SUMMER-19 EXAMINATION

Model Answer

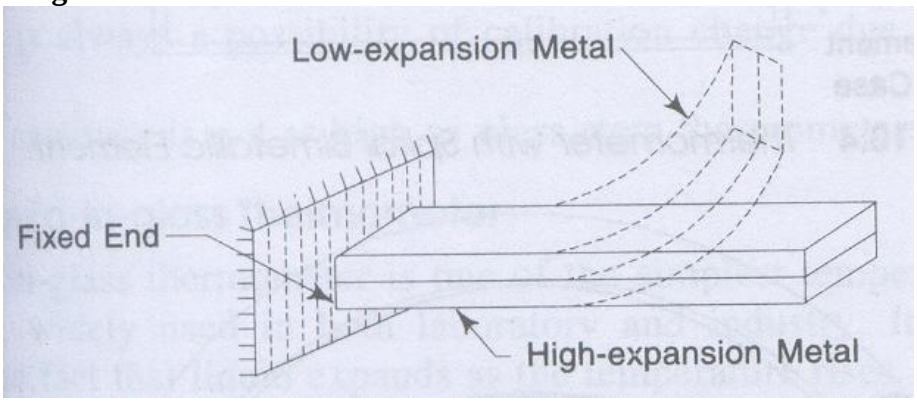
Subject title: Chemical Process Instrumentation & Control Subject code: 22407

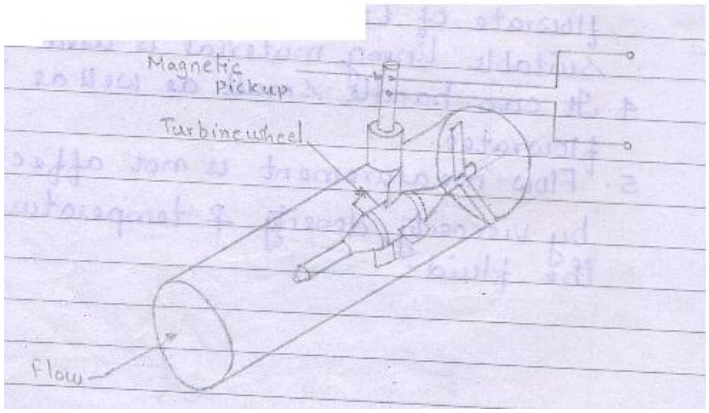
Important Instructions to examiners:

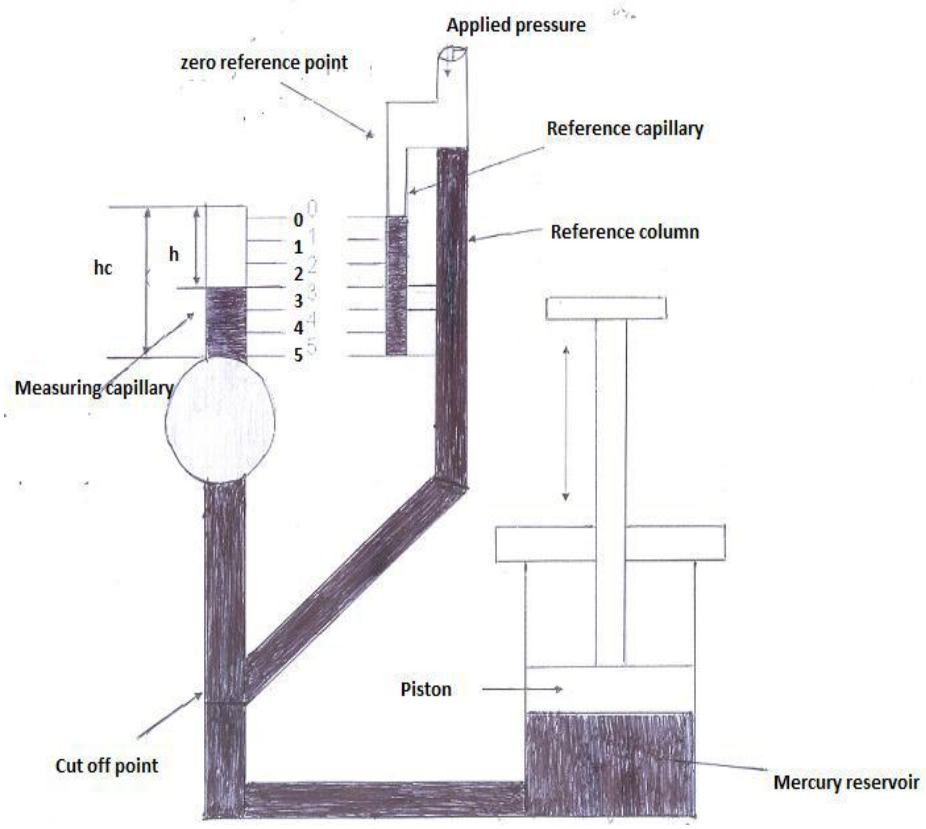
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling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

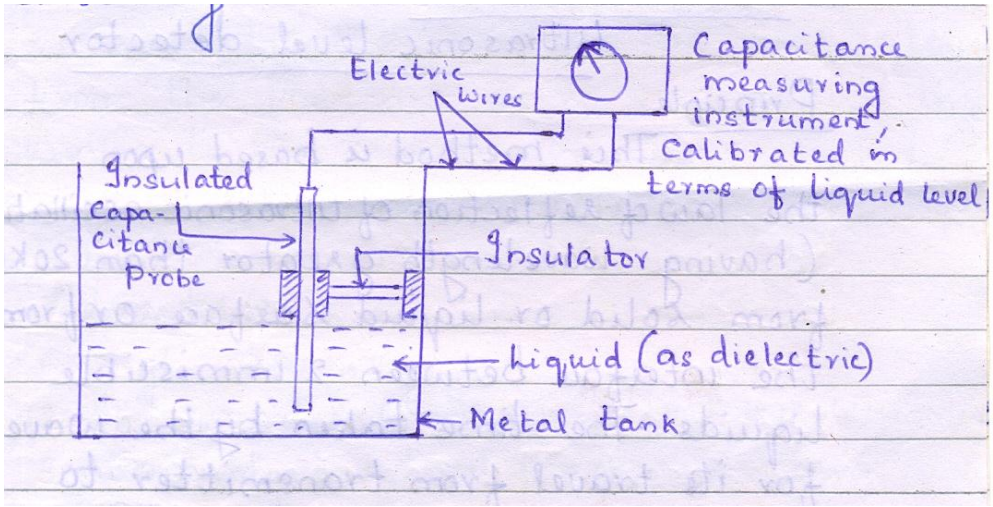
Q No.		Answer	Marking scheme
1		**Attempt any FIVE of the following**	**10**
1	a	**Definition:** **(i) Sensitivity:** It is the smallest change in the value of the measured variable to which an instrument responds. **(ii) Repeatability:** It is the closeness of agreement among a number of consecutive measurements of the output for the same value of input under the same operating conditions, approaching the measurement from the same direction.	1 1
1	b	**Temperature measuring devices(any four)** RTD, thermocouple, thermistor, thermometer, bimetallic thermometer, radiation pyrometer, optical pyrometer	½ mark each
1	c	**Pressure gauges used for pressure measurement (any four):** Bellows pressure gauge, diaphragm pressure gauge, strain gauge, Force balance pressure gauge (Dead weight pressure gauge) and Bourdon tube pressure gauge.	½ mark each
1	d	**Principle of ultrasonic flow meter:** In ultrasonic flow meters, the measurement of flow rate is determined by the variation in parameters of ultrasonic oscillations. Time Difference Type ultrasonic flow meters measure flow by measuring the time taken for ultrasonic wave to transverse a pipe section, both with and against the flow of liquid within the pipe.	2

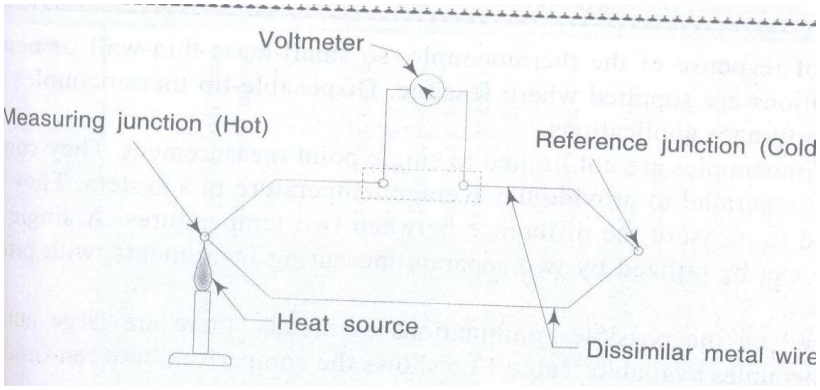
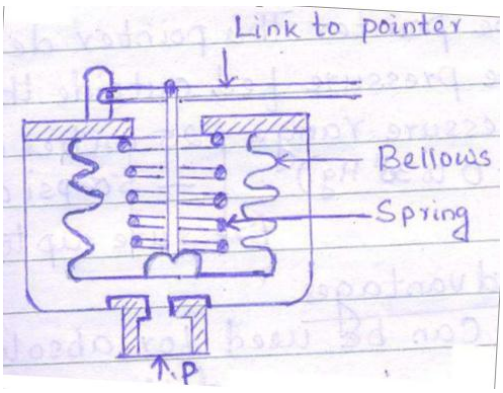
1	e	**Definition** **(i) Speed of response:** It is the rapidity with which an instrument responds to changes in the measured quantity. **(ii) Time lag:** It is the period during which the instrument does not respond to a change in the value of the variable.	1 1
1	f	**Controllers(four names)** 1.On-Off or Two position controller 2. Proportional (P)controller 3. Integral (I)controller 4. Derivative (D) controller 5. PD controller 6. PI controller 7. PID controller	½ mark each
1	g	**Types of control valve:** **1. Based on number of plugs:** Control valves can be classified as single seated valve and double seated valve **2. Based on action:** Control valves operated through pneumatic actuators can be either air to open or air to close **3. Based on flow characteristics** Control valves can be classified as quick opening valve, linear opening valve , equal percentage valve	2 marks for any one classification

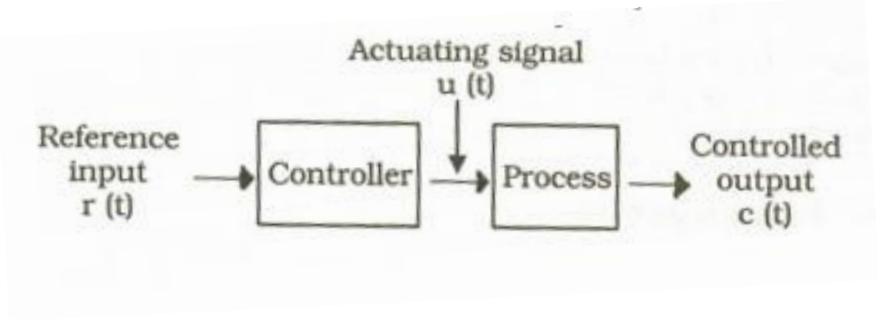
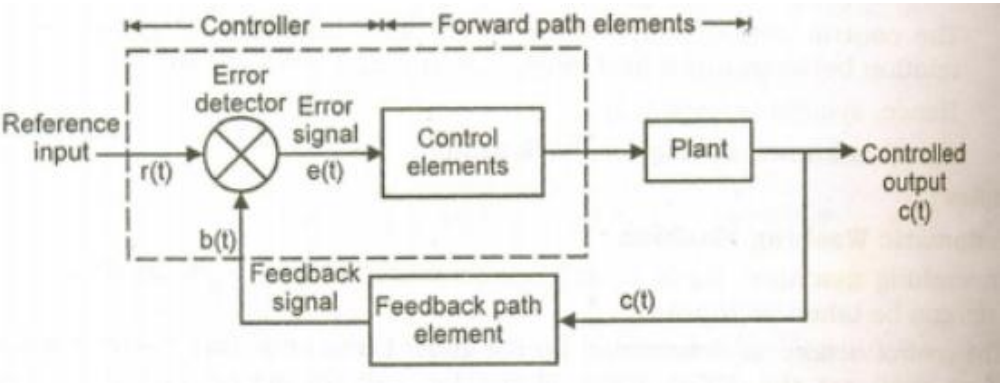
		4. Based on construction 1. Angle Valve 2. Globe valve 3. Diaphragm Valve 4. Butterfly valve 5. Rotary valve 6. Ball valve 7. Sliding cylinder valve	
2		**Attempt any THREE of the following**	**12**
2	a	**Bimetallic thermometer:** **Diagram**  **Construction and working:** Bimetallic strip consists of two strips of metal such as invar and brass welded together, each strip made from a metal having a different coefficient of thermal expansion. Whenever the welded strip is heated, the two metals change length in accordance with their individual rates of thermal expansion. The two metals expand to different lengths as the temperature rises. This forces the bimetallic strip to bend towards the side with low coefficient of thermal expansion as shown in Fig above. If one end of the bimetallic strip is	2 2

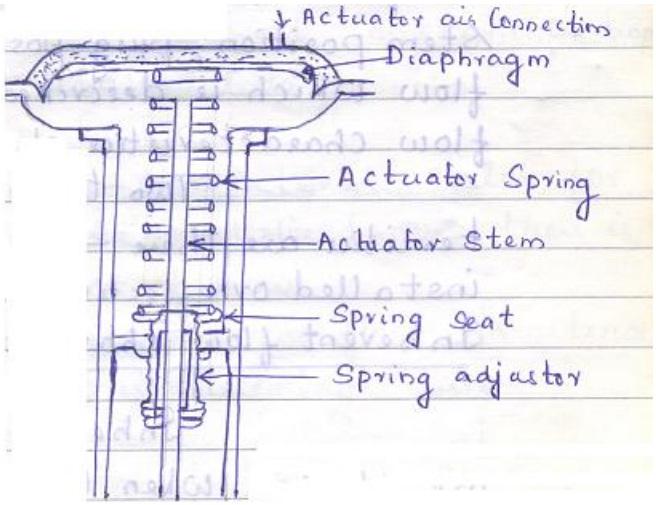
		fixed so that it cannot move, the distance the other end bends is directly proportional to the square of the length of the metal strip, as well as to the total change in temperature, and is inversely proportional to the thickness of the metal. The movement of the bimetallic strip is utilized to deflect a pointer over a calibrated scale.	
2	b	**Turbine flow meter:** **Diagram**  **Description:** It consists of a multibladed wheel mounted in a pipe along an axis parallel to the direction of fluid flow in the pipe. The flow of liquid past the wheel causes the wheel to rotate at a rate which is proportional to the velocity of the fluid. This is achieved by fabricating the turbine blades from a ferromagnetic material and placing a permanent magnet and coil inside the meter housing. A voltage pulse is induced in the coil as each blade on the turbine wheel moves past it and these pulses are measured by a pulse counter.	2 2

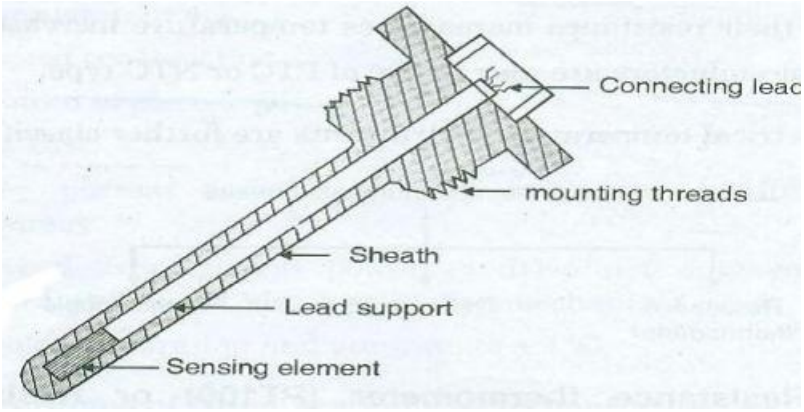
2	c	**McLeod gauge:**  	4
2	d	**Capacitance level indicator** **Explanation:** It consists of two conductors separated from each other by dielectric material between them. There is an insulated capacitance probe fixed near and parallel to tank wall such that the probe and metal tank wall acts as conductors with conducting liquid as the dielectric medium. These two conductors are connected to capacitance detecting element. As the liquid level changes, the dielectric constant changes due to which capacitance changes. Thus any change.	2

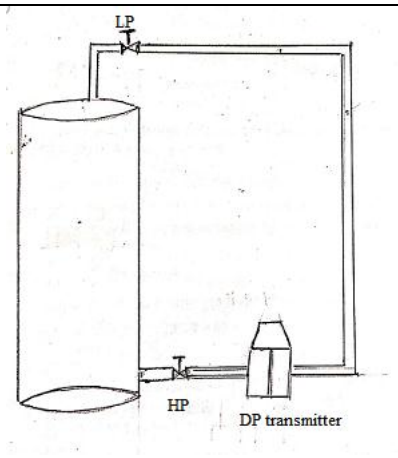
			2
3		**Attempt any THREE of the following**	**12**
3	a	**Definition of static error and dynamic error** **Static error**: It is the difference between the true value of a quantity not changing with time and the value indicated by the instrument **Dynamic error:** it is the difference between the true value of a quantity changing with time and the value indicated by the instrument if no static error is assumed.	2 2
3	b	**Different electrical temperature sensors:** 1. RTD 2. Thermistors 3. Thermocouples **Thermocouple:** **Explanation:** If two dissimilar metals are joined together so as to form a closed circuit, there will be two junctions where they meet each other. Inorder to prevent the	1 3

		formation of a second junction, the wires of thermocouple are insulated from each other by being threaded through porcelain insulators. Lead wires connect the measuring junction of the thermocouple to the indicating instrument. If one of these junctions is heated, then, a current flows in the circuit which can be detected by a galvanometer. The amount of the current produced depends on the difference in temperature between the two junctions and on the characteristics of the two metals.  ***(Due consideration should be given for any other type of electrical temperature sensors for temperature measurement)***	
3	c	**Bellows pressure gauge:** **Diagram:**  	2

		Principle: Bellows element is the elastic element which gets deflected at the free end when pressure is applied through fixed end. This free end deflection can be taken as the measure of pressure inside it.	2
3	d	**Open loop and closed loop system:** **Open system:**  When the input is independent of the output, the system is called open- loop system. The control action is based on only some predetermined settings. **Closed system:**  When the input is dependent on the output, the system is called closed- loop control system. The output is continuously measured and fed to the input.	2 2

4		**Attempt any THREE of the following**	**12**
4	a	**Working of spring diaphragm actuator:** Actuator is the portion of the valve that responds to the applied signal and results in the movement of the stem due to which the flow rate of fluid changes. It consists of a pressure tight housing sealed by a flexible diaphragm, stem and diaphragm returning spring. Signal air pressure from the controller is applied to upper diaphragm case, that exerts force on the diaphragm and the actuator assrmbly.by selecting proper spring rate or stiffness, desired stem displacement can be obtained for any given input signal. The diaphragm is made of neoprene or any other synthetic elastic element.  ***(Any other type of valve actuator should be given due consideration)***	4
4	b	**RTD:** **Construction and working:** Resistance thermometer bulbs consist of a coil of fine wire wound or in a frame of insulating material. The resistance wire itself must be homogeneous in order to avoid any localized emf. Industrial resistance thermometer always	4

		employ Pt, Cu or Ni. Resistance thermometer bulbs are generally used with a thermal well. Lead wires are used to connect the resistance bulb with the indicating element (Wheatstone bridge). Lead wires transmit the information regarding the temperature surrounding the bulb to indicating element. The electrical resistance of the sensing element changes with change in temperature surrounding it. Thus RTD is used to measure temperature in terms of change in resistance.  	
4	c	**Principle of Piston type variable area flow meter:** In piston type flow meters, the size of flow restriction is adjusted by an amount necessary to keep the pressure differential constant when the flow rate changes and the amount of adjustment required is proportional to flow rate.	4
4	d	**Differential pressure measurement as indirect method for level measurement:** **Closed vessel:**	4

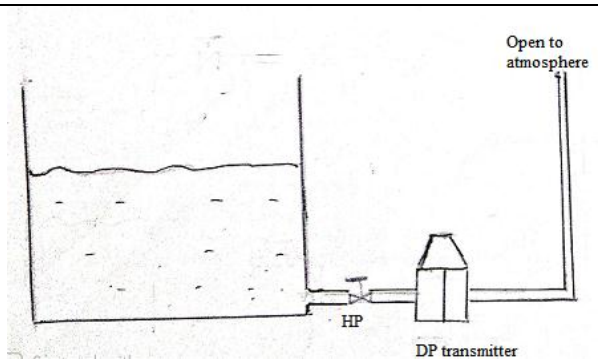


Differential pressure (DP) transmitters used for liquid level application measure hydrostatic pressure head. In a closed vessel, pressure above the liquid is due to the gas column above the liquid surface. This pressure affects the pressure measured at the bottom of the vessel. Pressure at the bottom is the sum of the liquid pressure as well as the gas pressure above the liquid. A valve at the bottom side of the vessel is connected to the high pressure (HP) side of the DP and a valve at the top of the vessel to the low pressure side. Thus the vessel pressure will get applied to both the high and low sides of the transmitter. The resulting differential pressure is proportional to the liquid level.

Therefore the differential pressure = $P_{high} - P_{low} = \rho gh$

(OR)

Open vessel

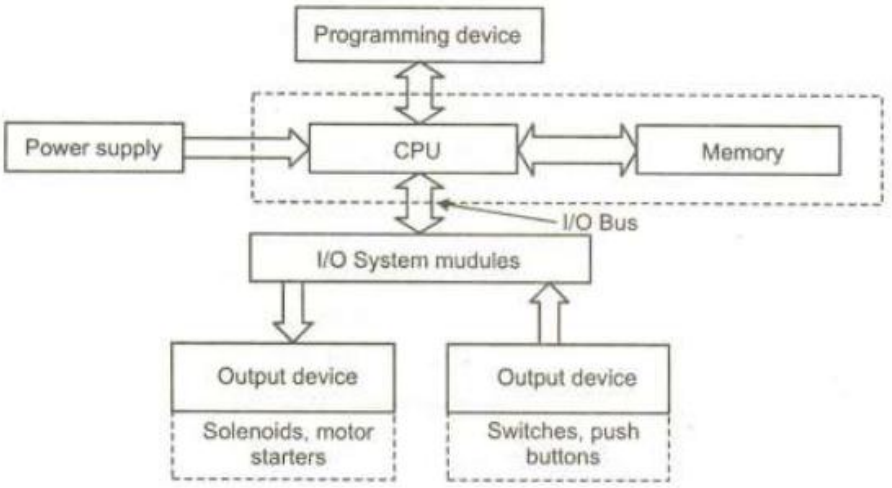


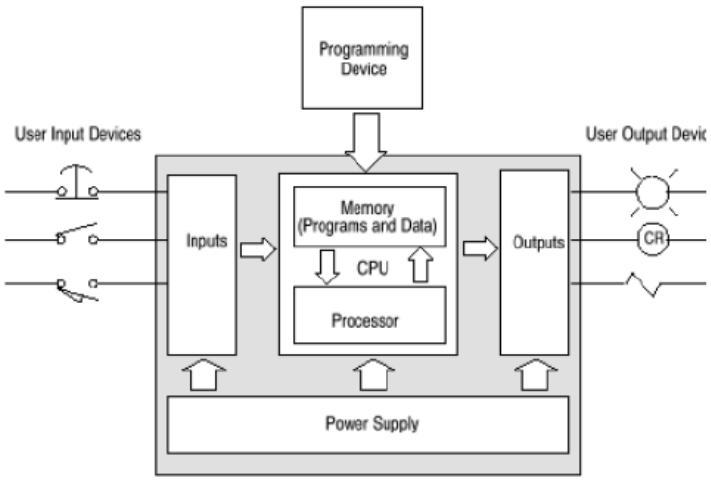
A differential pressure (DP) transmitter mounted near the bottom of the tank measures the pressure of the liquid inside it. A valve at the bottom side of the vessel is connected to the high pressure (HP) side of the DP and the low pressure side is vented to atmosphere.

Therefore the differential pressure = $P_{high} - P_{atm} = \rho gh$

4 e **Comparison of Servo & Regulatory process:** 1 mark each

Servo Control	Regulatory Control
The operation in which the purpose of control system is to make the process to follow the changes in set point for no load change.	The operation in which the purpose of control system is to maintain the controlled variable at set point, in spite of changes in load.
System has no load change.	System has no load change.
System response to changes in setpoint.	System response to changes in load.
Eg. Varying the temperature of a reactor according to a prescribed time-	Eg. Continuous chemical process in which the flow of process material is maintained at a constant value.

		temperature pattern. (OR) Processing of metals in which the set point is changed with certain time schedule so as to anneal the metal at different temperatures.		
5		**Attempt any TWO of the following**		**12**
5	a	**Programmable logic controller:** **Block Diagram:**  **OR**		3



Explanation:

PLCs are industrially hardened microcomputers that perform discrete or continuous control functions in a variety of processing plant and factory environments.

A PLC architecture consists of the following main units.

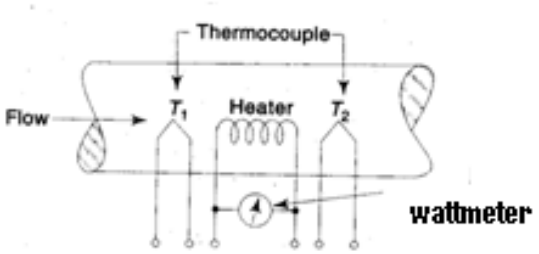
1. **Power supply**: Power supply unit converts power line voltages to those required by the solid state components.

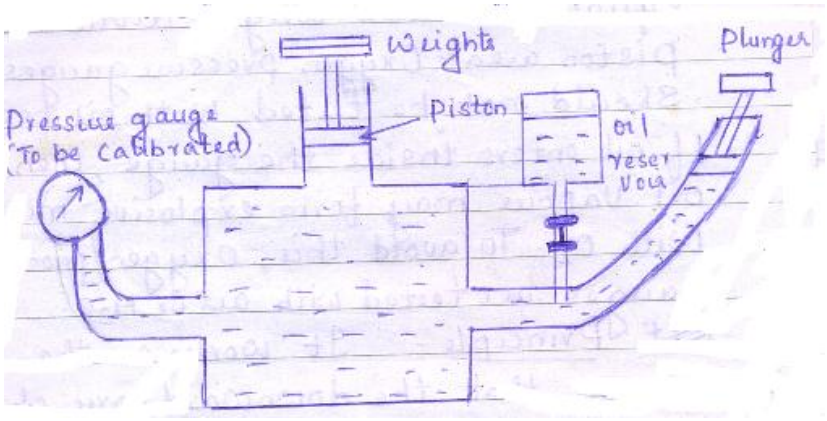
2. **Input / Output system**: Inputs are real world signals of sensors. These signals can be Analog or Digital, low or high frequency, continuous or momentary. Outputs can be of discrete, register or analog.

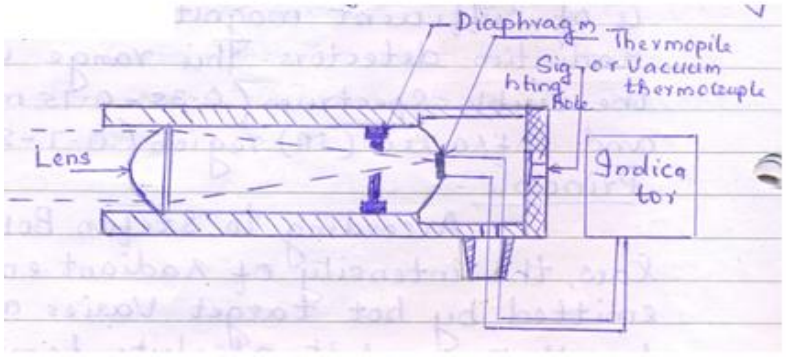
3. **Central Processing Unit (CPU):** It performs the tasks necessary to fulfill the PLC functions such as scanning, I/O bus traffic control, program execution, peripheral and external device communications, and data handling and self-diagnostics.

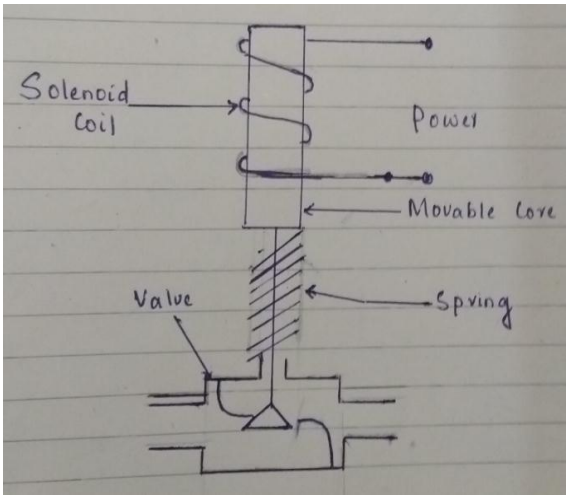
4. **Memory Unit**: This is the library where the application program, input data,

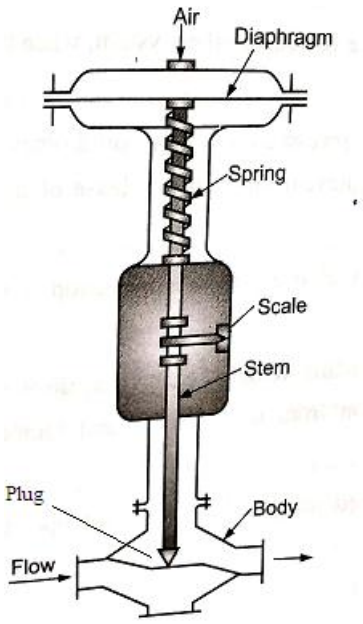
3

		as well as output data are being stored. 5. **Programmer Unit**: Programmer unit provides an interface between the PLC and user during program development, start-up and trouble shooting.	
5	b	**Thermal flow meter:** **Principle:** It works on the principle $Q = \dot{m}\, C_p \Delta T$ where Q is heat transfer $\dot{m}$ is mass flow rate C_p is specific heat of fluid. $\Delta T = T_2 - T_1$ where T_2 is temperature of fluid after heating and T_1 is the temperature of fluid before heating. **Construction and working**  It consists of an electric immersion heater for the heating of flowing fluid. Two thermocouples (or resistance thermometers) T1 and T2 are placed at each side of the heater. The thermocouple T1 measures the temperature of fluid before it is heated, while the thermocouple T2 measures the temperature so after. The power supply to the heater equals the heat transferred to the fluid, i.e. Q, and is measured by a wattmeter. Thus by measuring the values of Q, T1 and T2 the flow rate W of liquid is determined from the equation $\dot{m} = Q/Cp(T_2-T_1)$ Where	2 4

		Q=heat transfer $\dot{m}$ = mass flow rate of fluid Cp= specific heat of fluid T_1=initial temperature of the fluid after heat has been transferred T_2=final temperature after heating the fluid.	
5	c	**Dead weight tester:** **Construction:**  It consists of a very accurately machined, bored and finished piston which is inserted into a close-fitting cylinder. The cross sectional areas of both the piston and the cylinder are known. At the top of the piston is provided a platform on which the standard weight, of known accuracy, can be placed An oil reservoir with a check valve at its bottom is also provided. The oil from the reservoir can be sucked by a displacement pump on its upward stroke. **Working:** For calibration purpose, first a known (calculated) weight is placed on the platform and the fluid pressure is applied on the other end of the piston until enough force is developed to lift the piston-weight combination and the piston floats freely within the cylinder when the fluid gauge pressure equals the dead	3 3

		weight divided by the piston area.	
6		**Attempt any TWO of the following**	**12**
6	a	**Radiation pyrometer** **Principle:** According to Stefan Boltzmann's law, the intensity of radiant energy emitted by a hot target varies as the fourth power of its absolute temperature. $\Phi_b = \sigma A T^4$ σ –Stefan Boltzmann constant. T – Absolute temperature. A - Area **Diagram**  **Construction:** It consists of a lens, diaphragm, radiation receiving element, sighting hole and recorder or indicator. Lens is used to concentrate the radiant energy from the hot source on the diaphragm and on the thermopile. Sighting glasses enable the proper line of sight and proper focus to be established. **Working:**	1.5 1.5 1.5

		Radiation of all possible wave lengths from a hot body is focused by the lens on the radiation receiving element. When thermopile or vacuum thermocouple is used as radiation receiving element, the radiant energy from the target is focused in blackened measuring junction. Due to absorption of radiant energy, the measuring junction temperature rises. According to Seebeck effect, emf is developed between output leads which are proportional to temperature difference between measuring and reference junction. The emf developed is calibrated in terms of target temperature by using either a voltmeter or Wheatstone bridge circuit.	1.5
6	b	**Solenoid valve:** **Diagram:**  **Construction:** A solenoid valve consists of an electromagnetic coil and a valve. The electromagnetic coil actuates an armature or a valve stem in a magnetic field to control fluid flow. **Working:**	2 2

		When electrical power is supplied to the electromagnet, a magnetic field is created that causes the plunger to be positioned in the solenoid coil. The plunger is connected to a valve disc that opens or closes the orifice depending on the valve action ie whether the valve is energized to open or energized to close. Solenoid valves provide an on-off switching option in the system and are actuated by electric signals from remote locations.	2
6	c	**Diagram of control valve.**  	3 marks for diagram & 3 marks for labeling