SUMMER – 15 EXAMINATION

Subject Code: 17536 **Model Answer**

Important Instructions to examiners:

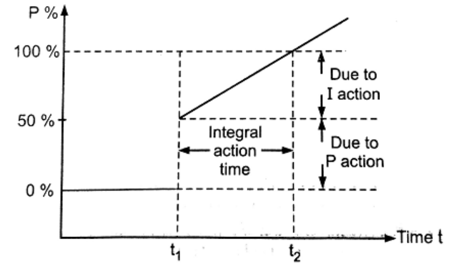
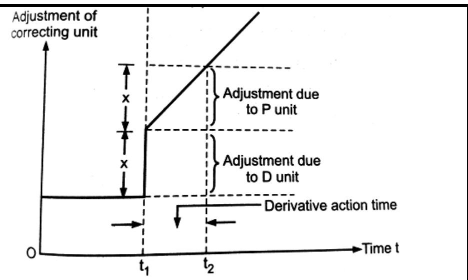
1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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 judgments 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.	Question & Model Answer	Remark	Total Marks
1.A	**Attempt any Three:**		**12**
a)	**Define stability and locate stable and unstable system poles on s-plane.**		**04**
Ans:	**Stability:** The system is said to be stable if it produces bounded output for a bounded input. It is used to define usefulness of the system. The stability implies that the system performance should not change even if there are small changes in system input. Any control system must be stable.	**2 marks**	
	The system is said to be stable if poles of closed loop the system lies on left half of s-plane	**1 mark**	
	The system is said to be unstable if poles closed loop of the system lies on right half of s-plane	**1 mark**	
	OR		
	STABILITY : A linear time invariant system is said to be stable if following conditions are satisfied: 1.) When the system is excited by a bounded input, output is also bounded and controllable.		

<table>
<tr><td></td><td>2.) In the absence of the input, output must tend to zero irrespective of the initial condition.

UNSTABLE: A linear time invariant system is said to be unstable if following conditions are satisfied:
1.) If for a bonded input it produces unbounded output.
2.) In absence of the input, output may not return to zero it shows certain output without input.
Note: 3 marks for stability and 1 mark for unstable system.</td><td></td><td></td></tr>
<tr><td>**b)**</td><td>**List various input/output modules of PLC.**</td><td></td><td>**04**</td></tr>
<tr><td>**Ans:**</td><td>i) Digital input card
ii) Analog input card
iii) Digital output card
iv) Analog output card
v) Solenoid Valve
vi) Relays
vii) Limit switches
viii) Contractors
ix) Pressure switch
x) Level switch
xi) Float (liquid level) switches
xii) Hall devices
xiii) Magnetic sensitive switches
xiv) Photo electric system
xv) Inductive sensitive switches
xvi) Single pole single throw switches
xvii) Single pole double throw switches
xviii) double pole double throw switches
xix) Push button
xx) Proximity switches
xxi) Selector switches</td><td>**Any 4 i/p & any 4 o/p module 2 marks each**</td><td></td></tr>
<tr><td>**c)**</td><td>**Differentiate between open loop and close loop system.**</td><td></td><td>**04**</td></tr>
<tr><td>**Ans:**</td><td><table><tr><th>N o.</th><th>Open loop Control System</th><th>Closed Loop Control System</th></tr></table></td><td></td><td></td></tr>
</table>

	1	It is simple and economical	It is complex and costlier	**Any 4 points – 1 mark each**	
	2	It is easier to construct, as it requires less number of components	It is not easy to construct, as it requires more number of components		
	3	It consumes less power	It consumes more power		
	4	It is more stable	It is less stable		
	5	It does not require feedback path element	It requires feedback path element		
	6	It has poor accuracy	It has better accuracy		
	7	It does not give automatic correction for any external disturbances	It give automatic correction for any external disturbances		
	8	It is more sensitive to noise	It is less sensitive to noise		
	9	It is dependent on operating conditions	It is not dependent on operating conditions		
	10	Its operation is degraded if non linearity are present	Its operation is independent on conditions		
	11	It has slow response	It has fast response		
	12	It has low bandwidth	It has high bandwidth		
d)	**Compare between PI and PD controller(any 4 points).**				**04**
Ans:		PI Controllers	PD controllers	**Any four points-1 Mark each**	
	1	It is combination of proportional control and integral control action	It is combination of proportional control and derivative control action		
	2	The proportional controller stabilizes gain but produces steady state error and integral controller minimize steady state error	The proportional controller stabilizes gain but produces steady state error and derivative controller minimize steady state error		
	3	$P = K_p . e_p + K_p K_i \int_0^t e_p(t). dt + P_I (0)$	$P = K_p . e_p + K_p K_D \frac{d}{dx}(e p) + P_{(0)}$		

4	 Relation between P & I control action	 Relation between P & D control action
5	It eliminate steady state error	It compensate rapidly changing error
6	It stabilizes controller gain	It increases controller gain during error change
7	It require expensive stabilization when process has many energy storage elements	It can not eliminate offset of proportional controller
8	It is used in control system with large load changes	It is used in temperature cascade system and batch neutralization.

1.B	**Attempt any One:**		**06**
a)	**Explain the need and benefits of PLC in automation.**		**06**

Ans:

Need of PLC in automation

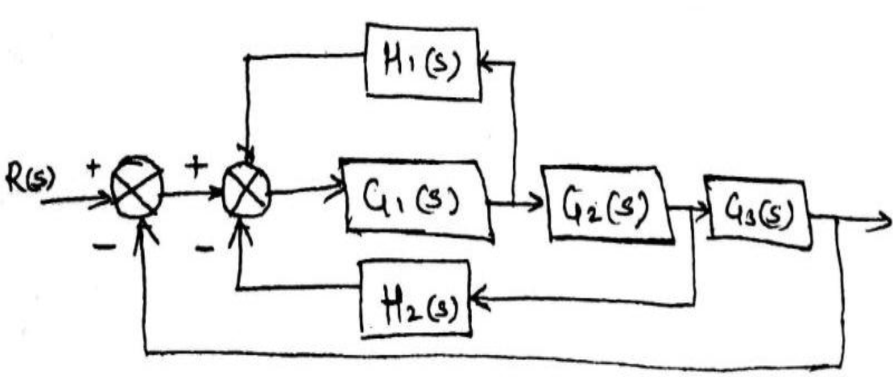
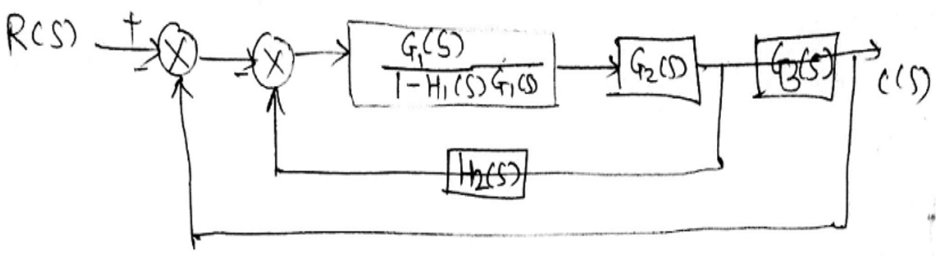
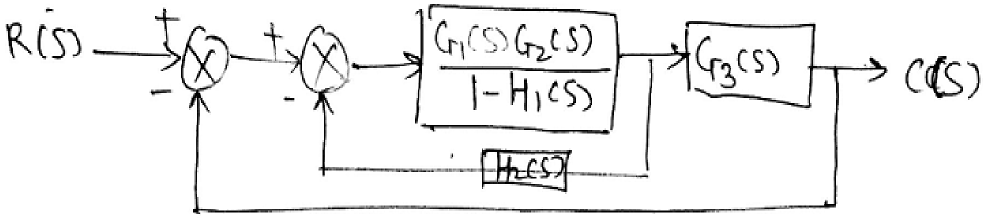
- To reduce human efforts.
- To get maximum efficiency from machine and control them with human logic
- To reduce complex circuitry of entire system
- To eliminate the high costs associated with inflexible, relay-controlled systems.
- Replacing Human Operators (Dangerous Environments & Beyond Human Capabilities)

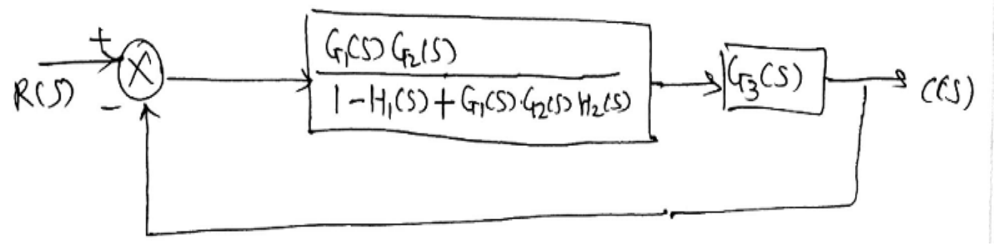
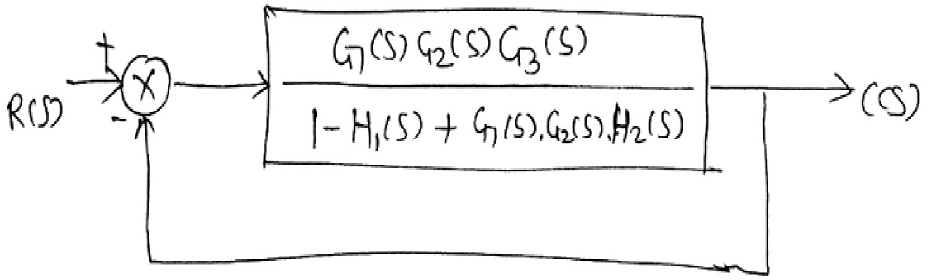
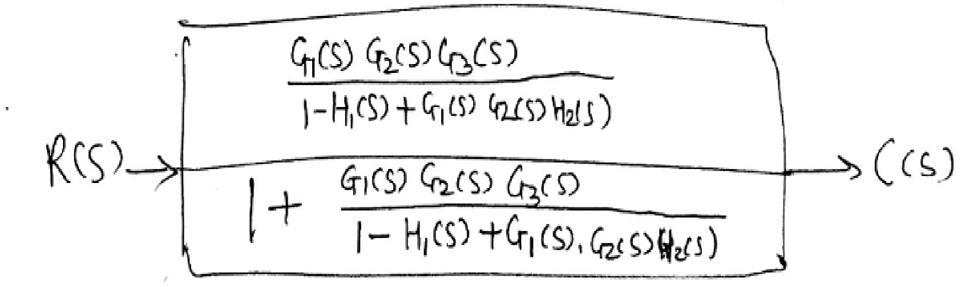
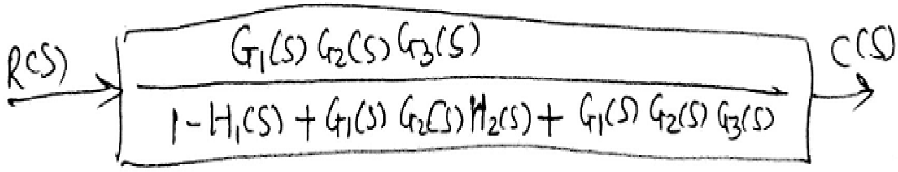
Any 3 points – 1 Mark each

Benefits of PLC in automation

- Higher productivity.
- Superior quality of end product.
- Efficient usage of energy and raw materials

Any 3 points – 1 Mark each

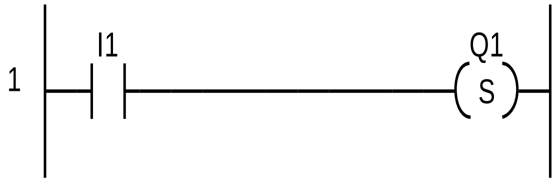
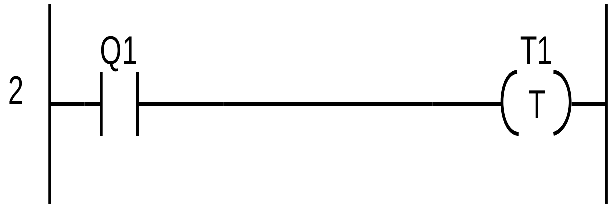
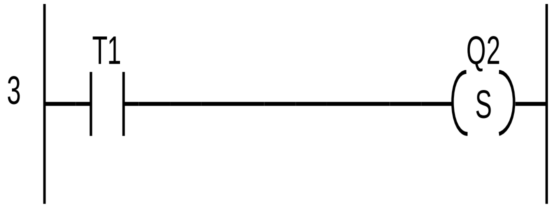
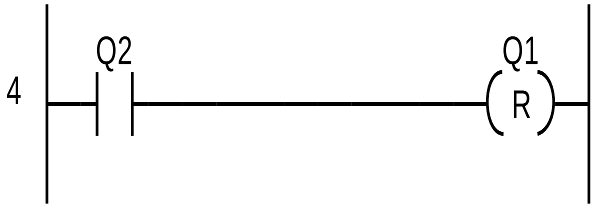
	• Improved safety in working conditions. • Fast • Easily programmed and have an easily understood programming language.		
b)	**Derive the transfer function of the block diagram.** 		**06**
Ans:	**Step1-Eliminating positive feedback loop H_1(s), we get**  **Step2-Combining G_2(s) and G_1(s) / [1- H_1(s).G_1(s)], we get** 	**1 mark for each step**	

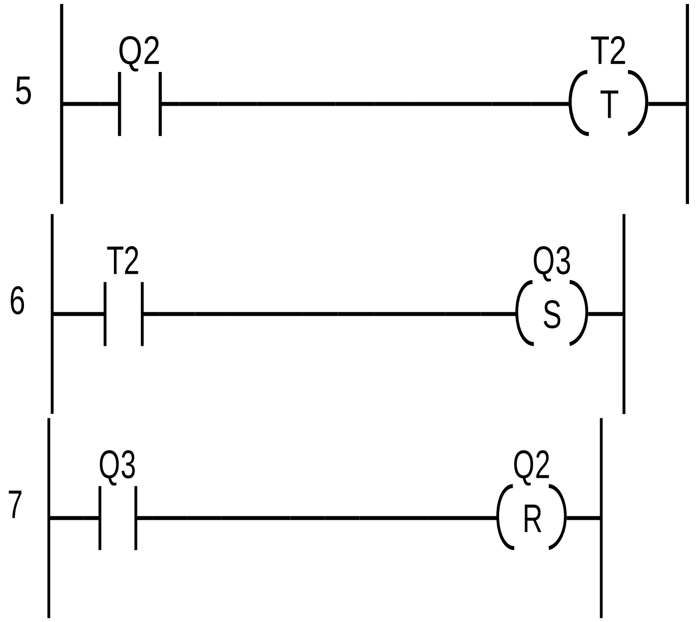
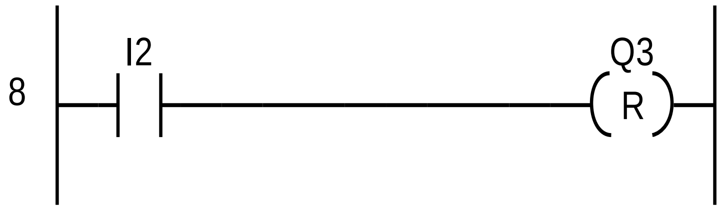
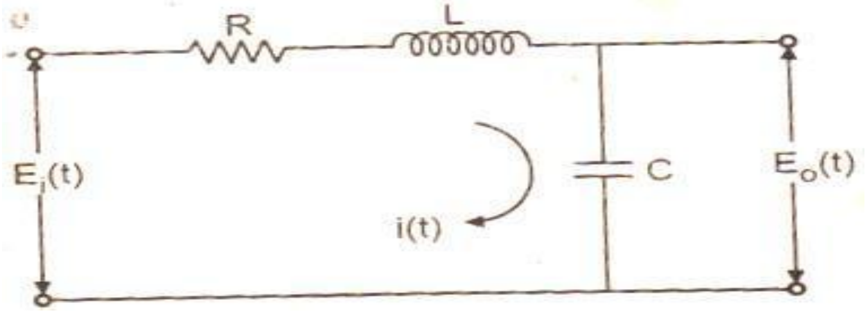
	Step3-Eliminating negative feedback loop H_2(s), we get  **Step4-Combining two blocks in cascade, we get**  **Step5-Eliminating feedback loop with unity feedback, we get**   **i.e.** **Thus, final transfer function will be** $\frac{C(s)}{R(s)} = \frac{G^1(s).\ G^2(s).\ G^3(s)}{\left(1 - H^1(s) + G^1(s).\ G^2(s).\ H^2(s) + G^1(s).\ G^2(s).\ G^3(s)\right)}$	**Final ans 1 mark**	

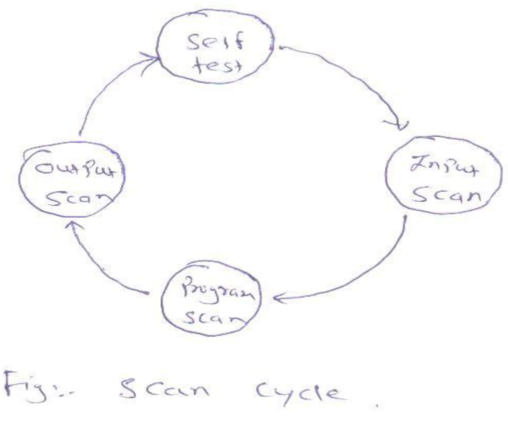
2.	**Attempt any Two:**		**16**
a)	**A unity feedback system, the open loop T.F.** $G(s) = \frac{25}{S(S+6)}$ **Find out:** **a) Rise time** **b) Peak time** **c) Max- overshoot** **d) Settling time**		**08**
Ans:	The open loop transfer function for unity feedback system is given by $\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)} = \frac{\frac{25}{s(s+6)}}{1+\left(\frac{25}{s(s+6)}\right)} = \frac{25}{s^2+6s+25} \ldots\ldots\ldots\ldots (1)$ Comparing equation 1 with standard equation, $\frac{Wn^2}{s^2+2\xi Wn.s+Wn^2}$, we get $W_n^2= 25$; So $\boxed{W_n = 5 \text{ rad /sec}}$ $2\zeta W_n= 6$; So $\boxed{\zeta=0.6 \text{ rad/sec}}$ $W_d= W_n\sqrt{1-\xi}$ So, $W_d = 5 \text{ x } 0.632$ i.e. $\boxed{W_d = 3.16 \text{ rad/sec}}$ i) Rise time is given by $t_r = \frac{\pi-\beta}{Wd}$ where $\beta = \frac{\sqrt{1-\zeta^2}}{\zeta} = \frac{0.8}{5} = 1.33$ Thus $\mathbf{t_r} = \frac{3.14-1.33}{3.16} = 0.572$ sec , ii) Peak Time is given by $t_p = \frac{\pi}{wd} = \frac{3.14}{3.16} = 0.993$ sec iii) Max overshoot is given by	**1 Mark** **1 Mark** **1 Mark** **1 Mark** **1 Mark**	

	Mp%= 100 x $e^{-\frac{\pi\xi}{\sqrt{1-\zeta^2}}} = 100\ x\ e^{-\left(3.14\ x \frac{0.6}{\sqrt{1-(0.6)^2}}\right)} = 100\ x\ e^{-2.355}$ Mp % = 9.48 % iv) Settling time is given by $ts\ = \frac{4}{\zeta\ Wn} = \frac{4}{0.6\ x\ 5} = \ 1.33\ \text{sec}$	2 Mark 1 Mark	
b)	**A unity feedback system, having $G(s) = \frac{5(s+1)}{s^2(s+3)(s+10)}$ determine type of system, error coefficient and steady state error for I/P r(t)=1+3t+$\frac{t^2}{2}$**		**08**
Ans:	Given $G(s) = \frac{5(s+1)}{s^2(s+3)(s+10)} \ldots\ldots\ldots\ldots\ (1)$ The standard equation is $G(s) = \frac{k^1(s+z^1)(s+z^2)\ldots\ldots}{s^n(s+p^1)(s+p^2)\ldots\ldots} \ldots\ldots\ldots\ldots\ (2)$ Comparing equation (1) with equation (2) we get n = 2. **This indicates that the given system is type 2 system** i) Positional error coefficient is given by Kp= $\lim_{s\to 0} G(s)H(s)$…….. Here H(s) = 1 Kp= $\lim_{s\to 0} \frac{5(s+1)}{s^2(s+3)(s+10)} = \infty$ ii) Velocity error coefficient is given by Kv = $\lim_{s\to 0} S.G(s)H(s)$…….. Here H(s) = 1 Kv= $\lim_{s\to 0} \frac{5(s+1)}{s(s+3)(s+10)} = \infty$ iii) Positional error coefficient is given by	2 Mark 1 Mark	

	Kp = $\lim_{s\to 0} S^2 . G(s)H(s)$…….. Here H(s) = 1 Kv= $\lim_{s\to 0}\frac{5(s+1)}{(s+3)(s+10)} = \frac{5(0+1)}{(0+3)(0+10)}$ = 0.166 iv) Steady state error is given by ess(t)= $\lim_{s\to 0}\frac{s.R(s)}{1+s.G(s).H(s)}$…..Here H(S)=1 & R(s) = L[1+3t+t^2/2] = $\frac{1}{s}+\frac{3}{s^2}+\frac{1}{s^3}$ So, ess(t)= $\lim_{s\to 0}\frac{s.(\frac{1}{s^3}+\frac{3}{s^2}+\frac{1}{s})}{1+s.\frac{5(S+1)}{s^2(s+3)(s+10)}}$ & After solving equation we get, ess(t) = $\lim_{s\to 0}\frac{(s^2+3s+1)(s+3)(s+10)}{s(s+3)(s+1)+5(s+1)}$ = $\frac{(0+0+1)(0+3)(0+10)}{0(0+3)(0+1)+5(0+1)} = \frac{30}{5} = 6$ ess (t) = 6	**1 Mark** **1 Mark** **1 Mark** **2 Mark**	
c)	**Draw ladder diagram for 3 motor operation for following condition:** **1) Start push button, start motor M_1.**		**08**

	2) When motor M_1 is ON after 5 min M_2 is ON and M_1 is OFF. **3) When M_2 is ON after 10 min M_3 is ON and M_2 is OFF.** **4) When stop push button is pressed M_3 is OFF.**		
Ans:	1) Start push button, start motor M_1  I1 is push button, Q1 is output relay for motor M_1 2) When motor $M_1$is ON after 5 min M_2 is ON and $M_1$is OFF (T_1 is ON for 0-5 sec)    3) When $M_2$is ON after 10 min $M_3$is ON and M_2 is OFF(T_2 is ON for 0-10 sec)	**1Mark** **3 Mark** **3mark**	

	 4) When stop push button is pressed M_3 is OFF  **Note: Any relevant ladder logic may considered.**	**1mark**	
3.	**Attempt any four:**		**16**
a)	**Derive transfer function of RLC network.**		**04**
Ans:	 Figure 1: RLC circuit		

	$Vi = iR + Ldi / dt + 1 / c\ idt.$ Take Laplace transform, $Vi(s) = I(s) [R + SL + 1/ SC]$ $I(s) / Vi(s) = 1 / [R + SL + 1/ SC]$ ----- (1) $Vo = 1 /C (idt)$ Hence, $Vo(s) = 1 / SC \times I(s)$ $I(s) = SC\ Vo(s)$ ------(2) Substituting value of I (s) in equation 1 $SC\ Vo(s)/ Vi(s) = 1/ [R + SL + 1/ SC]$ $Vo(s) / Vi(s) = 1 / SC[R + SL + 1 /SC]$ $Vo(s) / Vi(s) = 1 / S^2 LC + SRC +1$	**2 marks For Vi(s) and Vo(s)** **2 marks for transfer function**	
b)	**Define scan cycle. Explain its significance in PLC.**		**04**
Ans:	**Scan cycle:** It is number of states/steps which the controller follows when it is put in RUN mode. **Significance in PLC** : The loaded program is kept in memory of PLC and every time the program will be scan by the PLC. It has four states which are shown in fig. below.  Fig:- Scan cycle.	**Definition- 01 mark , Significance- 03mark**	

The significance of scan cycle in PLC is to test the program and make it error free by going through above four states i.e. self test, input scan, program scan and output scan.

c) **Differentiate between AC and DC servo system(4 points)** **04**

Ans:

Sr. no	**AC servo system**	**DC servo system**
1	Low power o/p	High power o/p
2	Maintenance is less	More maintenance
3	Efficiency is low	Efficiency is high
4	Stable and smooth operation	Noisy operation
5	Less problem of stability	More problem of stability
6	Non – linear characteristics	Linear characteristics

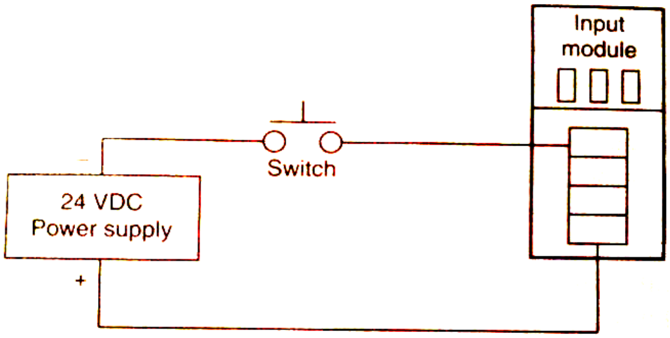
Any 4 points-04 marks

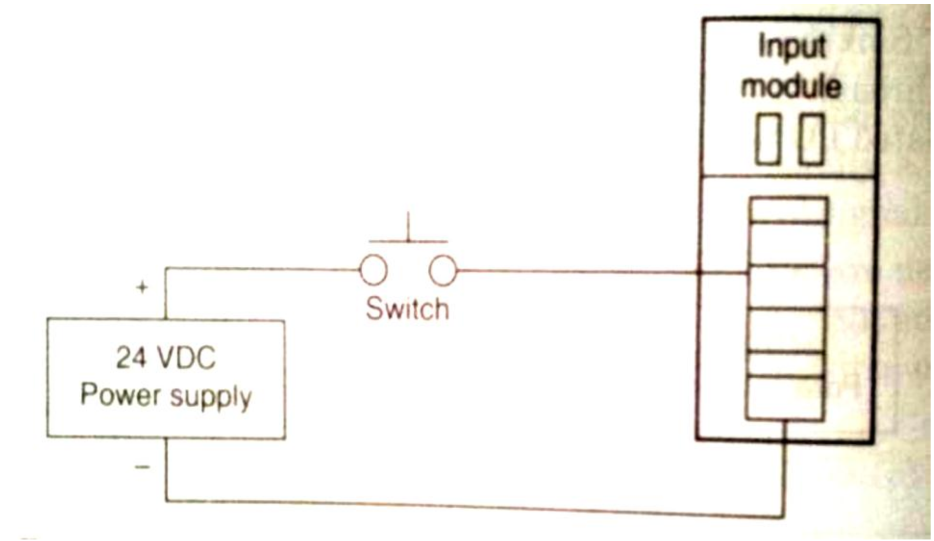
d) **Find out the range of K for the given system to be stable with** **04**

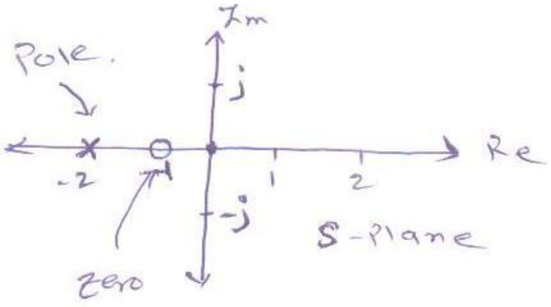
$$G(s)H(s) = \frac{\boldsymbol{K}}{\boldsymbol{s(s+4)(s^2+2s+2)}}$$

Ans:	$G(s)H(s) = \frac{k}{s(s+4)(s^2+2s+2)}$ $1 + G(s)H(s) = 0 \longrightarrow$ characteristics eq^n $1 + \frac{K}{s(s+4)(s^2+2s+2)} = 0$ $s(s+4)(s^2+2s+2)+K=0$ $(s^2+4s)(s^2+2s+2)+K=0$ $s^4+2s^3+2s^2+4s^3+8s^2+8s+K=0$ $s^4+6s^3+10s^2+8s+K=0$ $\begin{array}{c\|ccc} s^4 & 1 & 10 & K \\ \hline s^3 & 6 & 8 & 0 \\ \hline s^2 & 8.667 & \frac{6K}{6} & 0 \\ \hline s^1 & \frac{89.336-6K}{8.667} & 0 & \\ \hline s^0 & K & & \end{array}$ for System to be stable there should not be sign change in first column. $K>0$ from s^0 & $\frac{69.336-6K}{8.667} > 0$ from s^1 $69.336-6K>0$ $69.336 > 6K$ $\frac{69.336}{6} > K$ $11.556 > K$ Range of K is $0<K<11.556$	**Char. Equation -01 mark** **Routh's array- 2marks** **Range- 01mark**	
e)	**Define the term scanning cycle, speed of execution in PLC**		**04**
Ans:	**Scanning cycle :** It is also called as operating cycle and is defined as "the number of states through which the controller scan the program before execution" **Speed of execution:** The speed at which PLC scans memory and executes the program is referred as a speed of execution.	**Definition- 02 mark each**	

4.A.	**Attempt any three:**		**12**
a)	**Explain why derivative action is not alone. State its one advantage and disadvantage.**		**04**
Ans:	Derivative control action responds to the rate at which the error is changing. $P=K_D\frac{dEp}{dt}$ where, P-controller output K_D -Derivative gain Ep-error Derivative action is not used alone because it provides no output when error is constant. **Advantages:** 1. It improves damping and reduces maximum overshoot. 2. Reduces rise time and settling time. 3. Increases bandwidth. **Disadvantages:** 1. Note effective for lightly damped or initially unstable system. 2. May produce noise at higher frequency.	**2 Mark** **Any one 1 Mark** **Any one 1 Mark**	
b)	**Explain memory function an organization of ROM and RAM in PLC.**		**04**
Ans:	In PLC program instructions are stored in the memory. An internal communication high way also known as a bus system carries information to and fro from the CPU, Memory and I/O units under the control of CPU Memory unit for storage of program. The user ladder logic program is in the memory of PLC. The main program and other programs are necessary for operation of PLC. The organization of the data and information in the memory is called memory map. There are two types of memory used in PLC: Volatile and nonvolatile memory, in nonvolatile memories are generally used for storing user program so that the programs can return during power failure. Different types of memory that are generally used in PLC s are as	**Description- 04 mark**	

	follows: 1. RAM: 2. ROM: A.)EPROM B.)EEPROM **OR** Memory is classified into two types: 1. Storage memory: in storage memory store information on the status of i/o devices, pre assigned value of internal relay status and values for mathematical functions, this is called a data table or register table and stores information in two types: status and numbers,. Status is stored in the form of ON or OFF and numbers are stored in the form of 1's and 0's is unique bit of memory. 2. User memory: in this memory, ladder logic programming is carried out and stored. User memory consists of program files or register table and holds the complete operation.		
c)	**Explain with diagram sinking and sourcing concept in DCI/P modules.**		04
Ans:	 Fig 1 – Sourcing DC input Module with a sinking switch	**01mark for Each diagram**	

	 Fig 2 – Sinking DC input module with a Sourcing switch 1. Sinking and Sourcing are terms used to describe current flow through a field device in relation to the power supply and the associated input, output point. 2. Solid state input devices with NPN transistors are called “Sinking input device” while input devices with PNP transistor are called “Sourcing input devices”. 3. The commonly accepted definition by PLC manufactures about sinking& sourcing input & output circuit is current flows from positive to negative. 4. Basic principle retain to sinking & sourcing circuits. - NPN transistors are open collector current sinking devices which interface to a sourcing input module. - PNP transistors are open collector, current sources, which interface to a sinking input module. 5. In fig. no1 current flows from positive terminal of 24 volt DC supply to input module then through switch to negative terminal of supply, hence module acts as sinking device for DC supply but	**Brief Description- 02 marks**	

	sourcing device for switch. 6. In fig.2 current flows from positive terminal of 24 volt DC supply to switch then input module to negative terminal of supply, as far as input module is concern it act as sinking device for DC switch and sourcing device for 24 volt DC supply.		
d)	**Define pole and zero. Give its s-plane representation.**		**04**
Ans:	**Poles :** The value of 'S' for which the magnitude of transfer function |G(s)| becomes infinite after substitution in the denominator of system are called as poles of transfer function. The poles are denoted with cross (x) on S-plane. **Zeros :** The value of 'S' for which the magnitude of transfer function |G(s)| becomes 'Zero' after substitution in the numerator of system are called as Zeros of transfer function. The Zeros are denoted with small circle '0' on S-plane. **s-plane representation:** 	**Definition-1mark each** **representstion-02 marks**	
4.B.	**Attempt any one:**		**06**
a)	**Describe the wiring details of AC output modules of PLC.**		**06**
Ans:	The below fig 1 show the basic field wiring for digital 120V AC output module. The Wiring diagrams show how wires of output devices are connected to screw terminals of PLC modules. As per the wiring diagram, User has to connect the wires of input and output devices to PLC or Module. It can be thought of as a simple switch power can be provided to	**Description- 04 mark**	

<table>
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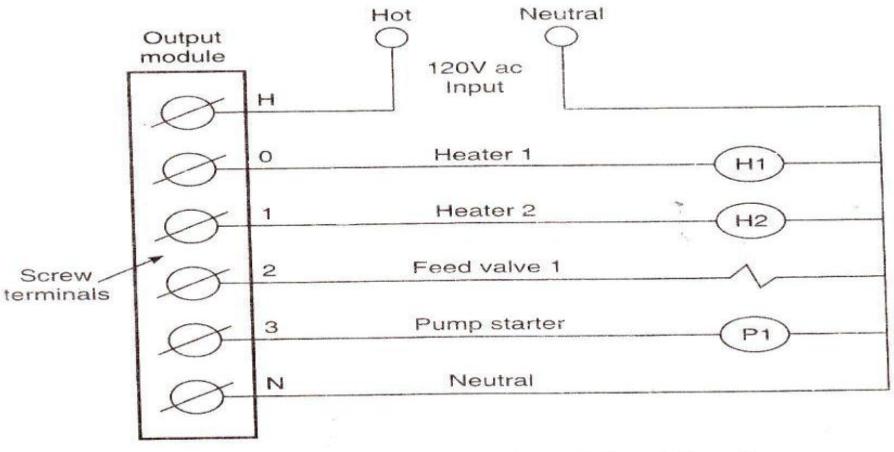
<td>control the output device. During normal operation, processor sends the output state that was determined by logic diagram of output module. The module then switches the power to the field devices. A fuse is normally provided in that the output circuit of the module to prevent excessive current from damaging the wiring to the field devices.



Typical discrete output module wiring diagram

Fig.1</td>
<td>Diagram – 02 mark</td>
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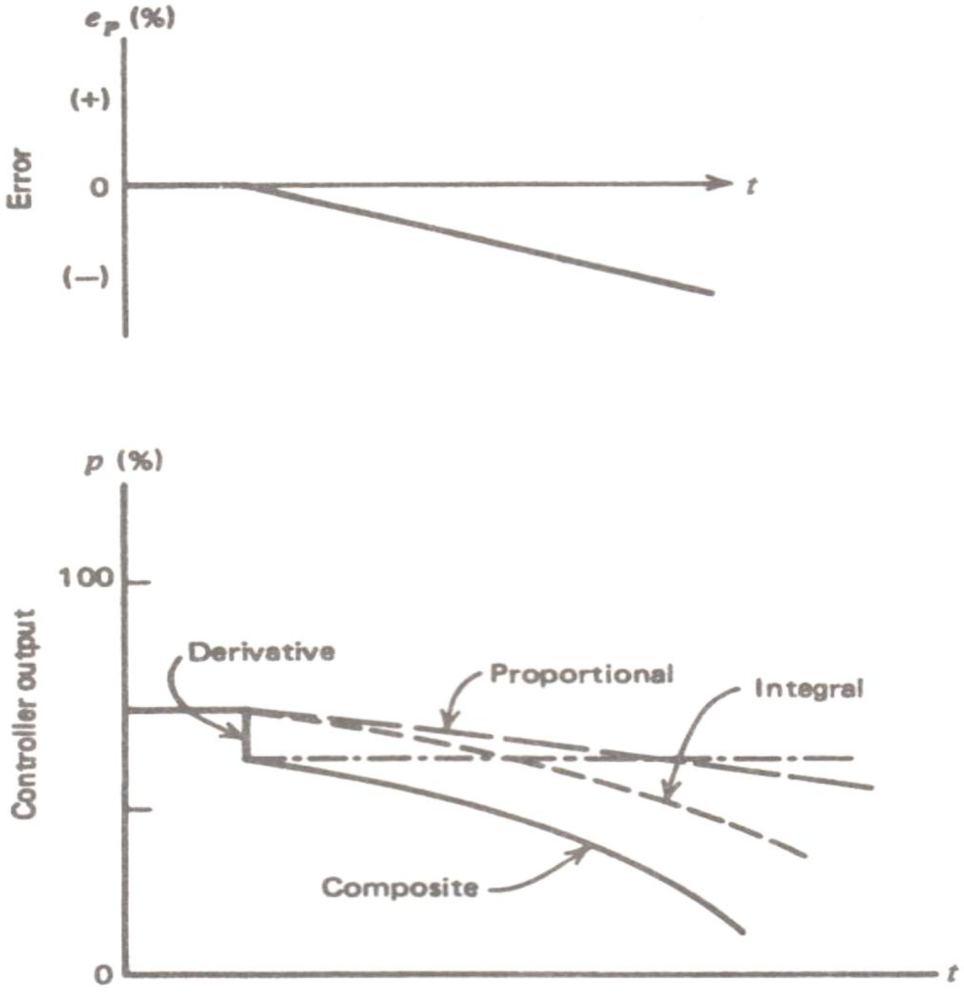
<tr>
<td>b)</td>
<td>Describe PID control action w.r.t. equation and response to error. State one advantage and one disadvantage of it.</td>
<td></td>
<td>06</td>
</tr>
<tr>
<td>Ans:</td>
<td>Output equation:

$P=K_PE_P+ K_PK_I\int E_Pdt+ K_PK_D\frac{dEP}{dt}+P_I(0)$

Advantages:
1. Most powerful mode of controller.
2. Eliminates offset.
3. Fast response.
4. Produces output depending upon magnitude duration, and rate of change of error.
Disadvantages:
1. Complex
2. Tuning of parameters (KP, KI, KD) is difficult.</td>
<td>1 mark
Anyone-1 mark
Anyone-1 mark</td>
<td></td>
</tr>
</table>

	Nature of output response to error: **(Note:** Response with respect to any other error can be considered) 	**3 mark**	
5.	**Attempt any Two:**		**16**
a)	**List and explain the timer instructions of PLC.**		**08**
Ans:	Depending on the time delay and operation there are two types timers ➢ **PLC timer-** (i) ON delay timer (ii) OFF delay timer ➢ **Description (i)** ON delay timer 1) This instruction counts time interval when conditions	**Each Descripti on-2 marks, each instructio**	

preceding it in the rung are true. Produces an output when accumulated reaches the preset value.

2) Use Ton instruction to turn an output on or off after the timer has been on for a preset time interval. The Ton instruction begins to count time base intervals when the rung conditions become true.

3) The accumulated value is reset when the rung condition go false regardless of whether the timer has timed out.

Instruction parameter- Timer TON is 3 word element.

	15	14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	
word 0	TT\EN	TT\EN DN	16 bit
word 1	preset value		16 bit
word 2	Accumulator value		16 bit

Status bit explanation-

i) **Timer done bit (bit13)-**DN is set when the accumulated value is equal to or greater than the preset value. It is reset when rung condition become false.

ii) **Timer enable bit (bit 14)-**EN is set when rung condition are true. It is reset when rung condition become false.

iii) **Timer timing bit (bit15)-**TT is set when rung conditions are true & the accumulated value is less than the preset value. It is reset when the rung conditions go false or when the done bit is set.

- **Description (ii)** OFF delay timer

1) This instruction counts time interval when conditions preceding it in the rung are false. Produces low output when accumulated value reaches the preset value.

n parameter-1 mark, each status bit explanation-1 mark

2) Use Toff instruction to turn an output on or off after the timer has been off for a preset timer has been off for a preset time intervals. The Toff instruction begins to count time base intervals when the rung makes a true to false to transition.

3) As long as rung conditions remains false the timer increments its accumulated value each scan until it reaches the preset value.The accumulated value is reset when the rung conditions go true regardless of whether the timer has timed out.

Instruction parameter- Timer TOFF is 3 word element.

	15	14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	
word 0	TT\EN	TT\EN DN	16 bit
word 1	preset value		16 bit
word 2	Accumulator value		16 bit

Status bit explanation-

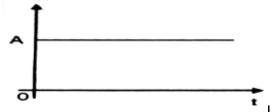
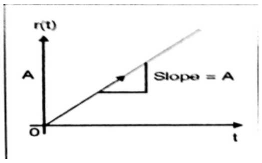
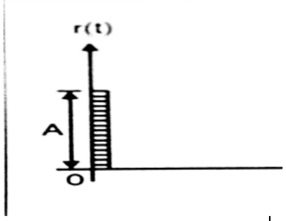
i) Timer done bit(bit13)-DN is reset when the accumulated value is equal to or greater than the preset value.It is set when rung condition are true.

ii) Timer enable bit(bit 14)-EN is set when rung condition are true. It is reset when rung condition become false.

iii) Timer timing bit(bit15)-TT is set when rung conditions are false & the accumulated value is less than the preset value. It is reset when the rung conditions go true or when the done bit is reset.

b) Explain with Laplace representation standard test inputs. State its need and significance. **08**

Ans:

Standard test input	**Laplace Representation**	**Waveforms**
Step input(position function) r(t)	L.T of r(t) =R(s)=A/s	
Rampinput(Velocity function) r(t)	L.T of r(t) = R(s)=A/s^2	
Parabolic input(Acceleration r(t) function)	L.T of r(t) = R(s)=A/s^3	
Impulse input r(t)	L.T of r(t) = R(s)= 1 if A=1	

laplace representation-04 mark

Need and significance-

1) In practice many signals are available which are functions of time and can be used as reference input for the analysis of any control system.

2) These signals are step, ramp, impulse, parabolic, sawtooth, square wave, triangular etc.But while analysing the systems, it is highly impossible to consider each and every signal as an input and study the response.

Need and significance-04 mark

3) Hence from analysis point of view, those signals which are most commonly used as reference inputs are defined as standard test inputs.

c) **Consider the system with characteristic equation. $s^5+2s^4+3s^3+6s^2+2s+1=0$. Determine stability of the system using Routh's criteria.** **08**

Ans: (1) Find even & odd coefficient from characteristics equation

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

(2) Makes Routh's array

Making 3 Routh's array-6 marks

$$\begin{array}{c|ccc}
S^5 & 1 & 3 & 2 \\
S^4 & 2 & 6 & 1 \\
S^3 & 0 & 1.5 & 0 \rightarrow \boxed{\text{Sp.case I}} \\
S^2 & \infty & \cdots & \cdots\cdots \rightarrow \boxed{\text{Routh test fail}} \\
S^1 & \ldots.. & & \\
S^0 & 1 & &
\end{array}$$

(3) Following method is used to remove above said difficulty- stitute a small positive number ϵ inplace of a zero occurred as a first element in a row .complete array with this number ϵ. Then examine the sign change by taking $\lim_{\epsilon\to 0}$

$$\begin{array}{c|ccc}
S^5 & 1 & 3 & 2 \\
S^4 & 2 & 6 & 1 \\
S^3 & \epsilon & 1.5 & 0
\end{array}$$

S^2	$\frac{6\epsilon-3}{\epsilon}$	1…	0
S^1	$\frac{1.5\left(\frac{6\epsilon-3}{\epsilon}\right)-\epsilon}{\frac{6\epsilon-3}{\epsilon}}$	0	0
S^0	1		

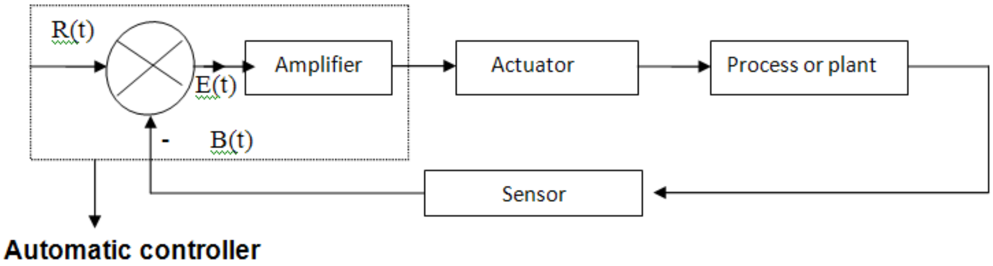
- To examine sign change

$$\lim_{\epsilon\to 0}\left(\frac{6\epsilon-3}{\epsilon}\right)=6-\lim_{\epsilon\to 0}\frac{3}{\epsilon}$$
$$=\quad 6-\infty$$
$$=\quad -\infty$$ ….. Sign is negative

- $\lim_{\epsilon\to 0}\frac{1.5(6\epsilon-3)-\epsilon^2}{6\epsilon-3}$ = +1 .5 sign is positive

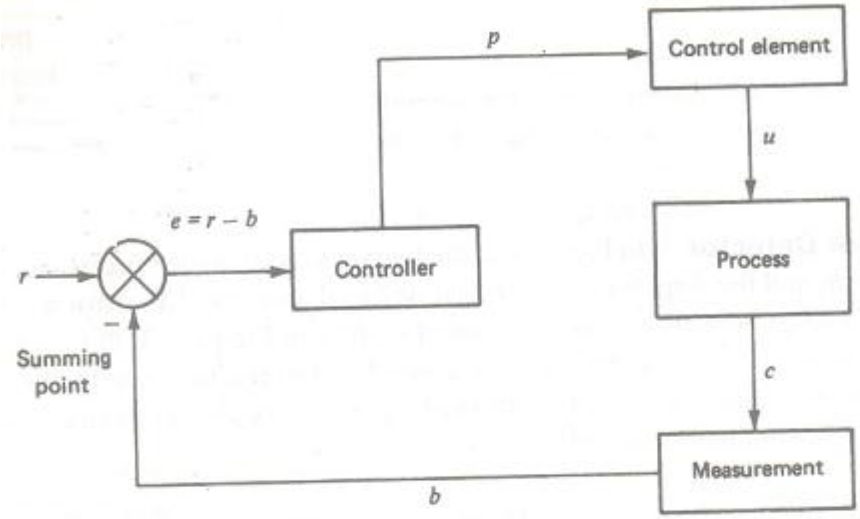
4) Routh's array with all coefficients is

S^5	1	3	2
S^4	2	6	1
S^3	$+\epsilon$	1.5	0
S^2	$-\infty$	1	0
S^1	+1.5	0	0

	S^0 1 Conclusion – As in the first column of Routh's array there is two n changes hence system is unstable.	**Conclusion-2 mark**	
6.	**Attempt any four:**		**16**
a)	**Draw and explain block diagram of process control system.**		**04**
Ans:	 **Explanation** - Process control system consists of process or plant nsor, error detector, automatic Controller, actuator or control element. 1) Process or plant- process means some manufacturing sequence. It has one variable or multivariable output. Plant or process is an important element of process control system in which variable of process is to be controlled. 2) Sensor measuring elements – It is the device that converts the output variable into another suitable variable which can acceptable by error detector Sensor is present in f/b path of close loop system. 3) Error detector – Error detector is he subtracting summing points whose output is an error signal i.e. $e(t)=r(t)\pm b(t)$ 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.	**Diagram 2-mark** **Explanation- 2 mark**	

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.

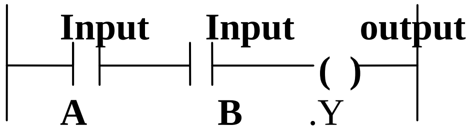
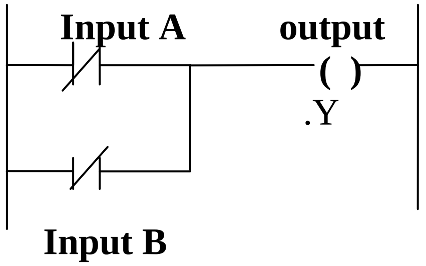
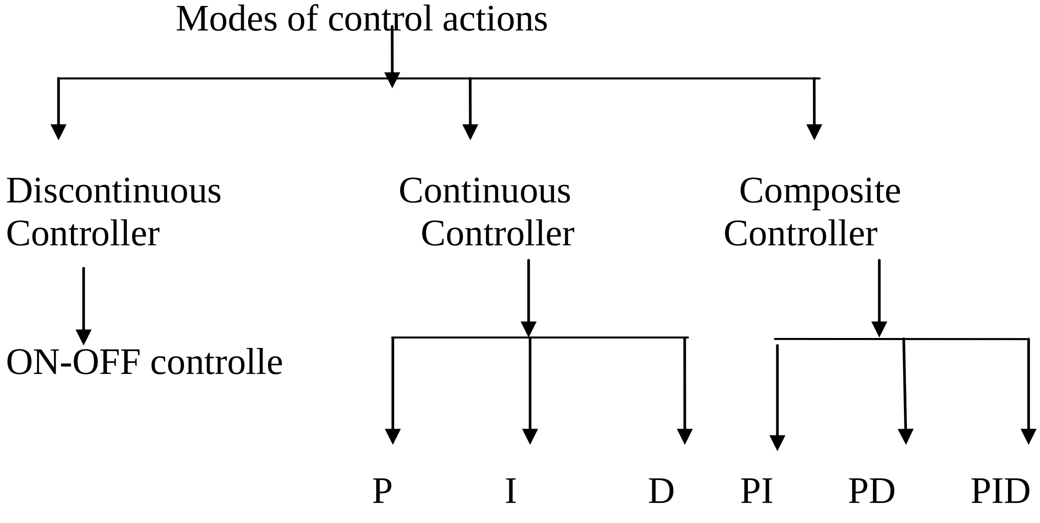
2) Error detector : It receives two inputs: set point 'r' and controlled variable 'p'. The output of the error detector is given by e= r-b. 'e' is applied to the controller.

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

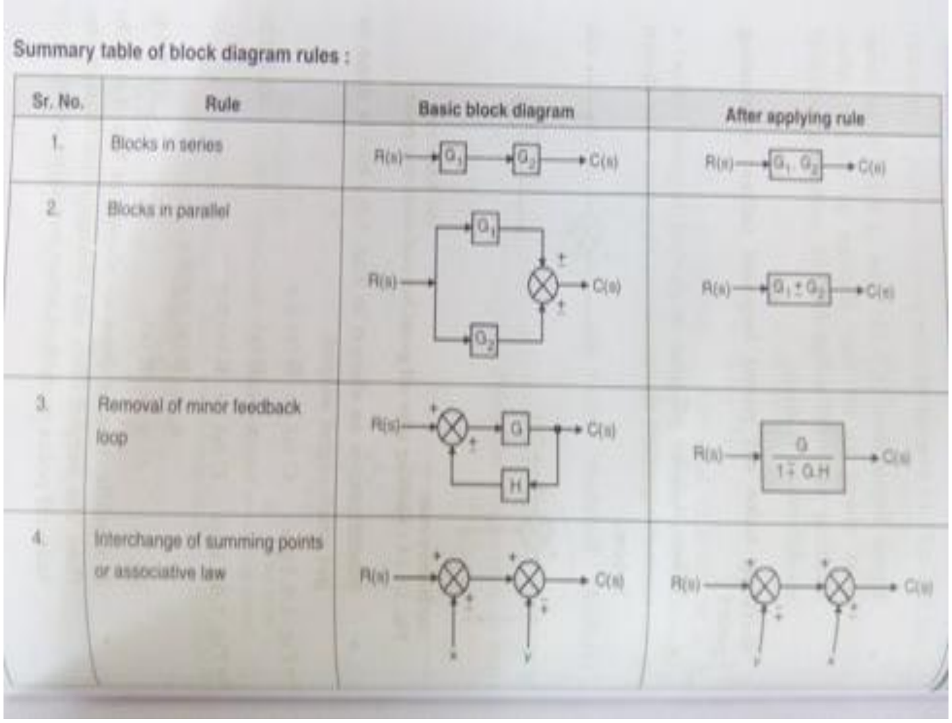
4) Final control element: It accepts the input from the controller which is then transformed into some proportional action performed by the process. Output of control element is denoted by 'u'.

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)	**State Routh's stability criteria. Describe different cases to find stability of a system.**		**04**
Ans:	**Statement-** The necessary & sufficient condition for system to be stable is "All the terms in the first column of array must have same sign. There should not be any sign change in the first column of Routh's array". If there are any sign changes existing then, (1) System is unstable (2) The no of sign changes equal the no of roots lying in the right half of the S- plane. **Special case 1** 1) Statement – First element of any of the rows of Routh's array is zero & the same remaining rows contains at least one non zero element. 2) Effect-The terms in the next row become infinite and Routh's test fails. 3) Solution for this said difficulty-Substitute a small positive number 'ϵ'in place of a zero occured as a first element in a row and complete the array with this number 'ϵ'.Then examine the sign change by taking $lim_{\epsilon\to 0}$. **Special case 2** 1) Statement-All the elements of a row in a Routh's array are zero. 2) Effect-The terms of the next row cannot be determined &Routh's test fails. 3) Solution for this said difficulty- a) Form an equation by using the coefficients of a row which is just above the row of zeros. Such an equation is called as auxiliary equation denoted as A(s) . b) Take the derivative of an auxiliary equation with respect to 's' c) Replace row of zeros by the coefficients of dA(s)/ds d) Complete the array in terms of these new coefficients &by observing the first column of Routh's array state the stability of the system.	**statement-1 mark** **case one - $1\frac{1}{2}$ mark** **case-two $1\frac{1}{2}$ mark**	

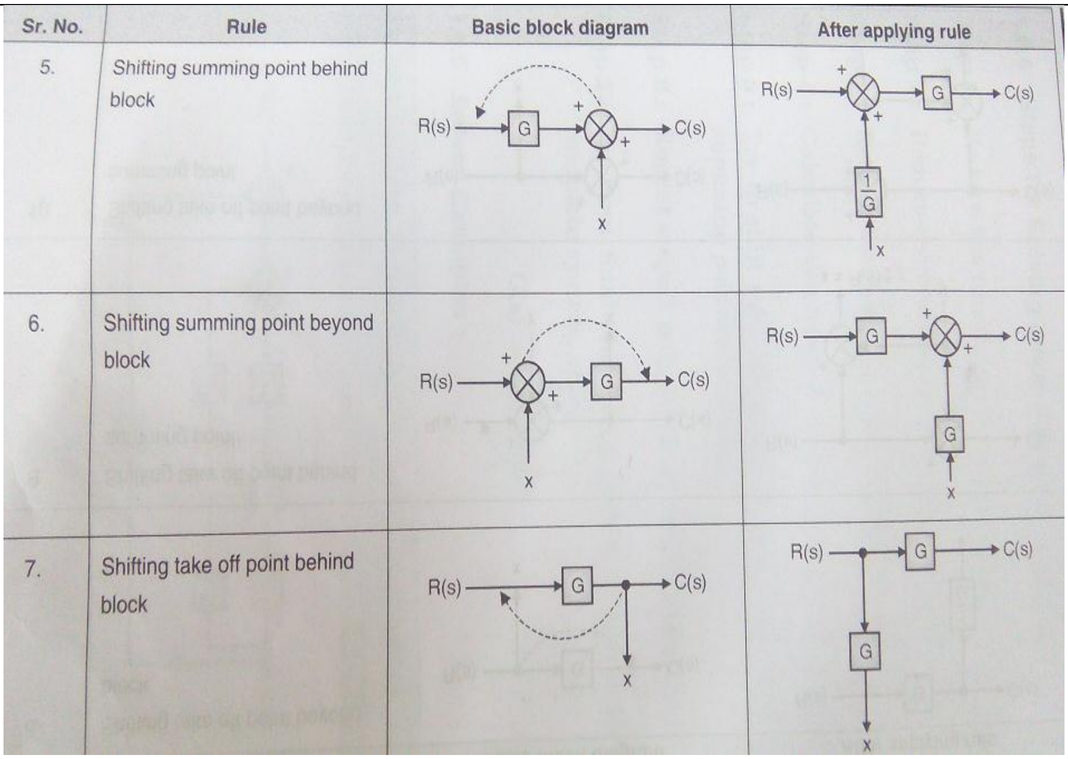
c)	**Draw the ladder diagram for to verify:** **1) AND gate 2) NAND gate logic.**		**04**
Ans:	AND gate Y= A.B  NAND gate $Y = \overline{A}+\overline{B}=\overline{A.B}$  	**each ladder diagram -2 mark**	
d)	**List type of control action. Give one advantage and disadvantage.**		**04**
Ans:	 **Advantage of ON-OFF controller** 1. It is most simple in construction.	**Types-1 mark** **Advanta ges&Disa**	

	2. It is most economical &cheapest **Disadvantage of ON-OFF controller** 1. It is not very suitable for complex system 2. It has a slow response **Advantage of PI mode** 1. It eliminates offset error i.e improves the steady state accuracy. 2. It decreases bandwidth of the system. **Disadvantage of PI model** 1. It takes the longer time to stabilize controller gain. 2.It makes the response more oscillatory **Advantage of PD mode** 1. It improves the damping &reduces overshoot. 2. It reduces the rise time. **Disadvantage of PD mode** 1. It cannot eliminate offset error. 2. It is not very effective for lightly damped system. **Advantage of PID mode** 1. It reduce the overshoot which often occurs when integral control action is added to proportional control action . 2. It eliminates the offset introduced by proportional control action. **Disadvantage of PID mode** 1. Some what complexity in design. **Note: Any four relevant control action/mode with advantages and disadvantages may considered.**	**dvantage s-3 marks**	
e)	**List any two rules of block diagram of reduction technique.**		**04**
Ans:			

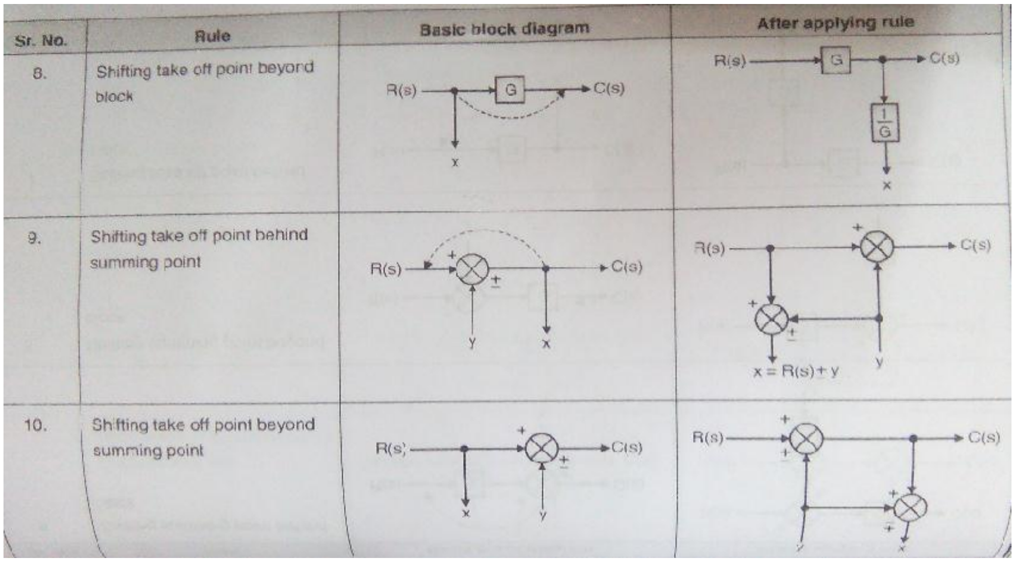
		**Any one rules- 2marks**	

Summary table of block diagram rules :

Sr. No.	Rule	Basic block diagram	After applying rule
1.	Blocks in series		$G_1 . G_2$
2.	Blocks in parallel		$G_1 \pm G_2$
3.	Removal of minor feedback loop		$\frac{G}{1 \mp G.H}$
4.	Interchange of summing points or associative law		



Sr. No.	Rule	Basic block diagram	After applying rule
5.	Shifting summing point behind block		
6.	Shifting summing point beyond block		
7.	Shifting take off point behind block		



Sr. No.	Rule	Basic block diagram	After applying rule
8.	Shifting take off point beyond block		
9.	Shifting take off point behind summing point		
10.	Shifting take off point beyond summing point		