MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

MODEL ANSWER

WINTER– 17 EXAMINATION

Subject Title: Control System And PLC Subject Code: 17536

Important Instructions to examiners:

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

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q.1		**Attempt any FIVE:**	**20M**
	(a)	**Write any four applications and four Advantages of Servo System.**	**4M**
	Ans:	**Applications -** • Robotics • Solar tracking system • Automobile machine tools • Elevator **Advantages -** • Closed loop control system • Higher torque at higher speed • Very efficient • Better choice for variable load system	**2M** **(Any other relevant point)** **2M**
	(b)	**Derive the transfer function of Fig. (1-b) using block diagram simplification method.**	**4M**

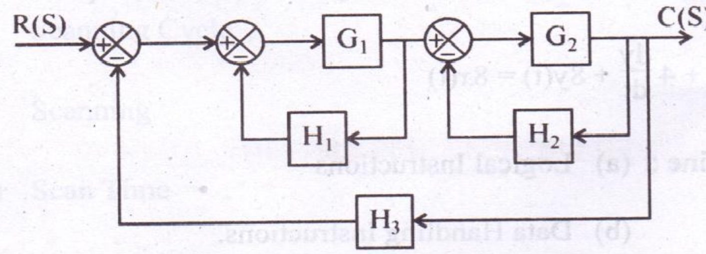
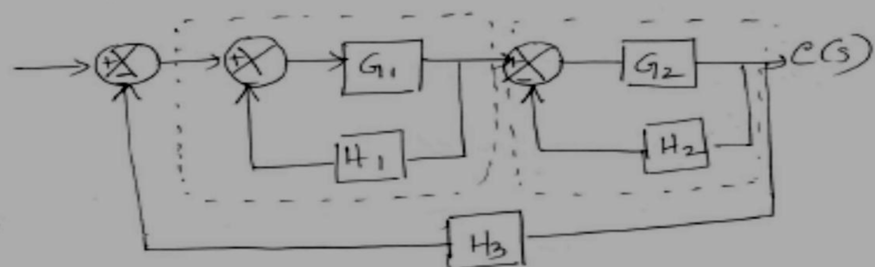


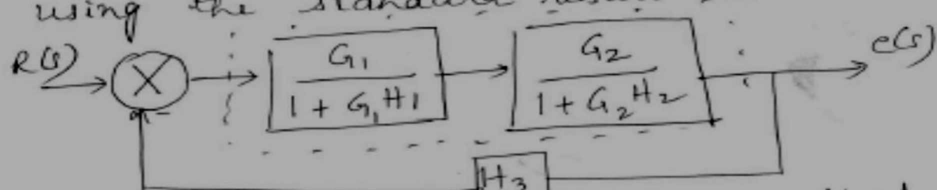
Fig. (1-b)

Ans:

Solution:

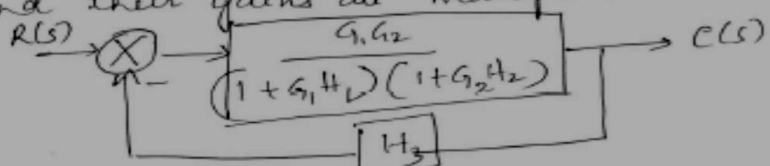


There are two simple feedback loops, which can be simplified using the standard result derived



1M

Two Blocks in series can be combined and their gains are multiplied.

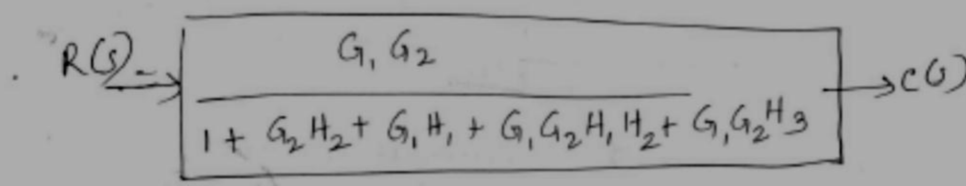


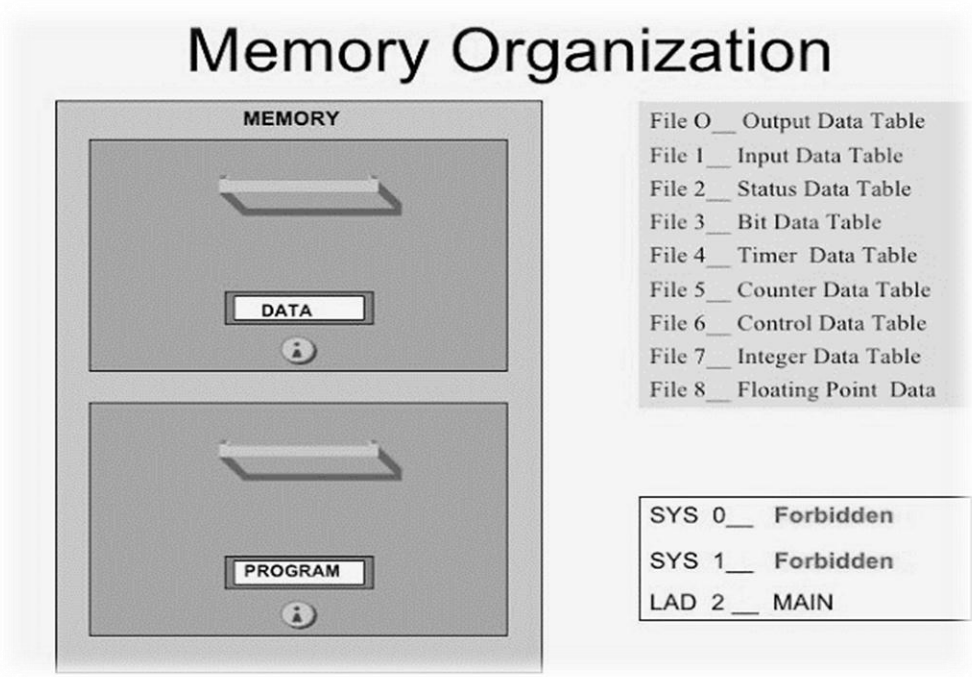
1M

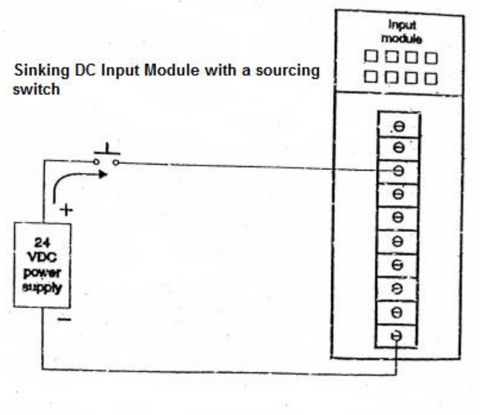
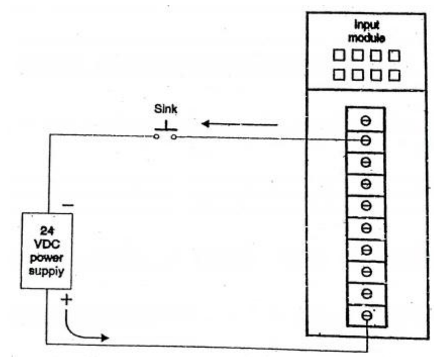
Again there is a simple feedback loop

$$\frac{\dfrac{G_1 G_2}{(1+G_1H_1)(1+G_2H_2)}}{1+\dfrac{G_1G_2}{(1+G_1H_1)(1+G_2H_2)}\cdot H_3}$$

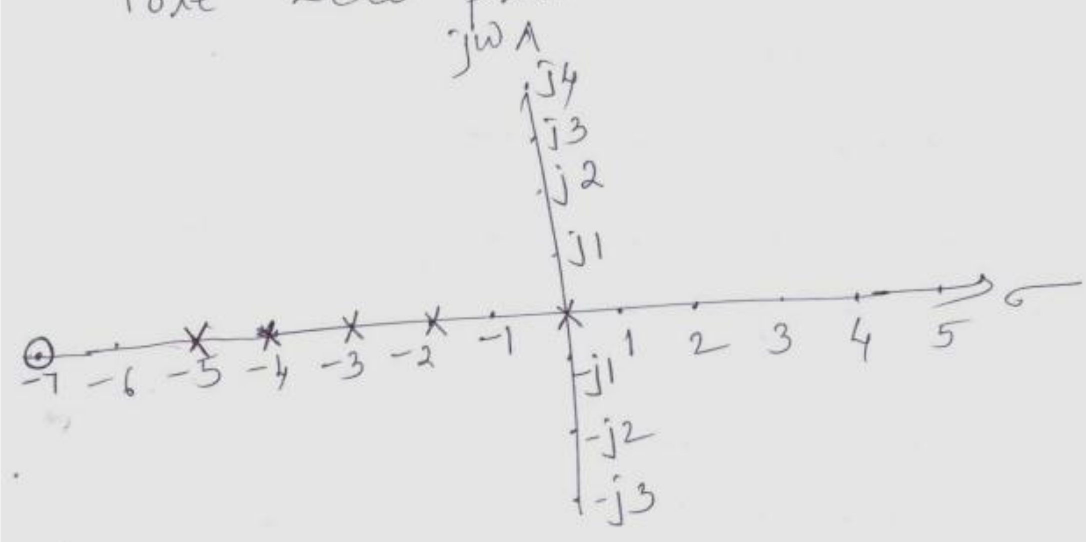
1M

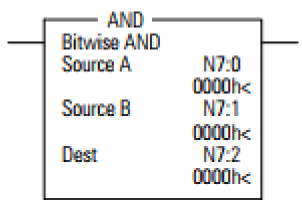
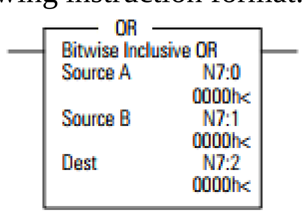
		$\dfrac{\dfrac{G_1G_2}{\cancel{(1+G_1H_1)(1+G_2H_2)}}}{\dfrac{(1+G_1H_1)(1+G_2H_2)+G_1G_2H_3}{\cancel{(1+G_1H_1)(1+G_2H_2)}}}$ 	**1M**
	(c)	**Define the following term :** **(i) Time Response** **(ii) Transient Response** **(iii) Steady State Response** **(iv) Steady State error**	**4M**
	Ans:	• Time Response :The response given by the system which is a function of time to the applied excitation is called time response of the system. • Transient Response :The output variation during the time the system takes to achieve its final value is called transient response. • Steady State Response :The part of the response that remains after the transient have died out is called steady state response. • Steady State error:The difference between the desired output and actual output in the steady state is called steady state error.	**1M each**
	(d)	**List the various factors which govern the selection of PLC for particular use. (minimum eight points)**	**4M**
	Ans:	**<u>Following points can be considered while selecting PLC for a particular use: (any eight)</u>** * System (task) requirements. * Application requirements. * What input/output capacity is required? * What type of inputs/outputs are required? * What size of memory is required? * What speed is required of the CPU? * Electrical requirements. * Speed of operation. * Communication requirements. * Software requirements. * Operator interface. * Physical environments.	**½ M each Point**

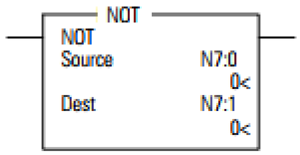
	(e)	**Draw and explain memory organization ofPLC.**	**4M**
	Ans:	**<u>Diagram:</u>**  ***<u>Note: any other suitable diagram can also be considered.</u>***	**2M**
		<u>Explanation:</u> The PLC's CPU has 1000's of memory location that stores information in the form of 0 or 1. These are known are words or registers. The purpose of memory is to store system program user program, status of various inputs and outputs, timer data, counter data, alphanumeric data related to program etc. All above information which is stored in memory must be stored in an orderly manner, so that whenever processor requires to fetch any specific information that can be easily available. Therefore to achieve this processor memory is divided into two parts such as : 1) Program files(ROM memory): PLC processor stores the system information configuration information and user program in program files. The capacity of Program Memory varies based on the type of processor. 2) Data Files(RAM memory): PLC processor stores data which is required to solve the user program in one group of files called data files. Different data files are arranged in sequential manner which are used to store different data such as – I/O status, timer status, processor status, counter status, integer data status, floating data status etc.	**2M**
	(f)	**Explain the sourcing and sinking concept in DC Input module.**	**4M**

	Ans:	**Sinking and sourcing concept in DC input Module:** **<u>Diagram:</u>** **Fig.1**  **Fig.2**  Sourcing DC input module with a sinking switch.	**2M**
		<u>Explanation:</u> Sinking and sourcing are the terms used to describe current flow through a field device in relation to the power supply and the associated I/O point. In a DC circuit there must be three parts: power supply, a switching device and the load. The relationship between the switching device, and the load and which one receives current first, defines whether we have a sinking or sourcing circuit. Fig.1 illustrates the sourcing switch with sinking DC module. The current flows from the positive terminal of the battery through the switch and onto the module which is the load. Notice that the switch is the source of current as far as module is concerned. As a result switch is called sourcing device and the module is called sinking device, as it sinks the current to ground. Fig. 2 illustrates the sinking switch and sourcing DC module. The current flows from the positive terminal of the battery through the module which is the load and onto the switch. Notice that the Module is the source of current as far as switch is concerned. As a result DC module is called as sourcing device and the switch is called as sinking device, as it sinks the current to ground.	**2M**

	(g)	**Define the following term :** **(i) Neutral Zone·** **(ii) Control Action**	**4M**
	Ans:	(i) **<u>Neutral Zone:</u>** The range of error in which there is no change in the controller output is called neutral zone. This is designed to reduce excessive cycling of ON-OFF Controller (ii) **<u>Control Action:</u>** An automatic controller produces the control signal is called control action. There are classified as: • Discontinuous controller (on-off) • Continuous controller (P,I,D) • Composite controller (PI,PD, PID)	**Neutral Zone· 2M** **Control Action:2M**
Q 2		**Attempt any two:**	**16M**
(a)	**(i)**	**For a given Transfer function** $$\frac{T.F. = K(S+7)}{S(S+2)(S+5)(S^2+7S+12)}$$ **find (i) Pole (ii) Zero (iii) Characteristics equation (iv) Pole Zero plot**	**4M**

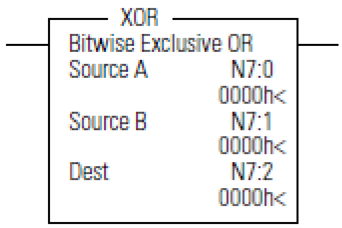
	Ans:	$T.F = \frac{K(s+7)}{s(s+2)(s+5)(s^2+7s+12)}$ i) Poles are the values of s for which the denomenator is zero. $s=0$ $s+2=0$ gives $s=-2$ $s+5=0$ gives $s=-5$ $s^2+7s+12=0 \Rightarrow (s+4)(s+3)=0$ gives $s=-4$ and $s=-3$ $\therefore \boxed{\text{Poles are } s=0, -2, -3, -4, -5}$	**1M**
		ii) Zeros are the values of s for which the numerator is zero $\boxed{\text{Zero } s=-7}$	**1M**
		iii) Characteristic equation $s(s+2)(s+5)(s^2+7s+12)=0$ $(s^2+2s)(s^3+7s^2+12s+5s^2+35s+60)=0$ $s^5+7s^2+12s^3+5s^4+35s^3+60s^2+2s^4+14s^3+24s^2+10s^3+70s^2+120s=0$ $s^5+7s^4+71s^3+161s^2+120s=0$	**1M**
		Pole Zero plot  	**1M**

	(ii)	**(1) Find the Transfer function of a given differential equation.** $$\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 8y(t) = 8x(t)$$ **2) Define:** **(a) Logical Instructions** **(b) Data Handling Instructions.**	**2M** **1M** **1M**
	Ans:	(1) **Transfer function of a given differential equation-** Taking Lapalce Transform, $S^2Y(S) + 4SY(S) + 8Y(S) = 8X(S)$ $Y(S)[S^2 + 4S + 8 = 8X(S)$ $$TF = \frac{Y(S)}{X(S)} = \frac{8}{S^2 + 4S + 8}$$ **2) (a) Different Logical instructions are :** i) **<u>AND :</u>** Logical AND is a output type of instruction which requires two data inputs Source A and Source B as shown in following instruction format.  **<u>ii) OR:</u>** Logical OR is an output type of instruction which requires two data inputs Source A and Source B as shown in following instruction format.  **<u>iii) NOT:</u>** Logical NOT is a output type of instruction which requires one data input as shown in following instruction format.	**2M** **½ M each any four**



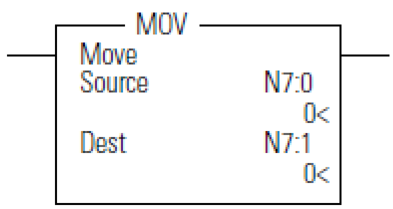
iv) <u>EX-OR :</u>

Logical EX-OR is a output type of instruction which requires two data inputs Source A and Source B as shown in following instruction format.



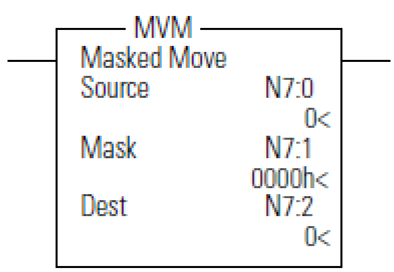
(b) Different Data handling Instructions are :

i) <u>MOV</u>



The MOV instruction is used to move data from the source to the destination. Aslong as the rung remains true, the instruction moves the data each scan.

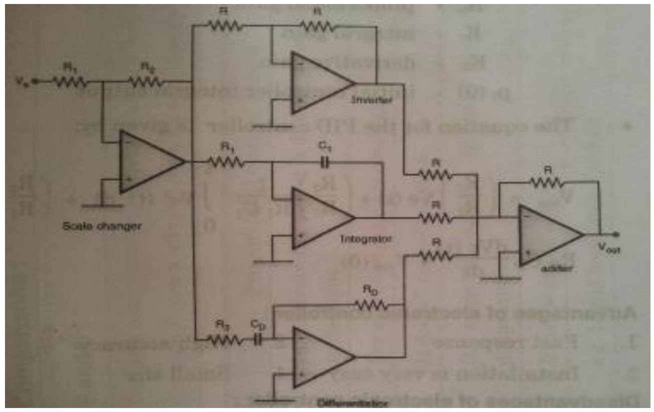
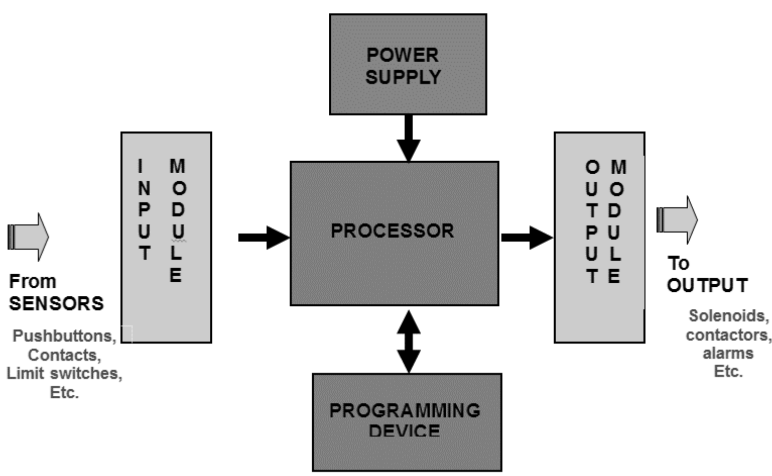
<u>ii) Masked Move</u>



The MVM instruction is used to move data from the source to the destination, Allowing portions of the destination to be masked.

b)	**(i)**	**A system has** $G(S) . H(S) = \frac{K}{S(S+2)(S+4)(S+8)}$ **where K is positive**	**4M**

		Find (1) Characteristics equation **(2) Range ofK value for stability.**	
	Ans:	$G(s)H(s) = \frac{K}{s(s+2)(s+4)(s+8)}$ i) Characteristic equation is $1 + G(s)H(s) = 0$ $1 + \frac{K}{s(s+2)(s+4)(s+8)} = 0$ $\frac{s(s+2)(s+4)(s+8) + K}{s(s+2)(s+4)(s+8)} = 0$ $(s^2+2s)(s^2+8s+4s+32)+K=0$ $s^4+8s^3+4s^3+32s^2+2s^3+16s^2+8s^2+64s+K=0$ $\boxed{s^4+14s^3+56s^2+64s+K=0}$ Routh's array is s^4	1 56 K s^3	14 64 s^2	51.4 K s^1	$\frac{3289.6-14K}{51.4}$ s^0	K For the system to be stable from s^0 row, $K>0$ from s^1 row $3289.6-14K>0$ $3289.6>14K$ $235>K$ $\therefore$ Range of K is $0<K<235$	1M 2M 1M
	ii)	**Draw electronic PID controller and explain operation of its each stage. Give two advantages and two disadvantages of Electronic Controller.**	**4M**
	Ans:		

		Diagram- 	**2M**
		Advantages Electronic Controller: 1)small in size 2)Less noise 3) Fast response 4)More accurate 5)No moving parts **Disadvantages of Electronic Controller:** 1)Low Power 2)Expensive initial cost 3)Complexity of algorithms/troubleshooting 4)Risk of radio frequency interference 5)Risk of fire hazards due to arcs, sparks 6)Risk of electricution, short circuits, grounds	**Any two advantages-1M,** **Any two Disadfvantages-1M**
c)		**Draw the basic block diagram of PLC and write the function of each block.**	**8M**
	Ans:	**Diagram:** 	**4M**

Explanation: **4M**

The Basic PLC structure consists of –

1) Input Module:
   Input Module works as an interface between the CPU and the real world input devices attached to input module .The devices connected to input module are called as input devices. It accepts the incoming signal and convert this signal in the form which is compatible with CPU.
2) Output Module:
   Output module works as an interface or link between the CPU and the real world devices attached to the output module. The main function of output module is to take control signal from CPU and based on signal received from CPU it changes the status of output devices.
3) Central processing unit:
   The CPU is the main part of any PLC .The CPU solves the user program logic, by using real time input status from input module and updates the status of outputs through output module.
4) Power supply:
   Power supply is the part of PLC which is used to supply required amount of power to CPU, input module and output module.
5) Programming device:
   The programming device is used for communication between user and PLC. The programming device help the user to entre and modify the required program into the PLC memory and trouble shoot PLC ladder logic program.

Q. 3 **Attempt any FOUR:** **16M**

a) **Compare open loop system and closed loop system on the basis of following point:** **4M**
(i) Feedback path
(ii) Complexity of design
(iii) Cost and maintenance
(iv) Accuracy and bandwidth

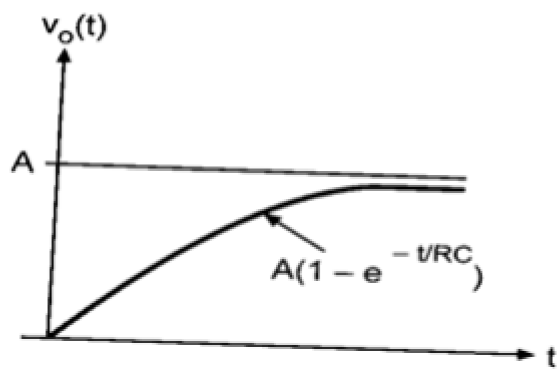
Ans: **(1M each)**

	Open loop system	**Closed loop system**
Feedback path	It does not require feedback path element	It require feedback path element
Complexity of design	Less Complex	More Complex
Cost and maintenance	Less Cost	Costlier
Accuracy and bandwidth	It has poor accuracy and It has high bandwidth	It has better accuracy and It has low bandwidth

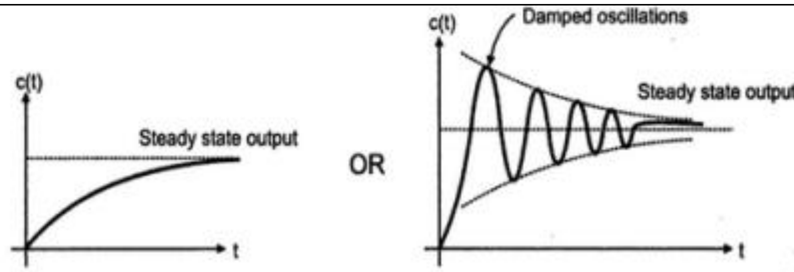
(b) **Define the following term related to PLC :** **4M**
(i) Scanning Cycle
(ii) Scanning
(iii) Scan Time
(iv) Speed of Execution

Ans: **1) Scanning Cycle:**

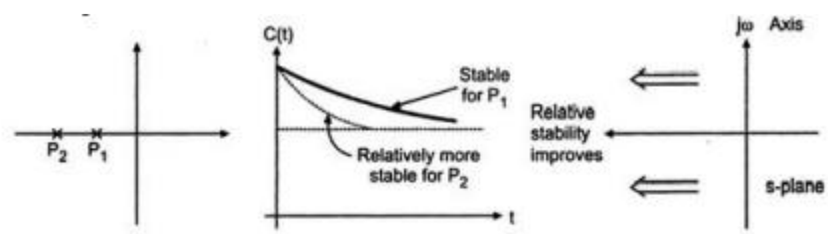
		In RUN mode PLC processor starts scanning of ladder program. This scanning of ladder program is performed sequentially and repeatedly in four steps that are – Input scan, program scan, output scan and communication and memory management. This cycle is called as scanning cycle. **OR** When PLC is put into RUN mode by the user, CPU starts scanning of ladder program sequentially and repeatedly. Completion of one sequence of program scan is called as scanning cycle. **2) Scanning :** Scanning is the process in which ladder program scanned by the PLC processor rung by rung and instruction by instruction. During scanning PLC processor uses the status of input devices to solve the logic and after scanning processor updates the statuses of output devices. **3) Scan Time:** The time taken by the PLC processor to complete one scanning cycle is called as scan time. **4) Speed of Execution:** Speed at which a PLC scans memory and executes the program is called as speed of execution. The speed of execution of PLC depends on the length of the program and scan rate of the processor.	**1M each**
	(c)	**Derive an expression for unit step response C(t) of first order system. Also draw Response Curve.**	**4M**

	Ans:	The T.F. of First order system is , $$\frac{V_0(s)}{V_i(s)} = \frac{1}{1+sRC}$$ For Unit Step input $V_i(s) = \frac{1}{s}$ So, $V_0(s) = \frac{1}{s(1+sRC)} = \frac{A'}{s} + \frac{B'}{1+sRC}$ Where : A' = 1 and B' = - RC $$Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC} = \frac{1}{s} - \frac{1}{s + \frac{1}{RC}}$$ Taking Laplace inverse, $Vo(t) = 1 - e^{\frac{-t}{RC}}$ => Css + ct(t) Css = 1 and $ct(t) = -e^{\frac{-t}{RC}}$ **<u>Diagram-</u>** The Response is shown in fig. 	**Expression – 2M** **2M**
	(d)	**Define following term related to control action:** **(i) Controller** **(ii) Error Signal** **(iii) OFF Set**	**4M**

		(iv) Proportional Band	
	Ans:	**(i) Controller :** It generates the correct signal which is then applied to the final control element. Controller output is denoted by “m”. **(ii) Error Signal :** It is the difference between the set point and actual output **(iii) OFF Set :**When the load changes, the output deviates from the set point in the proportional controller. Such deviation is called as offset **(iv) Proportional Band:** The range of error to cover the 0% to 100% controller output is called proportional band. It also specifies the percentage error that results in a100% change in the controller output.	**1M each**
	(e)	**Give the functional descriptions for following Timer Instructions:** **(i) ON Relay** **(ii) OFF Relay** **(iii) Retentive** **(iv) Reset** ***Note- In question Instead of (i) ON Relay (ii) OFF Relay it is (i) ON Delay (ii) OFF Delay***	**4M**
	Ans:	**(i) ON Delay** : This instruction counts time interval when condition preceding it in the rung are true. Produces an output when accumulated values reaches the preset value. **(ii) OFF Delay** : This instruction counts time interval when condition preceding it in the rung are false. Produces low output when accumulated values reaches the preset value. **(iii) Retentive** : This is on delay timer that retains accumulated value when - Rung condition go false - The mode changes to program from run to test - The processor losses power - A fault occurs **(iv) Reset**: Reset the accumulated value of a timer	**1M each**
	(f)	**What is the importance of stability? Define absolute & relative stability.**	**4M**
	Ans:	Importance of stability: The concept of stability in common and engineering sense reflects necessity to keep response of a disturbed system within acceptable limits. If deviations describing response of the system from a given regime (e.g. state of equilibrium) lie within the prescribed limits, the system is called stable. Otherwise, the system is called unstable. Disturbances, response, and prescribed limits can be specified in each case in different ways. The stability of a control system is often extremely important and is generally a safety issue in the engineering of a system. An example to illustrate the importance of stability is the control of a nuclear reactor. An instability of this system could result in an unimaginable catastrophe or in case of a robot arm controller that is unstable may cause the robot to move dangerously. Also, systems that are unstable often incur a certain amount of physical damage, which can become costly. The stability of a system relates to its response to inputs or disturbances. A system which remains in a constant state unless affected by an external action and which returns to a constant state when the external action is removed can be considered to be stable. Absolute Stability: A linear time invariant system is said to be absolutely stable w.r.t. a parameter if the system is stable for all values of that parameter.	**Importance – 2M Definition- 2 M**



Relative Stability: The system is said to be relatively more stable on the basis of settling time. If the settling time for a system is less than that of another system then the former system is said to be relatively more stable than the second one.



Q. 4		**Attempt any TWO:**	**16M**
	(a)	**A unity feedback system with open loop transfer function.** $$G(S) = \frac{10\,(S+2)\,(S+3)}{S\,(S+1)\,(S+4)\,(S+7)}$$ **Find out (i) Types of system and K_p, K_v, K_q** **(ii) Steady state error for input = $3 + t + t^2$**	**8M**
	Ans:	**Types of system: 1**	**Types of system 1M**

$$K_p = \lim_{s \to 0} G(s)H(s) \qquad H(s) = 1$$

K_P:1M

$$= \lim_{s \to 0} \frac{10(s+2)(s+3)}{s(s+1)(s+4)(s+7)}$$

$$= \frac{10(0+2)(0+3)}{0(0+1)(0+4)(0+7)}$$

$$= \underline{\underline{\infty}}$$

$$K_v = \lim_{s \to 0} s\,G(s)H(s)$$

K_V:1M

$$= \lim_{s \to 0} \cancel{s} \frac{10(s+2)(s+3)}{\cancel{s}(s+1)(s+4)(s+7)}$$

$$= \frac{10\cdot(0+2)(0+3)}{(0+1)(0+4)(0+7)}$$

$$= \frac{\overset{5}{\cancel{10}}\cdot \cancel{2}\cdot 3}{1\cdot \underset{2}{\cancel{4}}\cdot 7} = \underline{\underline{\frac{15}{7}}}$$

$$K_A = \lim_{s \to 0} s^2 G(s)H(s)$$

K_A:1M

$$= \lim_{s \to 0} \cancel{s^2}^{\,s} \frac{10(s+2)(s+3)}{\cancel{s}(s+1)(s+4)(s+7)}$$

$$= \frac{0\cdot 10(0+2)(0+3)}{(0+1)(0+4)(0+7)}$$

$$= \underline{\underline{0}}$$

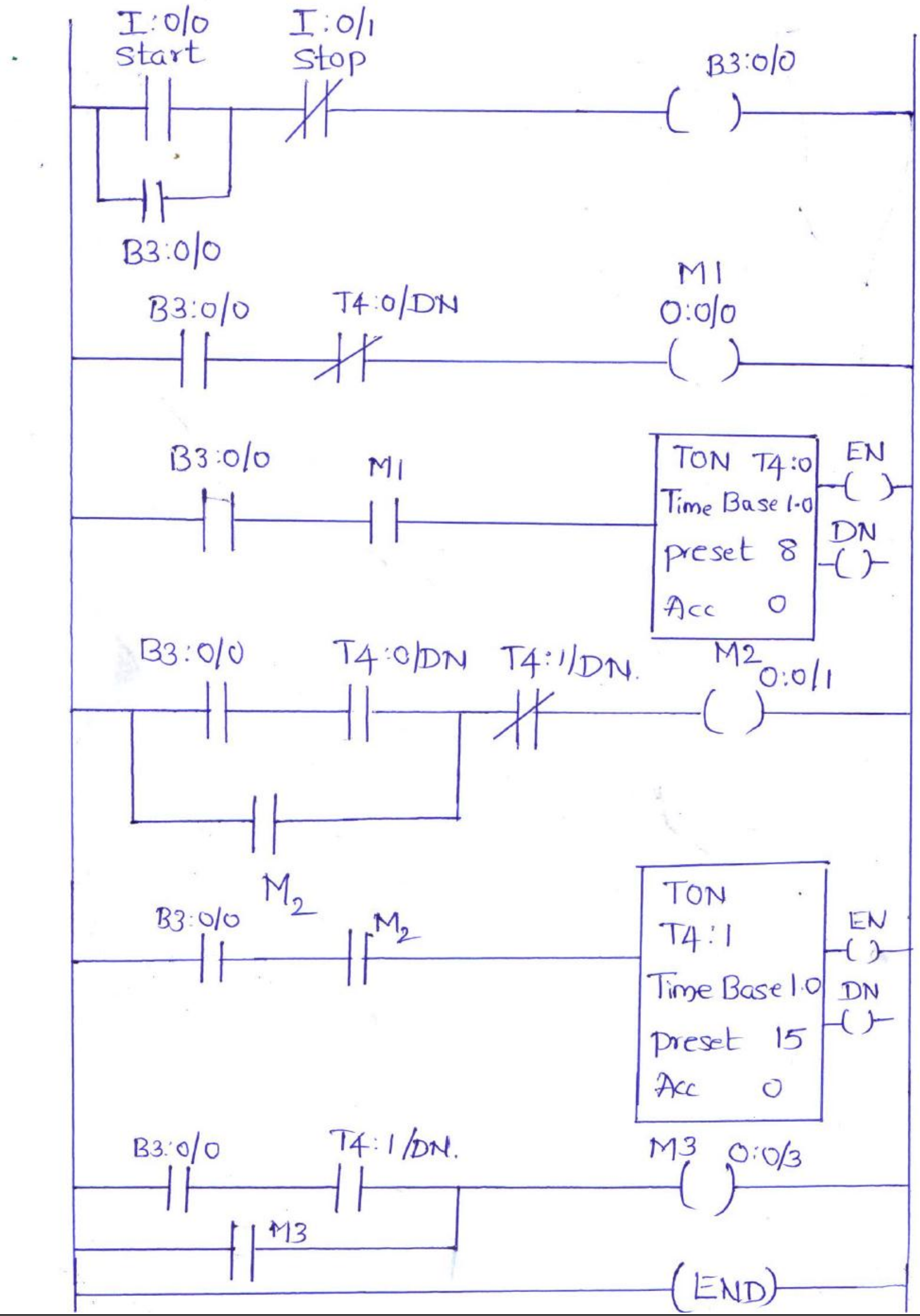
		ii) The steady state error for step input is $e_{ss_1} = \frac{A_1}{1+K_p}$ A_1 - Magnitude of step input $A_1 = 3$ and $K_p = \infty$ $e_{ss_1} = \frac{3}{1+\infty} = \underline{\underline{0}}$ The steady state error for ramp input is $e_{ss_2} = \frac{A_2}{K_v}$ A_2 - Magnitude of Ramp input $= 1$ $e_{ss_2} = \frac{1}{15/7} = \underline{\underline{\frac{7}{15}}}$ The steady state error for parabolic input is $\frac{A}{2} = 1$ $e_{ss_3} = \frac{A_3}{K_a}$ A_3 - Magnitude of Parabolic input $= \underline{\underline{2}}$ $K_a = 0$ $e_{ss_3} = \frac{2}{0} = \underline{\underline{\infty}}$ $e_{ss} = e_{ss_1} + e_{ss_2} + e_{ss_3}$ $= 0 + \frac{7}{15} + \infty$ $= \underline{\underline{\infty}}$	**Steady state error 4M**
	(b)	**Compare Relay logic control and Programmable logic control. (minimum eight points)**	**8M**

Ans: **1M each**

Parameter	Conventional Control	PLC-Based Control
Tool used for automation	Hard wiring.	Software programs.
Space requirements	Requires a large amount of space to house the relays and the connecting wires.	Compact systems and can be installed in much smaller space.
Power consumption	Higher power consumption. Approximate power requirement for a contactor consisting of 500 I/O devices is 220 volts x 0.2 amps x 500 = 22 KVA.	Much lower power consumption. Approximate power requirement for a PLC controlling 500 I/O devices is 0.1 KVA. This is because PLCs do not require hard wiring and actual circuits for controlling the operations.
Installation	The installation process is very difficult as the individual relays first need to be made using electronic circuits and then connected using hard wiring. Each relay needs to be tested individually for proper functioning.	The installation process is much easier and the controls can be easily programmed using the ladder logic and tested in a simulated environment. In addition, the installation of PLCs can be made modular. In other words, different parts of a process can be automated in different phases.
Maintenance	Regular wear and tear of relay and hard wire takes place. As a result, extensive maintenance of the system is required.	As the software program is not subject to wear and tear, not much effort is required in normal maintenance. Only the cables connecting the real-world devices to the PLC need to be maintained.
Flexibility	Not very adaptable to changes. Any change in the process requires shutting down the entire system and adding/removing the concerned relays.	Very adaptable to change. To change a process, a modification in the program is required. The modified program can be tested outside the system, and after the robustness of program is checked, the program can be installed in the system.
Reliability	Prone to mechanical faults and other failure.	Highly reliable as there are much lesser chances of mechanical failures.
Diagnosing problems	Very difficult to diagnose problems because each concerned relay and its wiring needs to be examined manually.	Easy to diagnose problems as the software contains options for troubleshooting and diagnosing the problems. A check needs to be performed on the software and the required bug can be easily fixed.

(c) **Draw ladder diagram for 3 motor operation for following condition:** **8M**

(i) S tart push button, start motor M, .
(ii) When motor M1, is ON after 8 minute M2 is ON and M1 is OFF.
(iii) When M2 is ON after 15 minute M3 is on and M2 is OFF.
(iv) When stop push button is pressed M3 is OFF.

	Ans:		**8M**
Q.5		**Attempt any FOUR :**	**16M**
	(a)	**Compare proportional and Integrated controller on the basis of following point:** **(i) Equation**	**4M**

(ii) Advantages
(iii) Response to Error
(iv) Application

Ans:

Parameter	proportional	Integrated
Equation	$K_P \cdot e(t)$ +Po	$K_I \cdot \int_{t_0}^{t} e(t)$ + P(o)
Advantages	Controller output is proportional to the error	It eliminates offset
Response to Error	It responds to the present error	It responds to the past history of errors
Application	Used in processes with small to moderate process time lags	Used in processes with small process time lags like flow and level control system

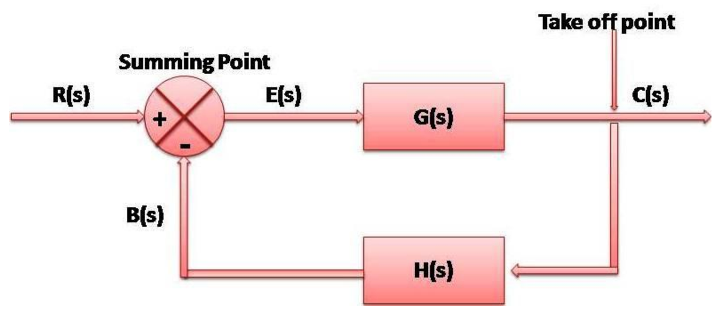
1M for each point

(b) Define transfer function and derive the expression of transfer function of closed loop system with positive feedback. **4M**

Ans: Transfer function of a system is defined as laplace transform of output to the laplace transform of the input under zero initial condition.

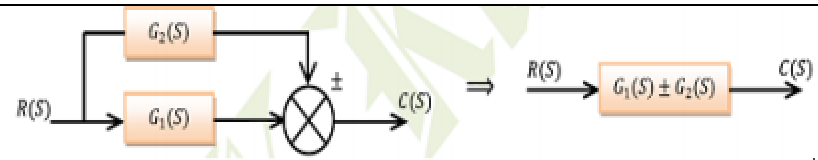
Definition - 1M

$$T(s) = \frac{\text{Laplace transform of output}}{\text{Laplace transform of input}} = \frac{C(s)}{R(s)}$$

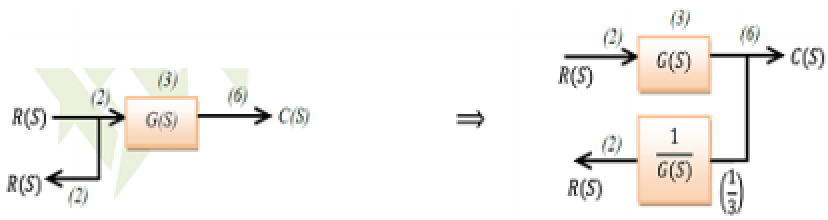


Derivation- 3M

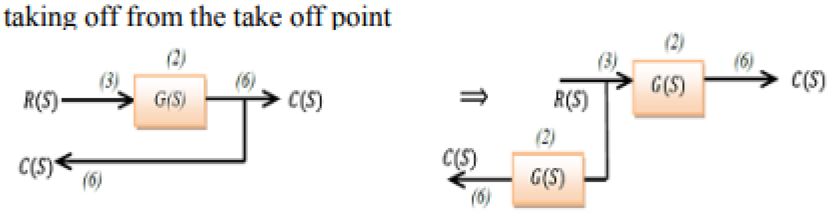
		G(s) = equivalent forward path transfer funⁿ H(s) = equivalent feedback path transfer funⁿ $E(s) = R(s) \pm B(s)$ —— (I) $B(s) = C(s) \cdot H(s)$ $C(s) = E(s) \cdot G(s)$ —— (II) Put the value of B(s) in eqⁿ - (I) we get, $E(s) = R(s) \pm C(s) \cdot H(s)$ .... (A) $\therefore E(s) = \frac{C(s)}{G(s)}$ ..... from eqⁿ (II) Put the value of E(s) in above eqⁿ in eqⁿ (A) $\therefore \frac{C(s)}{G(s)} = R(s) \pm C(s) \cdot H(s)$ $\therefore C(s) = R(s) \cdot G(s) \pm C(s) \cdot H(s) \cdot G(s)$ $\therefore C(s) \pm G(s)\, C(s)\, H(s) = R(s) \cdot G(s)$ $\therefore C(s)\left[1 \pm G(s) \cdot H(s)\right] = R(s) \cdot G(s)$ $\therefore \boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s) \cdot H(s)}}$ +ve sign indicate -ve feedback -ve sign indicate +ve feedback $R(s) \rightarrow \boxed{\frac{G(s)}{1 \pm G(s) \cdot H(s)}} \rightarrow C(s)$	
	(c)	**Write any four rules of block diagram simplification**	**4M**
	Ans:	i) Combining a block in cascade: When two or more blocks are connected in series, their overall transfer function is the product of individual block transfer function.  ii) Combining two blocks in parallel: When two or more blocks are connected in parallel, their overall transfer function is the addition or difference of individual transfer function.	**1M each (any four relevant rules to be considered)**



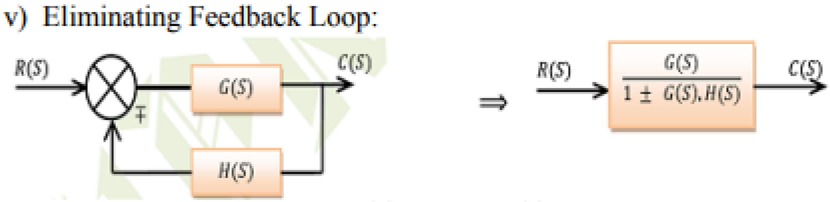
iii) Shifting a take off point after a block: To shift take off point after a block, we shall add a block with transfer function 1/G in series with signal having taking off from that point.



iv) Shifting a take off point before a block: To shift take off point before a block, we shall add a block with transfer function G in series with signal having taking off from the take off point

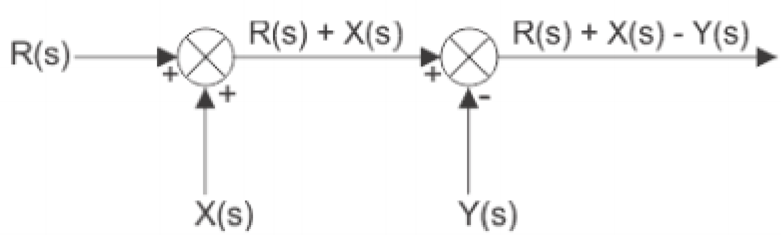


v) Eliminating Feedback Loop:

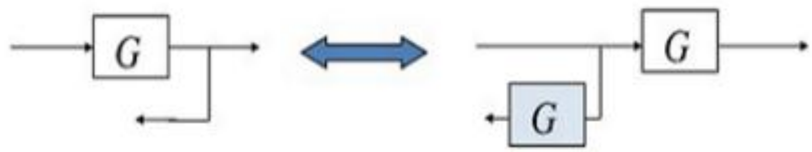


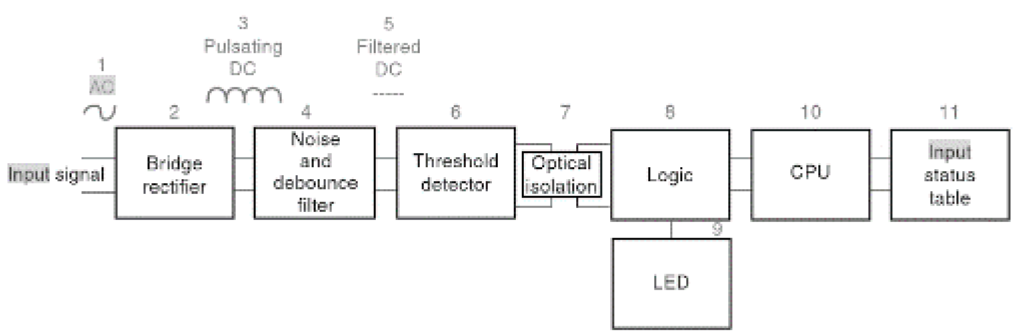
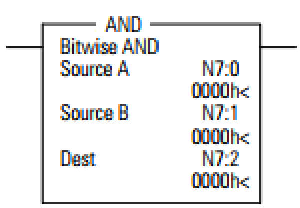
$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s).H(s)}$$

vi) Interchanging Summing Points: The order of summing points can be interchanged, if two or more summing points are in series and output remains the same.



vii) Moving Take off point before a summing point: To shift a take off point before summing point, add a summing point in series with take off point.

		 viii) Moving Take off point after a summing point: To shift a take off point after summing point, one more summing point is added in series with take off point.  ix) Moving summing point after a block: To shift summing point after a block, another block having transfer function G is added before the summing point. x) Moving summing point before a block: To shift summing point before a block, another block having transfer function 1/G is added before the summing point.	
	(d)	**Define and write the formula of following :** **(i) Delay time (td).** **(ii) Settling time (ts)** **(iii) Peak time (tp)** **(iv) Peak over shoot (Mp)**	**4M**
	Ans:	1) **Delay Time** (T_d) − It is the Time required for the response to reach 50 % of the final value in the first attempt. It is given by $Td = \frac{1 + 0.7\zeta}{\omega_n} sec$ **Settling Time**(T_s) − This is defined as the time required for the response to decrease & stay within specified % of its final value . $Ts = \frac{4}{\zeta\omega_n}$ (3) **Peak time** (T_p) − It is the time required for the response to reach its peak value **OR** The time at which response undergoes the first overshoot, which is always peak overshoot. $Tp = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} sec$	**1M Each**

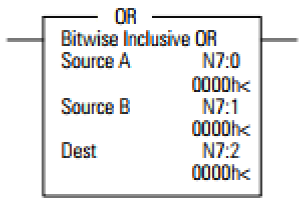
		Peak overshoot (M_p) – It is the largest error between reference input & output during the transient period. $\%Mp = \left[e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \right] * 100$	
	(e)	**Write any four advantages and disadvantages of Routh's criterion**	**4M**
	Ans:	**<u>Advantages:</u>** 1)Easy to calculate. 2)Time required is less. 3)It gives number of poles of the system. 4)Relative stability of the system can be easily judged. 5)It helps in finding the ranges of values of K for system stability. **<u>Disadvantages:</u>** 1)It is valid only for real coefficient of the characteristic equation. 2)It does not provide exact location of the closed loop poles in left or right half splane. 3)it does not suggest methods of stabilizing an unstable system. 4)Applicable only to linear system.	**2M** **2M**
	(f)	**Draw the block diagram of AC Discrete Input module of PLC.**	**4M**
	Ans:	**<u>Diagram-</u>**  Block diagram of a typical AC input circuit.	**4M**
Q.6		**Attempt any FOUR:**	**16M**
	(a)	**Give the functional descriptions for AND, OR, EX-OR and NOT instructions.**	**4M**
	Ans:	The logical instructions perform bit-wise logical operations on individual words. **1.<u>AND instruction:</u>** Logical AND is a output type of instruction which requires two data inputs Source A and Source B as shown in following instruction format.  	**1M each**

The AND instruction performs a bit-wise logical AND of two sources and places
The result in the destination as shown below-

Destination = A AND B															
Source: A															
1	1	1	1	1	0	1	0	0	0	0	0	1	1	0	0
Source: B															
1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	1
Destination:															
1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0

2.<u>OR Instruction:</u>

Logical OR is an output type of instruction which requires two data inputs Source A and Source B as shown in following instruction format.

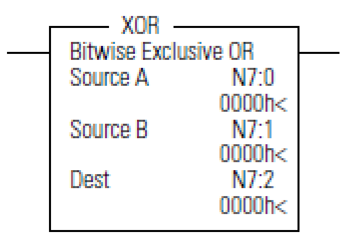


The OR instruction performs a bit-wise logical OR of two sources and places
The result in the destination as shown below-

Destination = A OR B															
Source: A															
1	1	1	1	1	0	1	0	0	0	0	0	1	1	0	0
Source: B															
1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	1
Destination:															
1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1

3. <u>EX-OR Instruction:</u>

Logical EX-OR is a output type of instruction which requires two data inputs Source A and Source B as shown in following instruction format.



The EX-OR instruction performs a bit-wise logical EX-OR of two sources and places the result in the destination as shown below-

Destination = A XOR B

Source: A

1	1	1	1	1	0	1	0	0	0	0	0	1	1	0	0

Source: B

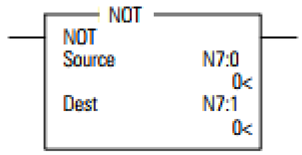
1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	1

Destination:

0	0	1	1	0	1	0	1	1	1	0	0	1	1	1	1

4. <u>NOT instruction:</u>

Logical NOT is a output type of instruction which requires one data input as shown in following instruction format.



The NOT instruction performs a bit-wise logical NOT of source and places
The result in the destination as shown below-

Destination = A NOT B

Source:

1	1	1	1	1	0	1	0	0	0	0	0	1	1	0	0

Destination:

0	0	0	0	0	1	0	1	1	1	1	1	0	0	1	1

(b) Describe ON-OFF control action with equation and response curve. **4M**

Ans:

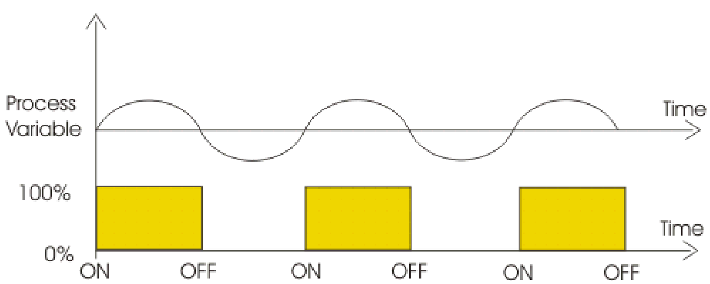
This controller has only two fixed positions such as ON or OFF. **2M**

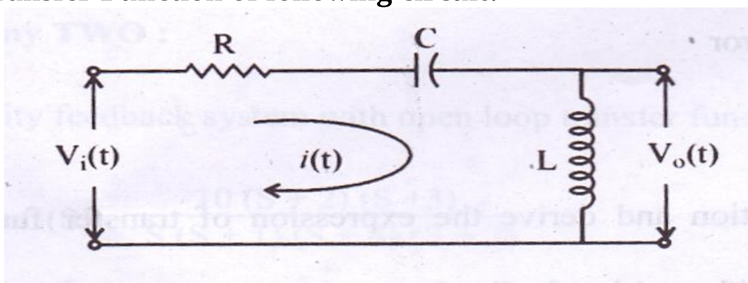
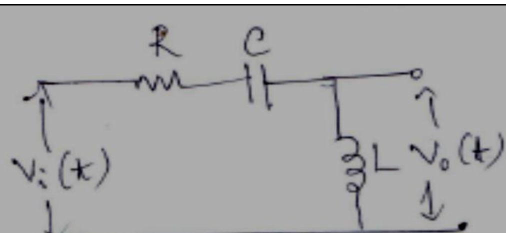
The output signal P of the controller remains either 0%(minimum value) or 100%(maximum value) depending on whether the error is negative or positive.

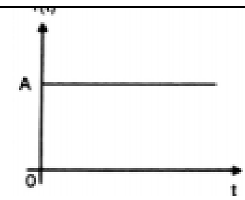
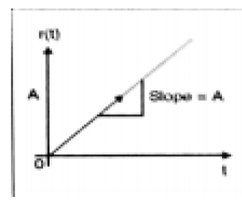
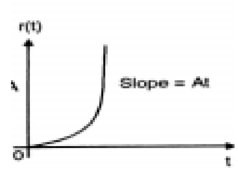
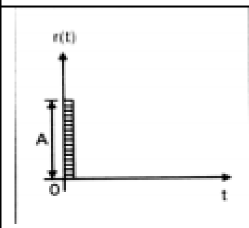
P=100% fore>0

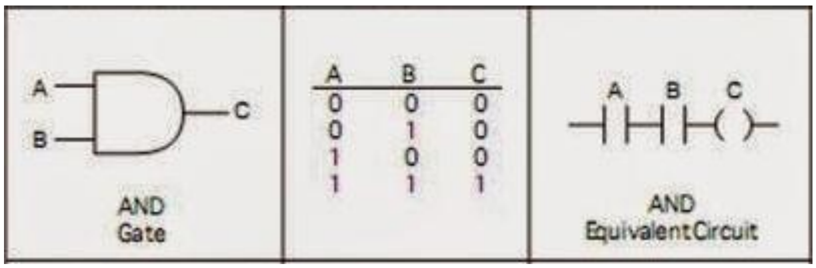
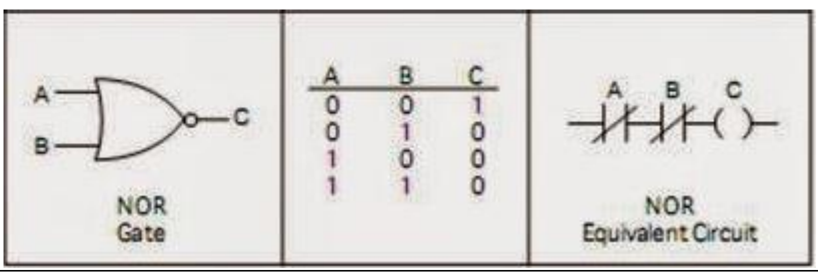
P=0% fore<0

2M



	(c)	**Derive the Transfer Function of following circuit:**  	**4M**
	Ans:	 Applying KVL to the input loop. $V_i(t) = R\,i(t) + \frac{1}{C}\int i\,dt + L\cdot\frac{di}{dt}$ Laplace transform is $V_i(s) = R\,I(s) + \frac{1}{Cs}I(s) + Ls\cdot I(s)$ $V_i(s) = \left(R + \frac{1}{Cs} + Ls\right) I(s)$ $V_i(s) = \left(\frac{RCs+1+s^2LC}{Cs}\right) I(s)$ —— ① Applying KVL to the o/p loop. $V_o(t) = L\cdot\frac{di}{dt}$. Laplace transform is $V_o(s) = Ls\cdot I(s)$ —— ② Transfer function $= \frac{\text{Laplace transform of o/p}}{\text{Laplace transform of i/p}}$ $\frac{②}{①} = \frac{Ls\cdot I(s)}{\left(\frac{RCs+1+s^2LC}{Cs}\right)I(s)} = \boxed{\frac{s^2LC}{s^2LC+RCs+1}}$	**1M** **1M** **1M** **1M**
	(d)	**What are the Different Standard Test Signal? Draw them and give their Laplace representation.**	**4M**

<table>
<tr><td></td><td>Ans:</td><td>Standard test input</td><td>Laplace Representation</td><td>Waveforms</td><td></td><td>List-1M Waveform and Laplace representation-3M</td></tr>
<tr><td></td><td></td><td>Step input(position function) r(t)</td><td>L.T of r(t) =R(s)=A/s</td><td>
</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Ramp input(Velocity function) r(t)</td><td>L.T of r(t) = R(s)=A/s^2</td><td>
</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Parabolic input(Acceleration r(t) function)</td><td>L.T of r(t) = R(s)=A/s^3</td><td>
</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Impulse input r(t)</td><td>L.T of r(t) = R(s)= 1 if A=1</td><td>
</td><td></td><td></td></tr>
<tr><td></td><td>(e)</td><td colspan="4">Define the following term:
1. Stable System
2. Unstable System
3. Relatively Stable System
4. Critically Stable System</td><td>4M</td></tr>
<tr><td></td><td>Ans:</td><td colspan="4"><u>STABLE :</u> 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. 2.) In the absence of the input, output must tend to zero irrespective of the initial condition.
<u>UNSTABLE</u>: 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.
<u>CRITICALLY STABLE</u>: A linear time invariant system is said to be critically stable</td><td>1M each</td></tr>
</table>

		if for a bounded input its output oscillates with constant frequency and amplitude. **CONDITIONALLY STABLE**: A linear time invariant system is called as conditionally stable system if the stability of system depends on certain conditions of parameters of the system.	
	(f)	**Draw the ladder diagram to verify** **(i) AND Gate logic** **(ii) NOR Gate logic**	**4M**
	Ans:	**(i) AND Gate logic :**  **(ii) NOR Gate logic:**  	**2M** **2M**