

## **T.E. (MECHANICAL ENGINEERING)**

**302050: MECHATRONICS**

### **UNIT NO- I: INTRODUCTION TO MECHATRONICS, SENSORS & ACTUATORS**

Q.1	Explain various elements in mechatronics system with block diagram.	6
Q.2	Give any two definitions of Mechatronics. Explain the scope and importance of Mechatronics and applications.	6
Q.3	Explain generalized measurement system with the help of block diagram. Also explain the function of each element.	6
Q.4	Define (i) Accuracy (ii) Precision (iii) Zero drift (iv) Threshold (v) Sensitivity drift (vi) Reproducibility (vii) Hysteresis (viii) Drift (xi) Sensitivity (x) Resolution (xi) Linearity (xii) Repeatability	10
Q.5	Explain different types of dynamic characteristics of measurement systems such as Response time, Rise time and Settling time	6
Q.7	Differentiate between (i) Accuracy and Precision (ii) Sensitivity drift and Zero drift	6
Q.8	Compare an LVDT with a potentiometer as a position sensor. How direction of motion is sensed using LVDT? Explain with appropriate figure	6
Q.9	Explain the working principle of LVDT along with its specifications, advantages, limitations and applications. Also explain the characteristics of LVDT	8
Q.10	Differentiate between Inductive and Capacitive sensors.	6
Q.11	Describe application of using a proximity sensor working on principle of magnetic sensing	6
Q.12	Explain capacitive and inductive principles used in position sensing also state the applications of the same	6
Q.13	Describe proximity sensor with application	6
Q.14	Enlist the transducers used for position measurement and explain any one of them.	6
Q.15	Explain basic operation of rotary encoder.	5
Q.16	Explain the principle and working of 3 bit absolute optical encoder.	5
Q.17	Compare Absolute and Incremental encoders.	6
Q.18	Using a suitable diagram, explain the construction as well as the working of a digital optical encoder.	6
Q.19	How Variable Reluctance Sensor works? Explain with example	6
Q.20	Explain the working principle of RTD with neat sketch and state advantages	6

and limitations.

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|------|--|---|
| Q.21 | What are the basic temperature measurement principles and main differences between the following temperature sensors (i) Thermistor and thermocouple (ii) RTD and thermocouple     | 8 |
| Q.22 | Explain the construction and working of thermocouples along with its applications  | 6 |
| Q.23 | Explain in detail pressure sensors with suitable diagram   | 6 |
| Q.24 | Discuss various types of strain gauges   | 6 |
| Q.25 | Compare semiconductor gauges with metal strain gauges  | 6 |
| Q.26 | Explain the temperature compensation technique used in strain gauge circuits   | 6 |
| Q.27 | Write a short note on load cells   | 6 |
| Q.28 | Strain in a cantilever beam is to be measured using strain gauges. For this, draw the setup and explain the principle of working.  | 6 |
| Q.29 | With respect to construction, advantages and applications explain Strain gauges for force measurement.   | 6 |
| Q.30 | Suggest the type of Sensor & signal conditioning circuit required (i) To transform an input temperature change to resistance change (ii) To transform a displacement to a voltage. | 8 |
| Q.31 | Explain the working principle and construction details of servo motor and its application.   | 6 |
| Q.32 | Explain the working principle and construction details of stepper motor and its application.   | 6 |
| Q.33 | Flow inside a pipe is to be measured using a flow sensor. For this draw the setup and explain the principle of working of the said sensor.   | 6 |
| Q.34 | Temperature of a hot plate is to be measured using Thermocouple. For this, draw the set-up and explain the principle of working  | 6 |
| Q.35 | A capacitive type proximity sensor is to be used for displacement measurement. Discuss the criterion for selection of this sensor.   | 6 |
| Q.36 | Explain the construction and working of Solenoids with a neat sketch.  | 6 |

### NUMERICALS

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| Q.37 | A 300° wire-wound potentiometer has 300 turns and a total resistance of 1 kΩ. What is the resolution in ohms? In degrees?              | 2 |
| Q.38 | An optical encoder of 1500 ppr is rotating with a speed of 300rpm. Find out resolution of encoder.                                     | 2 |
| Q.39 | A voltmeter requires a change of 5 V in its coil to produce a change in deflection of the pointer by 10 mm. Determine its sensitivity. | 2 |

- Q.40 An ammeter requires a change of 3 A in its coil to produce a change in deflection of the pointer by 12 mm. Determine its sensitivity. 2
- Q.41 A Wheatstone bridge requires a change of 10 ohm in the unknown arm of the bridge to produce a change in deflection of 4 mm of the galvanometer. Determine the sensitivity of the instrument 5
- Q.42 The amplifier system of CRO is stated to have a sensitivity of 2.2 cm/V. What would be the deflection on the screen for an input of 0.38 V? 5
- Q.43 The output of LVDT is connected to a 5 V voltmeter through an amplifier of amplification factor 250. The voltmeter scale has 100 divisions and the scale can be read to of a division and output of 2 mV appears across the terminals of the LVDT when the core is displaced through a distance of 0.5 mm. Calculate:(i)The sensitivity of LVDT (ii)The sensitivity of whole set up. (iii) The resolution of the instrument is in mm. 6
- Q.43 Sensitivity of a thermocouple is  $0.01\text{V}/^{\circ}\text{C}$ . Find the output voltage if the temperature is  $200^{\circ}\text{C}$ . Also find temperature for 3.5V output. 6
- Q.44 The individual sensitivities of different elements comprising a temperature measuring system are: Transducer =  $0.3\text{ ohm}/^{\circ}\text{C}$ ; Wheatstone bridge =  $0.01\text{ V/ohm}$ ; amplifier gain =  $80\text{ V/V}$ ; pen recorder =  $1.2\text{ mm/V}$ . Determine the overall sensitivity and the temperature change corresponding to a pen recorder movement of 30 mm. 6
- Q.45 A quartz piezoelectric crystal having a thickness of 2 mm and a voltage sensitivity of  $0.055\text{ Vm/N}$  is subjected to a pressure of  $1.38 \times 10^6\text{ N/m}^2$ . Calculate the voltage output. 6
- Q.46 A potentiometer which is used to measure the rotational position of a shaft has 850 turns of wire. The input range is from  $-160^{\circ}$  to  $+160^{\circ}$ . The output range is from 0V to 12V. Determine sensitivity in volts per degree and average resolution in volts 6
- Q.47 A ammeter has a uniform scale with 100 divisions, the full scale reading is 50 mA and  $1/15$  of a scale division can be calculated with fair degree of certainty. Determine the resolution of the instrument in amperes. 6
- Q.48 The output of a LVDT is connected to a 10 V ammeter through an amplifier whose amplification factor is 200. An output of 3 mA appears across the terminals of LVDT when the core moves through a distance of 0.75 mm. calculate the sensitivity of LVDT and that of whole setup. The milli ammeter scale has 100 divisions. The scale can be read to  $1/10$  of a division. Determine the resolution of the instrument in millimeters. 6

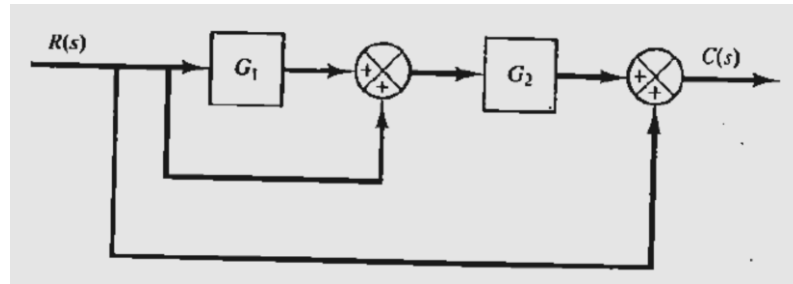
## **UNIT 02: BLOCK DIAGRAM REPRESENTATION**

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| Q.1  | Describe the key elements of the mechatronics system.   | 6  |
| Q.2  | What is a block diagram? Explain representation of a system using block diagram   | 6  |
| Q.3  | Discuss the Temperature control system as closed loop control system. Identify reference input, error signal, plant, controlled variable, feedback signal and load on the system.   | 6  |
| Q.4  | Compare Open Loop and Closed Loop Control System with respect to definition, block diagram and application.   | 8  |
| Q.5  | With suitable example, explain Closed Loop Control System & also write its advantages & disadvantages.  | 6  |
| Q.6  | With suitable example, explain Open Loop Control System & also write its advantages & disadvantages   | 6  |
| Q.7  | Discuss the significance of the transfer function approach when modeling a mechanical system.   | 6  |
| Q.8  | Explain Direct action and Reverse action w.r.t. controllers with the help of block diagrams.  | 6  |
| Q.9  | Write various Block diagram reduction principle with figure   | 10 |
| Q.10 | Using a suitable block diagram explain the working of Automatic Washing Machine   | 8  |
| Q.11 | Using a suitable block diagram explain the working of Microwave Oven  | 8  |
| Q.12 | Using a suitable block diagram explain the working of Automatic Refrigerator  | 8  |
| Q.13 | Using a suitable block diagram explain the working of Fuel Injection System   | 8  |
| Q.14 | Using a suitable block diagram explain the working of Electric Power Steering Mechanism   | 8  |
| Q.15 | Using a suitable block diagram explain the working of Tool Monitoring system  | 8  |
| Q.16 | Using a suitable block diagram explain the working of Automatic Conveyor System   | 8  |
| Q.17 | Explain Engine RPM control system with accelerator as input and engine speed as output as open loop control system showing input and output and all components involved in between. | 8  |

## NUMERICALS

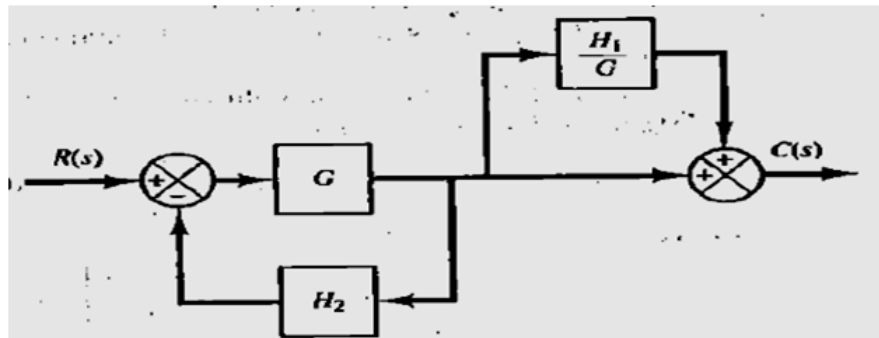
- Q.18 Figure shown below is a block diagram. Simplify and find the Relation between  $C(s)/R(s)$ .

4



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- Q.19 Figure shows a block diagram. Simplify and find the Relation between  $C(s)/R(s)$ .



Q.20

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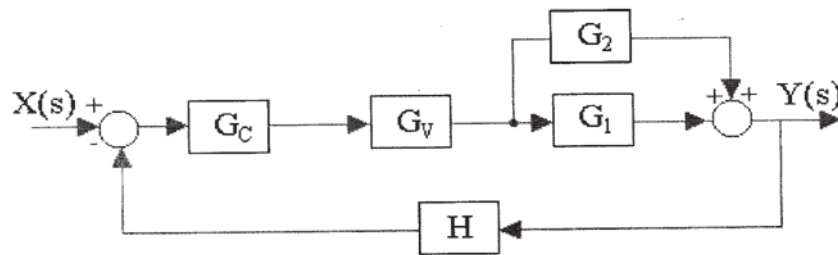
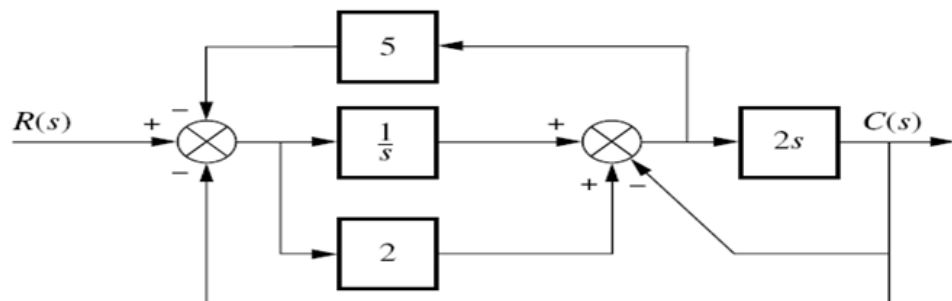


Figure 3b

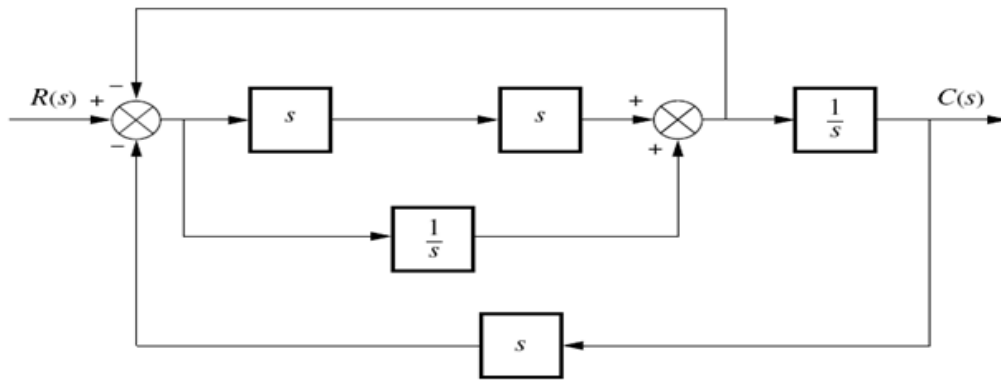
Reduce the block diagram in Figure 3b and determine the transfer function:  $Y(s)/X(s)$ .

- Q.21 Carry out block diagram reduction for following system shown in Figure below.

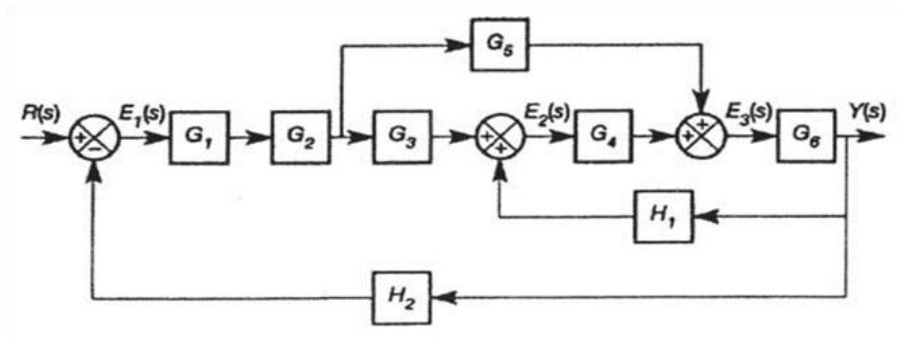
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Q.22 Carry out block diagram reduction for following system shown in Figure below. 6



Q.23 Use block diagram reduction to simplify the block diagram shown in Figure below. 8



Q.24 Determine the composite transfer function,  $C/R$ , for the system in Figure 1. 5

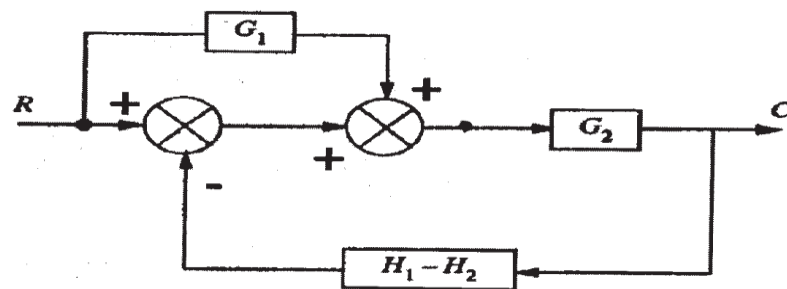


Figure 1

Q.25 Determine, using block reduction technique, the overall transfer function,  $Y(s)/X(s)$  for the system in Figure 4b 4

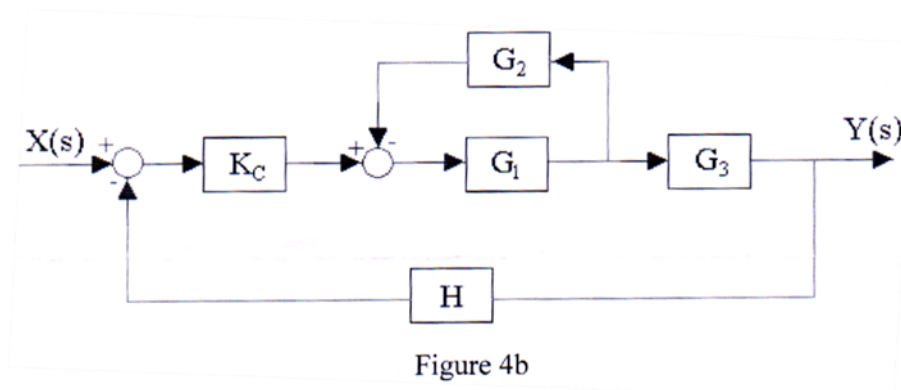
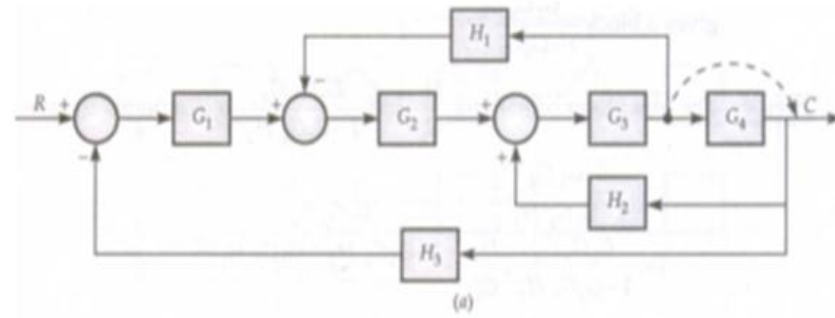
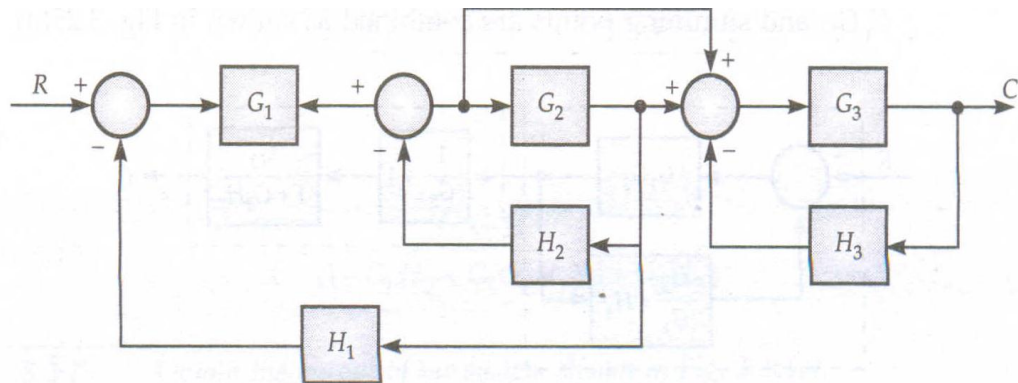


Figure 4b

- Q.26 Using block diagram reduction technique for the system shown in Figure below. Find the input-output relationship 6



- Q.27 Using block diagram reduction technique for the system shown in Figure below. Find the input-output relationship 6



### **UNIT 03: DATA ACQUISITION**

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|------|--|---|
| Q.1  | Explain the detailed functioning of Data Acquisition System with the help of a detailed block diagram.   | 6 |
| Q.2  | What are the functions performed by DAQ?   | 6 |
| Q.3  | Explain significance of sampling theorem with appropriate example.   | 6 |
| Q.4  | What is meant by Nyquist frequency and how it is used in sampling of analog signals  | 4 |
| Q.5  | Write sample specifications of DAQ system and explain its significance.  | 4 |
| Q.6  | Using a suitable diagram explain Aliasing.   | 6 |
| Q.7  | For an Analog to Digital Conversion explain the purpose and working of Sample and Hold circuit with neat sketch. Also write down the limitations of the same | 8 |
| Q.8  | Explain role of voltage in signal conditioning.  | 4 |
| Q.9  | Draw the flowchart and explain the working of a Successive Approximation Register type ADC.  | 6 |
| Q.10 | Draw a circuit diagram of R-2R based DAC and explain how it works  | 6 |
| Q.11 | Draw suitable diagrams and explain the construction, working and performance characteristics of a Current Amplifier.   | 6 |
| Q.12 | Draw suitable diagrams and explain the construction and working of a two stage current Amplifier   | 6 |
| Q.13 | Using a suitable circuit diagram explain the working of a voltage amplifier.   | 6 |

#### **NUMERICALS**

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| Q.14 | A 4-bit DAC has a reference voltage range of 0 to 10 v. Find the binary input is 1110. Find the analog output voltage.  | 4 |
| Q.15 | Find the resolution of a DAC with a reference voltage of 30 volts and 4 inputs.   | 4 |
| Q.16 | A 4-bit ADC with a 0 to 10V range is used for the purpose of sampling the voltage of an analog sensor. Determine the digital output code that would correspond to the following: (a) 2.5 V; (b) 5 V; (c) 7.5 V. | 6 |
| Q.17 | A 4-bit DAC produces $V_{out} = 0.3$ volt for a digital input of 0001. Find the value of $V_{out}$ for an input 1111.   | 4 |
| Q.18 | Determine the smallest step size of a 4 bit ADC in the range -10 v to + 10 v.   | 4 |
| Q.19 | An 8 bit DAC produces an output voltage of 2 volts for an input code of 01100100 what will be the value of $V_{out}$ for an input code of 10110011  | 5 |



- Q.20 A 4-bit R-2R type DAC is supplied with 2.56 volts dc reference potential. 5  
Determine the full scale output potential and the Least significant Bit(LSB).
- Q.21 A 4 bit DAC has a step size of 5 mV. Determine the full scale output voltage 5  
and the percentage resolution

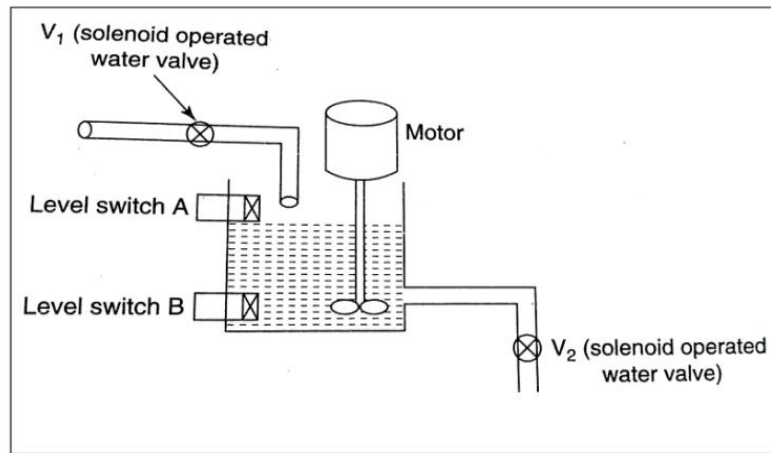
## **UNIT 04: PROGRAMMABLE LOGIC CONTROL**

Q.1	Write short note on application of PLC in automation	4
Q.2	Write any four specifications of PLC	4
Q.3	Explain with block diagram the components and their working in PLC	4
Q.4	Explain basic elements of the PLC systems and its applications	6
Q.5	List the steps the PLC take to execute the ladder diagram	5
Q.6	Explain advantage of PLC ladder diagram over relay ladder program	6
Q.7	Write a note on ladder diagram	6
Q.8	Construct the ladder logic diagram for OR gate, AND gate, NOT gate. Also develop a truth table for all.	8
Q.9	With respect to objectives, symbol used, types and specifications, discuss two different timers used in PLC programming	8
Q.10	Write short note on Examine ON and Examine OFF conditions used in PLC programming	8
Q.11	Write a short note on counters used in PLC programming	8
Q.12	List the criterion for the selection of a PLC and explain any three criteria in details.	8
Q.13	Write short note on relay logic and state the uses of it.	8
Q.14	Draw a suitable ladder diagram and explain the application of counter in a PLC.	8
Q.15	Explain on Delayed, off Delayed Timers used in PLC programming with one application and corresponding ladder program.	8
Q.16	Write a short note on pressure switches, level switches, flow switches, Temperature switches, limit switches	8

### **NUMERICALS**

Q.15	A small house has 3 windows and 2 doors. Each window and door has a switch attached such that the contacts close when a door or window opens. Develop a PLC ladder that will turn ON a light if one or more windows are open, or if both doors are open	8
Q.16	Develop a ladder diagram for the following (1) A Motor is put on by the START button which is NO. A pump is started after a delay of 100 seconds (2) after starting the motor. The motor is switched off by a STOP button. When the motor is switched off there should be a delay of 10 seconds before the pump is switched off.	8

- Q.17 Write ladder logic for a simple traffic light controller for the following sequence of operations as below:
- Step 1: Turn Green ON for 35 seconds, 8
- Step 2: Turn Yellow ON for 5 seconds,
- Step 3: Turn Red ON for 40 seconds,
- Step 4: Repeat the sequence i.e. Step 1-Step 2-Step 3.
- Q.18 Develop ladder logic for a bottle filling station having following sequence 8
- When START button is pushed, the conveyor motor (Q1) starts.
  - When bottle reaches filling station, Proximity (P1) is ON, the conveyor (Q1) stops.
  - The solenoid valve is ON
  - When bottle is filled proximity 2(P2) is ON, and solenoid valve is OFF  
When proximity 2 (P2) is ON, the conveyor motor (Q1) starts  
When end station is reached proximity 3 (P3) is ON and conveyor motor (Q1) stops
  - Go to step 1 for the bottle
- Q.19 Given four normally open switches (P1, P2, S1 and S2) with DC motor (M) 8  
write a PLC program to satisfy following objectives
- When P1 (Start button) is pushed the cycle shall start. The cycle shall continue to remain on until P2 (Stop button) is pushed
  - When S1 is pushed and S2 is not pushed then motor is ON in clockwise direction
  - When S2 is pushed and S1 is not pushed then motor is ON in counter clockwise direction
  - When P2 is pushed the program stops
- Q.20 Develop a ladder diagram for the following: 8
- A process tank shown in fig. is sequenced to mix the liquid fertilizer according to the following sequence of operations.
- A start pushbutton is pressed to start the operation and water valve "V1" is being operated to open in order to fill the tank up to a preset level sensed by a level switch "A".
  - As the tank fills, a level switch "A" closes the NO contact to energize the stirrer motor to start automatically and operate it for 5 s to mix the fluid.
  - When the stirrer motor stops, the solenoid operated water valve "V2" is energized to empty the tank.
  - When the tank is completely empty the level switch "B" opens & de-energized the solenoid operated Valve "V2".
  - A stop button is operated to stop the operation.



- Q.21 Given two push to ON buttons (PB1 & PB2), RED & GREEN lamps, develop a 8 ladder logic diagram to meet the following objectives:
- When PB1 is pushed, RED lamp should be ON & it will continue to be ON till PB2 is pushed.
  - When PB2 is pushed, GREEN lamp should be ON & it will continue to be ON till PB1 is pushed.
  - If PB1 & PB2 both are pushed simultaneously, both lights should be OFF

## **UNIT 05: FREQUENCY DOMAIN MODELLING AND ANALYSIS**

- Q.1 Define transfer function. Derive transfer function for mechanical spring, mass and damper 8
- Q.2 Derive the model equation of a rotational mechanical system with torsional stiffness, damping and mass moment of inertia 8
- Q.3 Explain thermal system building blocks 8
- Q.4 Explain Fluid system building blocks 8
- Q.5 Using suitable diagram explain transient response specification 8
- Q.6 Define the following terms 6  
(i) Steady State Error (ii) Gain Margin (iii) Phase Margin (iv) Rise Time  
(v) Damping Frequency (vi) % Overshoot
- Q.7 Compare Time Domain and Frequency Domain techniques for analysis of a system. 8
- Q.8 Draw suitable sketch to depict the unit step response of a second order system when 8  
i) System poles are negative and real  
ii) System poles are complex conjugate pair with negative real part  
iii) System poles are positive and real  
iv) System poles are a imaginary pair with no real part

### **NUMERICALS**

- Q.9 For the system in figure 2, Assume  $M = \text{mass} = 1 \text{ kg}$ ,  $k = \text{stiffness} = 2 \text{ N/m}$  and  $d = \text{damping} = 0.5 \text{ Ns/m}$ . Also,  $F = \text{force input in N}$  and  $y = \text{displacement output in m}$ . 8
- For this system:
- (i) Determine the transfer function:  $y(s)/F(s)$ ,  
(ii) Identify the location of the Poles and Zeros and  
(iii) Comment on the stability of the system.

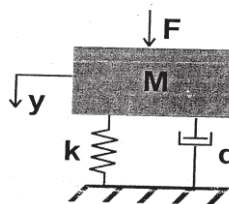
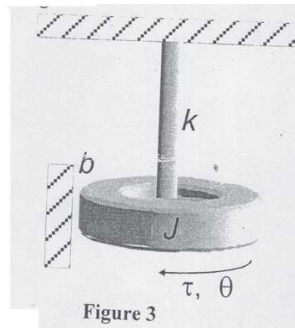


Figure 2

- Q.10 Consider a second -order unity feedback system with damping factor=0.6 and natural frequency = 5 rad/sec. Calculate the rise time, maximum overshoot and settling time when a unit-step input is applied to the system. 8

- Q.11 Derive the transfer function between output  $\theta$  and input  $\tau$  for the single DOF rotational system shown in Figure 3. 8
- rotational system shown in Figure 3.



- Q.12 Using the values of the natural frequency  $\omega_n = 1.414$  and the damping factor  $\zeta = 0.177$ , estimate the values for percentage overshoot & 2% settling time. 8

## UNIT 06: CONTROL SYSTEM

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|------|---|----|
| Q.1  | Derive the equation for the control signal, $u$ , for the Proportional plus Derivative (PD) controller in parallel form. Discuss, in detail, the advantages and disadvantages of adding a Derivative term to the Proportional term. | 10 |
| Q.2  | Draw a suitable block diagram and derive the transfer function of the Proportional Integral Derivative (PID) controller in series form. Also, discuss the significance of the Integral and the Derivate term in the PID controller. | 10 |
| Q.3  | Derive the equation for the control signal, $u$ , for the proportional Integral Derivative (PID) controller. Discuss, in detail, the advantages and disadvantages of adding Derivative term to the Proportional term.               | 10 |
| Q.4  | Discuss the role of transient specifications W.R.T the performance of the PID controller.   | 8  |
| Q.5  | A second order system is under damped, inherently. Discuss the step by step procedure for manual tuning of a PID controller so that the behavior of the system becomes that of a critically damped one.                             | 10 |
| Q.6  | Explain On Off control action with suitable application   | 6  |
| Q.7  | Explain working of PID control actions and why these control actions are mostly used in industry  | 8  |
| Q. 8 | Explain working of P+I control action with the help of neat block diagram.  | 6  |
| Q.9  | Using a suitable block diagram explain the working of PID control in Parallel form.   | 8  |

### NUMERICALS

- Q.10 Figure 3 shows an error time graph. Sketch the PID controller (series form) output w.r.t. time. Assume  $K_p=10$ ,  $K_i = 2$ ,  $K_D= 0.5$  and  $P_0=0$  i.e the controller output is zero when the error is zero.

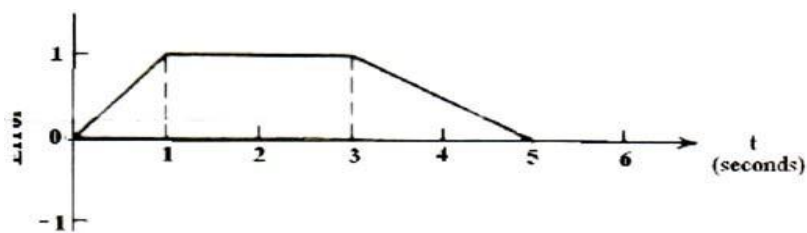


Figure 3

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|------|---|----|
| Q.11 | An integral controller is used for speed control with a set point of 12 rpm within a range of 10 to 15 rpm. The controller output is 22% initially. The constant $K_i= -0.15\%$ controller output per second per percentage error. If the speed jumps to 13.5 rpm, calculate the controller output after 2 sec for a constant $e_p$ . | 8  |
| Q.12 | Figure 4 shows an error time graph. Sketch the PID controller (parallel form) output w.r.t time. Assume $K_p=10, K_i=2$ , $K_D=0.5$ and $P_0=0$ i.e the controller output is zero when the error is zero  | 12 |

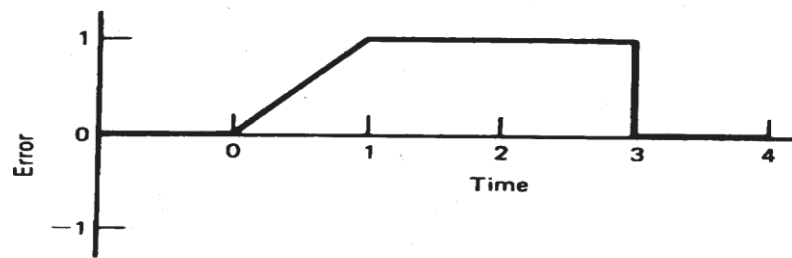


Figure 4

- Q.13 Figure 5 shows an error time graph. Sketch the PID controller (series form) output w.r.t time. Assume  $K_p=10$ ,  $K_i=2$ ,  $K_D=0.5$  and  $P_O = 0$  i.e the controller output is zero when the error is zero. 12

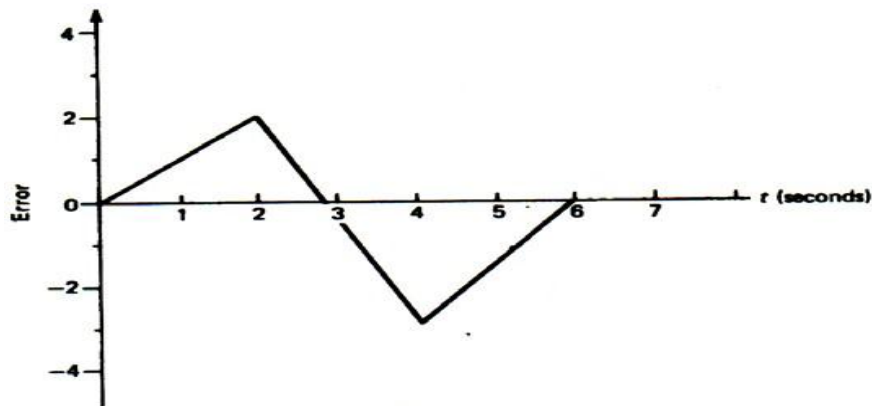


Figure 5

- Q.14 A proportional controller is used to control temperature within  $50^\circ\text{C}$  to  $130^\circ\text{C}$  with a set point of  $73.5^\circ\text{C}$ . The set point is maintained with 50% controller output. The offset error is corresponding to load change which causes 55% controller output. If the proportional gain is 2 find the % controller output if the temperature is  $61^\circ\text{C}$  8
- Q.15 A PI Controller has a gain  $K_p=2$  and an integral action rate  $K_i=0.02 \text{ s}^{-1}$ . The initial output is assumed to be zero. The graph of the error signal is given in figure. Determine the value of the controller output at  $t=70\text{s}$  8
- Q.16 Using the values of the natural frequency  $\omega_n=1.414$  and the damping factor  $\zeta=0.177$ , determine the values for overshoot, rise time and 2% settling time 8
- Q.17 A proportional controller outputs 4 to 20 mA. DC to control the motor from 0 rpm to 1440 rpm. The proportional gain is 5 and controller output at zero error is 50% of the full range and set point is 720 rpm. If the motor speed is 650 rpm then calculate (i) The error in % corresponding to 650 rpm (ii) The controller output corresponding to this error 8
- Q.18 An Integral controller is used for speed control with a set point of 12 rpm within the range of 10 to 15 rpm. The controller output is 22% initially. The constant  $K_i=-0.15\%/ \text{sec}/\%$ . If the speed jumps to 13.5 rpm, calculate the controller output after 2 seconds for constant  $e_p$  8