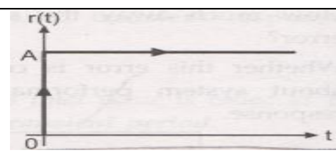
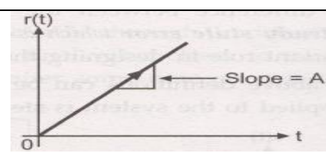
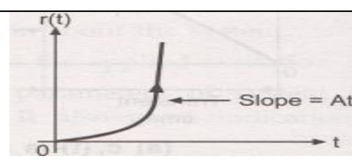
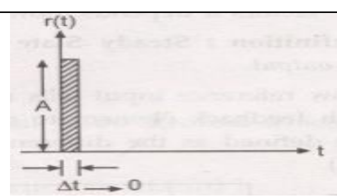
SUMMER - 2017 EXAMINATION

Subject Code:17538 **Model Answer**

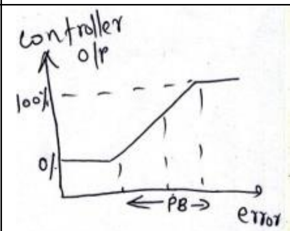
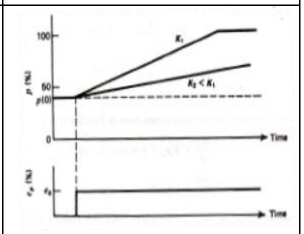
Important Instructions to examiners:

1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

<table>
<tr><th>Q. No.</th><th>Question & its Answer</th><th>Remark</th><th>Total Marks</th></tr>
<tr><td>01 A)</td><td>Attempt any THREE</td><td></td><td>12</td></tr>
<tr><td>a)</td><td>Sketch the diagrams of the four standard test signals.</td><td>04</td><td></td></tr>
<tr><td>Ans.</td><td>
<table>
<tr><th>Test Signal</th><th>Graphical representation</th></tr>
<tr><td>Unit Step Input</td><td>
</td></tr>
<tr><td>Unit Ramp Input</td><td>
</td></tr>
<tr><td>Unit Parabolic Input</td><td>
</td></tr>
<tr><td>Unit Impulse</td><td>
</td></tr>
</table>
</td><td>01 mark each</td><td></td></tr>
<tr><td>b)</td><td>Define the following terms related with frequency response:</td><td>04</td><td></td></tr>
</table>

	i) Resonant Frequency **ii) Cut-off frequency** **iii) Gain margin** **iv) Phase margin**		
Ans.	(i) **Resonant Frequency:** Frequency at which resonant peak takes place in the system response. (ii) **Cut off frequency:** Frequency at which the magnitude of closed loop response is 3db down from its zero frequency value. (iii) **Gain margin:** Margin in the gain allowable by which gain can be increased till system reaches on the verge of instability. (iv) **Phase Margin** : The amount of additional phase lag which can be introduced in the system till system reaches on the verge of instability	**01 mark each**	
c)	**Define stable, unstable, critically stable & conditionally stable system**	**04**	
Ans.	i) **Stable system** :- If the poles are located on the left half of the s-plane system is said to be stable. OR When the system is excited by a bounded input, the output is also bounded and controllable. In the absence of the input, output must tend to zero irrespective of the initial condition. ii) **Unstable system** :- If the poles are located on the right half of the s-plane system is said to be unstable. OR When the system is excited by a bounded input, the output is unbounded. iii) **Critical stability**: - If the poles (non repeated) are located purely on imaginary axis of s-plane, system is said to be critically stable. iv) **Conditional stability**:- If the Stability of system depends on condition of parameter of the system, such a system is called conditionally stable system.	**01 mark each**	
d)	**Differentiate between P and I control actions (Any four points).**	**04**	

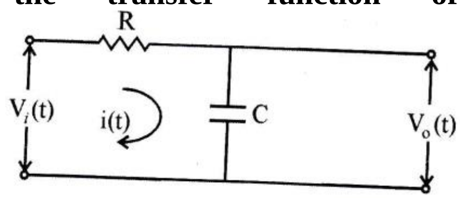
Ans.

Control action	**P**	**I**
Equation	$P_{out}=K_pE_p+P_0$	$P(t) = K_I \int_0^t e_p \, dt + P(0)$
Nature of output	Controller output is proportional to error	Rate of change of controller output is proportional to error
Nature of response		
Offset	Generates offset	Eliminates offset
Response of Error	Responds to direction of error	Responds to size of error
Speed of action	Moderate	Slow

01 mark each (Any four points)

01 B) **Attempt any ONE** **06**

a) **Find the transfer function of the given R-C circuit** **06**



Ans. Input equation :

$$V_{in} = R\, i(t) + \int \frac{i(t)}{C}\, dt$$

Laplace Transform:

$$V_{in}(s) = RI(S) + \frac{I(S)}{C}$$

02 marks

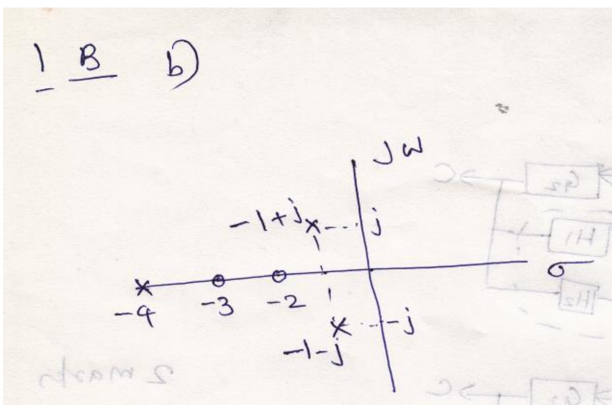
Output equation :

$$V_{out} = \int \frac{i(t)}{C}\, dt$$

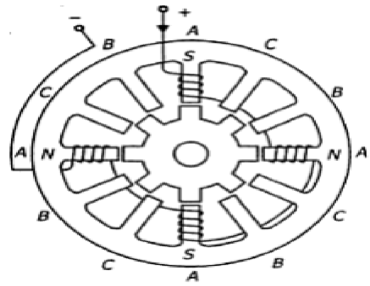
Laplace Transform:

$$V_{out}(s) = \frac{I(S)}{C}$$

02 marks

	Transfer function TF= $\frac{V_{out}(s)}{V_{in}(s)} = \frac{\frac{I(S)}{C}}{RI(S)+\frac{I(S)}{C}}$ TF= $\frac{1}{RCS+1}$	**02 marks**	
b)	**For the given function F(s), find the poles & zeros present and mark them on the S-plane :** $F(S) = \frac{(S+2)(S+3)}{(S+4)(S+1+j)(S+1-j)}$	**06**	
Ans.	Zeros: -2,-3 Poles:-4, -1+j, -1-j 	**02 marks** **02 marks** **02 marks for pole-zero plot**	
02	**Attempt any TWO**		**16**
a)	**The characteristics equations of two systems are given. Construct the Routh's Hurwitz table & comment on the stability of the Systems:** **(i) $S^3+4S^2+8S+12=0$** **(ii) $S^4+S^3-S-1=0$**	**08**	
Ans.	**(i)$S^3+4S^2+8S+12=0$** S^3 | 1 | 8 S^2 | 4 | 12 S | 5 | 0 S^0 | 12 | 0 No sign change in the first column of Routh array , so system is stable.	**04 marks (03 marks for Routh array and 01 mark for conclusion)**	

	(ii) $S^4+S^3-S-1=0$ S^4 : 1, 0, -1 S^3 : 1, -1 S^2 : 1, -1 S : 0, 0 S^0 : All element of row S^2 are zero. hence Routh criteria fails. Consider Routh array special case II. Form an auxillary equation $A(S)=S^2-1$ $\frac{dA(S)}{dS} = 2S - 0 = 2S$ From auxillary equation. Construct again Routh array, S^4 : 1, 0, -1 S^3 : 1, -1 S^2 : 1, -1 S^1 : 2, 0 S^0 : -1 From first column of Routh array, there is one sign change. Hence system is unstable and one root lies on right half of s-plane.	**04 marks (03 marks for Routh array and 01 mark for conclusion)**	
b)	**(i) Describe the working of variable reluctance stepper motor with neat diagram.** **(ii) Draw the characteristics of AC servomotor. In what way it is different from normal two phase induction motor.**	**08**	
Ans.	i) The variable reluctance stepper motor is characterized by the fact that there is no permanent magnet either on rotor or stator. The rotor is made of soft iron stamping of variable reluctance and carries no windings as shown in the figure. The stator is also made up of soft iron stampings and is of salient poles type and carries stator windings.	**03 marks for explanation**	



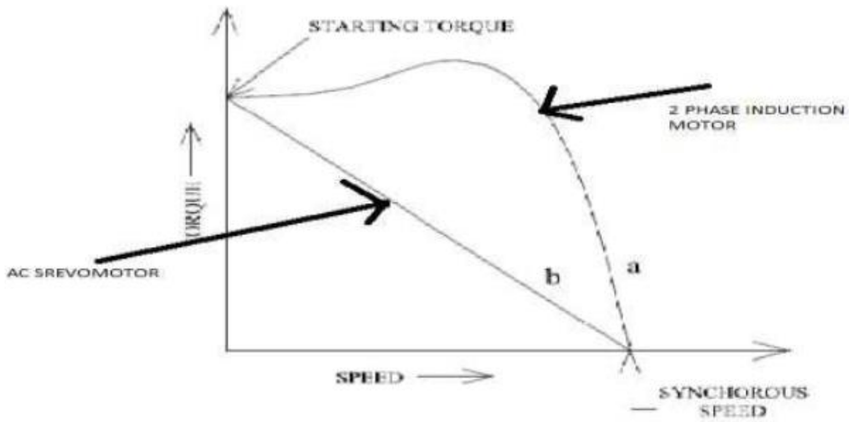
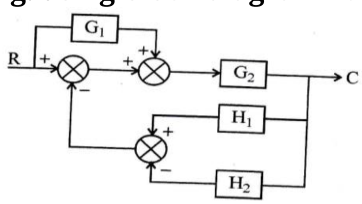
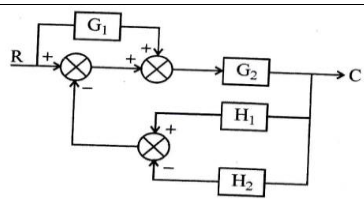
01 marks for diagram

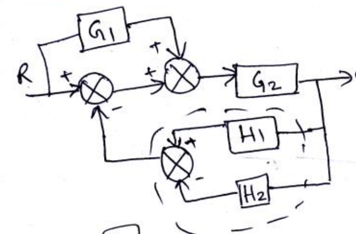
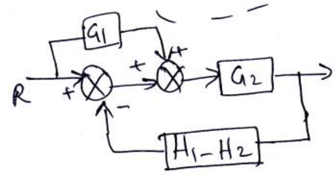
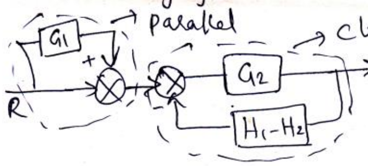
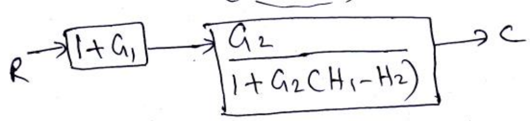
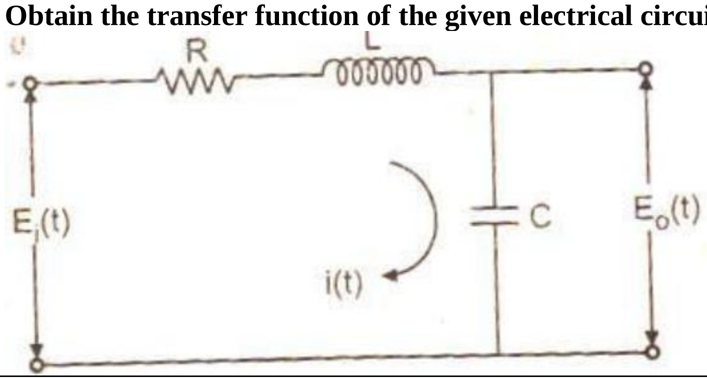
As shown in the figure, when phase A is energized through supply, the rotor moves to the position in which the rotor teeth align themselves with the teeth of phase A. In this position the reluctance of the magnetic circuit is minimum. After this if phase A is deenergised and phase B is energized by giving proper supply to its winding (not shown in fig.), the rotor will rotate through an angle of 150 in a clockwise direction so as to align its teeth with those of phase B. After this, deenergising phase B and energizing phase C will make the rotor rotate by another 150 in clockwise direction. Thus, by sequencing power
supply to the phases the rotor could be made to rotate by a step of 150each time. The direction of rotation could be reversed by changing the sequence of supply to the phase, that is, for anti-clockwise rotation, supply should be given in the sequence of ACB.

ii)

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

03 marks for any three points

	 Torque-speed Characteristic	**01 mark for characteristics**	
c)	**Derive the transfer function of the system shown in the following fig. using block diagram reduction method.**  	**08**	
Ans.	 		

	2.C   2 marks Interchanging the summing points, 2 marks   2 marks $Tf = \frac{C(S)}{R(S)} = (1+G_1)\frac{G_2}{[1+G_2(H_1-H_2)]}$ 2 marks		
03	**Attempt Any FOUR**		**16**
a)	**Obtain the transfer function of the given electrical circuit.**  	**04**	
Ans.	$Vi(t) = Ri(t) + L\frac{di(t)}{dt} + \frac{1}{c}\int_0^b i(t)dt$ Take Laplace transform,		

	$V_i(s) = I(s)\,[R + SL + \frac{1}{S.C}]$ $\frac{I(S)}{Vi(S)} = \frac{1}{[R + SL + \frac{1}{S.C}]}$ ----- (1) $Vo = \frac{1}{c}(i.dt) =$ $= \frac{1}{c}\, i(t)dt$ Hence, $Vo(s) = \frac{1}{S.C} I(s)$ $I(s) = SC.Vo(s)$ ------(2) Substituting value of I (s) in equation 1, we get $\frac{SC\ Vo(s)}{Vi(s)} = \frac{1}{[R + SL + \frac{1}{S.C}]}$ $\frac{Vo(s)}{Vi(s)} = \frac{1}{SC.[R + SL + \frac{1}{S.C}]}$ $\frac{Vo(s)}{Vi(s)} = \frac{1}{S^2 LC + SRC + 1]}$	**V_i(s) -01 Mark** **Vo(S)- 01 Mark** **01 Mark Calculation** **01 Mark Final Ans**	
b)	**Compare stepper motor and DC servo motor(any four points).**	**04**	
Ans.	(table below)	**01 mark each point (any four points)**	

No.	Stepper Motor	DC Servomotor
1	No control winding	Control winding is present
2	Number of steps can be precisely controlled	It gives continuous rotation
3	It is brushless	It has brushes
4	Due to absence of brushes, no wear and tear and hence maintenance is not required.	Maintenance is required

5	Load and No load condition does not affect the running current of stepper motor	These conditions affect the running current
6	Speed (stepping rate) is governed by frequency of switching	Speed is controlled by supply voltage

c) **Derive the unit step response of first order system. Draw its response.** **04**

Ans. The T.F. of First order system is ,

$$\frac{Vo(s)}{Vi(s)} = \frac{1}{1+sRC}$$

For Unit Step Input $V_i(s) = \frac{1}{s}$ **01 Mark**

So, $Vo(s) = \frac{1}{s(1+sRC)} = \frac{A}{s} + \frac{B}{1+sRC}$

Where A' = 1 & B' = –RC

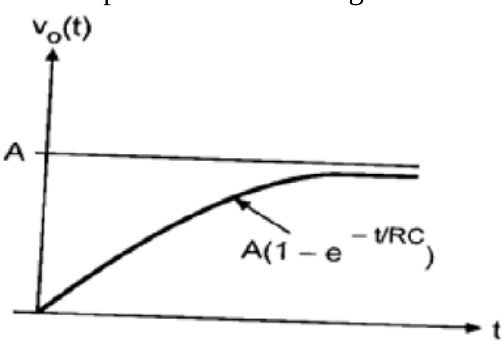
So, $Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC}$ **01 Mark**

Taking Laplace inverse, we get

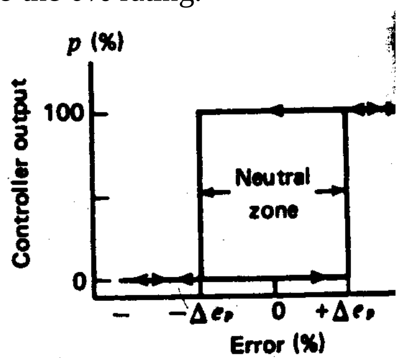
$Vo(t) = 1 - e^{-\frac{t}{RC}} = C_{ss} + C_t(t)$

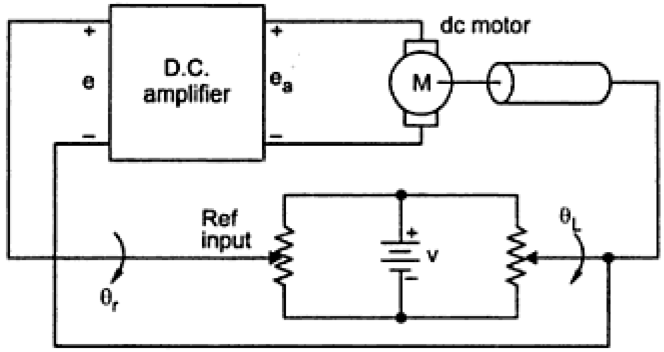
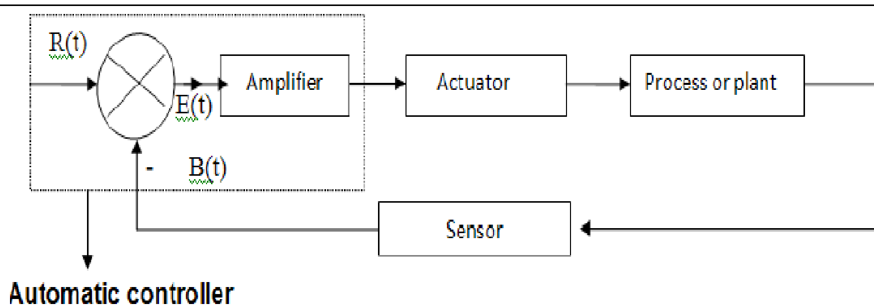
So, $C_{ss} = 1$ and $C_t(t) = -e^{-\frac{t}{RC}}$ **01 Mark- Css, Ct(t)**

The Response is shown in fig.



01 Mark for Response curve

d)	**State the concept of neutral zone & proportional band.**	**04**	
Ans.	**Neutral Zone:** In virtually any practical implementation of the two – position controller, there is an overlap as e_p increases through zero or decreases through zero, In this span, no change in controller output occurs. Fig shows p versus e_p for ON-OFF Controller. Until an increasing error changes by Δ e_p above zero, the controller output will not change state. In decreasing it must fall Δ e_p below zero before the controller changes to the 0% rating.  **Proportional Band:** Proportional band is defined as the amount of change in the controlled variable required to drive the loop 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. Which specifies the percentage error that result in a 100% change in the controller output.	**02 Marks for Neutral Zone** **02 Marks for Proportional Band**	
e)	**Draw the diagram of potentiometer as error detector and describe its working.**	**04**	
Ans.			

	 **Explanation :** DC Motor control systems potentiometers can be used as position feedback as shown . This type of arrangement allows comparison of two remotely located shaft positions. The output voltage is taken across the variable terminals of the two potentiometers. Output of this differential potentiometer is =Ks[θr(t) – θL(t)] This is then is fed to DC Amplifier, which is further amplifying the armature current of the DC Motor. The motor, in turn moves and with it the shaft connected to the load potentiometer in such a way as to make the output voltage zero. That is the output (Load) potentiometer shaft moves in accordance with the shaft of the input(reference) potentiometer.	**02 Marks Diagram** **02 Marks Explanation**	
Q4 A)	**Attempt Any THREE**		**12**
a)	**Draw block diagram of Process Control System& explain each blocks.**	**04**	
	 **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	**02 Marks Diagram** **02 Marks Explanation**	

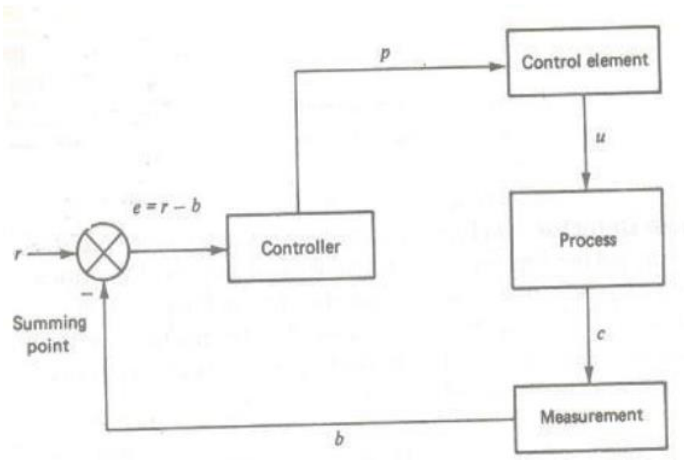
error detector Sensor is present in f/b path of close loop system.

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.

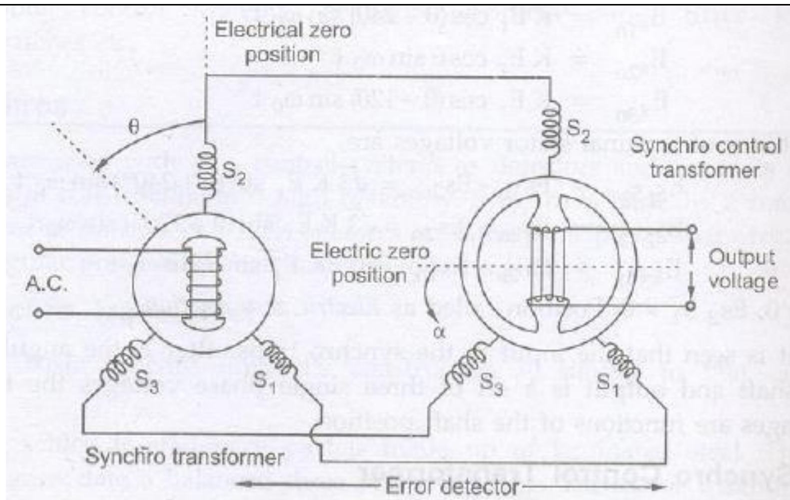
3) Controller: It generates the correct signal which is then applied to the final control element. Controller output is denoted by "p".

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".

b)	**For the given transfer function** $T.F. = \dfrac{S+8}{S(S+4)S^2+6S+25)}$ **Find i) Poles, ii)Zeros, iii)Characteristics equation & iv) order of the system**	**04**	
Ans.	**1) Poles:** We can get poles from equations in the denominator 1)$(s^2+6s+25)=0.$ For the quadratic equation $ax^2+bx+c=0$, the poles are = $\frac{-b\pm\sqrt{b^2-4ac}}{2a} = \frac{-6\pm\sqrt{6^2-4.1.25}}{2.1}$= i.e. - $\frac{-6\pm\sqrt{-64}}{2} = \frac{-6\pm 8j}{2}$ = –3± 4j 2) (s + 4) = 0 So, S = – 4 3) s = 0 Therefore poles are **0, –4, –3+ 4j & –3–4j** **2)Zeros:** We can get zeros from equation in the numerator So for (s+8) equation we can get roots by comparing it with zero. **(s + 8) = 0** So zeros i.e. roots of the equation are **–8** **3)Characteristic equation:** $s(s+4)(s^2+6s+25)$ = 0 **4)Order of the system:** It is highest power of 'S' at denominator of closed loop T.F. So in this equation order of system is '4'.	**01 Mark** **01 Mark** **01 Mark** **01 Mark**	
c)	**State two advantages and disadvantages of frequency domain analysis (response).**	**04**	
Ans.	**Advantages :** 1)It is easy to get a frequency response in laboratory with good accuracy	**01 Mark each (any two advantages)**	

	2)It is useful to determine the transfer function of complicated system, which can not 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. 5)With the increased use of digital computers and available software's, it is not used for analysis	**01 Mark each (any two disadvantages)**	
d)	**Draw the diagram of synchro as error detector & describe its working**	**04**	
Ans.	**Diagram of Synchro as error detector**		

<table>
<tr><td></td><td>

Working:

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.

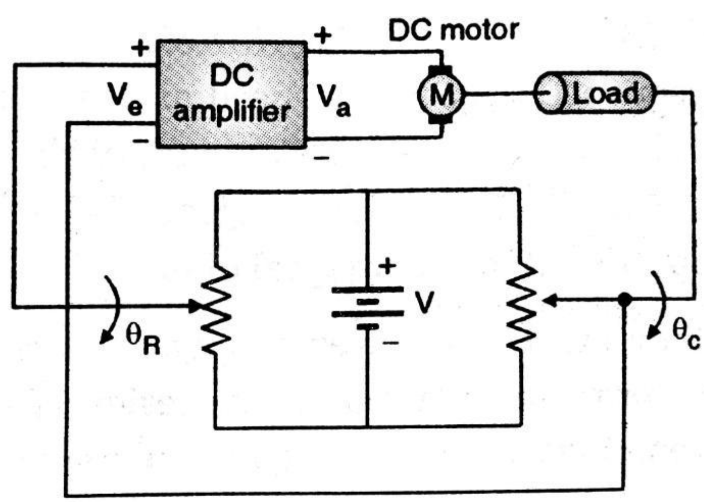
The output of the Synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils Circulating currents of same phase but different magnitude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

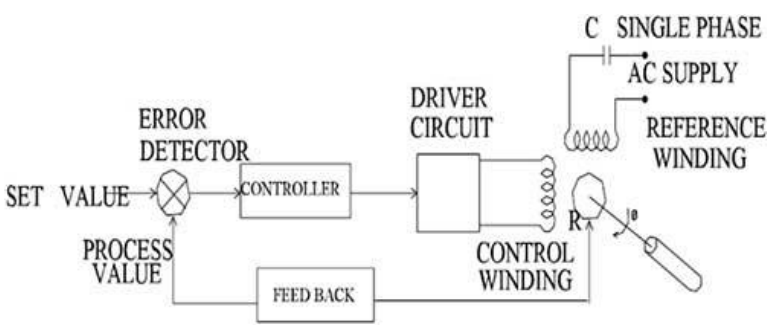
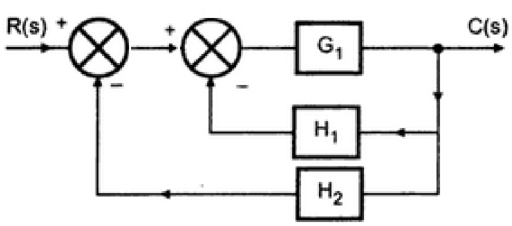
$$e_0(\mathrm{t}) = \bar{V_r}\ \sin \bar{\omega} t + \cos\bar{\phi}$$

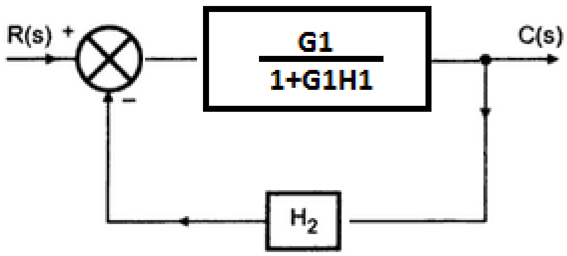
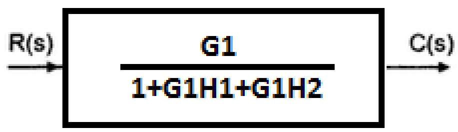
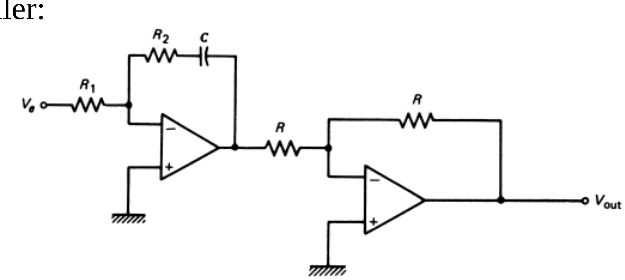
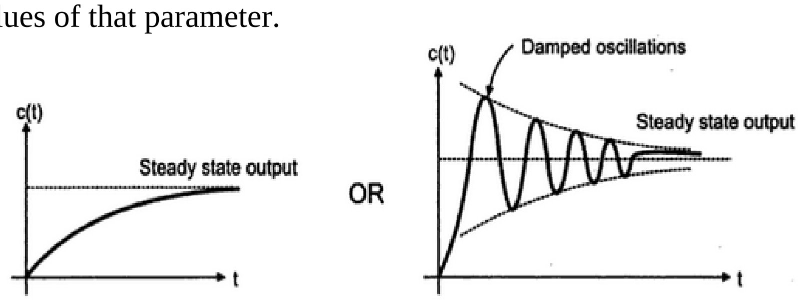
where Vr sin wt = input voltage to the transmitter rotor and ϕ is the angular difference between both rotors. When ϕ=90 both rotors are perpendicular to each other and the output voltage is zero This position is called electrical zero and is used as reference position.</td><td>**02 Marks Diagram**

02 Marks for relevant Explanation</td><td></td></tr>
<tr><td>**Q4 B)**</td><td>**Attempt any ONE**</td><td></td><td>**06**</td></tr>
<tr><td>**a)**</td><td>**For the given by differential equation**
$\frac{d^2y}{dt^2} + 2\frac{dy}{dx} + 4\,y(t) = 4\,x(t).$</td><td>**06**</td><td></td></tr>
</table>

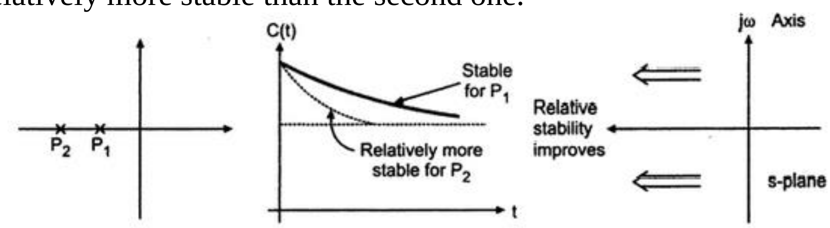
	Where y =o/p & x = i/p **Find i) Settling Time ii) Rise Time iii) Peak Time iv) Peak overshoot**		
Ans.	Taking Laplace transform for zero initial condition, we get, S^2 Y(s) + 2S.Y(s) + 4YS = 4.X(s) i.e. (S^2 + 2S + 4) Y(s) = 4.X(s) $\frac{Y(s)}{X(s)} = \frac{4}{S^2 + 2S + 4}$ Comparing equation with standard equation, $\frac{C(s)}{R(s)} = \frac{Wn^2}{S^2 + 2.\xi.Wn.S + Wn^2}$, We get, $Wn^2 = 4$, So, Wn = 2 rad /s $2.\xi.Wn = 2$ So, ξ= 0.5 Wd = Wn $\sqrt{1-\xi}$ $Wd = Wn\sqrt{1-\xi^2}$ =$2\sqrt{0.75}$ = 1.732 rad/sec Ideally the above 4 listed parameters can be given as, i) Rise time is given by tr =$\frac{\pi - \beta}{Wd}$,where $\beta = \frac{\sqrt{1-\xi^2}}{\xi}$ $\beta = \frac{\sqrt{1-\xi^2}}{\xi} = \frac{\sqrt{1-0.25}}{0.5} = \frac{0.866}{0.5}$ = 1.732 tr = $\frac{\pi - \beta}{Wd}$ $=\frac{3.14-1.732}{1.732} = 0.8129\ sec$ ii) Peak Time is given by $t_p = \frac{\pi}{Wd}$ $=\frac{3.14}{1.732} = 1.81\ sec$	 **Zeta- 01 Mark** **Wd -01 Mark** **Tr -01 Mark** **Tp- 01 Mark**	

	iii) Max overshoot is given by $Mp\% = 100 \times e^{-\frac{\pi\xi}{\sqrt{1-\zeta^2}}}$ $Mp = 100 \times e^{-\frac{\pi.\xi}{\sqrt{1-\xi^2}}} = 100 \times e^{-\frac{3.14 \times 0.5}{\sqrt{1-0.25}}} = 100 \times e^{-\frac{1.57}{0.866}}$ $Mp = 100 \times e^{-1.81} = 16.36\ \%$ iv) Settling time is given by $ts = \frac{4}{\zeta.Wn} = \frac{4}{0.5*2} = 4\ sec$	**Mp- 01 Mark** **Ts- 01 Mark**	
b)	**Draw the block diagram of DC and AC servo system & describe its working principle.**	**06**	
Ans.	 Fig- DC Servo system **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.	**01 Mark DC Servo motor diagram** **02 Mark DC Servomotor explanation**	

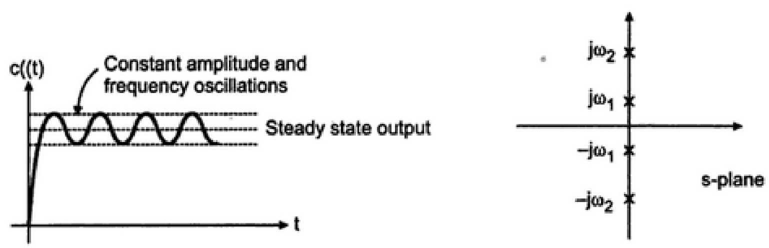
	In DC servo system potentiometer has two input i.e one is reference input and another is actual load position. Potentiometer finds the error between two positions. The errors between two positions is given to DC amplifier which amplify the error. Output of DC amplifier is given to DC motor &finally DC 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. **A.C servomotor** :  The symbolic representation of an **A.C servomotor** with control system component is shown in figure - 6. The reference winding of **A.C servomotor** is excited by a constant voltage source with frequency of 50Hz. The speed of **A.C servomotor** is controlled by controlling the control voltage. The error output of error detector is fed to PI controller, due to the error, controller take control action (i.e. to give control voltage) to firing circuit. The firing circuit generates the pulse's to rotate the motor at required speed.	**01 Mark AC Servomotor diagram** **02 Marks AC servomotor explanation**	
05	**Attempt any FOUR**		**16**
a)	**Determine the overall transfer function of the given block diagram:** 	**04**	
Ans.	**Step 1:Minimizing the internal feedback loop [G1 & H1]**		

	 **Step 2:Minimizing the feedback loop [G1 & H1]**  $\frac{C(s)}{R(s)} = \frac{G1}{1+G1H1+G1H2}$	**02 marks** **02marks**	
b)	**Draw electronic PI controller. State the components used & write equation.**	**04**	
Ans.	PI controller:  Components used: 1. Integrator **2.** Inverter Equation: $$V_{out} = \left(\frac{R_2}{R_1}\right) V_e + \left(\frac{R_2}{R_1}\right) \frac{1}{R_2 C} \int_0^t V_e \, dt + V_{out}(0)$$	**01 mark** **01 mark** **02 marks**	
c)	**Describe the concept of stability with respect to absolute, relative and marginal stability.**	**04**	
Ans.	**Absolute Stability:** A linear time invariant system is said to be absolutely stable w.r.t. a parameter if the system is stable for all values of that parameter.  **Relative Stability:** The system is said to be relatively more stable	**01 mark**	

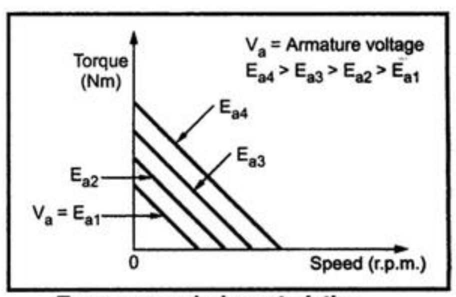
<table>
<tr><td></td><td>on the basis of settling time. If the settling time for a system is less than that of another system then the former system is said to be relatively more stable than the second one.



Marginally Stable: If all roots of characteristic equation has a negative real part except one or more non repeated roots on jw axis, the system is marginally stable system. The zero input response of such a systems is bounded but non asymptotic i.e. c(t) doesn't tend to zero as t→∞.

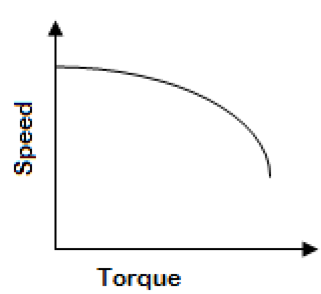

</td><td>**1½ marks**

1½ marks</td><td></td></tr>
<tr><td>**d)**</td><td>**Draw characteristics of DC servomotor. In what way it is different from normal DC motor ?**</td><td>**04**</td><td></td></tr>
<tr><td>**Ans.**</td><td>Torque-Speed characteristic of DC servomotor:



Torque-speed characteristics armature controlled d.c. servomotor

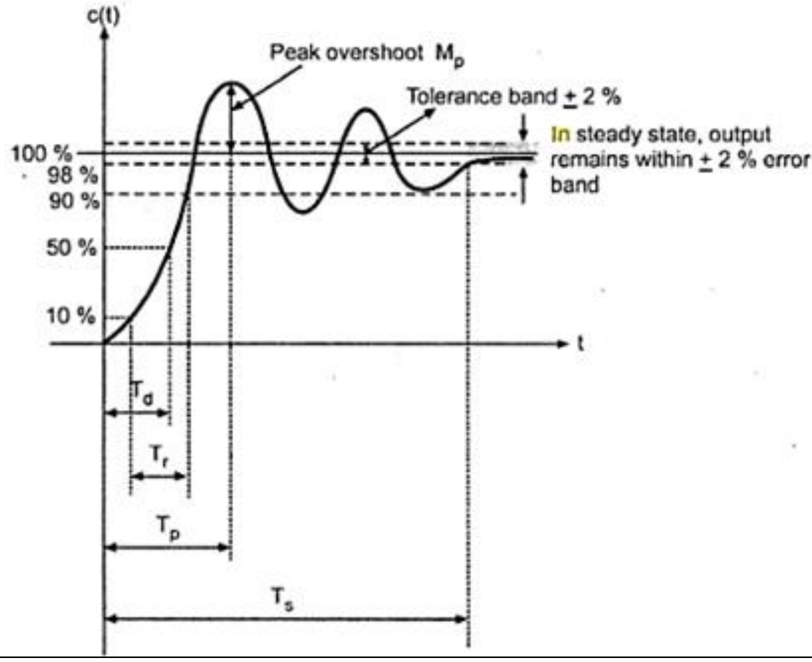
Torque-Speed characteristic of DC motor:

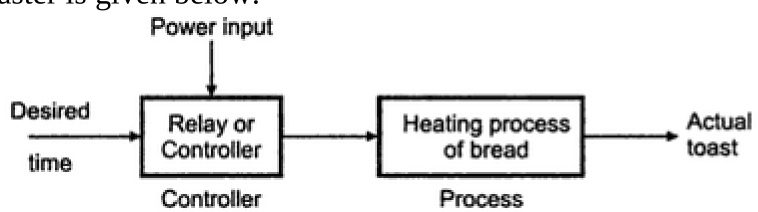
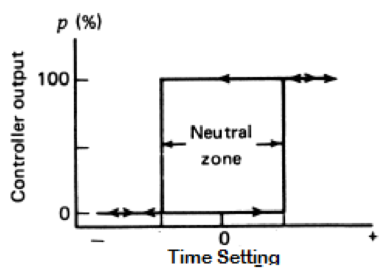


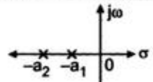
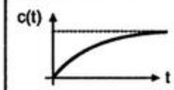
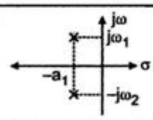
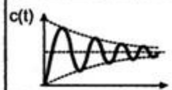
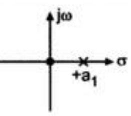
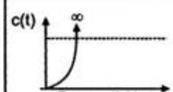
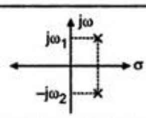
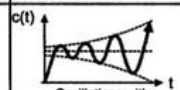
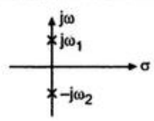
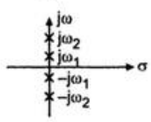
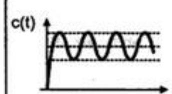
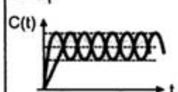
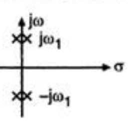
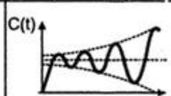
Difference over normal DC motor:

1. They produce high torque at all speeds including zero speed.
2. They are capable of holding a static position.</td><td>**01 mark**

03 marks(Any three points)</td><td></td></tr>
</table>

	3. They are able to accelerate and de-accelerate quickly. 4. They are able to return to a given position time after time without drift. 5. It has low inertia hence able to reverse the direction quickly.		
e)	**Draw the labeled time response of second order under damped control system.**	**04**	
Ans.	Time response of second order under damped control system:  	**02 marks for response** **02 marks for labeling**	
f)	**A second order system is given by** $$\frac{C(S)}{R(S)} = \frac{25}{S^2 + 6S + 25}$$ **Find, (i) ζ (ii) Wn (iii) tp (iv) ts**	**04**	
Ans.	Comparing the above equation with the standard form below, $W_n^2 = 25$, hence, $W_n = \sqrt{25} = 5$ rad/sec. $2\zeta W_n = 6$ $\zeta = 0.6$ $W_d = W_n\sqrt{(1 - \xi^2)} = 4$ rad/s . Peak Time $T_p = \pi/W_d = \pi/4 = 0.785$ sec Settling Time $Ts = \frac{4}{\xi W_n}$ $Ts = \frac{4}{0.6x5} = 1.25$sec	**01 mark** **01 mark** **01 mark** **01 mark**	

	i) $\zeta = 0.6$ ii) $W_n = 5$ rad/sec iii) $T_p = 0.785$ sec iv) $T_s = 1.25$sec		
06	**Attempt any FOUR**		**16**
a)	**Whether toaster is open loop or closed loop system, justify it with the help of control action.**	**04**	
Ans.	Toaster is an open loop system. **Justification:** An open loop system doesn't have the feedback. Its output depends only on present input and not the past output. In toaster quality of toast depends upon the time for which the toast is heated. Depending on the time set by user, bread is heated. User itself has to judge the quality of toast and should decide the time for heating the toast. Hence the system is open loop. The block diagram of toaster is given below.  In toaster actuator is a relay. When user set the time setting the controller will continuously monitoring the timer setting when it reaches to the required time, it will disconnect the supply to heating coils.  **(Note : Diagram of neutral zone is optional)**	**01 mark** **03 marks for relevant justification**	
b)	**Draw the diagram for stability of the system w.r.t. root location in S plane.**	**04**	
Ans.	**Stability of the system w.r.t. root location in S plane:**	**04 marks(Any four points)**	

Sr. No.	Nature of closed loop poles	Locations of closed loop poles in s-plane	Step response	Stability condition
1.	Real, negative i.e. in L.H.S. of s-plane		 Pure exponential	Absolutely stable
2.	Complex conjugate with negative real part i.e. in L.H.S. of s-plane		 Damped oscillations	Absolutely stable
3.	Real, positive i.e. in R.H.S. of s-plane (Any one closed loop pole in right half irrespective of number of poles in left half of s-plane)		 Exponential but increasing towards ∞	Unstable
4.	Complex conjugate with positive real part i.e. in R.H.S. of s-plane		 Oscillations with increasing amplitude	Unstable
5.	Non repeated pair on imaginary axis without any pole in R.H.S. of s-plane	 or  two non repeated pairs on imaginary axis.	 Frequency of oscillations = ω_1  Sustained oscillations with two frequency components ω_1 and ω_2	Marginally or critically stable Marginally or critically stable.
6.	Repeated pair on imaginary axis without any pole in R.H.S. of s-plane		 Oscillations of increasing amplitude	Unstable

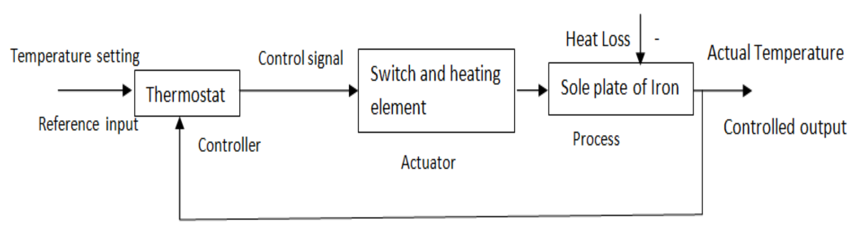
c) **Consider 4th order system with characteristic equation given by $s^4 + 2s^3 + 8s^2 + 4s + 3 = 0$. Determine the stability using Routh's criterion.** **04**

Ans.

s^4	1	8	3
s^3	2	4	
s^2	6	3	
s^1	3		
s^0	3		

03 marks

As there is no sign change in 1st column of Routh's array, hence system is stable. **01 mark**

d)	**Explain ON-OFF controller. Give Example.**	**04**	
Ans.	**ON-OFF controller** is a two position discontinuous controlling mode. The mathematical equation of ON-OFF controller is given below. **Output Equation:** $P = 0\,\%, \quad e_p < 0$ $100\,\% \quad e_p > 0$ Where, P is the controller output and e_p is the error signal. **OR** ON-OFF controller – it is simplest and cheapest type of discontinuous type of controller. In this controller when measured value is less than SP 100% controller output results. When it is more than SP controller output is zero. **Explanation:** In automatic electric iron, a resistive heating element is used to generate heat. A thermostat is used as controller to control the temperature. The reference input is the desired temperature setting on the thermostat. The controlled output is the actual temperature of the electric iron. When the output temperature is less than the thermostat reference setting, the thermostat is actuated which, in turn, switches on the heating element. As a result, the temperature increases, and when it exceeds the thermostat setting (desired value of temperature) by a small amount, the heating element is turned off. The temperature then starts decreasing. When it falls below the thermostat setting by a small amount, the heating element is once again switched on. The heating cycle is thus repeated. The sole plate of the iron of which the temperature is to be controlled is the Process. The actuator is the heating element and the thermostat acts as the error detector and controller. Disturbance to the system is the heat loss due to radiation. **Diagram of Electric Iron as On-Off Controller:**  Block diagram of Electric Iron as On-Off Controller	**03 marks for ON-OFF controller brief explanation** **01 mark For example**	
e)	**A unity feedback system has** $G(s) = \dfrac{40(s+2)}{s(s+1)(s+2)}$ **Determine : (i) The type of system** **(ii) All error coefficients**	**04**	

Ans.	As there is only one root at origin, system is a type one system. **Error Coefficients:** $Kp = \lim_{s\to 0} G(s)H(s) = \lim_{s\to 0} \frac{40(s+2)}{s(S+1)(s+2)} = \infty$ $Kv = \lim_{s\to 0} s\ G(s)H(s) = \lim_{s\to 0} s\frac{40(s+2)}{s(S+1)(s+2)} = \lim_{s\to 0} \frac{40(s+2)}{(S+1)(s+2)} = 40$ $Ka = \lim_{s\to 0} s^2\ G(s)H(s) = \lim_{s\to 0} s^2\frac{40(s+2)}{s(S+1)(s+2)} = \lim_{s\to 0} s\frac{40(s+2)}{(S+1)(s+2)} = 0$	**01 mark** **01 mark** **01 mark** **01 mark**	