WINTER-19 EXAMINATION

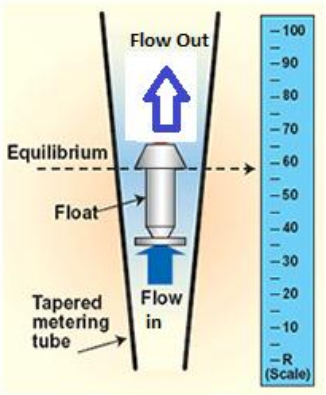
Model Answer

Subject title: Chemical Instrumentation & Process 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)Drift:** Drift is the gradual shift in the indication or record of the instrument over an extended period of time during which the true value of the variable does not change **(ii) Sensitivity:** It is the smallest change in the value of the measured variable to which an instrument responds.	1 1
1	b	**Temperature measuring instruments: (any four)** RTD, thermocouple, thermistor, mercury in-glass thermometer, bimetallic thermometer, radiation pyrometer, optical pyrometer	½ mark each
1	c	**Pressure measuring instruments: (any four):** LVDT, bellows pressure gauge, diaphragm pressure gauge, strain gauge, Force balance pressure gauge (Dead weight pressure gauge) Bourdon tube pressure gauge, Mc Leod gauge etc.	½ mark each
1	d	**Electrical temperature measuring devices:** RTD, thermocouple, thermistor	2
1	e	**Flow meters used for flow measurement (any four):** Rotating vane meter, ultrasonic flow meter, Piston type flow meter, thermal flow meter, electromagnetic flow meter.	½ mark each
1	f	**Types of controllers:**	½ mark

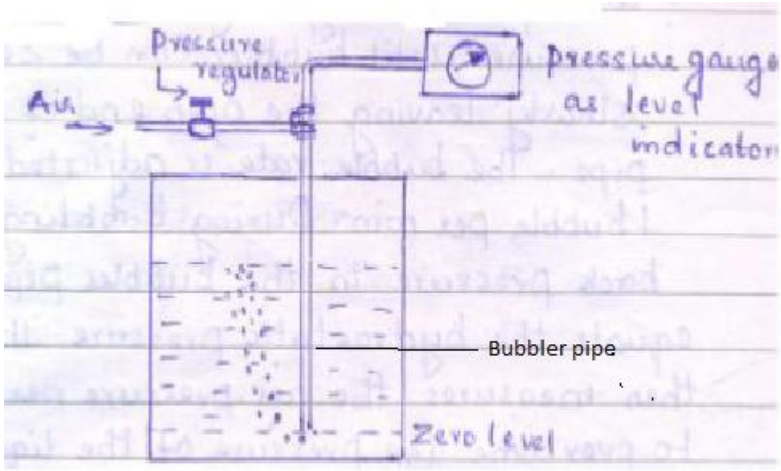
		1.On-Off or Two position controller 2. Proportional (P)controller 3. Integral (I)controller 4. Derivative (D) controller 5. PD controller 6. PI controller 7. PID controller	each for any 4
2		**Attempt any THREE of the following**	**12**
2	a	**Construction of rotameter:**  It consists of a tapered glass tube mounted vertically with smaller end on the lower side. A float is installed in the tube after the meter is mounted in the flow line. Floats are usually made of corrosion resistant metals like aluminium, bronze, monel, nickel etc. Usually a series of slanting notches are cut in the underside of float rim that gives rotation to float so as to reduce the friction. Float material decides the flow range of the rotameter. Flow scale is marked on the glass tube. Rotameter is installed in the pipeline by means of flanges or threads along with the inlet and outlet piping supported in bracket.	4

<table>
<tr><td>2</td><td>b</td><td>Temperature scales with ice point and boiling point of water (any four):
<table>
<tr><td>Temperature scale</td><td>Ice point</td><td>Boiling point</td></tr>
<tr><td>Centigrade or Celsius</td><td>0^oC</td><td>100^oC</td></tr>
<tr><td>Kelvin</td><td>273K</td><td>373K</td></tr>
<tr><td>Fahrenheit</td><td>32^oF</td><td>212^oF</td></tr>
<tr><td>Rankine</td><td>491.69^oR[1]</td><td>$671.69\ ^oR$[1]</td></tr>
<tr><td>Reaumur</td><td>0^oR</td><td>$80\ ^oR$</td></tr>
</table></td><td>1 mark each</td></tr>
<tr><td>2</td><td>c</td><td>Dead weight tester:
Principle:
It works on the principle that the downward force of the weight on the top of the piston is balanced by the pressure exerted by the fluid beneath the piston
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 weight divided by the piston area.</td><td>2

2</td></tr>
<tr><td>2</td><td>d</td><td>Air purge method for of level measurement:
Principle:
When liquid is held in a tank, then it exerts equal pressure on the walls of the tank. Such a pressure is due to the weight of liquid present above a certain reference point or base and is called hydrostatic head or pressure.
Air purge system works on measuring the pressure required to force a gas into a liquid at a point beneath the surface. This method uses a source of clean gas or air and is connected through a restriction to a bubble tube immersed at a</td><td>2</td></tr>
</table>

fixed depth in to the vessel.

Explanation(construction/working):



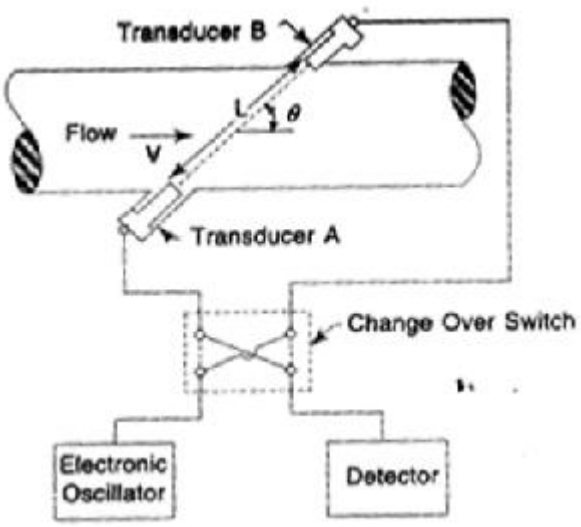
Construction:

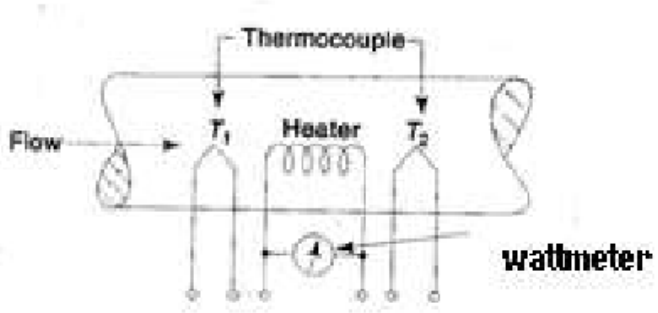
The air purge system consists of a 1 inch bubbler pipe installed vertically having its open end 3 inch above the bottom of the vessel containing the liquid. The other end of bubbler pipe has two connections; out of which one is connected to regulated metered and filtered air or gas supply while the other is connected to pressure gauge.

Working:

To make level measurement, the air supply is adjusted so that the pressure is slightly higher than the pressure due to the height of the liquid and bubbles can be seen slowly leaving the open end of the pipe. The bubble rate is adjusted as 1 bubble / minute. During bubbling, the back pressure in the bubbler pipe exactly equals the hydrostatic pressure. The gauge then measures the air pressure needed to overcome the pressure of the liquid.

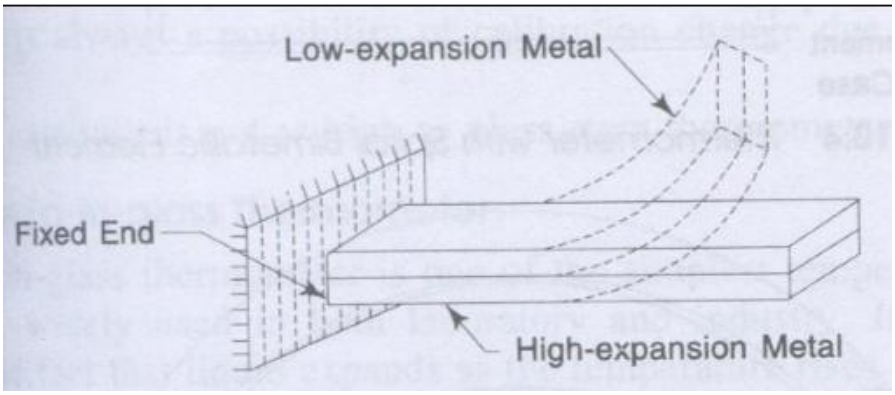
Construction/ Working: 2

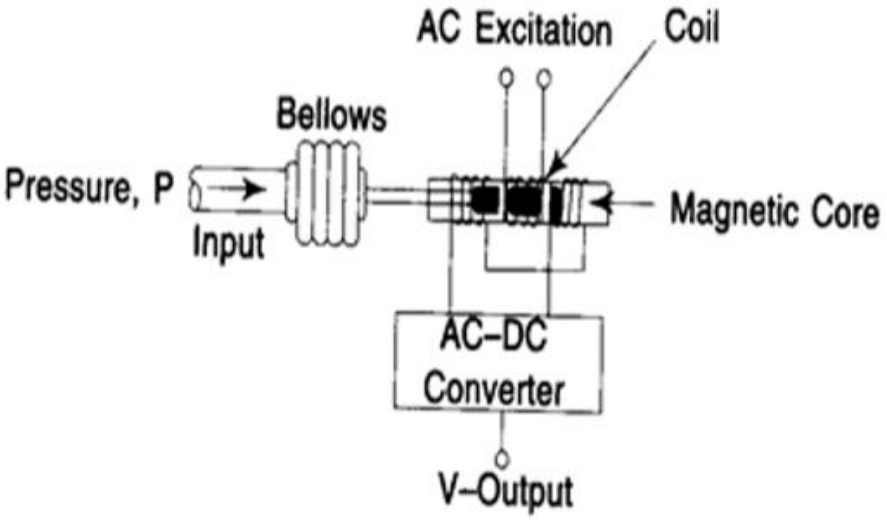
3		**Attempt any THREE of the following**	**12**
3	a	**Diagram of ultrasonic flow meter (Time Difference Type):**  ***(Any other type of ultrasonic flow meter should be given due consideration)***	4
3	b	**Thermal flow meter:** **Principle:** It works on the principle $Q = \dot{m}\, C_p \Delta T$ where 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. **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	2

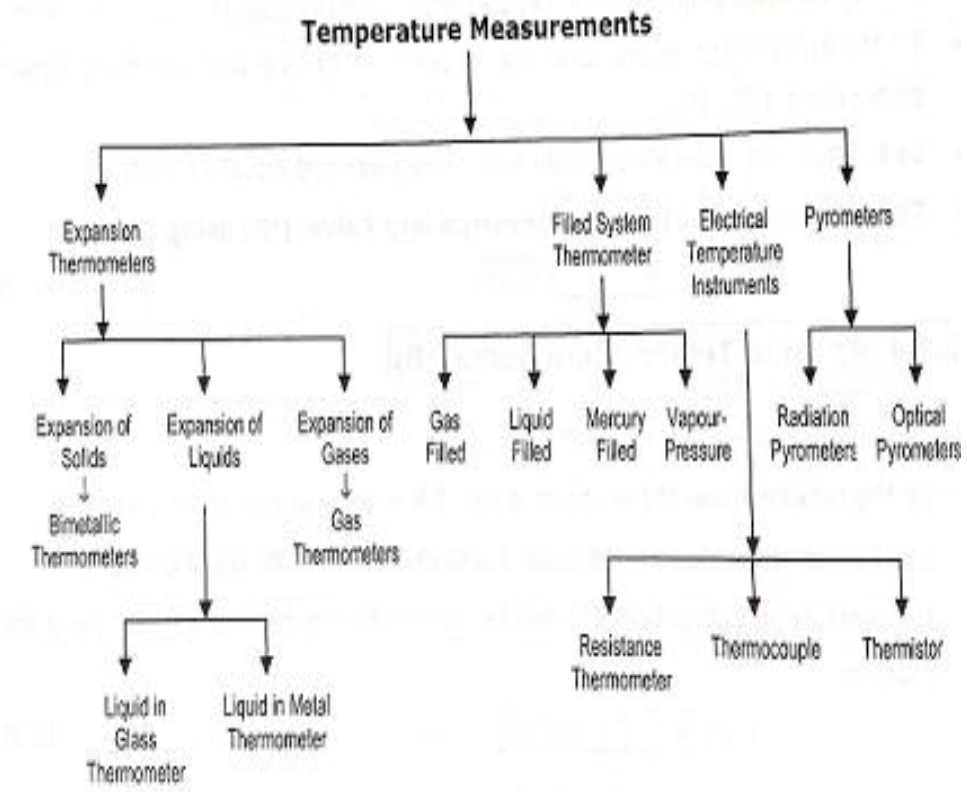
		after. The power supply to the heater equals the heat transferred to the fluid, i.e. Q, and is measured by a wattmeter. Thus by measuring the values of Q, T1 and T2 the flow rate W of liquid is determined from the equation $\dot{m}$ =Q/Cp(T_2-T_1)  	2
3	c	**Difference between open loop and closed loop control system (four points):**	1 mark each

Sr No.	**Open loop control system**	**Closed loop control system**
1	Feedback doesn't exists	Feedback exists
2	Output measurement is not necessary	Output measurement is necessary
3	Any change in output has no effect on input	Changes in output affects the input
4	Error detector is absent	Error detector is present
5	Inaccurate and unreliable	Highly accurate and reliable
6	Highly sensitive to disturbance	Less sensitive to disturbance
7	Highly sensitive to environmental changes	Less sensitive to environmental changes

		8	Simple in construction and cheap	Complicated in construction and hence costly	
		9	Highly affected by non-linearities	Reduced effect of non-linearity	
3	d	**Definition of dead zone:** It is the largest range of values of a measured variable to which the instrument does not respond. It is the largest change of input quantity for which there is no output of the instruments. It is basically range of input value for which output is zero. Dead zone is also known as Dead band or dead space or neutral zone **Reasons of dead zone:** Dead zone can be intentional or unintentional. Unintentional dead zone is caused by friction or by permanent set in highly stressed material. Intentionally dead zone is provided to increase the life span of the instrument.			2 2
4		**Attempt any THREE of the following**			**12**
4	a	**Bimetallic thermometer:** **Principle:** When heated different solids expand differently depending on their coefficient of thermal expansion. **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			2 2

		shown in Fig above. If one end of the bimetallic strip is 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.  	
4	b	**Bourdon tube:** **Advantages:** 1) Low cost 2) Simple construction 3) Wide pressure range 4) High accuracy in relation with low cost **Disadvantages:** 1) Low spring gradient 2) Susceptible to shock and vibration 3) Susceptible to hysteresis	1 mark each for any two 1 mark each for any two
4	c	**LVDT:** **Principle:** The differential voltage of two secondary windings of a transformer is varied	2

		by positioning the iron core through an externally applied force. **Working**  When the pressure inside the bellows changes, its free end gets deflected along with the movable core. When the core is symmetrically positioned between the two secondary coils, the magnetic coupling of the core with both the secondary coils is equal. In this position, equal but opposite emfs are developed in the coil, and hence the net voltage between two secondary coils is zero. When core takes any other position, the magnetic coupling with each secondary coil is different, that induces different voltages in the secondary coils. Hence some unbalance voltage is produced between the coils that depend upon the position of the core which in turn depends upon the pressure fed inside the bellows.	2
4	d	**Classification of temperature measuring instruments with one eg**	

			4
4	e	**Mc Leod gauge:** **Working:** To operate the gauge, the piston is first withdrawn, causing the level of mercury in the lower part of the gauge to fall below the level of the junction between the two tubes. The unknown pressure source is connected to the gauge from where it also flows and fills the bulb and capillary. Next, the piston is pushed in, moving the mercury level up to block the junction. At this stage,, the fluid in the capillary and the bulb is at pressure P. Further movement of the piston compresses the fluid in the tube and the mercury level is raised till it	2

reaches the zero reference point in R. Measurement of the height above the mercury column in the capillary allows the calculation of the compressed volume of the fluid.

The expression for calculating the unknown pressure is

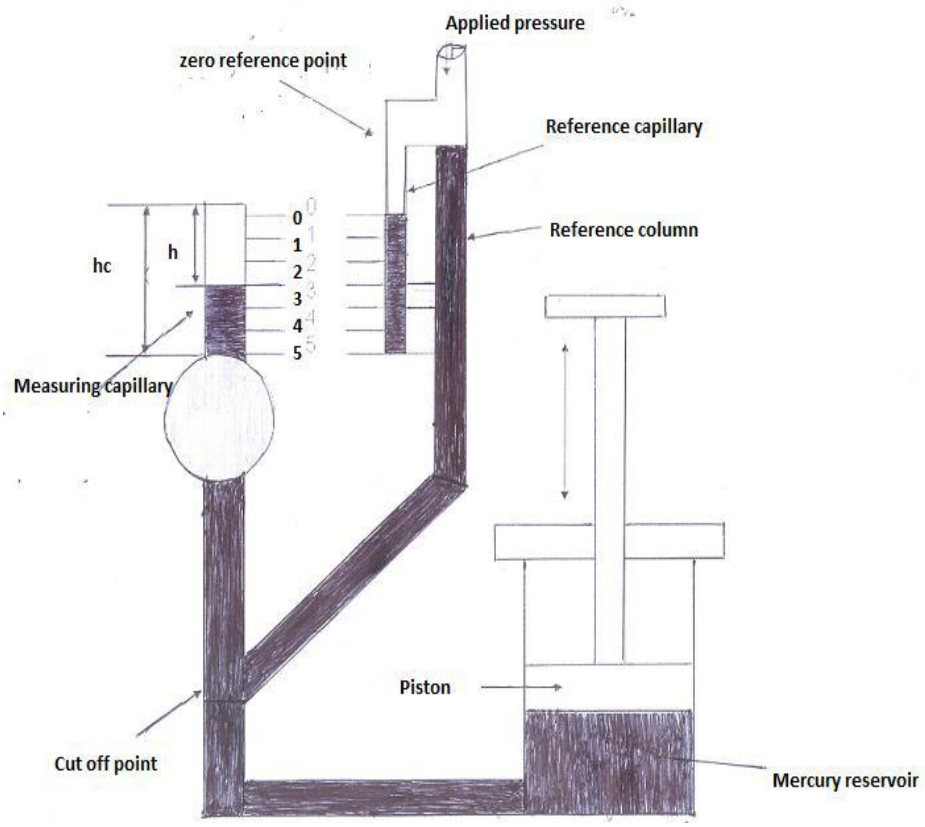
$P = A\rho gy^2 / V$

Where A is capillary area

ρ is density of fluid

y is height above the mercury column in capillary

Diagram:



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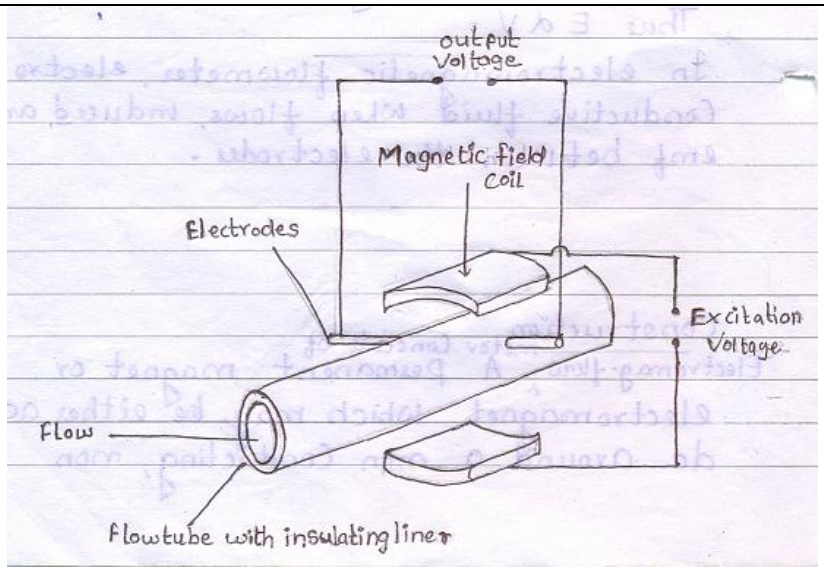
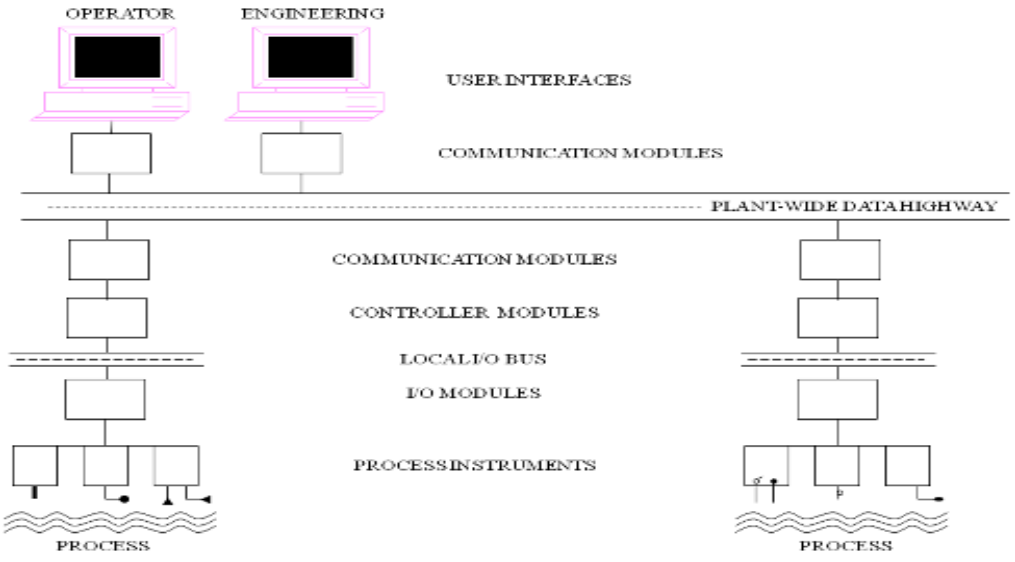
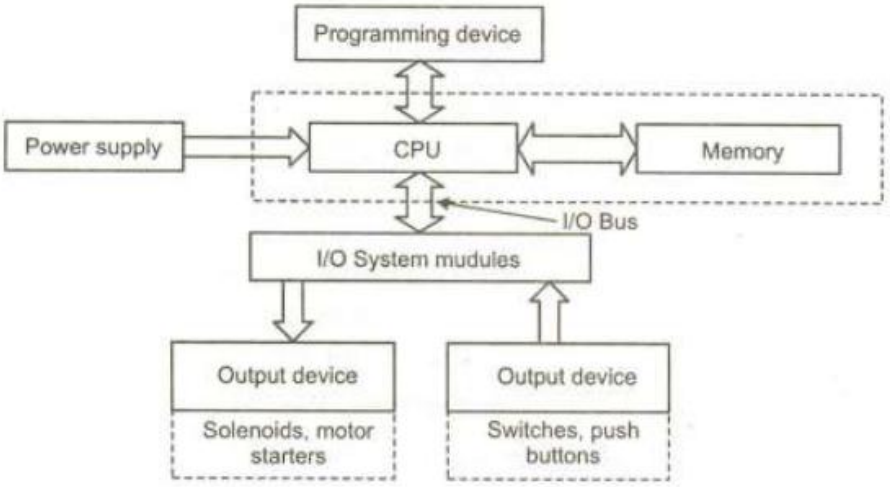
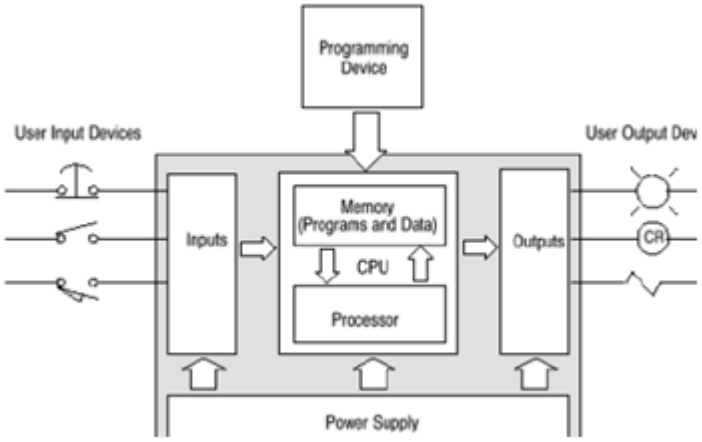
5		**Attempt any TWO of the following**	**12**
5	a	**Electromagnetic flow meter:** **Principle:** Electromagnetic flow meter works on the principle of Faraday's law of electromagnetic induction which states that when a current carrying conductor moves through stationary transverse magnetic field, an emf is induced between the ends of the conductor and this emf. is proportional to relative velocity between the conductor and magnetic field. The induced emf is given by E=Blv where E-emf l-Length of conductor B-Magnetic flux density v-Velocity of conductor **Working:** As the fluid flows through the pipe, due to magnetic field an emf is induced between the electrodes. The emf induced is proportional to the velocity of fluid. As the flow rate varies, velocity of fluid changes causing the induced emf to change. **Diagram:**	2 2

			2
5	b	**DCS architecture:** **Block diagram:**  **Explanation:** In DCS equipment is separated in functional area and is installed in different	3

		work areas of a process plant. The plant operator monitors and manipulates the set-points of the process parameter from central control room. Controlling portion of the DCS, distributed at various locations performs following two function at each location. 1. Measurement of analog variable and discrete inputs 2. Generation of output signals to actuators that can change process condition In Figure above the operator console in the control room is connected through a data highway to several distributed system components. A DCS consist of the following modules: 1 Operator stations that use microprocessor based CRT display and keyboard communication with control device and displays 2 Remote multifunction microprocessor based controllers (PLCs) 3 A digital data link (data highway) that connects the multifunction controllers with the central operator stations. The first priority of DCS is to provide operator interfacing and real time process control. DCS has flexibility of implementation of sequential control and integration among the various types of control.	3
5	c	**Factors to be considered for control valve selection:** The basic steps in control valve selection are 1. The first step in control valve selection involves collecting all relevant data and completing the ISA Form S20.50. The piping size must be set prior to valve sizing, and determining the supply pressure may require specifying a pump 2. The size of the valve is required; select the smallest valve Cv that satisfies the maximum Cv requirement at 90% opening. While performing these	1 mark each

		calculations, checks should be made regarding flashing, cavitation, sonic flow and Reynolds number to ensure that the proper equation and correction factors are used. As many difficulties occur due to oversized valves as to undersized valves. Adding lots of "safety factors" will result in a valve that is nearly closed during normal operation and has poor rangeability. 3. The trim characteristic is selected to provide good performance; goals are usually linear control loop behavior along with acceptable rangeability. 4. The valve body can be selected. The valve size is either equal to the pipe size or slightly less, for example, a 3-inch pipe with a 2-inch globe valve body. When the valve size is smaller than the process piping, an inlet reducer and outlet expander are required to make connections to the process piping. 5. The actuator is now selected to provide sufficient force to position the stem and plug. 6. Finally, auxiliaries can be added to enhance performance. A booster can be increase the volume of the pneumatic signal for long pneumatic lines and large actuators. A positioner can be applied for slow feedback loops with large valves or valves with high actuator force or friction. A hand wheel is needed if manual operation of the valve is expected.	
6		**Attempt any TWO of the following**	**12**
6	a	**Function of** **Valve actuator:** It is that 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 diaphragm, stem and diaphragm returning spring **Valve positioner:**	3

		The function of valve positioner is to sense both the instrument signal and the valve position and from this measurement ensure that the valve position is directly proportional to its controller output signal. Positioner is mounted on the control valve to be able to measure the stem position. When static frictional forces are large, valve positioner is used along with actuator so as to correctly position the valve stem in response to the control signal. Valve positioner improves the speed of response and reduces the hysteresis effect.	3
6	b	**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.

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, as well as output data are being stored.

5. **Programmer Unit**: Programmer unit provides an interface between the

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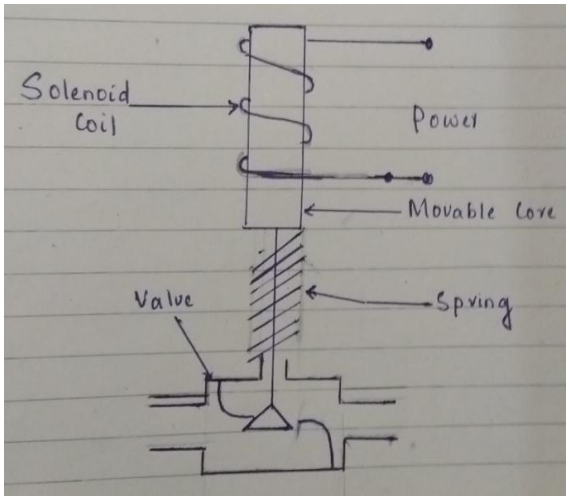
		PLC and user during program development, start-up and trouble shooting	
6	c	**Solenoid valve** **Construction:** A solenoid valve consists of an electromagnetic coil and a valve. The electromagnetic coil actuates an armature or a valve stem in a magnetic field to control fluid flow.  . **Working:** When 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.	3 3