			
S			
S^0			

2M

Due to the '0' in the first column, Routh's array should be modified by replacing '0' with a small positive value ε.

S^5	1	2	11
S^4	2	4	10
S^3	ε	6	0
S^2	$(4\varepsilon - 12)/\varepsilon$	10	0

2M

S	$\frac{\frac{6\times((4\,\varepsilon-12)}{\varepsilon}-10\varepsilon}{\frac{(4\,\varepsilon-12)}{\varepsilon}}$	0	0
S^0	10	0	0

Assuming $\varepsilon \to 0$, **1M**

$$\varepsilon \to 0\ \frac{(4\,\varepsilon-12)}{\varepsilon} = -\infty$$

And

$$\varepsilon \to 0 \frac{\frac{6\times(4\,\varepsilon-12)}{\varepsilon}-10\varepsilon}{\frac{(4\,\varepsilon-12)}{\varepsilon}} = \varepsilon \to 0 \frac{\frac{6\times(4\,\varepsilon-12)-10\varepsilon^2}{\varepsilon}}{\frac{(4\,\varepsilon-12)}{\varepsilon}} = \varepsilon \to 0\left(\frac{6\times(4\,\varepsilon-12)-10\varepsilon^2}{(4\,\varepsilon-12)}\right) = 6$$

New Routh's array **2M**

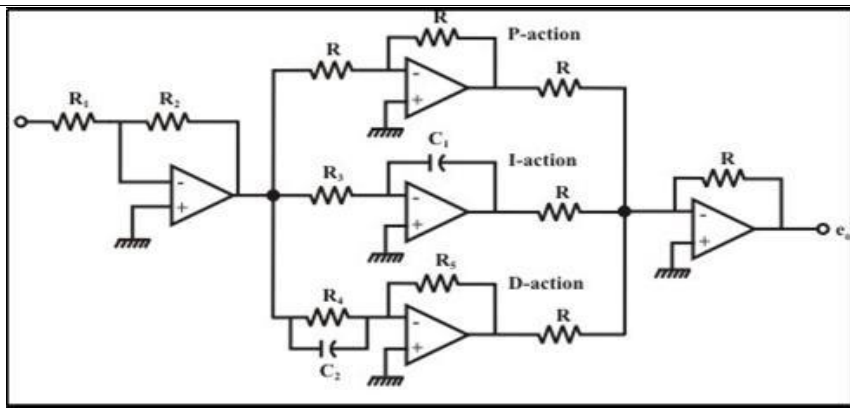
S^5	1	2	11
S^4	2	4	10
S^3	ε	6	0
S^2	$-\infty$	10	0
S	6	0	0
S^0	10	0	0

1M

There are 2 sign changes in the first column which shows two poles on RHS of S plane. So the system is unstable.

b) **Draw PID controller using OP-Amp. Give its out put equation. State two advantges of it.** **8M**

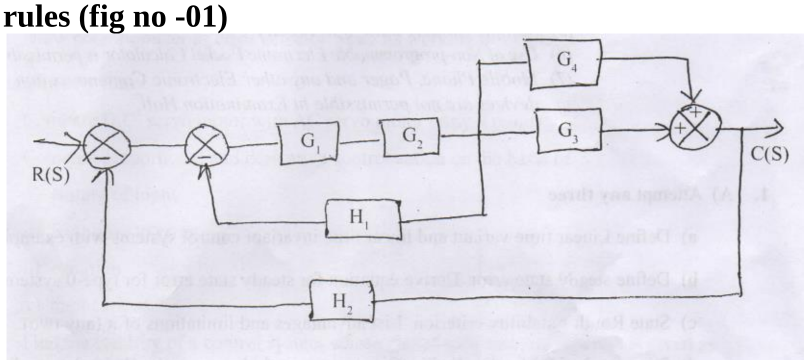
Ans:



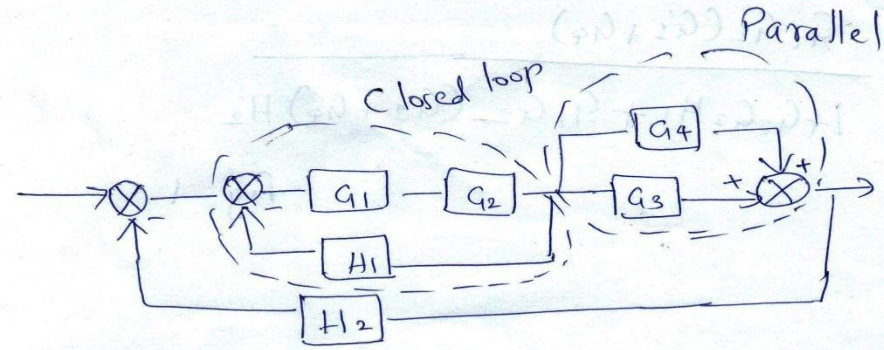
4 Marks for diagram

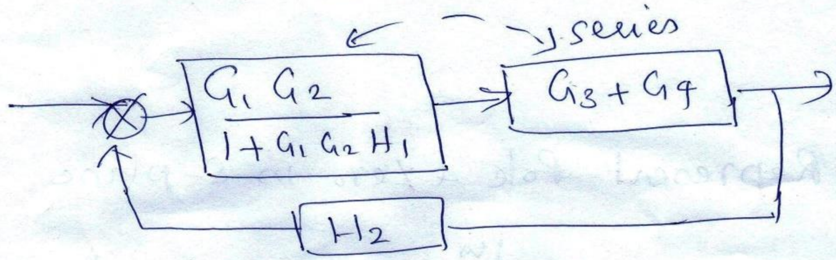
Equation:-

$$P(t) = K_p e_p + K_p K_i \int_0^t e(t)dt + K_p K_d \frac{d}{dt} e(t) + P(0)$$

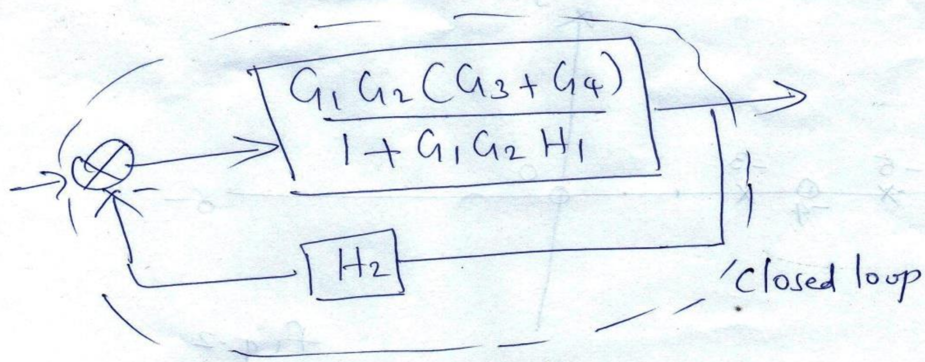
		OR $V_{out} = \left(\frac{R_2}{R_1}\right) V_e(t) + \left(\frac{R_2}{R_1}\right)\frac{1}{R_1 C_1}\int_0^t V_e(t)\,dt + \left(\frac{R_2}{R_1}\right) R_D C_D \frac{d V_e(t)}{dt} + V_{out}(0)$ Where K_p= Proportional gain K_d= Derivative gain K_i = Integral gain E_p = Error signal P(t) = Controller output P(0) =Controller output at t=0 **Advantages of PID controller over other composite controllers:** 1. Offset error is eliminated. 2. Settling time is less. 3. Provides a fast response	**2 Marks for equation** **2 Marks for Advantages.(any 2)**
	c)	**Dtermine transfer function of given block diagram using block diagram reduction rules (fig no -01)**  Fig. No. 1	**8M**

Ans:





4 M



2M

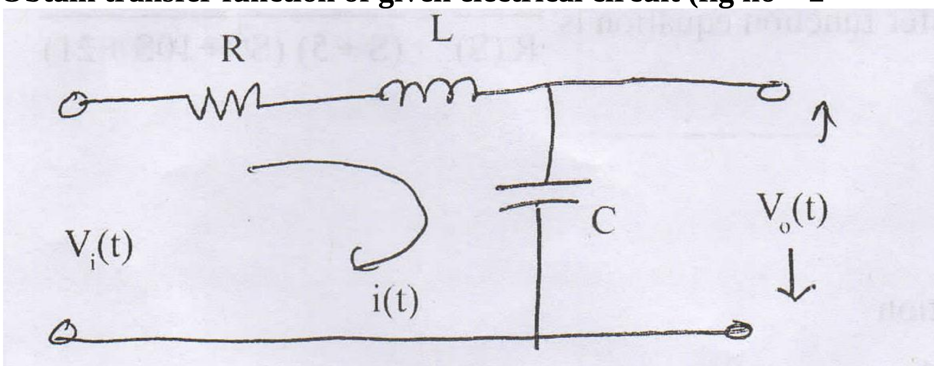
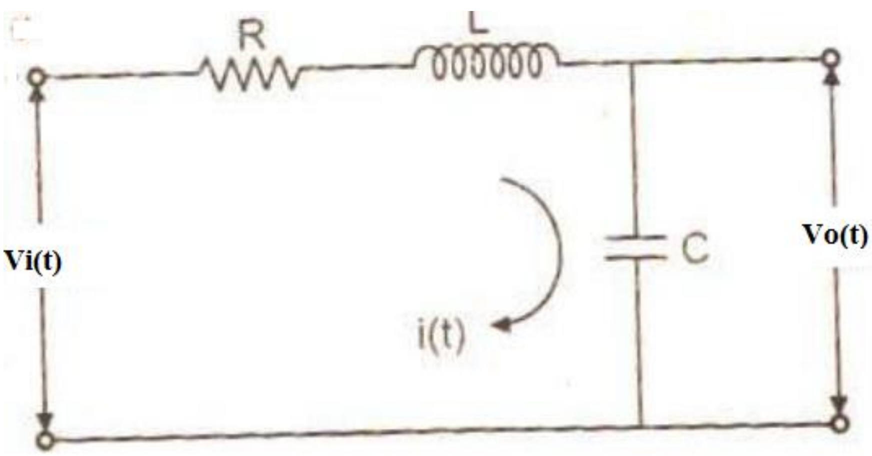
$$Tf = \frac{\dfrac{G_1G_2(G_3+G_4)}{1+G_1G_2H_1}}{1+\dfrac{G_1G_2(G_3+G_4)H_2}{1+G_1G_2H_1}} =$$

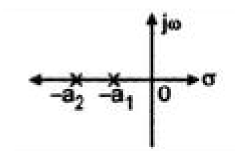
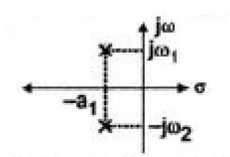
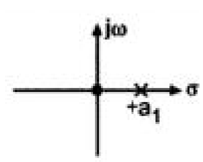
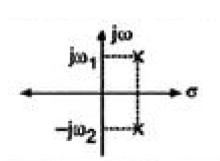
1 M

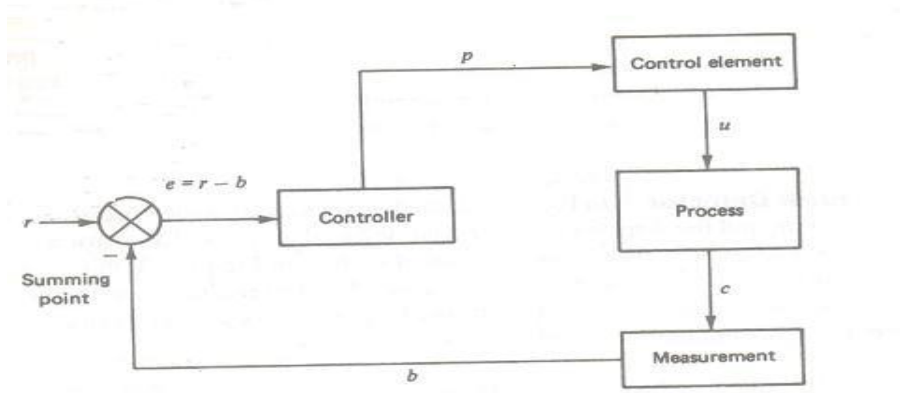
$$Tf = \frac{G_1G_2(G_3+G_4)}{1+G_1G_2H_1+G_1G_2(G_3+G_4)H_2}$$

1 M

fig: 1

Q. 3		**Attempt any FOUR:**	**16-Total Marks**
	a)	**Obtain transfer function of given electrical circuit (fig no – 2**  Fig. No. 2	**4M**
	Ans:	 $$Vi(t) = Ri(t) + L\frac{di(t)}{dt} + \frac{1}{c}\int i(t)dt$$ Take laplace transform of above equation $$V_i(s) = I(s)\left[R + SL + \frac{1}{S.C}\right] \quad \text{——— (1)}$$ Output equation- $$Vo = \frac{1}{c}\int i(t)dt$$ Take laplace of output equation $$\text{Hence, } Vo(s) = \frac{1}{S.C}I(s) \quad \text{——— (2)}$$ Divide equation 2 by 1 we get	**Equation of Vi(s)-1M** **Vo(s)-1M** **Final equation-2M**

		$$\frac{Vo(s)}{Vi(s)} = \frac{1}{SC.[R + SL + \frac{1}{S.C}]}$$ $$\frac{Vo(s)}{Vi(s)} = \frac{1}{S^2LC + SRC + 1]}$$	
	b)	**Draw the diagram od S-plane with root location. For** **1) Stable system 2)Unstable Sytem** **Define critically stable system**	**4M**
	Ans:	**1) Splane for stable system :** **For Real,negative closed loop poles i.e. in LHS of S plane**  **Or** **For complex conjugate with negative real part closed loop poles i.e. in LHS of S plane**  **2) Splane for unstable System:** **For Real,positive closed loop poles i.e. in RHS of S plane**  **Or** **For complex conjugate with positive real part closed loop poles i.e. in RHS of S plane**  **Critically stable system:** If the poles (non repeated) are located purely on imaginary axis of s-plane, system is said to be	**Splane for stable and unstabl e -1M each**

		critically stable. **Or** 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	**Definition-2M**
	c)	**Draw block diagram of Process Control system. Explain each block in details.**	**4M**
	Ans:	 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’.	**Block diagram-2M** **Explanation-2M**
	d)	**For unity feedback system whose open loop transfer function is** $G(S)\,.\,H(S) = \frac{K(S+2)}{S(S^2+7S+12)}$ **Determine** **i) Type of system** **ii) Kp, Kv, Ka.**	**4M**
	Ans:	**For unity feedback system H(s)=1** **G(s).H(S)=**$\frac{K(S+2)}{S(S+4)(S+3)}$ **Time constant form of above equation is-** **G(s).H(s)=**$\frac{K*2(1+0.5S)}{S*4*3(1+0.25S)(1+0.33S)}$ **G(s).H(s)=**$\frac{K*0.167(1+0.5S)}{S(1+0.25S)(1+0.33S)}$	**Type of the system-1m** **Kp,Kv, Ka-1M each**

By compairing with stand equation i.e.

G(s).H(s)=$\frac{K(1+a1S)(1+a2S)\ldots\ldots\ldots(1+anS)}{S^J(1+b1S)(1+b2S)\ldots\ldots\ldots(1+bnS)}$ **J is type of the system**

Where J=1
Therefor the type=1

Error coefficients

Kp=lim$_{s-0}\, G(S)H(S)$

Kp=lim$_{s-0}\, \frac{K*0.167(1+0.5S)}{S(1+0.25S)(1+0.33S)}$

Kp= $\frac{K*0.167}{0}$

Kp=∞

Kv=lim$_{s-0}\, SG(S)H(S)$

Kv=lim$_{s-0} S\, \frac{K*0.167(1+0.5S)}{S(1+0.25S)(1+0.33S)}$

Kv=0.167K

Ka=lim$_{s-0}\, S^2 G(S)H(S)$

Ka=lim$_{s-0}\, S^2 \frac{K*0.167(1+0.5S)}{S(1+0.25S)(1+0.33S)}$

Ka=0

e) **State how AC servo motor differ from a normal 2 – phase induction motor.** **4M**

Ans:

At least four point- 1M each

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

Q. 4 **A)** **Attempt any THREE :** **12- Total Marks**

a) **Find the under damped, over damped system from following:** **4M**

1) $\frac{9}{S^2+9}$

2) $\frac{9}{S^2+6S+9}$

3) $\frac{9}{S^2+3S+9}$

Ans: **Standard T.F. of second order system**

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

Compare both the equations

1)

$2\zeta\,\omega_n=0$

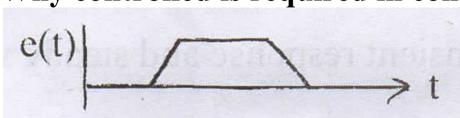
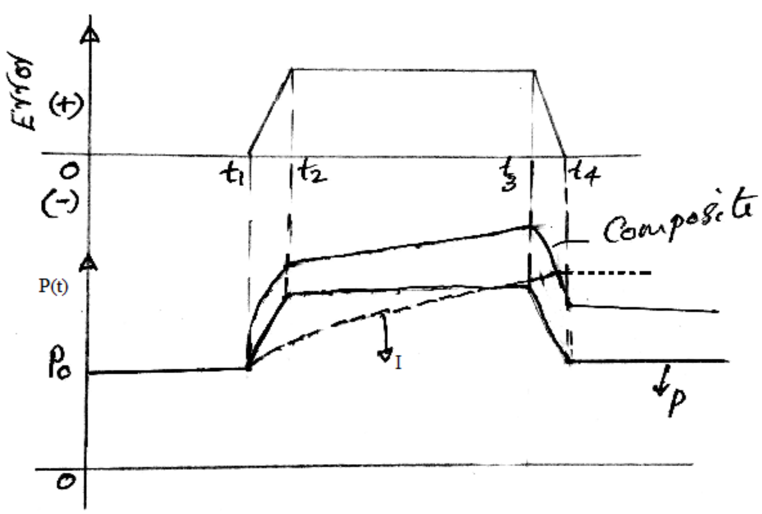
$\zeta=0$

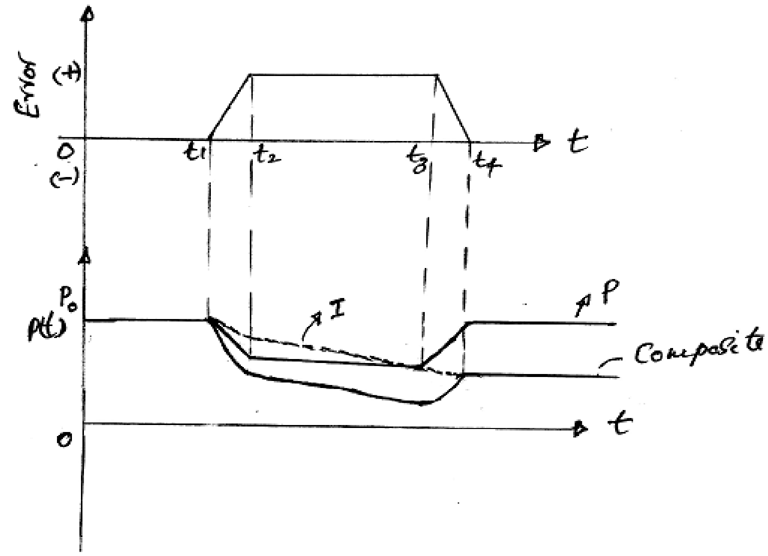
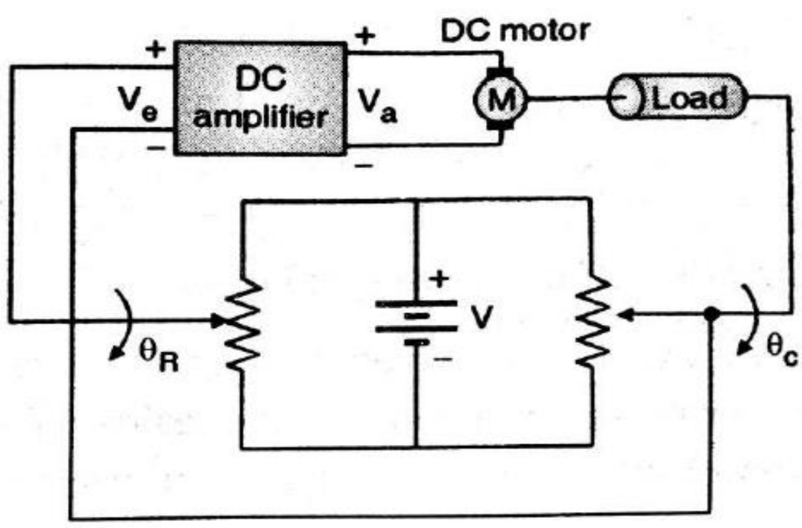
As $\zeta=0$, the system is Undamped

2)

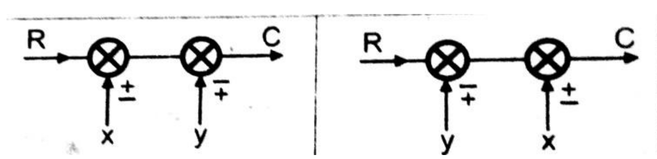
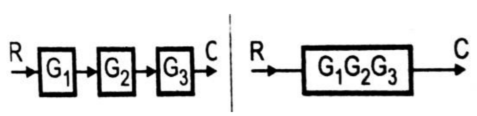
$2\zeta\,\omega_n=6$

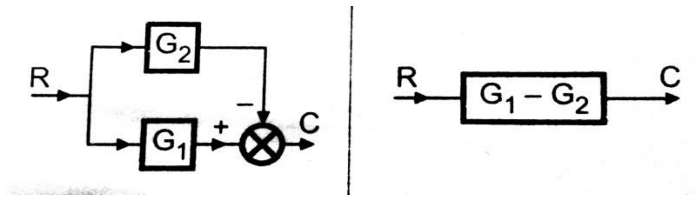
		$\zeta =6/(2^* \omega_n)$ $\zeta =1$ As $\zeta =1$, the system is critically damped 3) $2\zeta \omega_n=3$ $\zeta =3/(2^* \omega_n)$ $\zeta =0.5$ As $\zeta =0.5$,i.e. $0< \zeta<1$, the system is under damped	
	b)	**Write two advantages and disadvantages of frequency domain analysis.**	**4M**
	Ans:	**Advantages:** 1)It is easy to get a frequency response in laboratory with good accuracy 2)It is useful to determine the transfer function of complicated system, which cannot be determined by analytical technique. 3)The signal generators and precise measuring instruments for generation of sinusoidal signals of various ranges of frequency and amplitude are readily available. 4)The absolute stability and relative stability of closed loop control system can be estimated from the knowledge of open loop frequency response. 5)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. 6)The effect of noise disturbance and parameter variations can be easily visualized and assessed. 7)The transient response of a system can be obtained from its frequency response. 8)It can be extended to certain non-linear systems. 9)There is no need to evaluate the roots of the characteristics equation. 10)It can give more quickly the design and analysis specification of the control system having multiple loops and poles. **Disadvantages :** 1)It cannot be used for linear systems having large time constant. 2)It cannot be used for non-interruptible systems. 3)It gives only indirect indication of the nature of the time response of the system which is always the final aim of studying system behavior. 4)It can give approximate results only, as it is graphical method.	**Any two advantages-2M** **Any two Disadvantages-2M**

		5)With the increased use of digital computers and available software's, it is not used for analysis .	
	c)	**Why controlled is required in control system? Draw PI controller response to …….** 	**4M**
	Ans:	**Use of controller in control system:** 1. Controllers improve steady state accuracy by decreasing the steady state errors. 2. As the steady state accuracy improves, the stability also improves. 3. They also help in reducing the offsets produced in the system. 4. Maximum overshoot of the system can be controlled using these controllers. 5. They also help in reducing the noise signals produced in the system. 6. Slow response of the over damped system can be made faster with the help of controllers.  **PI response for direct action**	**2M** **2M for any one response graph**

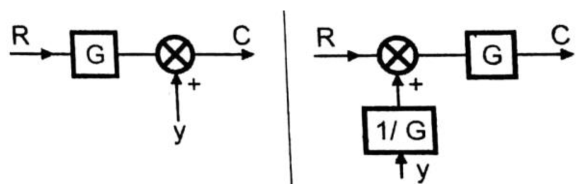
	 **PI response for reverse action** **(Note: In the first part of the question, the word 'controller' seems to be misspelled as controlled. May consider any relevant interpretation.)**	
d)	**Define servo system. List different servo components used in servo motor.**	**4M**
Ans:	Servo systems are automatic 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. **Servo Components:** • Error Detector: Potentiometer, synchro error detector • Servo amplifier: dc servo amplifier, ac servo amplifier • Servo Motor: dc servo motor, ac servo motor, stepper motor	**Definition-2M** **Servo components-2M**
B)	**Attempt any ONE :**	**6**
a)	**Draw the block diagram of DC servo system. Write the uses of servo system (two)**	**6M**
Ans:	**Block Diagram:**  **Uses of servo system:**	

		• In Solar Tracking System: • Antenna Positioning: • Ship stabilization system • Missile launching system • In automation system • In robotic system	
	b)	**Transfer function of system is given by** $\frac{C(S)}{R(S)} = \frac{100}{S^2 + 5S + 100}$ **Calculate:** **i) Damped frequency of oscillation** **ii) Peaked time (tp)** **iii) Peaked over shoot (% MP)** **iv) Settling time (ts)**	**6M**
	Ans:	**Standard T.F. of second order system** $\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$ $\omega_n^2 = 100$ ω_n=10 rad/sec $2\zeta\,\omega_n=5$ $\zeta= 0.25$ i)Damped frequency of oscillation: $\omega_d = \omega_n\sqrt{1-\zeta^2}$ $=10\sqrt{(1-0.25^2)}$ **=9.68 rad/sec** **ii) Peak time-** **Tp=**$\frac{\pi}{\omega d}$ **Tp=**$\frac{\pi}{9.68}$ **=0.3245sec** **iii) Peak Overshoot(Mp)**	**Damping frequency of oscillation-1M** **Peak time-1M** **Peak overshoot -2M** **Settling time-2M**

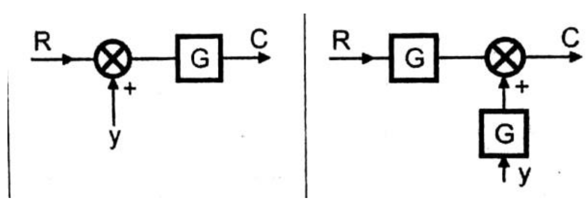
		$\%Mp = e^{(-\pi.\frac{\zeta}{\sqrt{1-\zeta^2}})}.100\%$ $\%Mp = e^{(-\pi.0.25/\sqrt{(1-0.25^2)})}.100\%$ $\%Mp = 44.43\ \%$ **iv)Settling time(ts)** $ts = \frac{4}{\zeta.\omega n} sec$ $ts = \frac{4}{0.25 * 10} sec$ **ts=1.6 sec**	
Q.5		**Attempt any FOUR :**	**16-Total Marks**
	a)	**State any four block diagram reduction rules.**	**4M**
	Ans:	**i) Associative law:** The two are more summing points directly connected can be interchanged.  **ii) Blocks in Series**: Transfer function of such blocks get multiplied  **iii) Blocks in Parallel** : Transfer function of such blocks get added algebraically	**4 marks for any four rules**



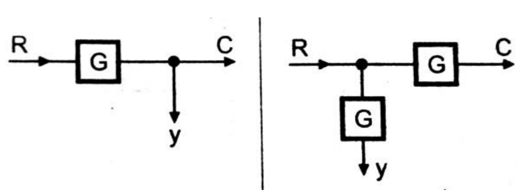
iv) Shifting Summing point behind the block:



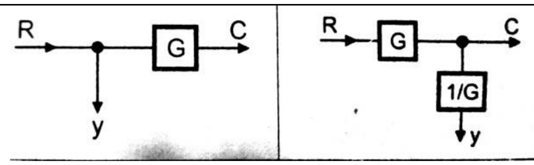
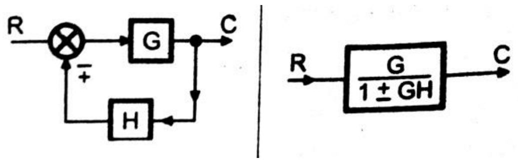
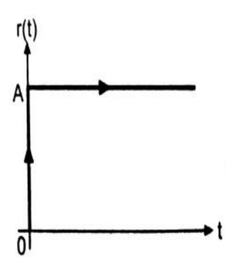
v) Shifting Summing point beyond the block:



vi) Shifting takeoff point behind the block:



vii) Shifting takeoff point beyond the block:

		 **viii) Removing the minor feedback loop:**  	
	b)	**List four standard test in put signals. Draw and define these test signals**	**4M**
	Ans:	The Standard test signals are 1.Unit Step Input 2.Unit Ramp Input 3.Unit Parabolic Input 4.Unit Impulse Input	**1 mark for listing**
		1) **Step Input** (Position function) : It is the sudden application of the input at a specified time as shown in figure. Mathematically it can be described as, $r(t) = A \quad \text{for } t \geq 0$ $= 0 \quad \text{for } t \leq 0$ If A=1, then it is called unit step function and denoted by u(t). Laplace transform of such input is A/s.  **2) Ramp Input** (Velocity Function): It is constant rate of change in input i.e. gradual	**3 marks for definitions and diagrams**

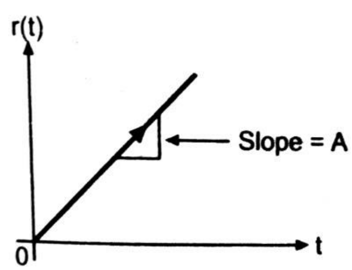
application of input as shown in the figure

Magnitude of ramp input is nothing but its slope. Mathematically it is defined as,

$r(t) = At$ for $t \geq 0$
$= 0$ for $t \leq 0$

If A=1, then it is called unit ramp input. It is denoted by r(t).

Its Laplace transform is A/s^2.



3) **Parabolic Input** (Acceleration function): This is the input which is one degree faster than a ramp type of input as shown in the fig.

Mathematically this function is described as,

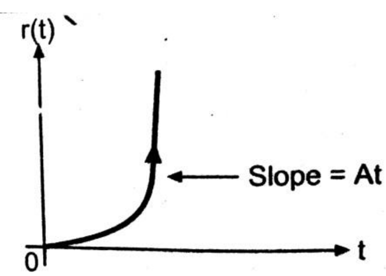
$r(t) = (A/2)\, t^2$, for $t \geq 0$

$= 0$, for $t \leq 0$

If A is called magnitude of the parabolic input.

If A = 1, i.e. $r(t) = t^2/2$ it is called unit parabolic input.

Its Laplace transform is A/s^3



4) **Impulse Input:**

It is the input applied instantaneously (for short duration of time) of very high amplitude as shown in the fig.

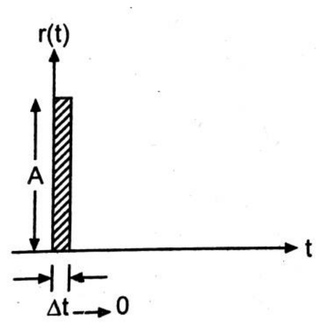
It is the pulse whose magnitude is infinite while its width tends to zero i.e. $t \to 0$, applied momentarily.

Area of the impulse is nothing but its magnitude. If its area is unity it is called Unit Impulse Input, denoted as $\delta(t)$.

Mathematically it can be expressed as,

$r(t) = A, \quad \text{for } t = 0$
$\quad = 0, \quad \text{for } t \neq 0$

If A is called magnitude of the parabolic input.



c) **Describe variable reluctance stepper motor with neat diagram.** **4M**

Ans:

Variable reluctance stepper motor:

(for any one type)

2 marks for description

2 marks for diagram

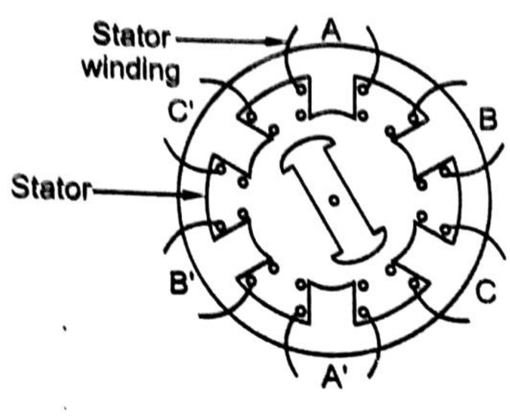


Figure:1

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 fig.2.

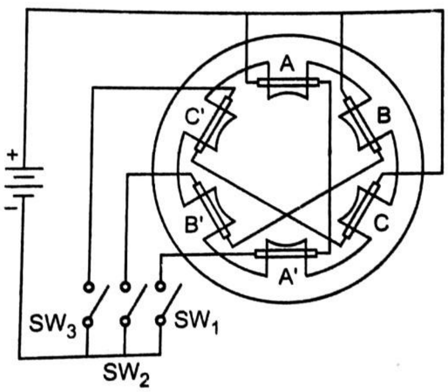


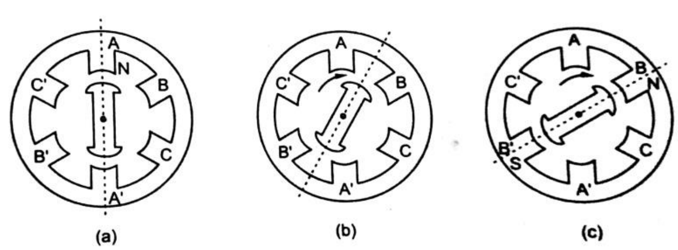
Figure:2

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.

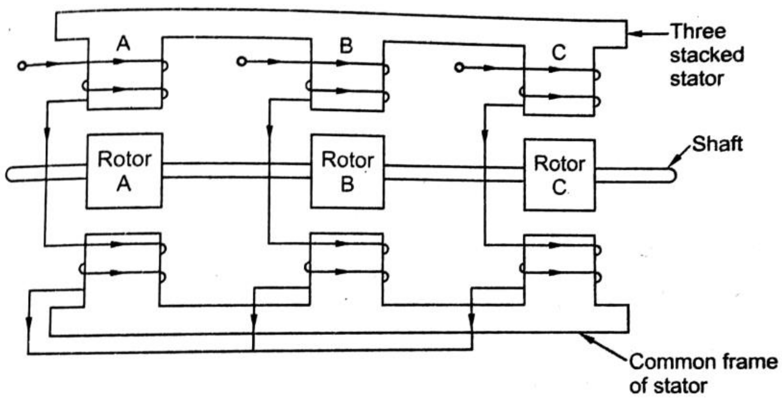


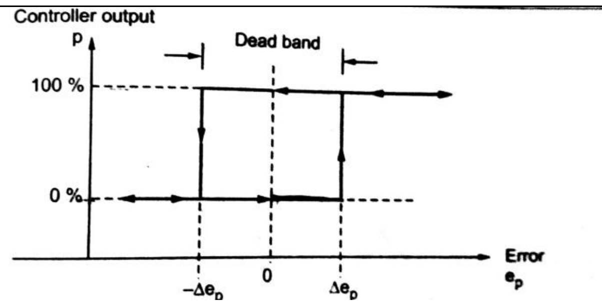
By successively exciting three phases in the specific sequence, the motor takes twelve steps to make one complete revolution.

OR

Multistack 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 .  	
	d)	**Define ON – OFF controller. Explain “Neutral Zone” in “ON-OFF” controller.**	**4M**
	Ans:	**ON-OFF controller :**Itis a two position discontinuous controlling mode. It has to control two positions of control element, either on or off. This control mode has two possible outputs states namely 0% or 100%. The mathematical equation of ON-OFF controller is P = 0% $e_p < 0$ = 100% $e_p > 0$ Where, P is the controller output and epis the error signal. Thus if the error rises above a certain critical value, the output changes from0% to 100%. If the error decreases below certain critical value, the output falls from 100% to 0%.	**2 marks for definition** **2 marks for Neutral zone**



Neutral Zone: In all the practical implementation of the ON-OFF controller, there is an 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. When the error changes by Δep there is no change in the controller output. Similarly while decreasing also the error must decrease beyond Δep below 0 to change the controller output.

e) **Determine the range of K for stable system with characteristic equation as follow:** **4M**

$$S^4 + 4S^3 + 13S^2 + 36S + K = 0$$

Ans:

5e) sol.

$$S^4 + 4S^3 + 13S^2 + 36S + K = 0$$

s^4	1	13	K
s^3	4	36	0
s^2	4	K	0
s^1	$\frac{144-4K}{4}$	0	
s^0	K		

For System to be stable there should be No sign changes in First column of Routh's array.

$\rightarrow \frac{144-4K}{4} > 0$

$\rightarrow 144 - 4K > 0$

$\therefore 144 > 4K$

$\therefore \frac{144}{4} > K$

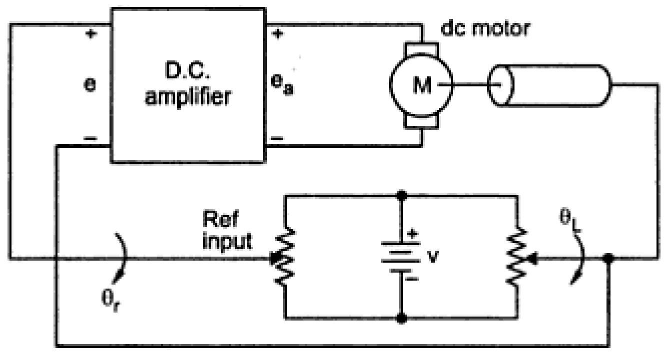
$\therefore 36 > K$

Hence to make the system stable range of K is $0 < K < 36$

$\therefore$ From s^0 row, we get $K > 0$.

4 marks

f) **Draw potentiometer as error detector. State its working principle.** **4M**

	Ans:	 **Explanation :** DC Motor control systems potentiometers can be used as position feedback as shown in figure . 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 $=K_s[\theta r(t) - \theta L(t)]$ 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 theinput(reference) potentiometer.	**2 marks for diagram** **2 marks for working**
Q.6		**Attempt any FOUR:**	**16-Total Marks**
	a)	**Compare DC servo motor with AC servo motor (any 04 points)**	**4M**
	Ans :	(table below)	**4 marks for any four points**

Sr.No	**DC servo motor**	**AC servo motor**
1	Deliver High power output	Low power output 1/2W to 100W
2	High efficiency	Efficiency is less about 5 to20%
3	Brushes and commutator are present	Brushes and commutator are present
4	Frequent maintenance required due to commutator.	Due to absence of commutator maintenance is less.

5	More problems of stability.	Less problems of stability.
6	Brushes produce radio frequency noise.	No radio frequency noise.
7	Noisy operation.	Relatively stable and smooth operation.
8	Amplifiers used have a drift.	A.C. Amplifiers used have no drift.
9	Linear response	Non- Linear response
10	No slip rings. Hence slip losses are zero	Slip rings produce slip losses.

b) **Compare proportional and derivative control action on the basis of** **4M**

- **i) Nature of input**
- **ii) Response to error**
- **iii) Equation**
- **iv) Applications**

Ans:

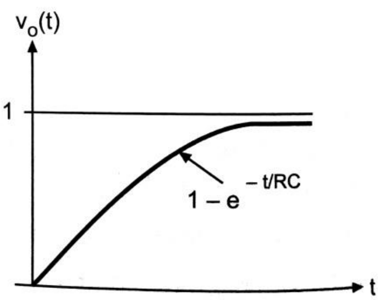
1 mark for each point

(Any one application)

Parameter	**Proportional control action**	**Derivative control action**
Nature of input	Any sort of error input	Rate of change of error input
Response to error	For constant error output is also a constant.	For constant error output is zero.
Equation	$p(t) = K_p e(t) + p(0)$	$p(t) = K_d \frac{d}{dt} e(t) + p(0)$
Applications	Proportional controller can be suitable where 1. Manual reset of the operating point is possible. 2. Load changes are small. 3. The dead time exists in the system is small.	This controller cannot be used alone. It is used as a composite controller along with P-controller for applications like: 1. Used in Motion control 2. Temperature control 3.Critical Processes that require fast control action 4.Processes prone to frequent external disturbances like Level

					control loop and Flow control loop.		
	c)	**Find the stability of a control system whose closed loop transfer function is given as** $T(S) = \frac{10}{S^5 + 7S^4 + 6S^3 + 42S^2 + 8S + 56}$					**4M**
	Ans:	6c) Sol $T(s) = \frac{10}{s^5+7s^4+6s^3+42s^2+8s+56}$ $\because T(s) = \frac{C(s)}{R(s)} = \frac{G(s)}{1+H(s)G(s)}$ $F(s) = 1+G(s)H(s) = 0$ $\therefore s^5+7s^4+6s^3+42s^2+8s+56 = 0$ s^5 | 1 6 8 s^4 | 7 42 56 s^3 | 0 0 0 s^2 | s^1 | s^0 | Row of zero's means the system is either unstable or marginaly stable $A(s) = 7s^4+42s^2+56 = 0$ $\frac{d}{ds}A(s) = 28s^3+84s = 0$ s^5 | 1 6 8 s^4 | 7 42 56 s^3 | 28 84 0 s^2 | 21 56 0 s^1 | 9.33 0 s^0 | 56					**4marks**

<table>
<tr><td></td><td></td><td>As there is no sign change, so system may be stable, But as there is row of zeros, system will be marginally stable or unstable

To examine this solve $A(s) = 0$
$$7s^4 + 42s^2 + 56 = 0$$
Let $s^2 = t$
$$\therefore 7t^2 + 42t + 56 = 0$$
$$t = \frac{-42 \pm \sqrt{1764 - 1568}}{14}$$
$$= \frac{-42 \pm 14}{14} = -3 \pm 1 = -2, -4$$
$\therefore s^2 = -2$ and $s^2 = -4$
$s = \pm j\sqrt{2}$ $s = \pm j2$
$\therefore$ Non repeated roots on imaginary axis
Hence system is marginally stable.</td><td></td></tr>
<tr><td></td><td>d)</td><td>Draw the time response of 1st order and 2nd order system.</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td>Time response of 1st order system


Time response of 2nd order system</td><td>2 marks for 1st order

2 marks for 2nd order</td></tr>
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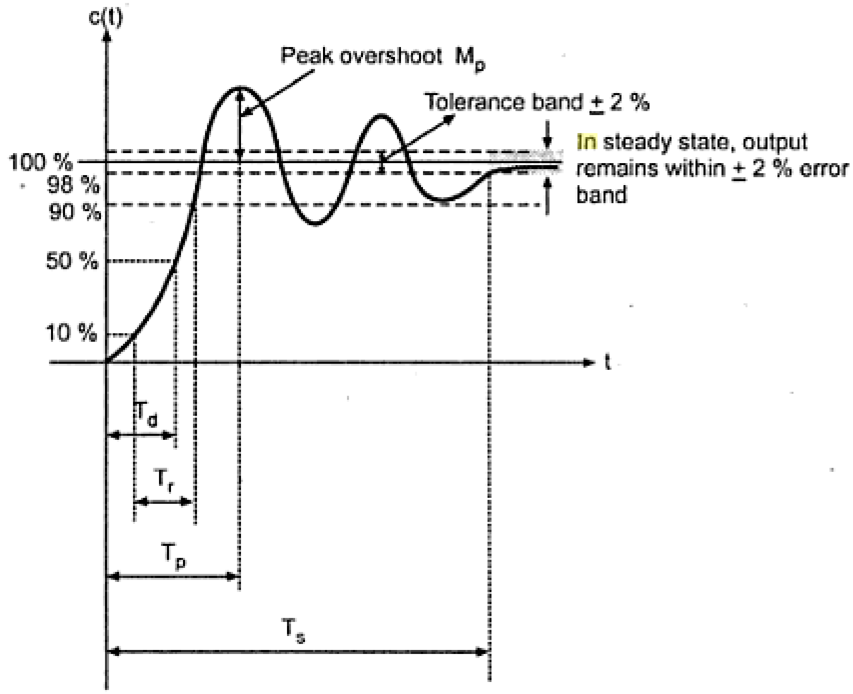
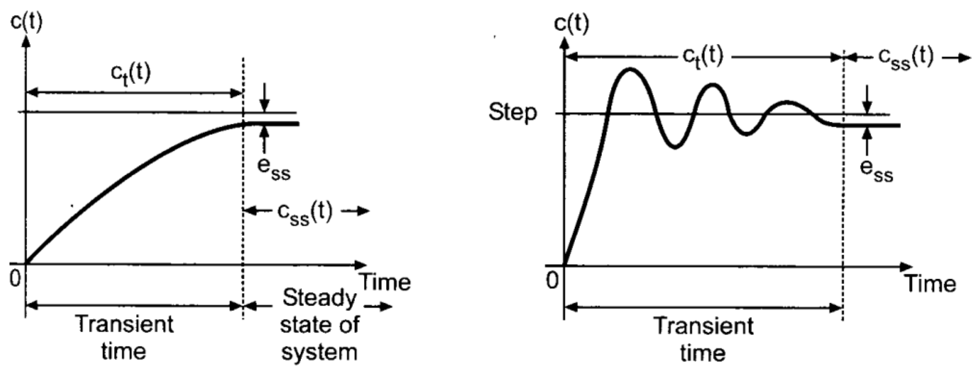
<tr><td></td><td></td><td>
</td><td></td></tr>
<tr><td></td><td>e)</td><td>Draw the time response of a system and indicate transient response and steady state response in it</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td>

(a) $c_t(t)$ is exponential (b) $c_t(t)$ is oscillatory</td><td>2 marks for response
2 marks for indication (Any 1 response)</td></tr>
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