WINTER – 19 EXAMINATION

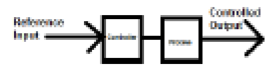
Subject Name: Control system **Model Answer** Subject Code **17538**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. 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 constantvalues may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
Q.1	**(A)**	**Attempt any THREE:**	**12-Total Marks**
	a)	**Compare open loop and closed loop systems.**	**4M**
	Ans:		**4M**

Basis For Comparison	**Open Loop System**	**Closed Loop System**
Definition	The system whose control action is free from the output is known as the open loop control system.	In closed loop, the output depends on the control action of the system.
Feedback loop	Non-feedback System	Feedback System
Construction	Simple	Complex
Reliability	Non-reliable	Reliable
Accuracy	Inaccurate	Accurate because of feedback.
Stability	Stable	Less Stable
Response	Fast	Slow
Linearity	Non-linear	Linear
Error correction	Not possible	possible
Bandwidth	Small	large
Examples	Traffic light, automatic washing machine, immersion rod, TV remote etc.	Air conditioner, temperature control system, speed and pressure control system, refrigerator, toaster.

Block Diagram		

	b)	**Define poles and zeros with respect to control system. Explain with example.**	**4M**

Ans: **4M**

Poles-The value of 'S', which make the transfer function infinite after substitution in the denominator of a T.F. are called poles of that T.F.

Zeros-The values of 'S' which make the T.F. zero after substituting in the numerator are called as 'zeros' of that T.F.

Example:

Assume transfer function of a system-

$$T.F. = \frac{2(S+2)}{S(S+4)}$$

Poles-The equation obtain by equating denominator to zero is,

$$S(S+4)=0$$

Therefore S=0 and S=-4

If these values are used in the denominator, the value of transfer function becomes infinity. Hence poles of this T.F. are S=0 and S=-4.

Zeros-The equation obtain by equating numerator to zero is,

$$2(S+2)=0$$

Therefore S= -2

If this value is used in the numerator, the value of transfer function becomes zero. Hence zero of this T.F. is S=-2.

	c)	**State the advantages and disadvantages of Routh's stability criterion.**	**4M**

Ans: **4M**

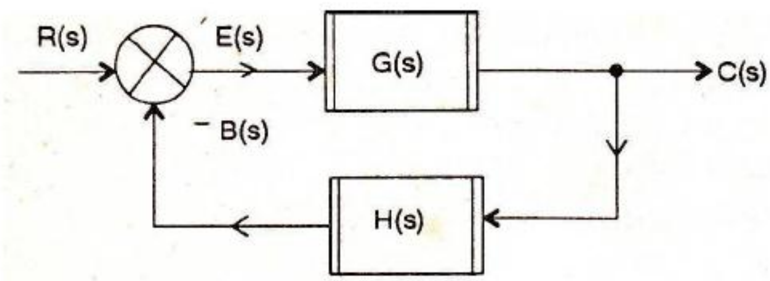
Advantages of Routh's array:

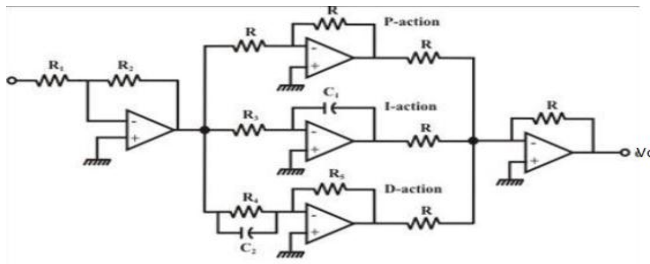
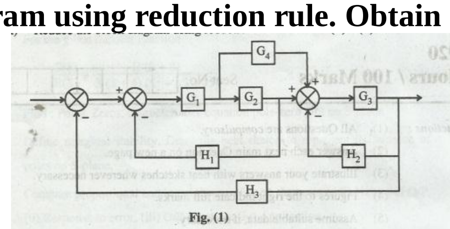
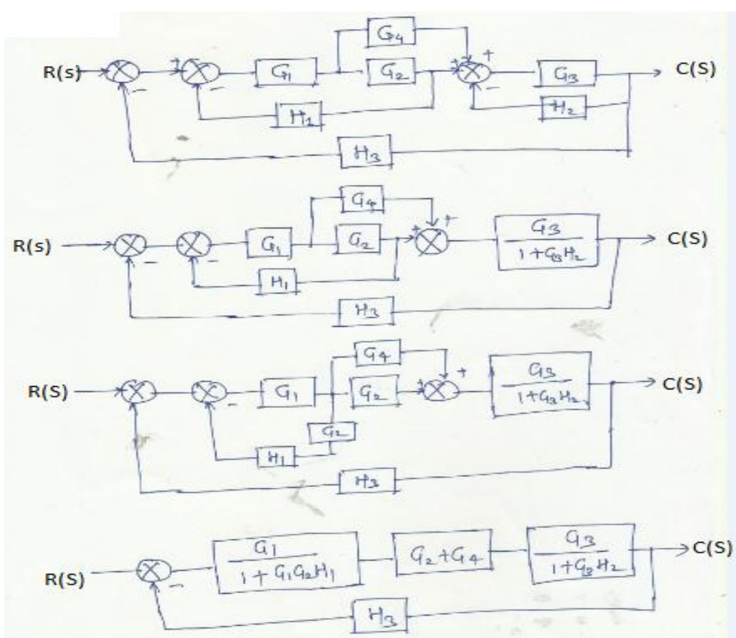
i. Simple criterion that enables to determine the number of closed loop poles which lie in right half of S-plane without factorizing the characteristic equation.
ii. Without actually solving characteristic equation, it tells whether or not there are positive poles in a polynomial equation
iii. By seeing the sign changes in the first column, it can be analysed whether system is stable or not.
iv. It tells the number of poles present on imaginary axis i.e. it tells about critical stability.

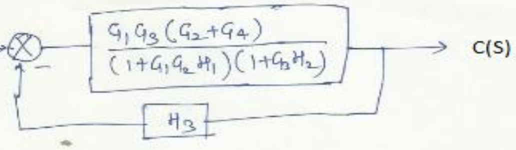
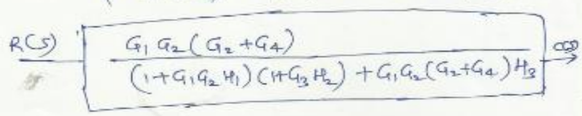
Disadvantages of Routh"s array:

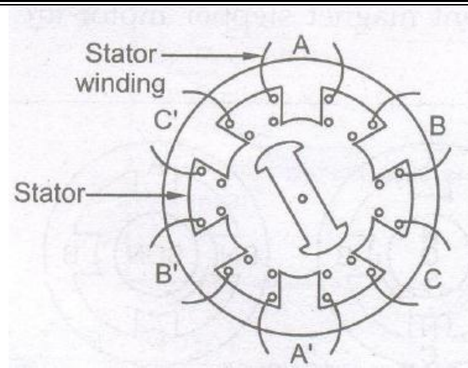
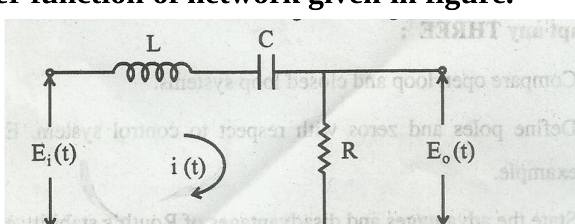
i. Cannot find out the value of poles.
ii. It is not a sufficient condition for stability.
iii. Lengthy procedure

	d)	**Define 'Electrical Zero position of Synchro' and give its applications.**	**4M**

	Ans:	When the rotor positions of the two synchro are perpendicular to each other, the voltage generated across the terminals of the rotor of control transformer is zero. This position is called as Electrical zero position of control transformer. **Application:** 1. As an error detector 2. As a Position transducer	**2M** **2M**
(B)		**Attempt any <u>ONE</u>:**	**6-Total Marks**
	a)	**Define tranfer function. Derive the equation of tranfer function for closed loop system.**	**6M**
	Ans:	Transfer Function is defined as the ratio of Laplace transform of Output to that of Laplace transform of input under the assumption that all initial conditions are zero. **Block diagram:** (for negative feedback system)  <u>Derivation</u>: $G(s) = \frac{C(s)}{E(s)}$ $E(s) = \frac{C(s)}{G(s)}$ $C(s) = E(s) \text{ x } G(s)$ $B(s) = C(s) \text{ x } H(s)$ $E(s) = R(s) - B(s)$ (for negative feedback) .... [.I.] Substitute for E(s) & B(s) in [.I.] $\frac{C(s)}{G(s)} = R(s) - C(s)\,H(s)$ $C(s) \; \{\frac{1}{G(s)+H(s)}\} = R(s)$ $C(s)\,\frac{[1+G(s)H(s)]}{G(s)} = R(s)$ Transfer Function: $\boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)*H(s)}}$	**Defination-2M** **Derivation-4M**
	b)	**Draw and explain electronic PID controller using OP- Amp. List its two advatages.**	**6M**

	Ans:	**Diagram**  **Explanation:** PID is combination of 3 control action- proportional + integral + derivative. The proportional corrects instances of error, the integral corrects accumulation of error, and the derivative takes the corrective action in anticipation. The effect of the derivative is to counteract the overshoot caused by P and I. When the error is large, the P and I will push the controller output. This controller response makes error change quickly, which in turn causes the derivative to more aggressively counteract the P and the I. **Advantages of PID controller:** 1. Offset error is eliminated. 2. Settling time is less. 3. Provides a fast response	**Diagram-2M** **Explanation-2M** **Advantage-2M**
Q.2		**Attempt any <u>TWO</u>:**	**16-Total Marks**
	a)	**Reduce the block diagram using reduction rule. Obtain C(S) /R(S).**  Fig. (1)	**8M**
	Ans	 	**6M(1M each formula applied)**

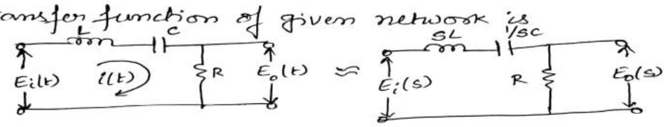
		 $= \dfrac{\frac{G_1G_3(G_2+G_4)}{(1+G_1G_2H_1)(1+G_3H_2)}}{1+\frac{G_1G_2(G_2+G_4)H_3}{(1+G_1G_2H_1)(1+G_3H_2)}}$ $= \dfrac{G_1G_3(G_2+G_4)}{(1+G_1G_2H_1)(1+G_3H_2)+G_1G_2(G_2+G_4)H_3}$  $\dfrac{C(S)}{R(S)} = \dfrac{G_1G_2(G_2+G_4)}{(1+G_1G_2H_1)(1+G_3H_2)+G_1G_2(G_2+G_4)H_3}$	**2M- Final answer**
b)	**A system has G(S) H(S) = $\frac{K}{S(S+2)(S+4)(S+8)}$ where K is positive. Determine the range of 'K' for the system to be stable. Using Routh's criteria.**		**8M**
Ans		Characteristic equation $1+G(S)H(S)=0$ $1+\frac{K}{S(S+2)(S+4)(S+8)}=0$ — 1M $S(S+2)(S+4)(S+8)+K=0$ $(S^2+2S)(S^2+8S+4S+32)+K=0$ $(S^2+2S)(S^2+12S+32)+K=0$ $S^4+12S^3+32S^2+2S^3+24S^2+64S+K=0$ $S^4+14S^3+56S^2+64S+K=0$ — 1M S^4 | 1 56 K S^3 | 14 64 0 S^2 | 51.42 K S^1 | $\frac{3291.43-14K}{51.42}$ S^0 | K — 4M From S^0, $K>0$ From S^1, $3291.43-14K>0$ $3291.43>14K$ $\frac{3291.43}{14}>K$ $235.102>K$ Range of values of K, $0<K<235.102$ — 2M.	**Characteristic equation-2M,** **Rouths aaray-4M,** **Range-2M**
c)	**Describe working of variable reluctance type stepper motor with suitable diagram and write applications of stepper motor.**		**8M**
Ans	**Diagram:**		**Diagram-3M**

		 **Construction :** The figure above represents a variable reluctance stepper motor with single stack whose stator is wound for 3 phases. The stator has six salient poles or teeth with concentrated exciting windings around each one of them. The rotor is made up of slotted steel laminations. It has 2 salient poles without any exciting windings. The coils of the driving circuit are wound around opposite poles such that they are connected in series. The three phases are energized from a DC source with the help of switches. **Working:** When any one phase is excited by the closing of the switch in series, the corresponding poles act as north and south poles. The rotor between them adjusts itself in minimum reluctance position between stator and rotor. When the next phase is excited by the closing of the second switch keeping the previous phase excited, the magnetic axis of the stator shifts by 30 degrees. So the rotor will also rotate through 30 degree step to attain the new minimum reluctance position. By successively exciting the three phases in specific sequence, the motor is made to complete one revolution. **Application of stepper motor-** 1. In floppy Disc driver 2. Computer printer 3. In automation systems 4. Robotics 5. Image scanner 6. Material handling	**Explaination-3M** **Application of stepper motor(any four)-2M**
Q.3		**Attempt any FOUR :**	**16-Total Marks**
	a)	**Find the transfer function of network given in figure.**  **Fig. (2)**	**4M**

Ans:

Sol

Transfer function of given network is



Applying KVL we can write

$$E_i(t) = L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)\,dt + i(t)R \quad \text{--- (1)}$$

$$E_o(t) = R\,i(t) \quad \text{--- (2)}$$

Taking laplace of equation (1) and (2)

$$E_i(s) = sL\,I(s) + \frac{1}{sC}I(s) + RI(s) \quad \text{--- (3)}$$

$$E_o(s) = R\,I(s)$$

$$E_i(s) = I(s)\left[sL + \frac{1}{sC} + R\right]$$

$$= I(s)\left[\frac{s^2LC + 1 + sCR}{sC}\right]$$

$$\frac{E_o(s)}{E_i(s)} = \frac{R\,I(s)}{I(s)\left[\frac{s^2LC + 1 + sCR}{sC}\right]}$$

$$\frac{E_o(s)}{E_i(s)} = \frac{sCR}{s^2LC + sCR + 1}$$

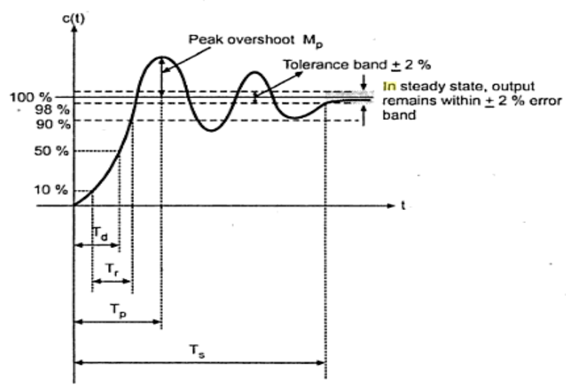
2 Marks for KVL equations

2 Marks for solving Transfer function

b) **Draw labelled time response of 2nd order control system and define rise time and settling time.** **4M**

Ans: **Time response of 2nd order control system**

2 Marks for Time response



Definition:

Rise Time: Time required for the response to rise from 10% to 90% of the final value for overdamped systems and 0% to 100% of the final value for underdamped systems.

Settling time: Time required for the response to decrease and stay within specified percentage of its final value and within tolerance band (usually 2%).

1 Marks for each definition

c) **Determine stability of the system using Routh's criterion.** **4M**

$$S^4 + 6S^3 + 26S^2 + 56S + 80 = 0.$$

Ans:

The stability by Routh's criterion

$$s^4 + 6s^3 + 26s^2 + 56s + 80 = 0$$

s^4	1	26	80
s^3	6	56	0
s^2	16.66	80	
s^1	27.21	0	
s^0	80		

As there is no sign change,
∴ system is stable.

3 Marks for solving Rouths criterion

1Marks for conclusion

d) **Explain the procedure to draw Bode plot.** **4M**

Ans: **Procedure to draw Bode plot:**

1. Express given G(s) H(s) into time constant form and sinusoidal TF
2. Find out the factors in it
3. Draw a line of 20 Log K dB
4. Draw a line of appropriate slope representing poles and zeros at the origin, passing through intersection point ω=1 and 0dB
5. Shift this intersection point on 20 Log K line and draw parallel line to the line draw in step 3 this is addition of constant K and no. poles or zeros at the origin.
6. Change the slope of this line at various corner frequencies by appropriate value and draw line with resultant slope. Continue this line till it intersects next corner frequency line. Change the slope and continue.
7. Prepare the phase table and obtain the table of ω and resultant phase angle Φ_R by actual calculation. Plot these points and draw the smooth curve obtaining the necessary phase angle plot.

4 Marks for proper Procedure

e) **(i) Define : (1) Offset, (2) Proportional band, (3) Neutral zone.**
(ii) List control actions. **4M**

Ans:

i) **Offset:** The proportional controller produces a permanent residual error in the controlled variable, when a change in load occurs. This is referred to as offset.

ii) **Proportional Band:** Proportional band is defined as the amount of change in the input error 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.

iii) **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.**

3 Marks for definition

ii) Control actions

1. Discontinues Mode
   ON-OFF controller
2. Continuous Mode

1 Marks for control actions

		i)Proportional (P)controller ii)Derivative (D)controller iii)Integral (I)controller 3. Composite controllers i)Proportional +Integral (PI)controller ii)Proportional +Derivative (PD)controller iii)Proportional +Integral +Derivative (PID)controller	
Q.4	**(A)**	**Attempt any THREE:**	**12 Total Marks**
	(a)	**T.F second order system is given by** $\frac{C(S)}{R(S)} = \frac{64}{S^{2}+5S+64}$ **, find T_S and M_P for unit step input.**	**4M**
	Ans:	$\frac{C(s)}{R(s)} = \frac{64}{s^2+5s+64}$ T.F of second order system is $\frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} \Rightarrow \frac{64}{s^2+5s+64}$ $\therefore \omega_n^2 = 64$, $\omega_n = \sqrt{64} = 8$ rad/sec $\Rightarrow 2\xi\omega_n = 5$ $\xi = \frac{5}{2\omega_n} = \frac{5}{2\times 8} = 0.312$ $\therefore T_s = \frac{4}{\xi\omega_n} = \frac{4}{0.312\times 8} = 1.60$ sec $\therefore M_p = e^{-\xi\pi/\sqrt{1-\xi^2}} \times 100$ $= e^{-0.312\pi/\sqrt{1-0.312^2}} \times 100$ $= e^{-0.980/0.950} \times 100$ $M_p = 0.356 \times 100 = 35.64\%$	**1 Marks for finding ξ value** **1 Marks for T_s** **2 Marks for M_p**

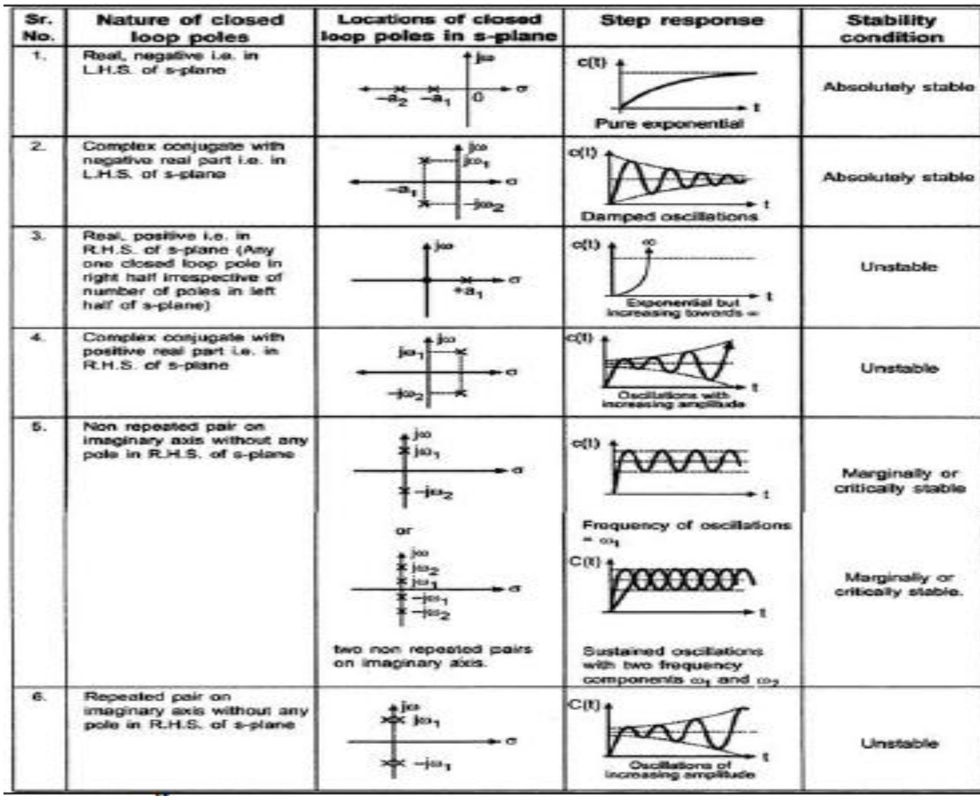
(b) **Define stability. Draw the location of poles for stable, unstable, critically stable system.** **4M**

Ans

Stability : A linear time invariant system is set to be stable if following conditions are satisfied.

i. When the system is excited by a bounded input the output is also bounded and controllable.
ii. In the absence of input output must tend to zero irrespective of the initial conditions.

1 Marks for Stability



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

Note: Any relevant diagram of s-plane with root location in both plane and imaginary axis may be considered.

3 Marks for location of poles

(c) **Describe the principle of ON – OFF controller with its one application in detail.** **4M**

Ans

ON-OFF controller (or) two position controller

2 Marks for Principle

1) The ON-OFF controller is a type of controller in which a controller output is changed to maximum or minimum value depending upon whether the measured value is greater or less than the set point.
2) It is the simples and cheapest mode of action, hence commonly used in industrial and domestic control systems.
3) The controller output is given by
   %P = 0 % , $e_p < 0$
   %P = 100 %, $e_p > 0$
   Where e_p is input error, p is controller output and e = r – b where r = set point and b = measured or actual value
4) When the measured variable is below the set point, controller is ON and output is maximum. When the measured variable is above the set point the

2 Marks for any one relevant application

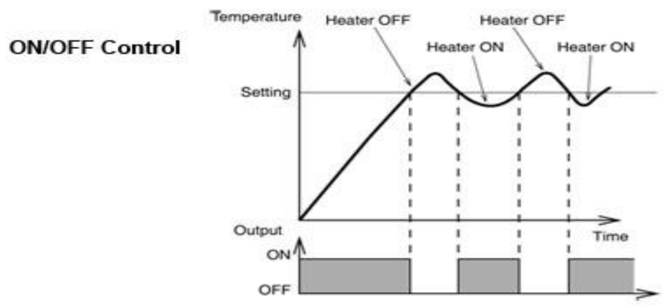
controller is OFF and output is minimum.

Application (any relevant application related to ON-OFF controller carry 2 marks)

Air Conditioner

In air conditioning system, when the temperature falls below a certain reference level, the error is positive the output is maximum i.e. 100 % controller output will stop the air supply to the air conditioner.

When the temperature rises above the certain reference level, the error will be negative i.e. output is zero . Now the controller output will start the electric supply to air conditioner.



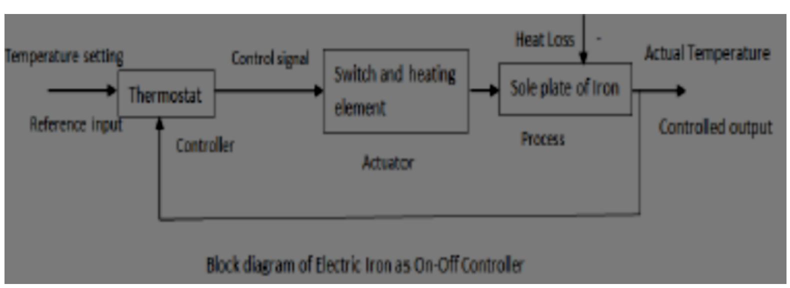
OR

Electric Iron:

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.

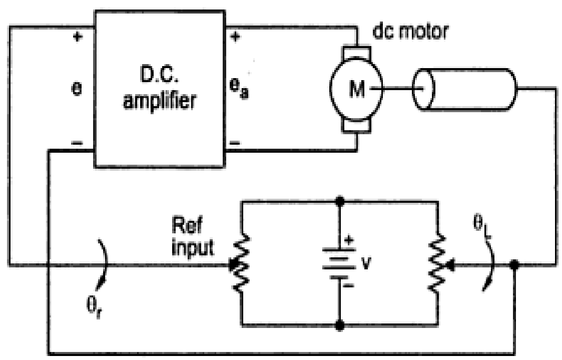
The sole plate of the iron of which the temperature is to be controlled is the Process. The actuator is the heating element and the thermostat acts as the error detector and controller. Disturbance to the system is the heat loss due to radiation.

Diagram of Electric Iron as On-Off Controller:



Block diagram of Electric Iron as On-Off Controller

	(d)	**Describe potentiometer as error detector with neat sketch.**	**4M**
	Ans	**Explanation :**	**2 Marks for**

<table>
<tr><td></td><td></td><td>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 the input (reference) potentiometer.

</td><td>Description

2 Marks for sketch</td></tr>
<tr><td></td><td>(B)</td><td>Attempt any ONE:</td><td>6M</td></tr>
<tr><td></td><td>(a)</td><td>A unity feedback system has $G(S) = \frac{10(S+1)}{S(S+2)(S+5)}$. Calculate the error coefficients K_p, K_v, K_a and steady state error, where r(t) = 3+10t.</td><td>6M</td></tr>
<tr><td></td><td>Ans</td><td>Sol.
Since unity feed back system $\therefore H(S) = 1$
Error coefficients are K_p, K_v, K_a.
$\because G(S) = \frac{10(S+1)}{S(S+2)(S+5)}$
$G(s) = \frac{10(1+S)}{S\,2(1+0.5S)\,5(1+0.2S)}$
$\therefore G(s) = \frac{(1+S)}{S(1+0.5S)(1+0.2S)}$
$\therefore K_p = \lim_{S\to 0} G(S)H(S)$
$= \lim_{S\to 0} \frac{(1+S)}{S(1+0.5S)(1+0.2S)} = \infty$
$\therefore K_v = \lim_{S\to 0} S\,G(S)H(S)$
$= \lim_{S\to 0} \frac{S\cdot(1+S)}{S(1+0.5S)(1+0.2S)} = 1$
$\therefore K_a = \lim_{S\to 0} S^2 G(S)H(S)$
$= \lim_{S\to 0} \frac{S^2(1+S)}{S(1+0.5S)(1+0.2S)} = 0$</td><td>3Marks for error coefficients

3Marks for steady state error</td></tr>
</table>

Steady state error

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

Input $r(t) = 3 + 10t$

$$\therefore R(s) = \frac{3}{s} + \frac{10}{s^2}$$

$$e_{ss} = e_{ss_1} + e_{ss_2}$$

$$e_{ss_1} = \lim_{s\to 0} \frac{s \times \frac{3}{s}}{1+\frac{(1+s)}{s(1+0.5s)(1+0.2s)}\times 1}$$

$$= \frac{3}{1+\infty} = 0$$

$$e_{ss_2} = \lim_{s\to 0} \frac{s \times \frac{10}{s^2}}{1+\frac{(1+s)}{s(1+0.5s)(1+0.2s)}\times 1} = \lim_{s\to 0} \frac{10}{s\left[1+\frac{(1+s)}{s(1+0.5s)(1+0.2s)}\right]}$$

$$= \lim_{s\to 0} \frac{10}{s + \frac{s\,(1+s)}{s(1+0.5s)(1+0.2s)}}$$

$$= \frac{10}{0+1} = 10$$

$$\therefore e_{ss} = e_{ss_1} + e_{ss_2}$$

$$e_{ss} = 0 + 10 = \underline{10}$$

	(b)	**Draw Bode plot for a control system having unity feedback and open loop transfer function as G(S) =** $\frac{80}{S(S+2)(S+20)}$ **.**	**6M**

Ans

Step 1 : Convert the G(s)H(s) in time constant form

Since H(s) = 1

$$G(s)H(s) = \frac{80}{s(s+2)(s+20)}$$

$$= \frac{2}{s(1+\frac{s}{2})(1+\frac{s}{20})}$$

Magnitude Plot (Factors)

1) K = 2, | M | = 20 log K = 6.02 dB

It is a straight line of magnitude 6 dB parallel to X axis (0 dB slope).

2) Pole at origin 1/s :

It is a straight line of magnitude +20 dB at origin and a constant slope -20 dB/decade cutting X axis at ω= 1

3) $\frac{1}{1+\frac{s}{2}}$

0 dB magnitude upto corner frequency ω_{c1} = 2 rad/sec and line of slope is -20 dB/decade from ω_{c1} = 2 rad/sec.

4) $\frac{1}{1+\frac{s}{20}}$

0 dB magnitude upto corner frequency ω_{c2} = 20 rad/sec. From ω_{c2} = 20 rad/sec straight line of slope is -20 dB/decade.

Resultant Magnitude

Resultant at origin = add magnitudes of all individual plots at origin

= 6+20+0+0 =26 dB

2Marks for calculating Magnitude Plot

2Marks for calculating phase Plot

2Marks for graph Plotting

Slope at Origin = 0-20+0+0= -20 dB/decade

The resultant is having a magnitude of 26 dB and proceeds parallel to -20dB/decade upto

ω_{c1}=2 rd/decade

At ω_{c1}=2, another slope of -20 dB/decade is added. Then new slope = -20+(-20) = -40 dB/dec upto ω_{c2} = 20

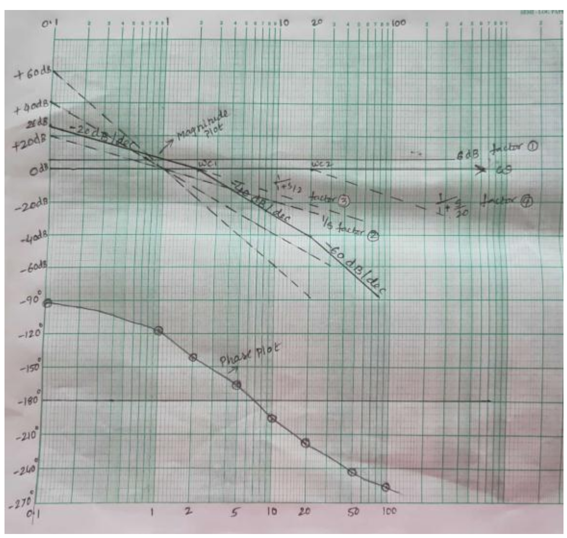
At ω_{c2}=20, new slope = -40+(-20) = -60 dB/decade

Phase plot :

Resultant $\emptyset = \emptyset_1 + \emptyset_2 + \emptyset_3 + \emptyset_4$

$$\emptyset_1 = 0° \quad \emptyset_2 = -90° \quad \emptyset_3 = -tan^{-1}\left(\frac{\omega}{2}\right) \qquad \emptyset_4 = -tan^{-1}\left(\frac{\omega}{20}\right)$$

ω	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ
0.1	0	-90°	-2.86°	-0.286°	-93.14°
1	0	-90°	-26.56°	-2.86°	-119.42°
2	0	-90°	-45°	-5.71°	-140.71°
5	0	-90°	-68.19°	-14.03°	-172.22°
10	0	-90°	-78.69°	-26.56°	-195.25°
20	0	-90°	-84.28°	-45°	-219.28°
50	0	-90°	-87.13°	-68.19°	-245.89°
100	0	-90°	-88.85°	-78.69°	-257.54°

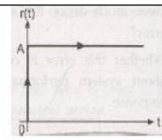
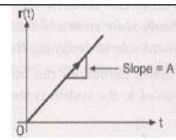
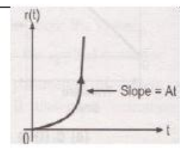
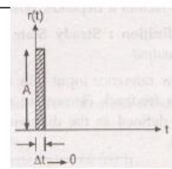


Q.5		**Attempt any FOUR:**	**12Total Marks**

(a) Name the standard test inputs. Draw then and given their Laplace transform. **4M**

Ans: The Standard test signals are : **4M**

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

Test Signal	Graphical representation	Laplace representation
Unit Step Input		$\frac{1}{s}$
Unit Ramp Input		$\frac{1}{s^2}$
Unit Parabolic Input		$\frac{1}{s^3}$
Unit Impulse		1

(b) Find the range of value of K so that system with following characteristics equation will be stable. $F(S) = S(S^2 + S+1) (S+4)+K = 0$. **4M**

Ans: The characteristics equation is given by,

$$s\,(s^2 + s + 1)\,(s + 4) + K = 0$$

$$(s^3 + s^2 + s)\,(s + 4) + K = 0$$

$$\text{i.e. } s^4 + 5.\,s^3 + 5.\,s^2 + 4.\,s + K = 0$$

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

S^4	1	5	K
S^3	5	4	0
S^2	4.2	K	0
S^1	$\frac{16.8-5K}{4.2}$		
S^0	K		

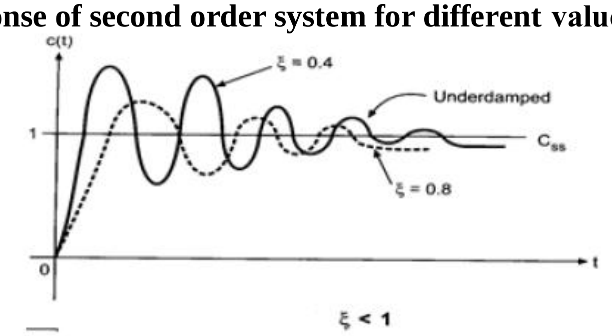
For stability all elements of 1st column should be positive.

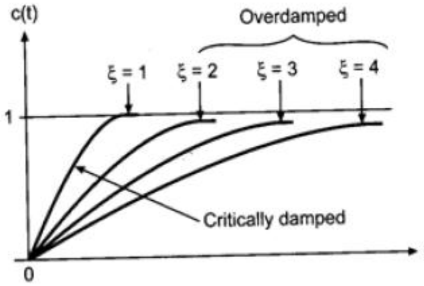
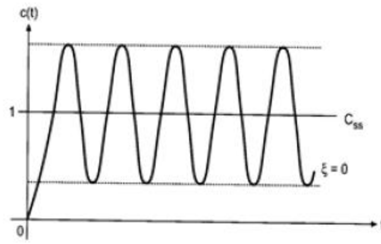
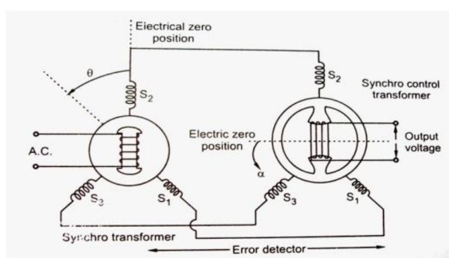
i.e. $\frac{16.8-5K}{4.2} > 0$ for S^1 row

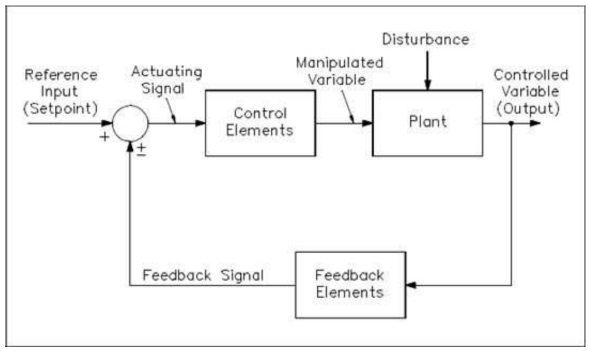
i.e. $K < \frac{16.8}{5}$

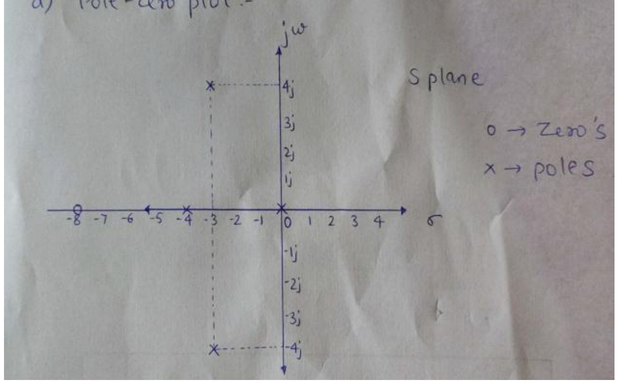
i.e. $0 < K < 3.36$

This is range of K for stable system.

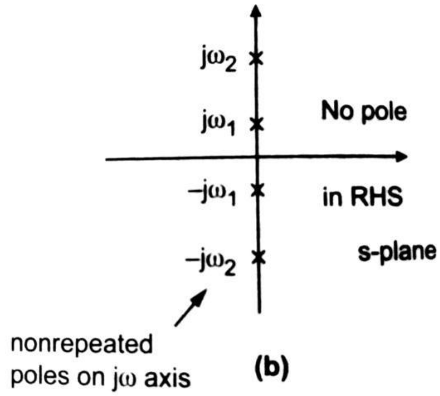
	(c)	**Define the following frequency response specification.** **(i) Response peak (ii) Bandwidth** **(iii) Cut off frequency (iv) Gain margin**	**4M**
	Ans:	**i) Response peak :** It is defined as the maximum value of magnitude of $\lvert M(jw) \rvert$. It is denoted by Mr. **(ii) Bandwidth :** It is 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. **(iii) 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. **(iv) 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	**1M for each correct definition**
	(d)	**Draw the transient response of second order system for different values of ξ (zeta).**	**4M**
	Ans:	**Transient response of second order system for different values of ζ (zeta) :**  	**4M**

		 $\xi \geq 1$  $\xi = 0$ Un-damped response	
	(e)	**Explain synchro as error detector with neat diagram.**	**4M**
	Ans:	**Diagram of synchro as error detector** Synchro as Error Detector  Punjab Edusat Society 26 **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:	**2M for diagram** **2M for explan ation**

		e0(t) =VrSin(ωt) +Cos(ϕ) where VrSin(ωt):input voltage to the transmitter rotor and ϕ is the angular difference between both rotors. When ϕ=90^0 both rotors are perpendicular to each other and the output voltage is zero. This position is called electrical zero and is used as reference position.	
	f)	**Draw and describe the block diagram of process control system.**	
		Block diagram of process control system consists of following blocks:-  **1.Plant or Process :** Plant or process is an important element of process control system in which variable of process is to be controlled. The Process means some manufacturing sequence. It has one variable or multivariable output. **2.Feedback element or Sensor :** The feedback element or sensor is the device which converts the output variable into another suitable variable which can acceptable by error detector. **3.Error detector :** The error detector compares between actual signal and reference input i.e. set point **.**The error detector is subtract summing points whose output is an error signal to controller for comparison and for the corrective action. **E(t)= r(t) b(t)** **4.Automatic controller :** The 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 :** The actuator is nothing but pneumatic or valve, a hydraulic motor or an electric motor, which produces an input to the plant according to the control signal getting from controller.	**2M for diagram** **2M for explan ation**
Q6.		**Attempt any FOUR:**	**16M**
	(a)	**For the given transfer function** $\frac{C(S)}{R(S)} = \frac{10(S+8)}{S(S+4)(S^2+6S+25)}$ **Find: Poles, Zero, Characteristics equation pole-zero plot on S-plane.**	**4M**

<table>
<tr><td></td><td>Ans:</td><td>
i) $\frac{C(s)}{R(s)} = \frac{10(s+8)}{s(s+4)(s^2+6s+25)}$
a) Poles : We can get poles from equations in the denominator.
i) $s^2+6s+25=0$
for the quadratic equation $ax^2+bx+c=0$
poles are $\frac{-b \pm \sqrt{b^2-4ac}}{2a} = \frac{-6 \pm \sqrt{6^2-4\cdot1\cdot25}}{2\cdot1} =$
i.e. $\frac{-6 \pm \sqrt{-64}}{2} = \frac{-6 \pm 8j}{2} = -3 \pm 4j$
ii) $s+4=0$
so, $s=-4$
iii) $s=0$
Therefore poles are $0, -4, -3+4j$ & $-3-4j$
b) Zeros : We can get zeros from equation in the numerator
So, for $s+8$ equation we can get roots by comparing it with zero
$\therefore s+8=0 \quad \therefore s=-8$
i.e. roots of the equation are -8.
c) Characteristic Equation :-
$s(s+4)(s^2+6s+25)=0$
$s[s^3+6s^2+25s+4s^2+24s+100]=0$
$\therefore s^4+10s^3+49s^2+100s=0$
d) Pole-Zero plot :-


</td><td>Poles, Zero, Characteristics equation pole-zero plot 1M each</td></tr>
<tr><td></td><td>(b)</td><td>Define marginal stability. Draw the neat sketch to represent its location of poles on S-plane.</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td>Marginal Stability: 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
For such systems, one or more pair of non-repeated roots is located on the j axis.
The location of roots of Marginally stable system is shown in fig b</td><td>(2M for definition)</td></tr>
</table>



(2M for sketch)

(c) **Compare proportional and integral controller on the basis of**
(i) Nature of O/P (ii) Response to error
(iii) O/P equation (iv) Application — **4M**

Ans: (**1M for each point**)

	Proportional controller	**Integral controller**
Nature of O/P	Controller output is proportional to error	Rate of change of controller output is proportional to error
Response to error	Responds to direction of error	Responds to size of error
O/P equation	Pout=KpEp+P_0	$P(t) = K_i \int_0^t e(t)dt + P(0)$
Application	Proportional controller can be used for temperature control of any material or fluid	Liquid Flow Control, Steam Pressure Control

(d) **Define steady state and transient response of a system. Give the expression for steady state error.** — **4M**

Ans:

Steady state response: Response of the system after the transients die out is called as steady state response.

Transient response: The response which shows how the system settles down to the final steady state is called transient response. It is due to the energy storage elements present in the system.

1M for each definition

Equation for Steady state error :

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

2M for equation

(e) **Compare stepper motor and DC servo motor. (Any 4 points)** — **4M**

Ans:

Stepper Motor	DC Servomotor
No control winding	Control winding is present.
Number of steps can be precisely controlled.	It gives continuous rotation.
It is brushless.	It has brushes.
Due to absence of brushes, no wear and tear and hence less maintenance	Maintenance is required
Load and no load condition does not affect the running current of stepper motor	These conditions affect the running current
Speed(stepping rate) is governed by frequency of switching	Speed is controlled by supply voltage.

Any 4 points- 4M