WINTER-19 EXAMINATION

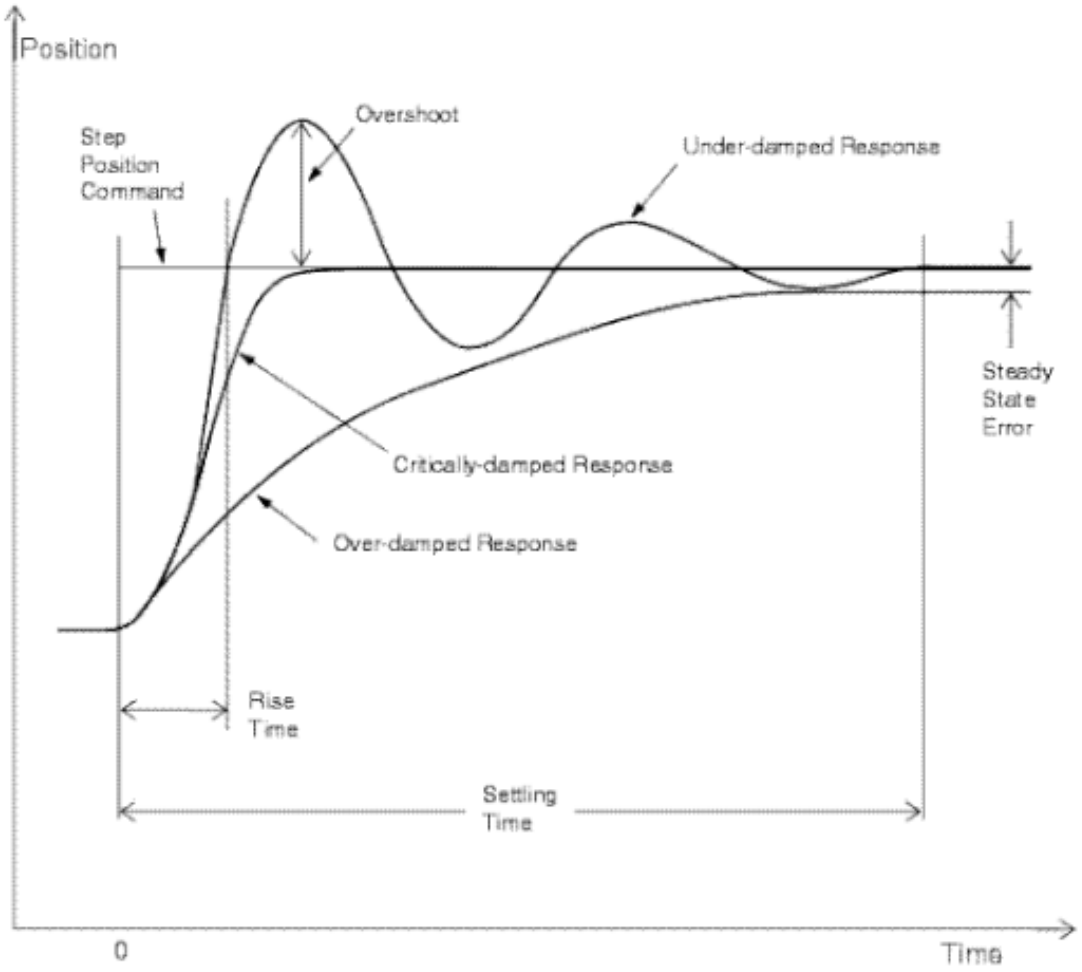
Subject Name: Control System and PLC **Model Answer** **Subject Code:** 22531

Important Instructions to examiners:

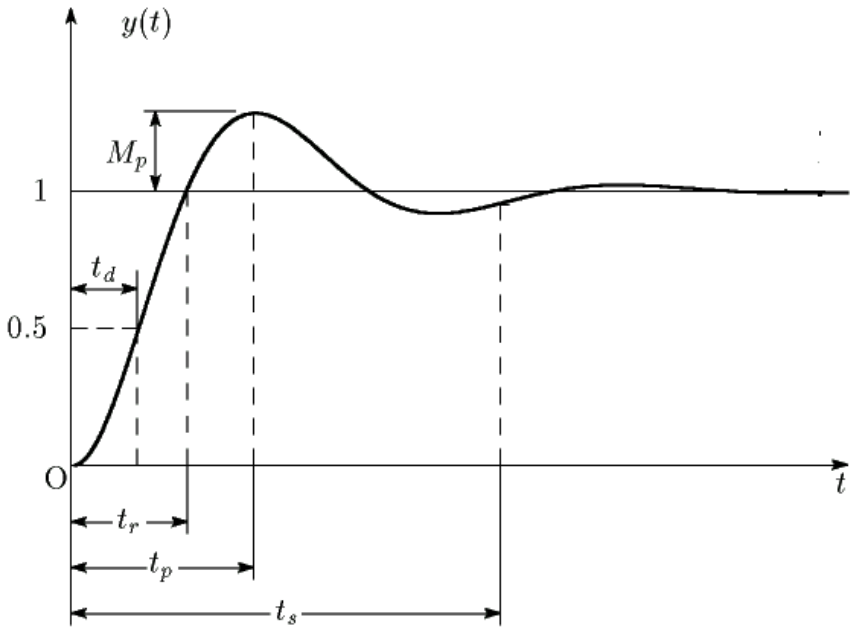
1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

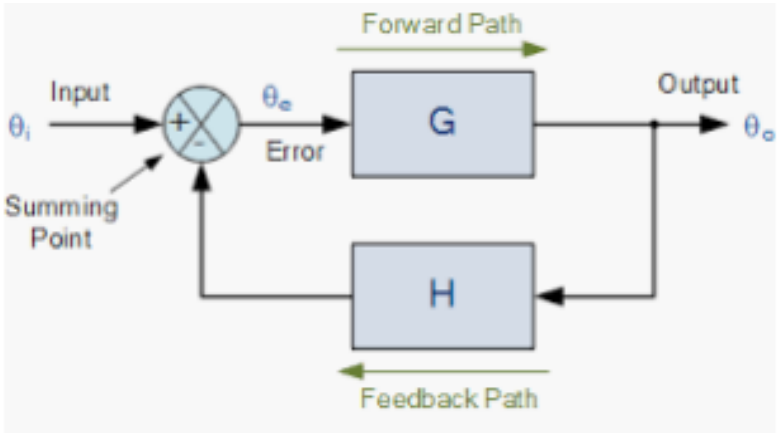
Q. No.	Sub Q. N.	Answers	Marking Scheme
1	**(A)**	**Attempt any FIVE of the following:**	**10- Total Marks**
	(a)	**List any four names of PLC programming languages.**	**2M**
	Ans:	1) Ladder diagram programming 2) Instruction list programming 3) Structured text programming 4) Function block diagram programming 5) Sequential function charts	**Any four: 2M**
	(b)	**Define transient response and steady state response for any system.**	**2M**
	Ans:	**Transient response**: The output variation during the time, it takes to achieve its final value is called transient response. **Steady state response:** It is that part of the time response which remains after complete transient response vanishes from the system output	**Definitio n : 1M each**

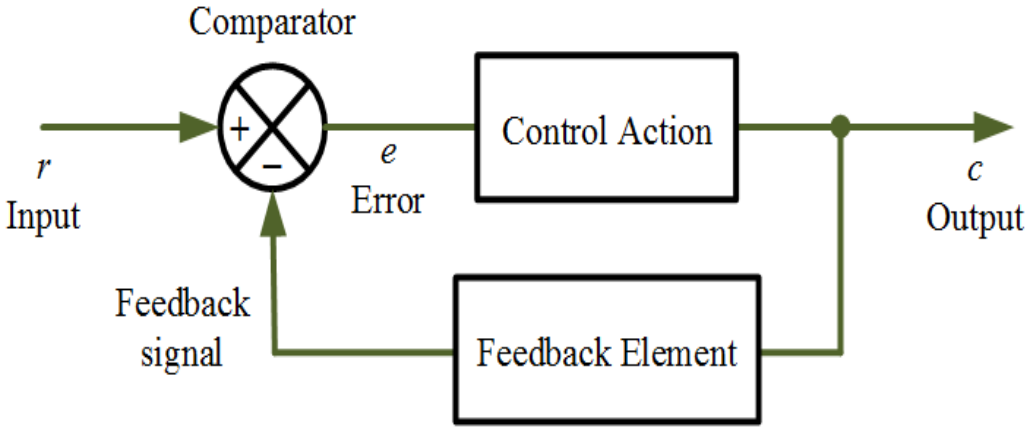
		OR It is defined as the response of the system as time approaches infinity from the time at which transient response completely dies out.	
	(c)	**Calculate the order of following system.** **G(s) =** $\frac{(S+2)(S+5)}{S(S+3)(S+4)}$	**2M**
	Ans:	**G(s) =** $\frac{(S+2)(S+5)}{S(S+3)(S+4)}$ **G(s) =** $\frac{(S+2)(S+5)}{(S+4)(S^2+3S)}$ **G(s) =** $\frac{(S+2)(S+5)}{(S^3+7S^2+12S)}$ Highest power of 'S' in denominator is 3 Therefore, Order of the system is 3.	**Order : 2M**
	(d)	**List two inputs and two output devices of PLC.**	**2M**
	Ans:	**Input devices:** 1) Mechanical switches 2) Proximity switches 3) Photoelectric switches 4) Encoders **Output devices:** 1) Contactors 2) Relays 3) Motors **4)** Lights	**Any two inputs : 1M** **Any two outputs : 1M**
	e)	**Sketch and label the time response for second order system.**	**2M**

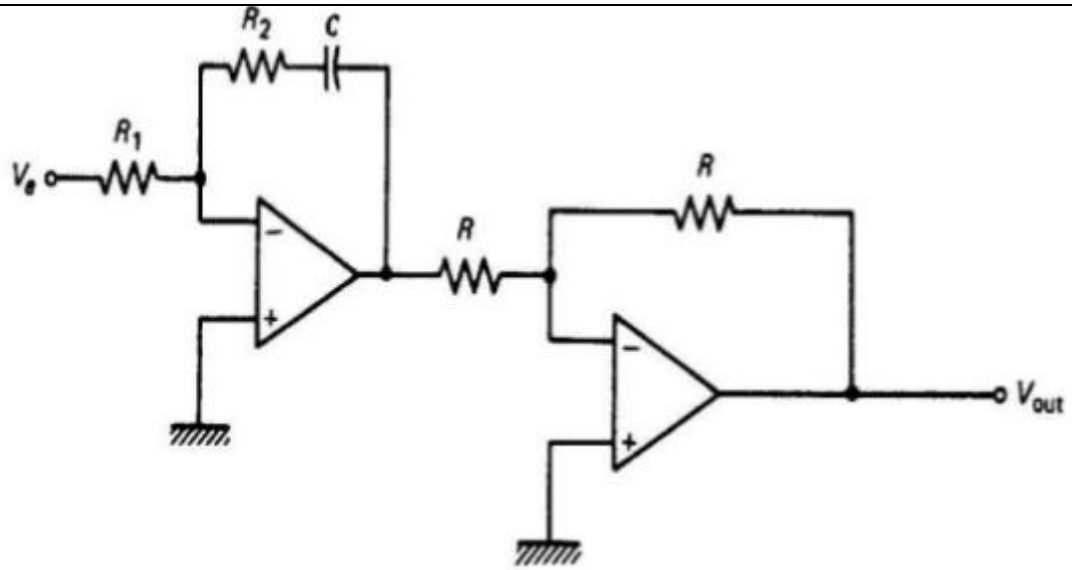
	Ans:		**Diagram : 2M**

OR



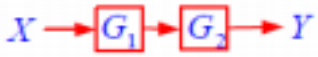
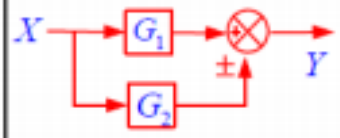
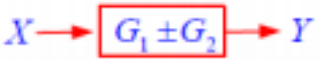
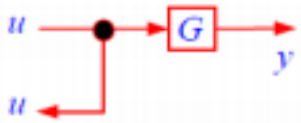
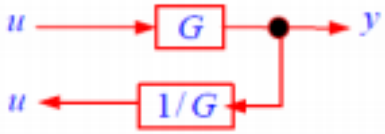
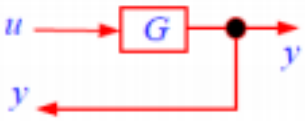
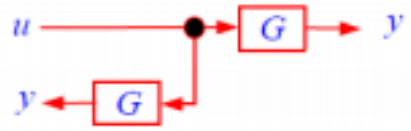
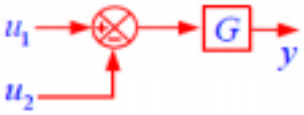
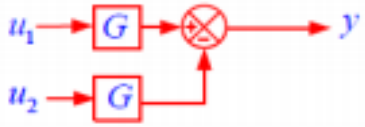
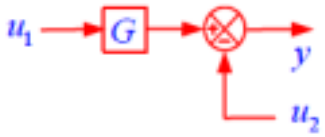
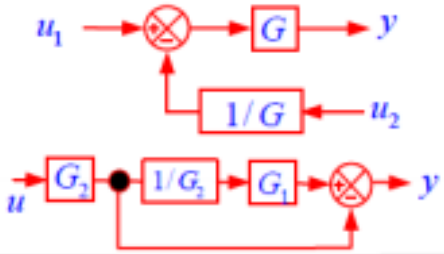
	f)	**Draw the general block diagram of closed loop control system.**	**2M**
	Ans:	 **Or**	**Diagram : 2M**



	g)	**Draw electronic PI controller using Op-amp.**	**2M**
	Ans:		**Diagram : 2M**

Q. No.	Sub Q. N.	Answers	Marking Scheme
2		**Attempt any THREE of the following:**	**12- Total Marks**
	a)	**State any four block diagram reduction rules with neat diagram.**	**4M**

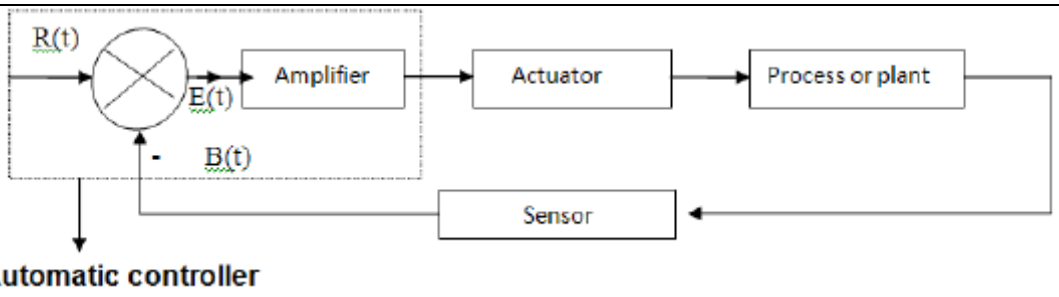
Ans:

Manipulation	Original Block Diagram	Equivalent Block Diagram
Combining Blocks in Cascade		
Combining Blocks in Parallel; or Eliminating a Forward Loop		
Moving a pickoff point behind a block		
Moving a pickoff point ahead of a block		
Moving a summing point behind a block		
Moving a summing point ahead of a block		

Any four rules : 4M

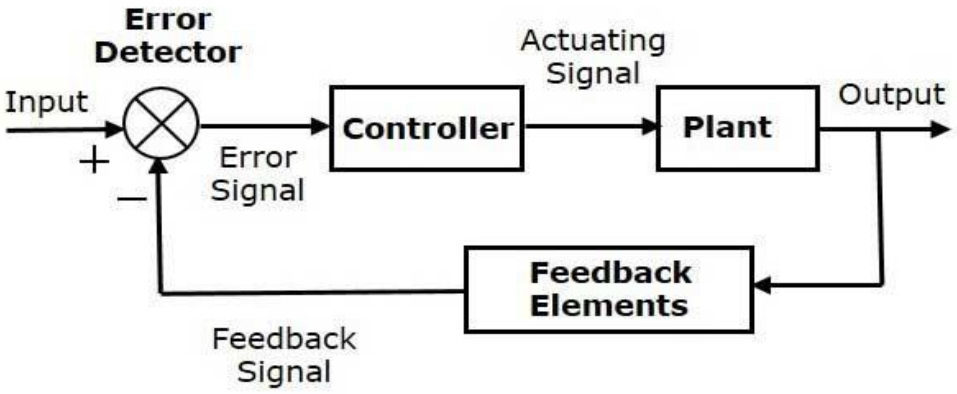
b) **Draw neat block diagram of process control system.** **4M**

Ans:

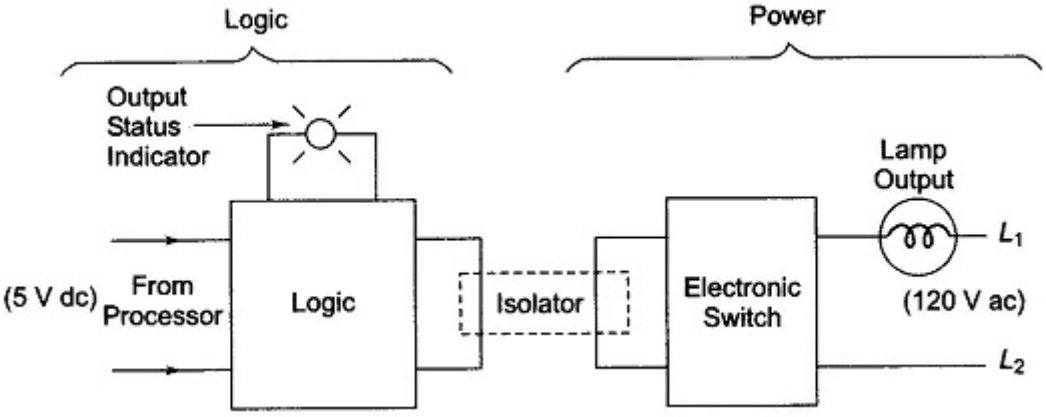


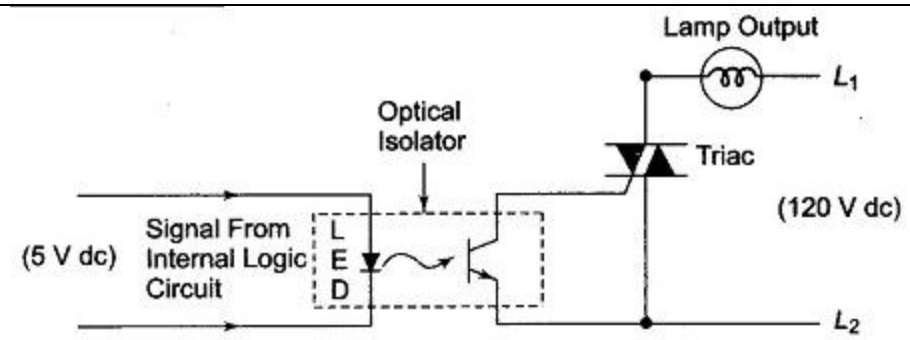
OR

Block Diagram -4M

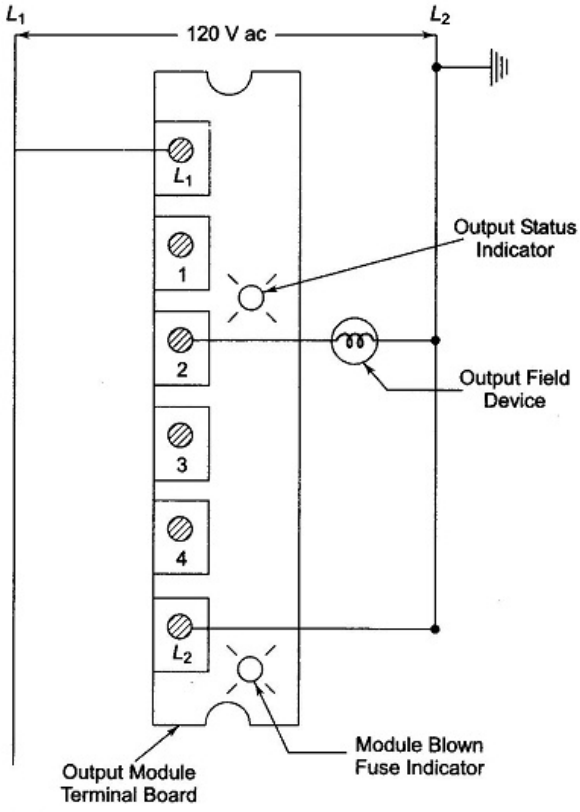


NOTE: Any relevant diagram must be considered

	c)	**Describe discrete AC output modules of PLC with the help of neat diagram.**	**4M**
	Ans:	**Block diagram of discrete AC output module**  It is composed of two basic sections, the power section and the logic section, coupled by an isolation circuit. The output interface can be considered of as a simple electronic switch to which power is applied to control output device. A simplified schematic and wiring diagram for one output of a typical ac output module is shown in Fig.	**Block diagram : 1M** **schematic diagram :1M** **Description :2M**



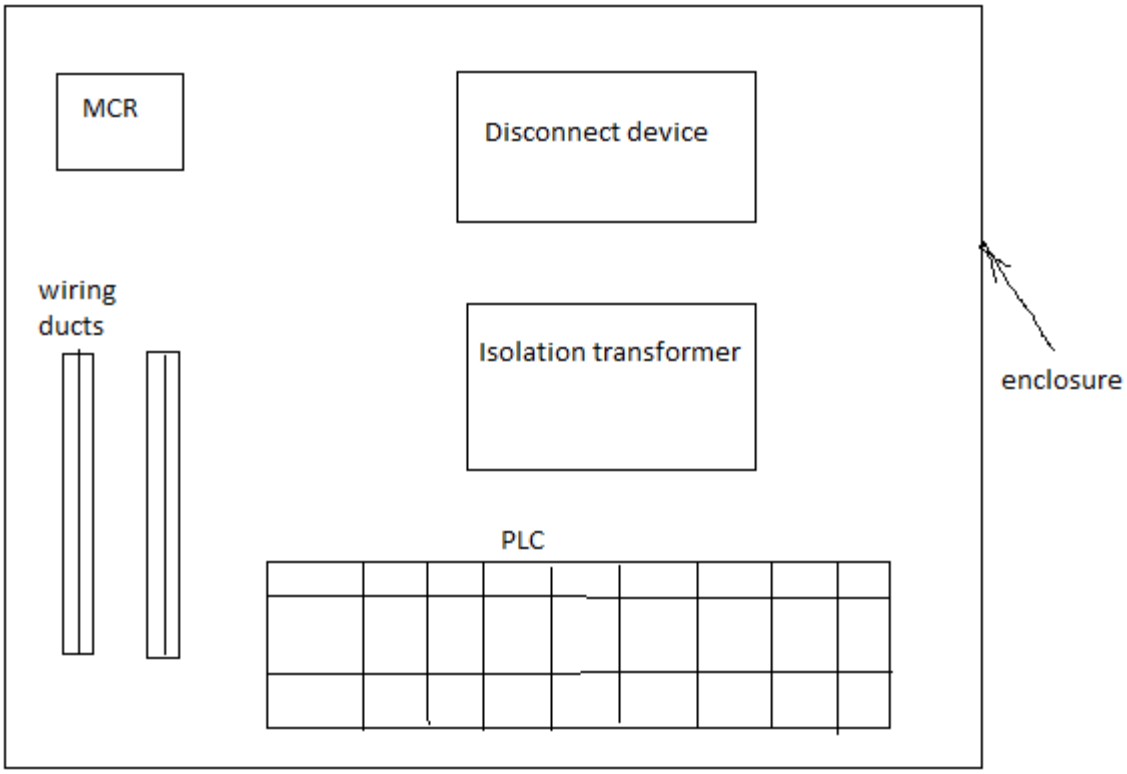
Simplified Schematic of an ac Output Module



Typical Output Module Wiring Connection

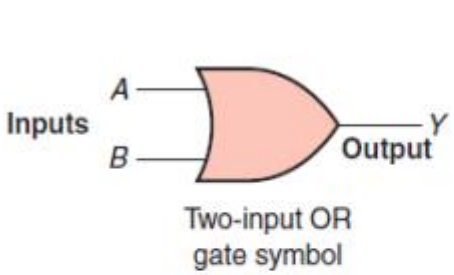
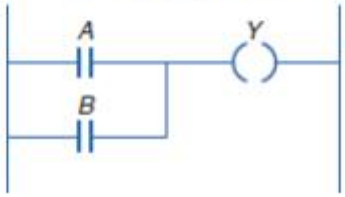
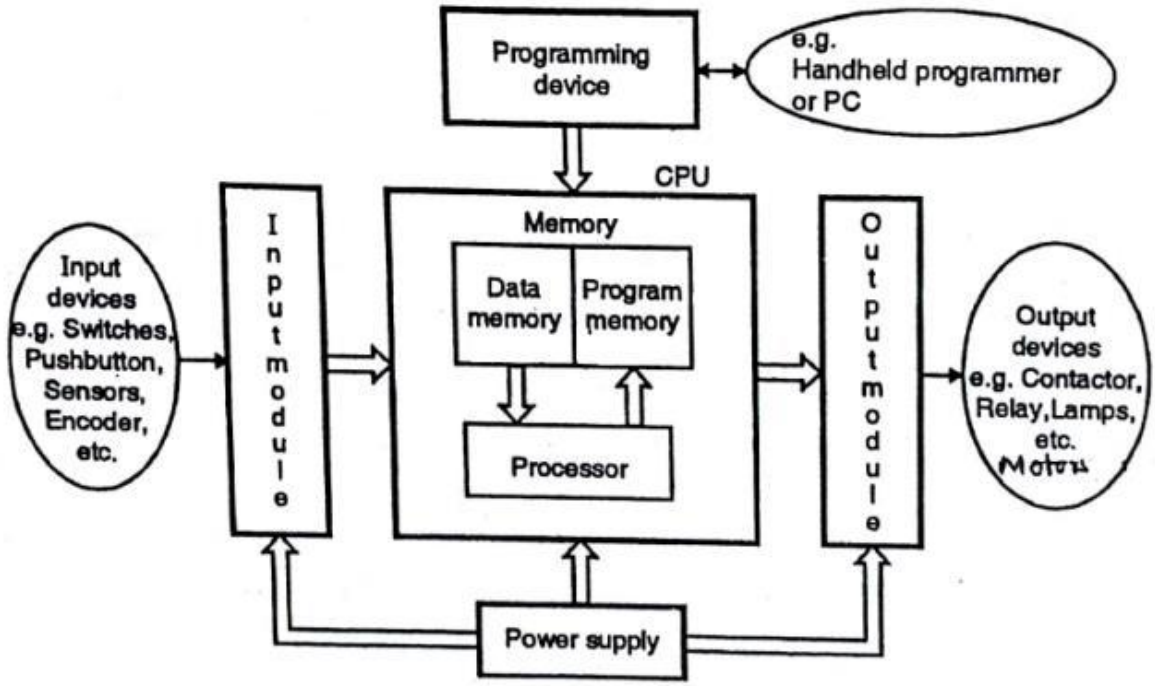
As part of its normal operation, the processor sets the output states according to the logic program. When the processor calls for an output, a voltage is applied across the LED of the isolator. The LED then emits light which switches on the phototransistor into conduction. This, in turn, switches a semiconductor switch such as Triac into conduction which turns on the lamp. Since the triac conducts in either direction, the output to lamp is ac.

The triac rather than having ON and OFF status, actually has low and high resistance levels respectively. In its OFF state (high resistance) a small leakage current of a few mA still flows

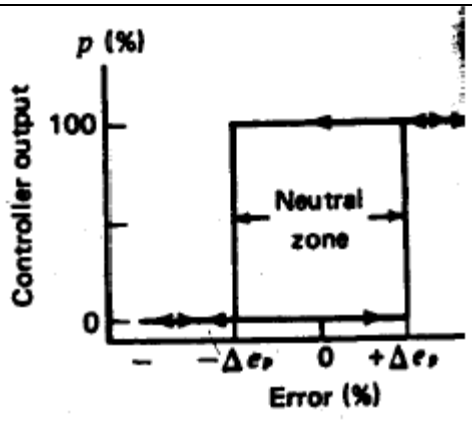
		through the triac. As with input circuits, the output interface is usually provided with LED's that indicate the status of each output	
	d)	**Illustrate the steps for PLC installation.**	**4M**
	Ans:	 The following parameters should be considered while installing the PLC, **1) Enclosure :** It is a metal or non- metal cabinet to fix the PLC and its supporting devices. It provides enough space between PLC and other components for air circulation to maintain temperature between 0 ° to 55° C. if the temperature exceeds 55°C the provide cooling fan. Install PLC away from high voltage equipments. **2) Disconnect device:** The enclosure should have power disconnect. So that, when required the PLC can be worked on with power OFF. **3) MCR:** Master control relay is used to interrupt power to the I/O rack in the event of a system failure. **4) Isolation transformer:**	**Steps : 4M**

		Provides physical isolation from the main power distribution. 5) When PLC is operated in noise polluted environment, then noise suppressors should be used. 6) Proper grounding is an important measure in PLC installation.	
Q. No.	Sub Q. N.	Answers	Marking Scheme
3		**Attempt any THREE of the following :**	**12- Total Marks**
	a)	**Discuss the special cases of Routh's criterion.**	**4M**

	Ans:	**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- (i) Form an equation by using the coefficients of a row which is just above the row of zeros. Such an equation is called as auxillary equation denoted as A(s) . (ii) Take the derivative of an auxiliary equation with respect to 's' (iii) Replace row of zeros by the coefficients of dA(s)/ds. (iv) Complete the array in terms of these new coefficients &by observing the first column of Routh's array state the stability of the system **Note: Marks can be given for relevant explanation too**	**for each case : 2M**
	b)	**Draw the PLC ladder diagram for two input OR logic gate.**	**4M**

	Ans:	**OR:**  Two-input OR gate symbol OR truth table Inputs A B / Output Y 0 0 0 0 1 1 1 0 1 1 1 1 **Fig. The OR gate symbol and truth table** Ladder logic program  	**Ladder diagram : 4M**
	c)	**Draw labeled block diagram of PLC.**	**4M**
	Ans:	 **Block diagram of PLC**	**Block diagram :4M**

	d)	**Elaborate ON – OFF controller with suitable example. State significance of neutral zone.**	**4M**
	Ans:	**ON – OFF controller :** **ON – OFF controller** has only two positions either it is fully closed or fully open. This control element does not operate at any intermediate position, i.e. partly open or partly closed position. The control system made for controlling such elements is known as **on off control theory**. In this control system, when process variable changes and crosses certain preset level, the output valve of the system is suddenly fully opened and gives 100 % output. Generally in **on off control system**, the output causes change in process variable. Hence due to effect of output, the process variable again starts changing but in reverse direction. During this change, when process variable crosses certain predetermined level, the output valve of the system is immediately closed and output is suddenly reduced to 0%. As there is no output, the process variable again starts changing in its normal direction. When it crosses the preset level, the output valve of the system is again fully open to give 100% output. This cycle of closing and opening of output valve continues till the said on-off control system is in operation. A common example of on-off control is the temperature control in a domestic heating system. When the temperature is below the thermostat set point the heating system is switched on and when the temperature is above the set point the heating switches off. **Significance of Neutral zone :** In any practical implementation of the two – position controller, there is an overlap as ep increases through zero or decreases through zero. In this span, no change in controller output occurs. It is called Neutral zone. Fig shows p versus ep for ON-OFF Controller. Until an increasing error changes by Δ ep above zero, the controller output will not change state. In decreasing it must fall Δ ep below zero before the controller changes to the 0% rating.	**Explanation : 2M** **Significance: 2M**



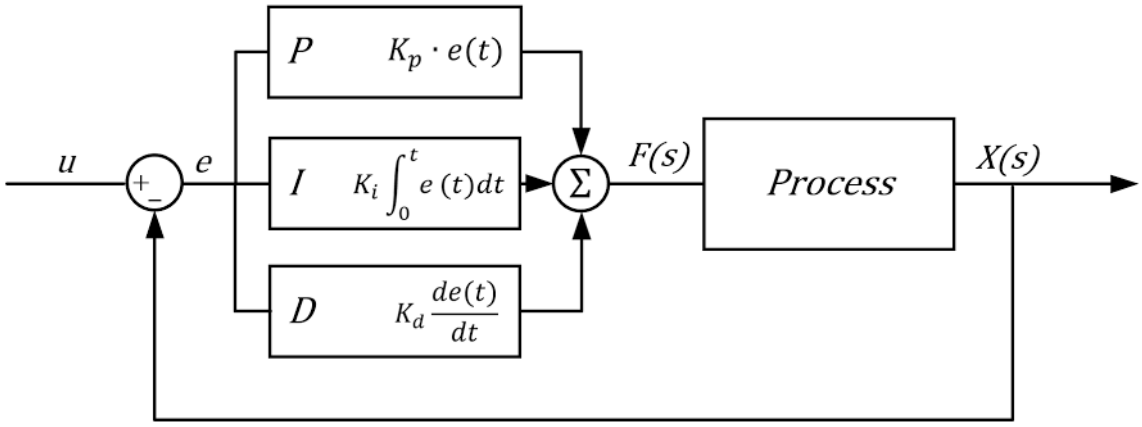
Q. No.	Sub Q. N.	Answers	Marking Scheme
4		**Attempt any THREE of the following :**	**12- Total Marks**
	(a)	**Classify Fixed and Modular PLC.**	**4M**

Ans:

Sr. No	Fixed PLC	Modular PLC
1	It is also known as an integrated PLC or Compact PLC.	It is also known as rack-mounted units.
2	In Fixed PLC, the number of inputs and outputs are fixed because I/O capabilities are decided by the manufacturer but not by the user.	In Modular PLC, the number of inputs and outputs are not fixed. Inputs outputs can be added to the modular PLC systems by the user.
3	It has inputs and outputs modular fitted with CPU.	In this PLC, several components are fitted on chassis or rack or bus with different slots.
4	Fixed PLC is not easily repaired.	Modular PLC is easy to maintain and repair as compared to fixed PLC.

Any four points :4M

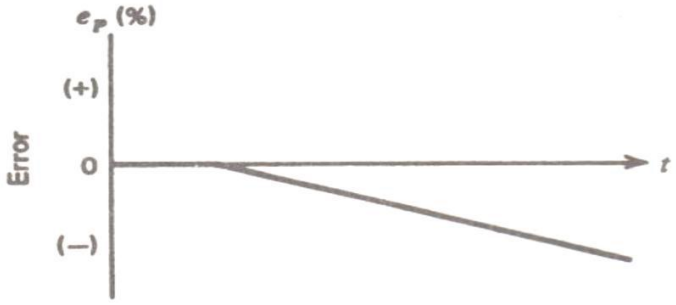
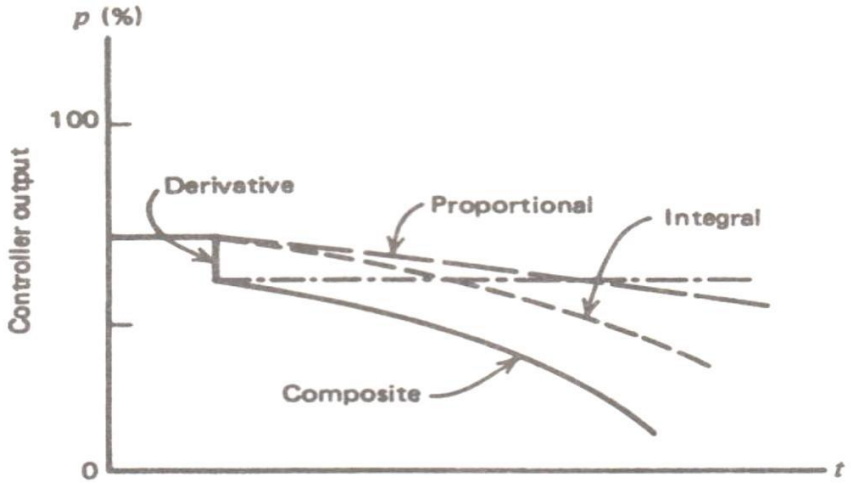
		5	It has fewer capabilities to store data/information.	It has more memory and capabilities to store more data.
		6	It is useful for the smaller applications and most suitable for the domestic purpose.	It is used for industrial purpose and also for future industrial expansion and growth.
		7	It is smaller in size.	It occurs in a large size with i/o connectivity, power supply, computing capabilities, etc.
		8	It is an economic model.	It is costlier than Fixed PLC.
	(b)	**Describe PID controller with neat diagram, output equation and response.**		**4M**
	Ans:	**PID controller**		**Diagram : 2M**



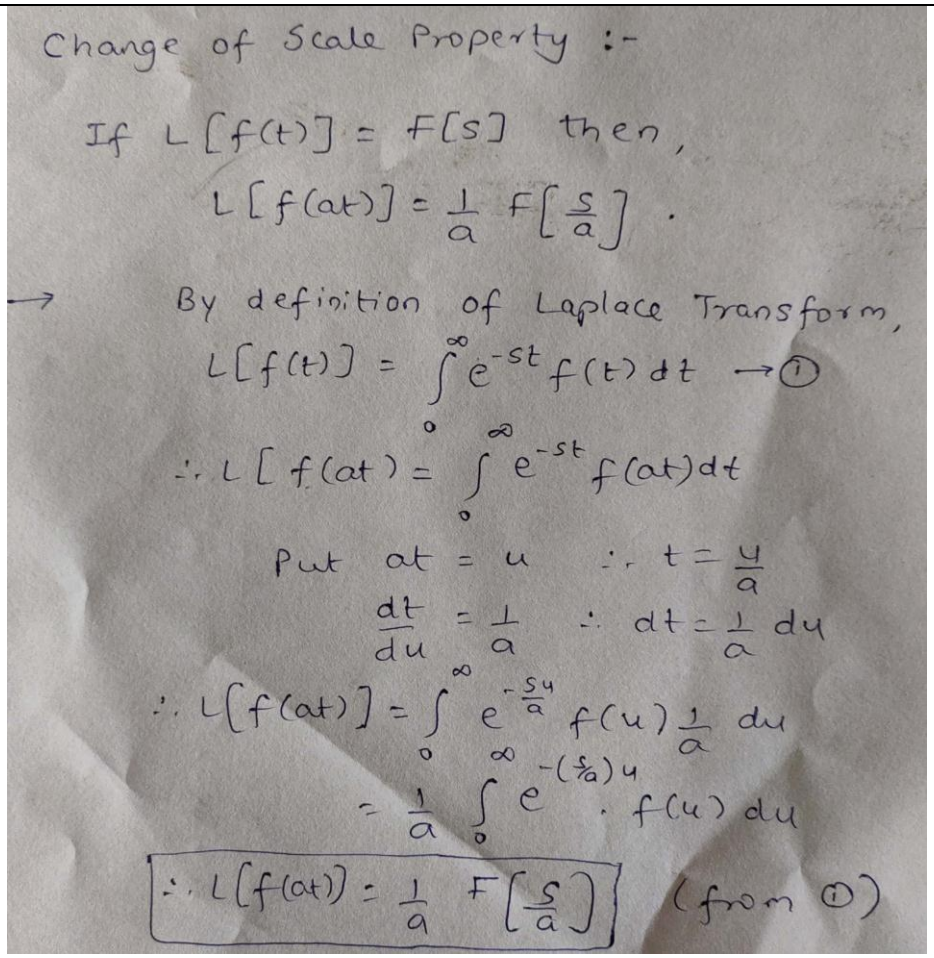
Note: Any other relevant diagram should be considered

Explanation:

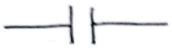
i) The combination of proportional control action, derivative control action and integral control action is called as PID controller action.
ii) The combined action has advantage of the three individual control actions. The proportional controller stabilizes gain but produces steady state error.
iii) The integral action reduces the steady state error. The derivative action reduces the rate of change of error.
iv) PID controller is a band pass or band attenuate filter, depending on the values of the controller parameters.
v) The response characteristics of PID controller is shown in figure. The proportional part of

		the control action repeats the change of deviation. vi) The derivative action of the control action adds on increment of manipulated variables so that the proportional plus derivative control action is shifted ahead in time. vii) The integral part of the control action adds a further increment of manipulated variable. Output equation: $P=K_pE_p+ K_pK_I\int E_p dt+ K_pK_D\frac{dEP}{dt}+P_I(0)$ **Nature of output response to error:** **(Note:** Response with respect to any other error can be considered)   	**Explanation : 1M** **Equation :1M** **Response :1M**
	(c)	**Define the following terms related to second order system.** **(i) Damping** **(ii) Damping ratio** **(iii) Undamped natural frequency**	**4M**

		(iv) Damped frequency	
	Ans:	**(i) Damping :** Every system has tendency to oppose the oscillatory behavior of the system which is called as damping . **(ii) Damping ratio :** The damping is measured by a factor or a ratio called damping ratio of the system **(iii) Undamped natural frequency :** Natural frequency is basically the frequency with which any oscillations takes place with no damping **(iv) Damped frequency :** It is the frequency at which a Damped system oscillates when not subjected to a continuous or repeated external force. It is given by formula : $\omega_d = \omega_n\sqrt{1-\zeta^2}$ $\zeta = damping\ ratio$ $\omega_d = damped\ frequency$ $\omega_n = natural\ frequency$	**Definition :1M each**
	(d)	**Describe linearity property and change of scale Property of Laplace Transform.**	**4M**
	Ans:	**Linearity Property :** The linearity property of the Laplace Transform states: $a\cdot f(t)+b\cdot g(t)\xleftrightarrow{\mathcal{L}} a\cdot F(s)+b\cdot G(s)$ This is easily proven from the definition of the Laplace Transform $\mathcal{L}\left(a\cdot f(t)+b\cdot g(t)\right)=\int_{0^-}^{\infty}\left(a\cdot f(t)+b\cdot g(t)\right)e^{-st}dt$ $=a\int_{0^-}^{\infty}f(t)e^{-st}dt+b\int_{0^-}^{\infty}g(t)e^{-st}dt$ $=a\cdot F(s)+b\cdot G(s)$	**Linearity property : 2M** **Change of scale property : 2M**



	(e)	**Describe Relay instructions for PLC.**	**4M**
	Ans:	**Relay type instructions** **1. Normally open (XIC)** **2. Normally closed (XIO)** **3. One shot instruction(OSR)** **4. Output instruction** **5. Output latch instruction(L)** **6. Output unlatch instruction(U)** **Explanation:** **1. Normally open (XIC) :**	**Description : 4M**

Symbol : 

When the contact is switched ON, the circuit is completed and current flows through the circuit.

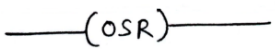
2. **Normally Close (XIO) :**

Symbol :

When the contact is switched ON, the circuit is broken and the current flowing through the circuit stops.

3. **One Shot Instruction (OSR) :**

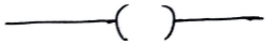
Symbol :



If the conditions of rung before OSR instruction are true or satisfied then OSR instruction is true for one scan cycle and also triggers o/even if rung conditions are still true.

4. **Output Instruction :**

Symbol :

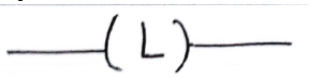


It becomes ON if the process finds true path in the rung containing this

o/p otherwise it remains OFF.

5. **Output latch instruction(L) :**

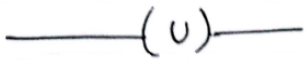
Symbol :



It is a latch type coil of the output. It is set to 1 when input becomes true for one input scan output stay ON even if input goes false.

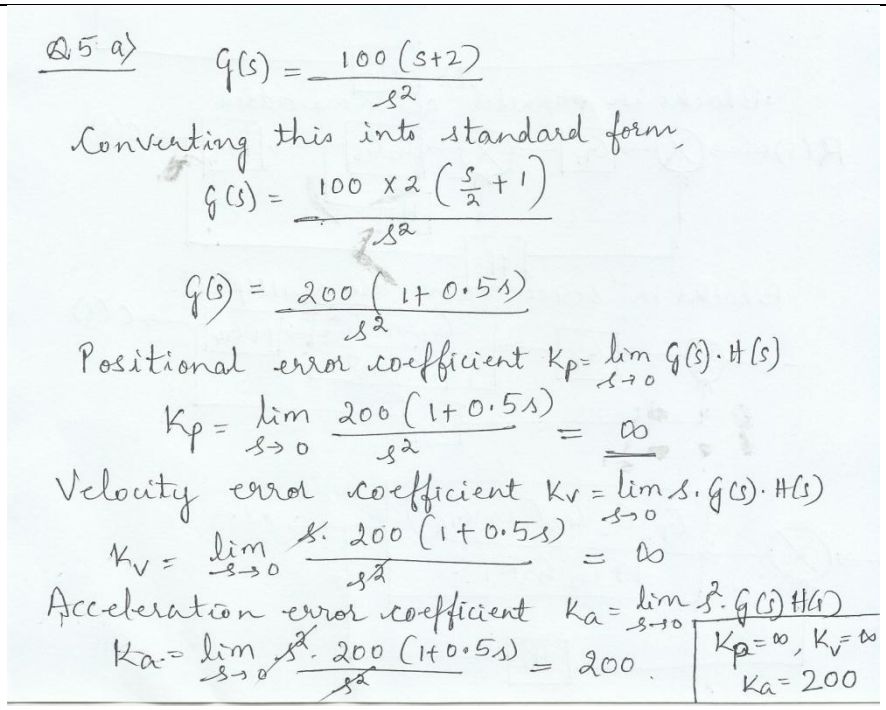
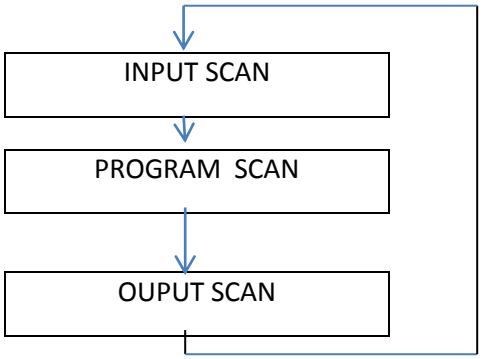
6. **Output unlatch instruction(U) :**

Symbol :



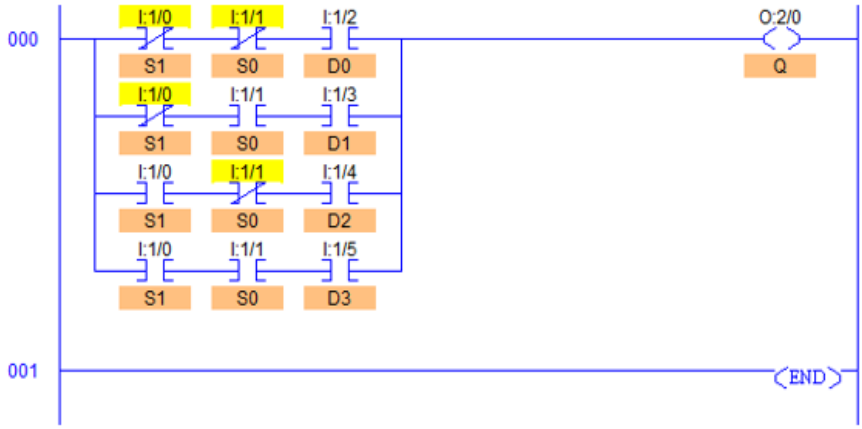
It is a latch type coil of the output. It is used to reset or unlatch the latched coil if the input become true or 1 for one input scan.

Q. No.	Sub Q. N.	Answers	Marking Scheme
5.		**Attempt any TWO of the following:**	**12- Total**

			Marks
	a)	**For unity feedback control system** $G(s) = \frac{100\,(S+2)}{S^2}$ **Calculate all error constants.**	**6M**
	Ans:		**2M for each error coefficient**
	b)	**Describe Operating cycle of PLC with neat diagram.**	**6M**
	Ans:	 **The scan cycle consist of three steps.** Input scan, program scan and output scan.	**Diagram : 2M** **Explanation : 4M**

		PLC checks ON or OFF status of each input point connected to the module. This information is stored in input status file. Then CPU starts executing user program left to right and top to bottom from the first instruction to the last. It updates the output status file depending on the program. In the output scan, data on the output status file is sent to the output module and the devices are energized or deenergised accordingly.	
	c)	**Develop a ladder diagram for 4:1 Multiplexer.**	**6M**
	Ans:	Truth table of 4:1 Multiplexer is as shown below. Depending on the signal on select lines one of the inputs is selected and directed to the output. Ladder Diagram:	**Truth Table: 2M** **Ladder Diagram :4M**

Select Data Inputs		Output
S_1	S_0	Y
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3



Q. No.	Sub Q. N.	Answers	Marking Scheme
6.		**Attempt any TWO of the following :**	**12- Total Marks**
	a)	**Illustrate PLC timer in detail.**	**6M**
	Ans:	Depending on the time delay and operation there are two types of timers PLC timer - (i) ON delay timer (ii) OFF delay timer **ON delay time**r: This instruction counts time interval when conditions preceding it in the rung are true. Produces an output when accumulated reaches the preset value. 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. 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.	**ON delay time**r:**3 M** **OFF delay timer:3 M**

	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.

(ii) **OFF delay timer** : This instruction counts time interval when conditions preceding it in the rung are false. Produces low output when accumulated value reaches the preset value. 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.

As long as rung conditions remain 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.

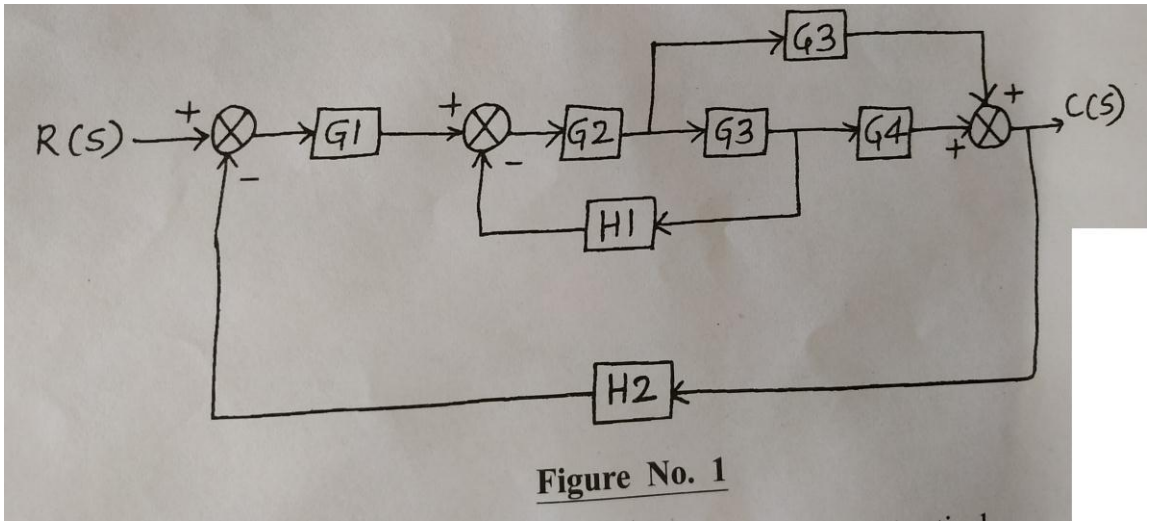
	15	14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	
word 0	TT\EN	TT\EN DN	16 bit
word 1	preset value		16 bit
word 2	Accumulator value		16 bit

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.

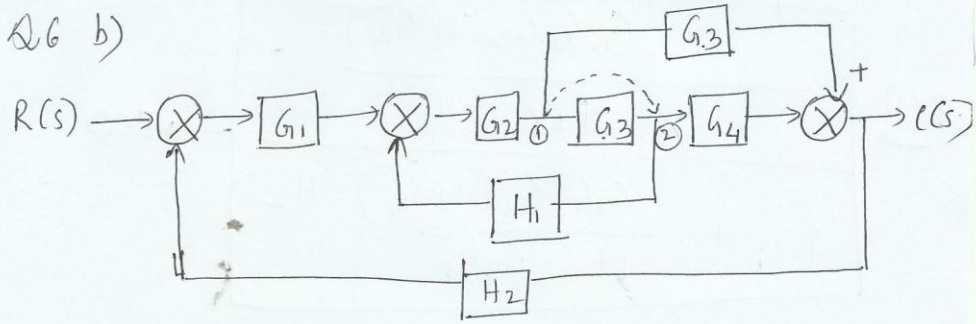
ii) Timer enable bit(bit 14)-EN is set when rung condition are true. It is reset when rung condition become false.

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.

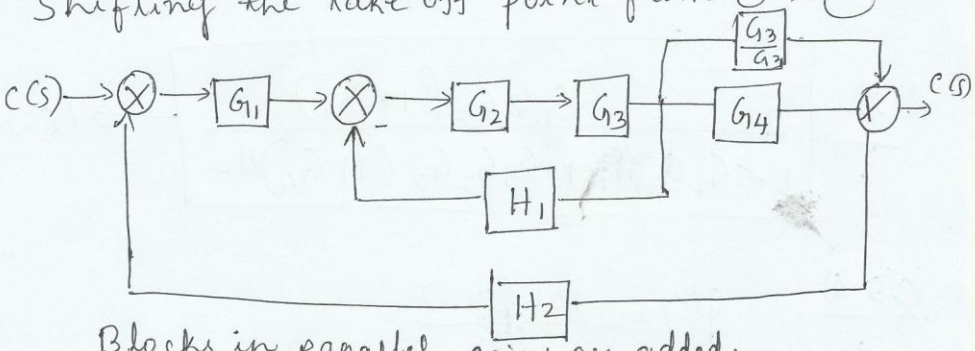
	b)	**Apply the block diagram reduction rule to obtain transfer function C(S)/R(S) of the following block diagram. (Refer Figure No. 1)**  **Figure No. 1**	**6M**

	Ans:		1M for each step

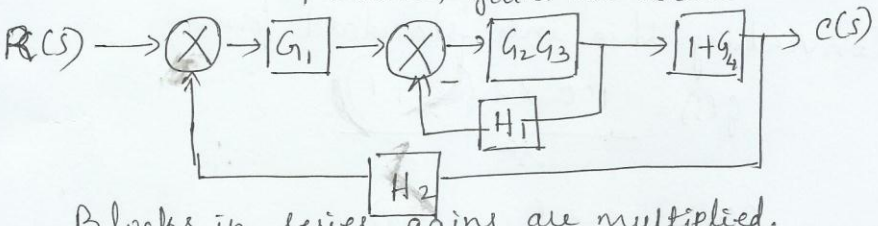
Q6 b)



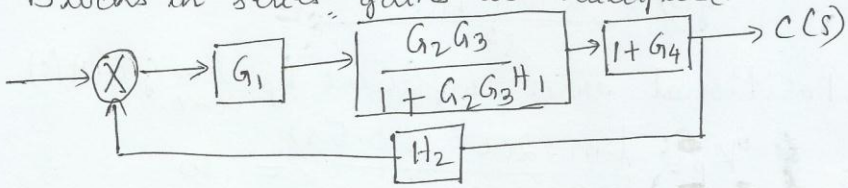
Shifting the take off point from ① to ②

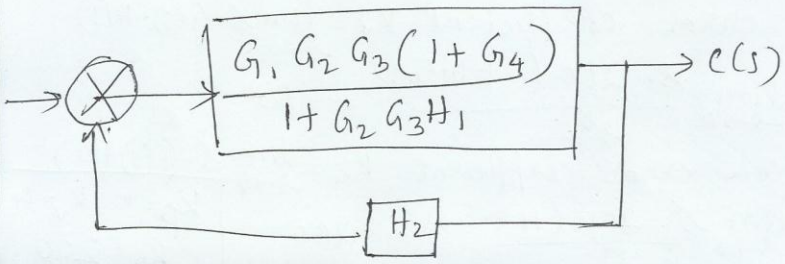


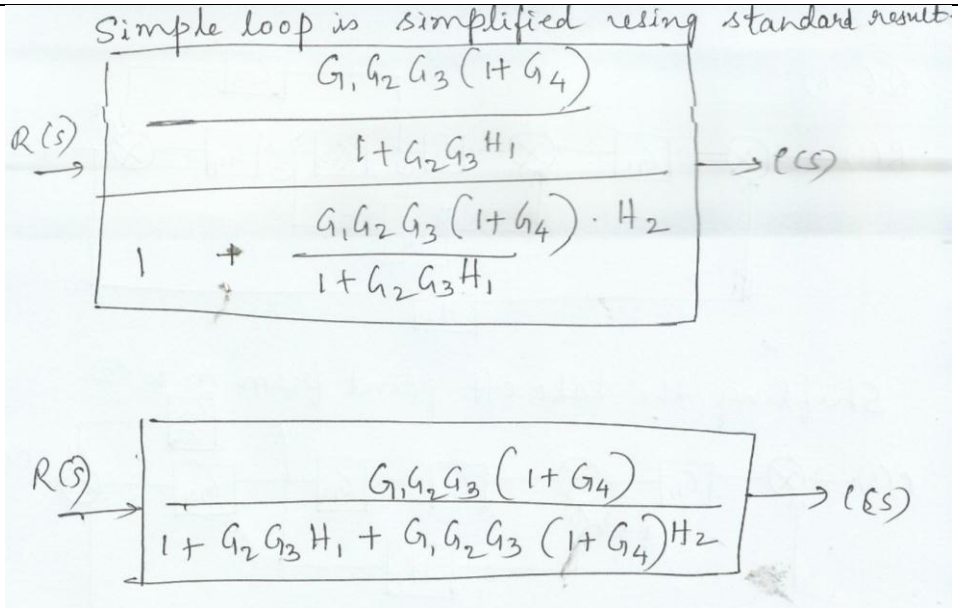
Blocks in parallel, gains are added.

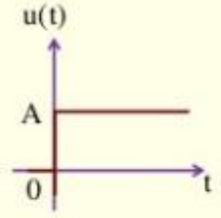


Blocks in series, gains are multiplied.



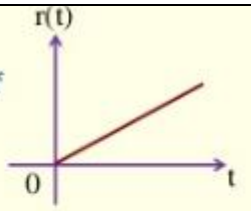




	c)	**Describe four standard test inputs with their mathematical expression and graphical representation.**	**6M**
	Ans:	Standard test inputs are . 1. Step input 2. Ramp input 3. Parabolic input 4. Impulse input; **Step-function** • The step signal imitate the sudden change characteristic of actual input signal. $u(t) = \begin{cases} A & t \geq 0 \\ 0 & t < 0 \end{cases}$  	**Each test input :1.5M**

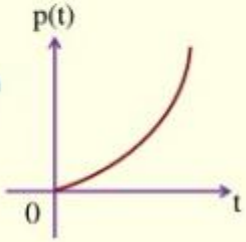
- **Ramp-function**
  - The ramp signal imitate the constant velocity characteristic of actual input signal.

$$r(t) = \begin{cases} At & t \geq 0 \\ 0 & t < 0 \end{cases}$$



- **Parabolic-function**
  - The parabolic signal imitate the constant acceleration characteristic of actual input signal.

$$p(t) = \begin{cases} \frac{At^2}{2} & t \geq 0 \\ 0 & t < 0 \end{cases}$$



- **Impulse-Function**
  - The impulse signal imitate the sudden shock characteristic of actual input signal.

$$u(t) = \delta(t) = \begin{cases} A & t = 0 \\ 0 & t \neq 0 \end{cases}$$